iii Tenosols

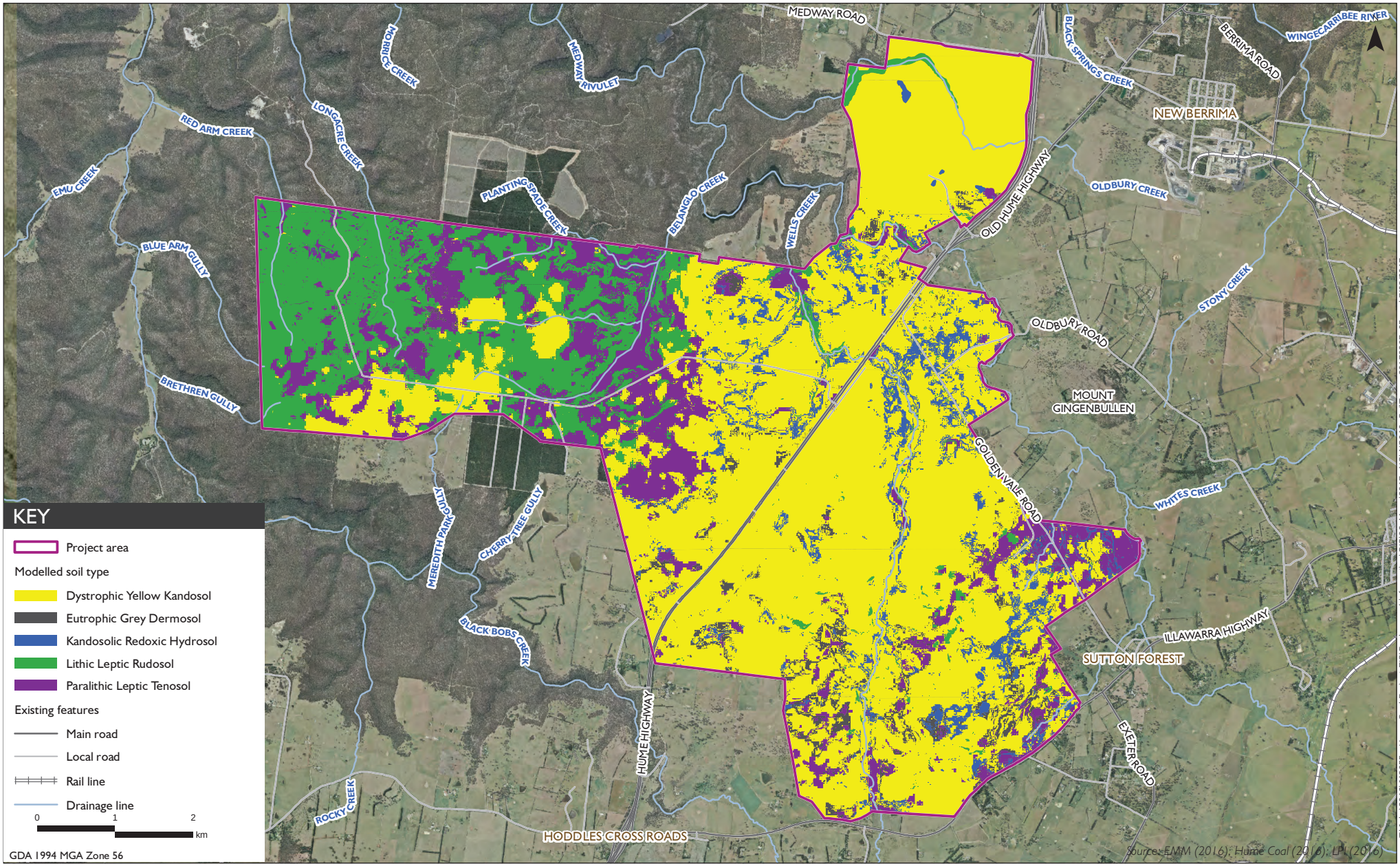
This soil order incorporates soils with generally weak pedologic organisation apart from the A horizons, encompassing a diverse range of soils. Tenosols generally have poor water retention, almost universal low fertility and occur in regions of low and erratic rainfall. They are mainly used for grazing based on native pastures. In better watered areas, such as the project area, limited areas support forestry. The Tenosol described in the project area is further classified as Paralithic Leptic Tenosol and is described in detail in Section 3.3.4.

iv Hydrosols

This order includes a range of seasonally or permanently wet soils which experience saturation of the greater part of the profile for prolonged periods (2-3 months). There is a large diversity in this soil group. The soils may or may not experience reducing conditions for all or part of the period of saturation, and thus manifestations of reduction and oxidation such as 'gley' colours and mottles may or may not be present. The Hydrosol described in the project area is further classified as Kandosolic Redoxic Hydrosol and is described in detail in Section 3.3.5.

v Dermosols

Dermosols are moderately deep and well-drained soils of wetter areas in eastern Australia. They have B2 horizons with structure more developed than weak throughout the major part of the horizon, and do not have clear or abrupt textural B horizons. These soils can support a wide range of land uses including cattle and sheep grazing of native pastures, forestry and sugar cane. Cereal crops, especially wheat, are commonly grown on the more fertile Dermosols. The Dermosol described in the project area is further classified as Eutrophic Grey Dermosol and is described in detail in Section 3.3.6.



Soil type distribution of project area (EMM mapping)

Hume Coal Project

Agricultural Impact Statement

Figure 3.6

3.3.2 Dystrophic Yellow Kandosol

The Dystrophic Yellow Kandosol soils are lacking strong texture contrast with silty clay loams over light clays, transitioning to medium clays at depth. The soil surface is mostly firm when dry and without surface coarse fragments. Topsoils have few coarse fragments and are without mottling. Subsoils have few coarse fragments, massive structure and are imperfectly drained. Mottling is common to many with colouring typically being orange or red. A soil profile description for a typical Dystrophic Yellow Kandosol is provided in Table 3.5.

Table 3.5 Dystrophic Yellow Kandosol typical soil profile summary

ASC:	Horizon name and average depth (m)	Colour, mottles and bleach	Moisture, laboratory pH (median) and drainage	Texture and structure	Coarse fragments, segregations and roots
	A1 0.0-0.19	Dark greyish brown, 10YR4/2 and no mottles or bleaching.	Moderately moist, pH 5.2 and well drained.	Silty loam and sub-angular blocky or massive.	No surface rock, few coarse fragments, no segregations and many roots.
	A2 0.19-0.36 (Sometimes A2e)	Pale brown, 10YR6/3 and no mottles or bleaching.	Moderately moist; pH 6.1 and well drained.	Clay loam sandy and sub-angular blocky or massive.	Few coarse fragments, no segregations and common roots.
	B21 0.36-0.53	Brownish yellow, 10YR6/8, common orange or red mottles and no bleaching.	Moist; pH 4.3 and imperfectly drained.	Light clay and massive.	Common coarse fragments, no segregations and few roots.
	B22 0.53-0.76	Brownish yellow, 10YR6/8, common to many orange or red mottles and no bleaching.	Moist to wet, pH 4.3 and imperfectly to poorly drained.	Medium clay and massive.	Common coarse fragments, no segregations and few to no roots.

Notes: 1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).

2. pH are laboratory results and the median values are presented.

Laboratory analysis of particle size distribution was carried out on a representative soil profile, and the results are presented in Table 3.6.

Table 3.6 Particle size analysis - Dystrophic Yellow Kandosol (Site 388)

Horizon	Depth mm	Clay (<2 µm) %	Silt (2-60 µm) %	Sand (0.06-2.00 mm) %	Gravel (>2mm) %
A1	0-10	16	32	51	1
A1	10-20	15	29	52	4
A1	20-30	18	25	51	6
A2	42-50	21	23	50	6
B21	50-60	24	22	48	6
B22	70-75	39	21	37	3

The Dystrophic Yellow Kandosol soil unit occurs on all slopes and crests of low rolling hills on shale surface geology (see Photograph 3.1). Land within the project area that is characterised by this soil type is extensively cleared primarily for grazing of improved pastures and pine forestry. The Dystrophic Yellow Kandosol is more common across the eastern and central part of the project area where it is associated with shale surface geology of low rolling hills. It occurs less regularly within the Belanglo State Forest due to the increased presence of sandstone surface geology.

Two variations were noted, a shallow phase variation (10% of total occurrences) and a variation with a redder hue in the upper B2 horizon (10%). The shallow phase variation typically exists on steep slopes or hillcrests. Another variation exists on spurs and ridge lines with a redder hue in the upper B2 horizon. Laboratory testing using a citrate-dithionite extractable iron procedure confirmed that the percentage of free iron oxide is less than 5% and so the red variation is not a Ferrosol.

Photograph 3.1 Dystrophic Yellow Kandosol (Site 688)

The Dystrophic Yellow Kandosol can be strongly acidic in the A1 horizon with pH values ranging from 3.8 to 6.2 (see Table 3.7). Out of the 73 sites which were tested for field pH in the A1 horizon, 68% were below pH 5.5, and 15% were below 4.5. These results were mirrored in the B horizon with 66% below pH5.5. The pH's of the majority of the soils in this soil unit are therefore generally unsuitable for cultivation, and restricted to grazing, forestry and nature conservation (OEH 2012). The soils with the more neutral pH may be suitable for some restricted cultivation and pasture cropping, depending on other factors such as slope.

The macronutrients (nitrogen, phosphorous, and potassium) and the micronutrients (copper, zinc, iron, manganese, boron) are mostly low which could restrict agriculture, although fertiliser could amend these concentrations. The cation exchange capacity (CEC) is also very low, which also may present some fertility issues.

All soil chemistry results are given in Table 3.7. The soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column, and are in reference to the median values with increasing depth. A summary of the agricultural potential of Dystrophic Yellow Kandosol is given in Table 3.8.

Table 3.7 Dystrophic Yellow Kandosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.19	A2 0.19-0.36	B21 0.36-0.53	B22 0.53-0.76	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	5.2 (3.8-6.2)	6.1 (4.3-6.5)	4.3 (3.8-7.1)	4.3 (4.0-7.2)	Strong (top of A horizon) to extreme acidity (B horizon).
Electrical conductivity – saturated extract (EC_{se})	dS/m	<1.9	0.49 (0.16-4.63)	0.26 (0.23-0.66)	0.19 (0.09-1.17)	0.13 (0.07-1.51)	Very low soil salinity.
Chloride (Cl^-)	mg/kg	<800	30 (20-50)	50 (50-50)	20 (10-140)	105 (30-200)	Not restrictive.
Plant available water capacity (PAWC)	mm	>80	11.4 (L-ZCL)	13.6 (ZL-ZCL)	17.0 (LC-LMC)	27.6 (LMC-HC)	Small (total of 69.6).
Macronutrients							
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	19.6 (0.1-333)	13.7 (12.9-14.5)	2.8 (0.1-12.2)	2.1 (0.8-6.8)	Moderate (top of A horizon) to very low (with depth).
Total Nitrogen as N	mg/kg	>1500	1485 (520-2680)	520 (390-940)	410 (200-960)	380 (110-530)	Deficient.
Phosphorous (P) (Colwell)	mg/kg	>10	3 (<2-46)	<2 (<2-5)	<2 (<2-24)	<2 (<2-26)	Very low (except in the A1 horizon).
Potassium (K) (Acid Extract)	mg/kg	>117	<100 (<100-300)	<100 (<100-<100)	<100 (<100-<100)	<100 (<100-200)	Insufficient.
K (Total)	mg/kg	>150	275 (200-790)	260 (220-320)	390 (140-610)	420 (170-830)	High (A horizon) to very high (B horizon).
Micronutrients							
Copper (Cu)	mg/kg	>0.3	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	Low (inconclusive).
Zinc (Zn)	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	<1.0 (<1.0-8.1)	<1.0 (<1.0-<0.1)	<1.0 (<1.0-2.9)	<1.0 (<1.0-2.0)	Low (inconclusive).
Manganese (Mn)	mg/kg	>2	47.0 (<1.0-74)	21.0 (<1.0-44)	<1.0 (<1.0-14)	<1.0 (<1.0-9)	Moderate (A horizon) to very low (B horizon).
Boron (B)	mg/kg	>1	0.95 (<0.2-1.6)	0.50 (<0.2-0.7)	0.50 (<0.2-3.3)	0.50 (<0.2-1.7)	Low (A1 horizon) to very low (A2 and B horizons).

Table 3.7 Dystrophic Yellow Kandosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.19	A2 0.19-0.36	B21 0.36-0.53	B22 0.53-0.76	Comments on median values (in increasing depth)
Exchangeable cations							
Cation Exchange Capacity (CEC)	meq/ 100g	12-25	3.8 (0.6-11.8)	2.1 (1.4-3.5)	0.8 (0.1-3.9)	0.3 (0.04-4.3)	Very low.
Calcium (Ca)	meq/ 100g	>5	2.9 (0.3-8.4)	1.7 (0.7-4.7)	1.1 (<0.1-4.4)	1.0 (0.2-5.5)	Low (A horizon) to very low (B horizon).
Magnesium (Mg)	meq/ 100g	>1	0.8 (0.3-3.5)	0.8 (0.2-3.3)	0.7 (0.4-5.9)	1.6 (0.6-7.7)	Low (A and B1 horizons) to moderate.
Sodium (Na)	meq/ 100g	<0.7	<0.1 (<0.1-0.2)	<0.1 (<0.1-0.2)	<0.1 (<0.1-0.3)	<0.1 (<0.1-0.4)	Very low.
K	meq/ 100g	>0.3	0.3 (<0.1-1.2)	<0.1 (<0.1-0.1)	<0.1 (<0.1-0.2)	<0.1 (<0.1-0.4)	Low (A1 horizon) to very low (A2 and B horizons).
Exchangeable sodium percentage (ESP)	%	<6	<2.70* (1.7-16.7)	<3.90* (2.41-11.1)	4.35 (2.8-16.7)	3.60 (2.8-11.1)	Non-sodic.
Ca:Mg ratio		>2	3.40 (1.0-6)	2.10 (1.4-3.5)	0.83 (0.1-3.9)	0.30 (0.04-4.3)	Stable A horizon. Unstable B horizon.
Organic Carbon	%	>1.2	2.0 (<0.5-4.1)	<0.5 (<0.5-2.2)	<0.5 (<0.5-1.8)	<0.5 (<0.5-1.8)	Moderate (A1 horizon) to very low (A2 and B horizons).

Notes: *1. Plant sufficiency sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).*

2. Values in brackets are the ranges measured.

** These values are an approximation based on calculations using the lowest measurable level.*

Table 3.8 Dystrophic Yellow Kandosol agricultural use summary

Elements	Comments
pH_{water}	Strongly acid at the surface, progressing to extremely acidic with depth. Outside of the desirable range for agriculture throughout most of the profile. Would restrict agriculture.
EC	Very low salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
PAWC	At the upper limit of a low plant available water capacity, which would restrict agriculture.
Fertility	
Macronutrients	Mostly low levels of macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Mostly low to very low levels of micronutrients, which present fertility issues. Would restrict agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately low - Kandosols (order), Any (sub-order), Dystrophic (Great Group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderately low (Group 2) **Explanation (Murphy et al. 2007):** Low fertilities that generally only support plants suited to grazing. Generally deficient in nitrogen, phosphorus and many other elements.

Table 3.8 Dystrophic Yellow Kandosol agricultural use summary

Elements	Comments
ESP	Low ESP indicating a non-sodic soil, which would not restrict agriculture.
Ca:Mg ratio	A mostly stable Ca:Mg ratio in the topsoil, but decreasing with depth to levels that suggest strong soil instability.
Organic Carbon	Indicative of good structural condition and structural stability in the A1 horizon. Low levels below this horizon.
Major limitations to agriculture	PAWC Macronutrients (eg nitrate, total nitrogen, phosphorus, potassium extract) Micronutrients (eg boron, calcium, magnesium, sodium, potassium)

3.3.3 Lithic Leptic Rudosol

Lithic Leptic Rudosol soils are shallow and weakly developed sands (most commonly clayey sands) to a depth of approximately 0.18 m over weakly to highly weathered sandstone. The soil surface is loose with common surface coarse fragments and rock outcrops. Lithic Leptic Rudosols have few coarse fragments throughout, no mottling and are highly permeable and rapidly drained. These soils typically have low fertility, are strongly acidic, non-sodic and non-saline. A soil profile description for a typical Lithic Leptic Rudosol is presented in Table 3.9. It is noted that the laboratory pH values presented are median values.

Table 3.9 Lithic Leptic Rudosol typical soil profile summary

ASC:	Horizon name and depth (m) (average)	Colour, mottles and bleach	Moisture, laboratory pH (median value) and drainage	Texture, structure and consistence	Coarse fragments, segregations and roots
	O 0-0.02	Very dark brown, no mottles and no bleaching.	Dry, pH 4.4, rapidly drained.	Loamy sand, crumb or granular and very weak force.	Surface coarse fragments of 10-20% stones and boulders, few coarse fragments, very high organic matter, no segregations and common roots.
	A11 0.02-0.09	Dark greyish brown, no mottles and no bleaching.	Dry, pH 4.6, rapidly drained.	Sandy loam, crumb or granular and very weak force.	Few coarse fragments, high organic matter, no segregations and common roots.
	A12 0.09-0.18	Dark greyish brown, no mottles and no bleaching.	Dry, pH 4.75, rapidly drained.	Sandy loam, crumb or granular and very weak force.	2-10% gravel, no segregations and common roots.
	R 0.18+	Parent material - Hawkesbury Sandstone.			

Note: 1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).

Laboratory analysis of particle size distribution was carried out on a representative soil profile, and the results are presented in Table 3.10. The soil is predominantly gravel and sand.

Table 3.10 Particle size analysis – Lithic Leptic Rudosol (Site 474)

Horizon	Depth	Clay (<2 µm)	Silt (2-60 µm)	Sand (0.06-2.00 mm)	Gravel (>2mm)
	mm	%	%	%	%
A11	0-3	9	27	53	11
A12	3-10	11	14	70	5

The Lithic Leptic Rudosol is a shallow soil that occurs on the plateaus, scarps and benches of steep hills on Hawkesbury Sandstone (sandstone-quartz and shale). Slopes vary from very gently inclined on the plateaus to steeply inclined on scarps with an average gradient of around 17%. Within the project area, common land uses on this soil type are low intensity grazing on native pastures and forestry. Coverage of the Lithic Leptic Rudosols is limited to the steep slopes associated with sandstone surface geology most commonly found within Belanglo State Forest (see Photograph 3.2).

Photograph 3.2 Lithic Leptic Rudosol (site 352)

Lithic Leptic Rudosol is very strongly acidic throughout the profile and is outside the desirable range for agriculture throughout most of the profile. It is typically on steep slopes with loose soils with course fragments, that make it suited only to some grazing, forestry and nature conservation.

Soil chemistry results for the Lithic Leptic Rudosol are presented in Table 3.11 the soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column, and are in reference to the median values with increasing depth. A summary of the agricultural potential of Lithic Leptic Rudosol is presented in Table 3.12.

Table 3.11 Lithic Leptic Rudosol soil chemistry results – median values (and ranges)

Constituents	Unit	Soil sufficiency[1]	A11 0.02-0.09	A12 0.09-0.18	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	4.60 (4.4-5.8)	4.75 (4.2-5.3)	Very strong acidity.
Electrical conductivity – saturated extract (EC_{se})	dS/m	<1.9	0.46 (0.21-0.46)	0.34 (0.24-0.44)	Very low soil salinity.
Chloride (Cl^-)	mg/kg	<800	30 (20-40)	30 (30-30)	Not restrictive.
Plant available water capacity (PAWC)	mm	>80	3.5 (CS-ZCL)	4.5 (CS-ZCL)	Very small (total of 8).
Macronutrients					
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	0.20 (0.2-0.5)	0.35 (0.2-0.5)	Very low.
Total Nitrogen as N	mg/kg	>1500	1270 (1270-2700)	1215 (750-1680)	Deficient.
Phosphorous (P) (Colwell)	mg/kg	>10	<2 (<2-6)	<2 (<2-5)	Very low.
K (Acid Extract)	mg/kg	>117	100 (<100-100)	<100 (<100-<100)	Insufficient - low.
Potassium (K) (Acid Extract)	mg/kg	>150	150 (130-180)	165 (120-210)	Moderate.
Micronutrients					
Cu	mg/kg	>0.3	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	Inconclusive.
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	<1.0 (<1.00-3.19)	<1.0 (<1.0-<0.1)	Inconclusive.
Mn	mg/kg	>2	<1.00 (<1.0-14.6)	2.79 (<1.00-4.57)	Very low (A11 horizon) to moderate (A12 horizon).
B	mg/kg	>1	<1.0 (<1.00-3.19)	<1.0 (<1.0-<1.0)	Low.
CEC	meq/ 100g	12-25	0.70 (0.6-7.5)	3.05 (0.4-5.7)	Very low.
Ca	meq/ 100g	>5	0.20 (0.1-6.1)	2.40 (<0.1-4.7)	Very low (A11 horizon) to low (A12 horizon).
Mg	meq/ 100g	>1	0.20 (0.1-1.2)	0.45 (<0.1-0.8)	Very low (A11 horizon) to low (A12 horizon).

Table 3.11 Lithic Leptic Rudosol soil chemistry results – median values (and ranges)

Constituents	Unit	Soil sufficiency[1]	A11 0.02-0.09	A12 0.09-0.18	Comments on median values (in increasing depth)
Na	meq/ 100g	<0.7	0.2 (<0.1-0.2)	<0.1 (<0.1-0.1)	Low (A11 horizon) to very low (A12 horizon).
K	meq/ 100g	>0.3	<0.1 (<0.1-0.2)	0.2 (<0.1-0.2)	Very low.
Exchangeable cations					
ESP	%	<6	0.33 (0.29-1.33*)	1.00* (0.25-1.75*)	Non-sodic.
Ca:Mg ratio		>2	1.00 (1.0-5.1)	3.44 (1.0-5.9)	Unstable (A11 horizon) to stable (A12 horizon).
Organic Carbon	%	>1.2	3.4 (2.9-7.0)	2.7 (1.8-3.9)	Very high.

Notes: *1. Sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).*

2. Values in brackets are the ranges measured.

** These values are an approximation based on calculations using the lowest measurable level.*

Table 3.12 Lithic Leptic Rudosol soil chemistry summary

Elements	Comments
pH_{water}	Very strongly acidic throughout the profile. Outside of the desirable range for agriculture throughout most of the profile. Would restrict agriculture.
EC	Very low soil salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
PAWC	A very small PAWC, which would restrict agriculture.
Fertility	
Macronutrients	Mostly low levels of macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Mostly low to very low levels of micronutrients, which present fertility issues. Would restrict agriculture.
CEC	Very low CEC, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Low - Rudosols (order), Leptic (sub-order), Any (Great Group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Low (Group 1) **Explanation (Murphy et al. 2007):** Soils which, due to their poor physical and/or chemical status, only support limited agriculture. The maximum agricultural use of these soils is low intensity grazing. Include shallow and sandy soils which by virtue of their poor water retention characteristics can only support limited agriculture.
ESP	ESP indicating a non-sodic soil that would not restrict agriculture.
Ca:Mg ratio	Unstable Ca:Mg ratio in the topsoil, but increasing stability with depth to levels that suggest soil stability.
Organic Carbon	Indicative of good structural condition and structural stability. Very high levels throughout that would not restrict agriculture.

Table 3.12 Lithic Leptic Rudosol soil chemistry summary

Elements	Comments
Major limitations to agriculture	pH
	PAWC
	Macronutrients (eg nitrate, total nitrogen, phosphorus, potassium extract)
	Micronutrients (eg manganese, boron, calcium, magnesium, sodium, potassium)

3.3.4 Paralithic Leptic Tenosol

The Paralithic Leptic Tenosols soils are weakly developed with a slight increase in clay content and lightening of soil colour with depth. They are typically sandy in the A1 horizon and the A2 horizon is a sandy loam. The soil surface is without coarse fragments and of loose condition. Paralithic Leptic Tenosols have few coarse fragments, which are spread evenly throughout the profile. Subsoils typically have few orange mottles with no segregations. Paralithic Leptic Tenosols are typically extremely acidic, highly permeable, rapidly drained and non-saline. Generally the Tenosol sites were underlain by a hard material, usually weathered rock, which varied in depth between sites from <500 mm to approximately 750 mm. It is noted that using Isbell (2002), the subgroup would be Brown-Orthic rather than Leptic. This difference would not affect interpretation of the soil's characteristics or the BSAL assessment outcome. A soil profile description for a typical Paralithic Leptic Tenosol is presented in Table 3.13.

Table 3.13 Paralithic Leptic Tenosol typical soil profile summary

	Horizon name and depth (average) (m)	Colour, mottles and bleach	Moisture, lab pH (median) and drainage	Texture, structure and consistence	Coarse fragments, segregations and roots
	A11 0-0.12	Yellowish brownish, no mottles and no bleaching.	Dry, pH 4.6 and rapidly drained.	Clayey sand, granular and loose.	Few surface coarse fragments, few coarse fragments, no segregations and few roots.
	A12 0.12-0.31	Yellowish brownish, few orange mottles and no bleaching.	Dry, pH 4.4 and rapidly drained.	Clayey sand, granular and loose.	Few coarse fragments, no segregations and few roots.
	A21 0.31-0.53	Brownish yellow, few orange mottles and no bleaching.	Dry, pH 4.4 and rapidly drained.	Loamy sandy, granular and loose.	Few coarse fragments, no segregations and no roots.
	A21 0.53-0.74	Pale yellow, few orange mottles and no bleaching.	Dry, pH 4.4 and rapidly drained.	Loamy sandy, granular and loose.	Few coarse fragments, no segregations and no roots.

Note: 1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).

Laboratory analysis of particle size distribution was carried out on a representative soil profile, and the results are presented in Table 3.14.

Table 3.14 Particle size analysis – paralithic leptic tenosol (Site 287)

Horizon	Depth	Clay (<2 µm)	Silt (2-60 µm)	Sand (0.06-2.00 mm)	Gravel (>2mm)
	mm	%	%	%	%
A1	0-10	11	8	80	1
A1	10-20	12	10	78	<1
A2	20-30	15	10	75	<1
B2	50-60	16	11	73	<1
B2	70-75	19	11	70	<1

The Paralithic Leptic Tenosol soil unit occurs on rises and low hills on the Hawkesbury Sandstone formation (sandstone-quartz) and less commonly on depositional foot slopes on shale geology. Their location is independent of elevation, with Tenosols just as likely to be present on low gradient hilltops as in stable low lying areas. Within the project area, they are most commonly found within and immediately surrounding the Belanglo State Forest. A transitional Tenosol (grading to a Kandosol) was recorded on an isolated sandstone outcrop to the east of Belanglo State Forest. Within the project area, land use on this soil type is typically for native and pine forestry (see Photograph 3.3), with low intensity grazing in some locations.

Photograph 3.3 Paralithic Leptic Tenosol (site 300)

Paralithic Leptic Tenosols are typically extremely acidic, highly permeable, rapidly drained and non-saline. The pH of the soils in this soil unit are below 5.5, and are therefore generally unsuitable for cultivation, and restricted to grazing, forestry and nature conservation (EOH 2012). The macronutrients (nitrogen, phosphorous, and potassium) and the micronutrients (copper, zinc, iron, manganese, boron) are mostly low which could restrict agriculture, although fertiliser could amend these concentrations. The cation exchange capacity (CEC) is also very low, which also may present some fertility issues.

All soil chemistry results are given in Table 3.15. The soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column, and are in reference to the median values with increasing depth. A summary of the agricultural potential of Paralithic Leptic Tenosols is given in Table 3.16.

Table 3.15 Paralithic Leptic Tenosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A11 0-0.12	A12 0.12-0.31	A21 0.31-0.53	A22 0.53-0.74	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	4.6 (4.0-4.6)	4.4 (4.3-4.5)	4.4 (4.4-4.5)	4.4 (4.3-7.4)	Very strong (A11 horizon) to extreme acidity (below A11).
EC_{se}	dS/m	<1.9	1.17 (0.36-2.53)	0.39 (0.26-0.62)	0.26 (0.17-0.38)	0.17 (0.08-0.24)	Low (A11 horizon) to very low soil salinity (below A11 horizon).
Chloride (Cl^-)	mg/kg	<800	20 (20-50)	50 (30-110)	150 (50-880)	290 (50-1500)	Not restrictive.
PAWC	mm	>80	4.8 (S-ZL)	7.6 (LS-ZL)	8.8 (LS-CLS)	8.4 (LS-CLS)	Very small (total of 29.6).
Macronutrients							
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	19.8 (0.4-87.1)	10.4 (1.4-13.0)	6.0 (1.2-9.9)	1.1 (0.6-2.8)	Moderate (A11 horizon) to very low (below A11 horizon).
Total Nitrogen as N	mg/kg	>1500	980 (270-2540)	550 (280-1150)	530 (280-740)	230 (140-320)	Deficient.
P (Colwell)	mg/kg	>10	11 (9-13)	3 (3-3)	2 (<2-2)	2 (<2-2)	Moderate (A11 horizon) to very low (below A11 horizon).
K (Acid Extract)	mg/kg	>117	<100 (<100-100)	<100 (<100-<100)	<100 (<100-<100)	<100 (<100-200)	Low (inconclusive).
K (Total)	mg/kg	>150	165 (60-310)	150 (80-160)	165 (80-240)	140 (80-280)	Moderate (A11 horizon) to low (gen. below A11 horizon).
Micronutrients							
Cu	mg/kg	>0.3	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	Low (inconclusive).
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	<1.0 (<1.0-8.1)	<1.0 (<1.0-<0.1)	<1.0 (<1.0-2.9)	<1.0 (<1.0-2.0)	Low (inconclusive).
Mn	mg/kg	>2	7.7 (<1.0-19.3)	<1.0 (<1.0-1.5)	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	Moderate (A11 horizon) to very low (below A11 horizon).
B	mg/kg	>1	1.6 (0.4-5.0)	0.5 (0.4-3.4)	0.5 (0.5-3.0)	0.5 (0.4-2.6)	Moderate (A11 horizon) to very low (below A11 horizon).

Table 3.15 Paralithic Leptic Tenosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A11 0-0.12	A12 0.12-0.31	A21 0.31-0.53	A22 0.53-0.74	Comments on median values (in increasing depth)
Exchangeable cations							
CEC	meq/100g	12-25	2.15 (1.2-4.0)	1.40 (1.1-2.3)	0.85 (0.6-2.3)	0.60 (0.1-1.3)	Very low.
Ca	meq/100g	>5	3.2 (2.2-5.7)	3.0 (0.2-3.6)	2.7 (0.3-10.7)	2.2 (0.2-12.8)	Low.
Mg	meq/100g	>1	3.1 (1.7-4.7)	3.2 (0.4-4)	3.8 (0.5-12.7)	4.8 (1-19.8)	Moderate.
Na	meq/100g	<0.7	0.5 (0.5-0.5)	0.5 (0.1-0.5)	0.4 (0.1-1.1)	0.6 (0.2-2.1)	Very low.
K	meq/100g	>0.3	0.3 (0.2-0.3)	0.1 (0.1-0.1)	0.1 (0.1-0.3)	0.1 (0.1-0.2)	Very low.
ESP	%	<6	<2.38* (1.54-4.46)	<6.81* (1.45-12.5)	<4.44* (3.08-16.70)	5.89* (3.33-16.42)	Generally non-sodic though sodic in A12 horizon.
Ca:Mg ratio		>2	1.21 (1.03-1.29)	0.85 (0.5-1.1)	0.56 (0.2-0.84)	0.47 (0.2-0.65)	Moderate (A11 horizon) to strongly unstable (below A11).
Organic Carbon	%	>1.2	3.1 (2.4-5.0)	1.4 (0.6-1.9)	1.0 (0.5-4.5)	0.95 (0.8-1.1)	High (A11 horizon) to low (A21 and A22).

Notes: *1. Sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).*
2. Values in brackets are the ranges measured.
** These values are an approximation based on calculations using the lowest measurable level.*

Table 3.16 Paralithic Leptic Tenosol soil chemistry summary

Elements	Comments
pH_{water}	Very strongly acid at the surface, progressing to extreme acidity with depth. Outside of the desirable range for agriculture throughout most of the profile. Would restrict agriculture.
EC	Low to very low soil salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
PAWC	At the upper limit of a small PAWC, which would restrict agriculture.
Fertility	
Macronutrients	Moderate to mostly low levels of macronutrients, which present fertility issues. Would restrict agriculture.
Micronutrients	Mostly low to very low levels of micronutrients, which present fertility issues. Would restrict agriculture.
CEC	Very low CEC, which may present some fertility issues.

Table 3.16 Paralithic Leptic Tenosol soil chemistry summary

Elements	Comments
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Low - Tenosols (order), Leptic (sub-order), Any (Great Group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Low (Group 1) **Explanation (Murphy et al. 2007):** Soils which, due to their poor physical and/or chemical status, only support limited agriculture. The maximum agricultural use of these soils is low intensity grazing. Include sandy soils which by virtue of their poor water retention characteristics, can only support limited agriculture.
ESP	ESP indicating a sodic soil. The low sodium levels for all samples analysed make it difficult to be conclusive in the topsoil.
Ca:Mg ratio	A moderate Ca:Mg ratio in the topsoil, but decreasing with depth to levels that suggest soil instability.
Organic Carbon	Indicative of good structural condition and structural stability in the A1 horizons. Low levels below this horizon.
Major limitations to agriculture	pH ; PAWC; Macronutrients (eg nitrate, total nitrogen, phosphorus, potassium extract) Micronutrients (eg manganese, boron, calcium, magnesium, sodium, potassium)

3.3.5 Kandosolic Redoxic Hydrosol

Kandosolic Redoxic Hydrosols are weakly to moderately developed, with variable textures and colour grades depending on the localised site morphology. A horizons are silty clay loam to light clay grading with depth towards medium to heavy clay B horizons. Surface condition is cracked and without coarse fragments. They have no coarse fragments throughout the profile. Orange mottles may be present at depth. Subsoils typically have no segregations. A soil profile description for a typical Kandosolic Redoxic Hydrosol is provided in Table 3.17.

Table 3.17 Kandosolic Redoxic Hydrosol typical soil profile summary

ASC:	Horizon name and depth (average) (m)	Colour, mottles and bleach	Moisture, laboratory pH (median value) and drainage	Texture, structure and consistence	Coarse fragments, segregations and roots
	A11 0-0.18	Yellowish brown, no mottles and no bleaching.	Moderately moist, pH 4.5 and poorly drained.	Light clay, sub-angular blocky and moderately weak force.	No surface coarse fragments, no coarse fragments, no segregations and many roots.
	A12 0.18-0.33	Yellowish brown, few orange mottles and no bleaching.	Moist, pH 5.2 and poorly drained.	Light clay, sub-angular blocky and moderately weak force.	No coarse fragments, no segregations and few roots.
	B21 0.33-0.58	Very dark greyish brown, few orange mottles and no bleaching.	Wet, pH 5.0 and poorly drained.	Light-medium clay, massive and moderately weak force.	No coarse fragments, no segregations and few roots.
	B22 0.58-0.80+	Dark greyish brown, common orange mottles and no bleaching.	Moist, pH 4.9 and poorly drained.	Medium-heavy clay, massive and very firm force.	No coarse fragments, no segregations and few roots.

Note: 1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).

Kandosolic Redoxic Hydrosol have moderately low fertility, are strongly acidic, slowly permeable, poorly drained, sodic in the B horizon and are moderately saline in the A horizon. The soils in this soil unit are therefore generally unsuitable for cultivation, and restricted to grazing (EOH 2012).

All soil chemistry results are given in Table 3.18. The soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column, and are in reference to the median values with increasing depth. A summary of the agricultural potential of Kandosolic Redoxic Hydrosol is given in Table 3.19.

The Kandosolic Redoxic Hydrosol is limited to drainage depressions and associated floodplains that experience regular inundation. This soil unit is spread throughout the project area and is directly associated with drainage lines and water bodies. Within the project area, land use on this soil type is generally for improved and native pastures (see Photograph 3.4).

Photograph 3.4 Kandosolic Redoxic Hydrosol (site 92)

Table 3.18 Kandosolic Redoxic Hydrosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A11 0-0.18	A12 0.18-0.33	B21 0.33-0.58	B22 0.58-0.80+	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	4.5 (3.7-5.2)	5.2 (3.8-5.2)	5.0 (4.0-5.1)	4.9 (4.3-6.5)	Extreme (A11 horizon) to very strong acidity (A12 and below).
EC_{se}	dS/m	<1.9	1.39 (0.89-4.46)	0.20 (0.19-1.02)	0.32 (0.13-3.27)	0.37 (0.13-5.53)	Low soil salinity.
Cl^-	mg/kg	<800	20 (20-50)	50 (30-110)	150 (50-880)	290 (50-1500)	Not restrictive.
PAWC	mm	>80	18.0 (ZL-MC)	15.0 (LC-LMC)	30.0 (LC-HC)	26.4 (LC-HC)	Moderate (total of 89.4).
Macronutrients							
Total Nitrogen as N	mg/kg	>1500	2540 (2320-2900)	1295 (670-1760)	890 (440-2000)	745 (400-1320)	Sufficient (A11 horizon) to deficient (below A12 horizon)
P (Colwell)	mg/kg	>10	11 (9-13)	2 (<2-3)	2 (<2-2)	2 (<2-2)	Moderate (A11 horizon) to very low (A12 and below).
K (Acid Extract)	mg/kg	>117	200 (100-200)	<100 (<100-<100)	<100 (<100-<100)	<100 (<100-100)	Moderate (A11 horizon) to low – insufficient (A12 horizon and below).
K (Total)	mg/kg	>150	490 (360-680)	380 (150-520)	450 (180-930)	455 (360-1040)	Very high.

Table 3.18 Kandosolic Redoxic Hydrosol soil chemistry result medians (and ranges)

Constituents	Unit	Soil sufficiency[1]	A11 0-0.18	A12 0.18-0.33	B21 0.33-0.58	B22 0.58-0.80+	Comments on median values (in increasing depth)
Micronutrients							
Cu	mg/kg	>0.3	1.91 (<1-3.1)	1.78 (<1-2.5)	1.05 (<1-1.9)	1.10 (<1-1.8)	Moderate.
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	2.3 (1.9-2.8)	<1.0 (<1.0-<0.1)	<1.0 (<1.0-1.1)	<1.0 (<1.0-<1.0)	High (A11 horizon) to low (inconclusive) (A12 and below).
Mn	mg/kg	>2	39.5 (31.4-123.0)	93.8 (4.25-138.0)	<1.0 (<1.0-78.8)	<1.0 (<1.0-17.9)	High (A horizon) to very low (B horizon).
B	mg/kg	>1	1.40 (1.4-1.6)	0.75 (0.6-1)	0.80 (0.6-1.8)	0.75 (0.3-1.8)	Moderate (A11 horizon) to low (A12 horizon and below).
Exchangeable cations							
CEC	meq/ 100g	12-25	6.50 (4.2-11.2)	7.00 (0.8-7.6)	6.50 (0.7-24.8)	7.95 (1.6-34.9)	Low.
Ca	meq/ 100g	>5	3.20 (2.2-5.7)	3.00 (0.2-3.6)	2.75 (0.3-10.7)	2.20 (0.2-12.8)	Low.
Mg	meq/ 100g	>1	3.10 (1.7-4.7)	3.25 (0.4-4.0)	3.80 (0.5-12.7)	4.80 (1.0-19.8)	High.
Na	meq/ 100g	<0.7	<0.10 (<0.1-0.5)	0.30 (<0.1-0.5)	0.40 (0.1-1.1)	0.50 (<0.1-2.1)	Low to moderate.
K	meq/ 100g	>0.3	0.3 (0.2-0.3)	0.1 (<0.1-0.1)	0.1 (<0.1-0.3)	0.1 (<0.1-0.2)	Low to very low.
ESP	%	<6	2.40 (<1.5*-4.5)	6.81 (1.5-<12.5*)	4.40 (3.1-16.7)	5.90 (<3.3*-16.4)	Non-sodic to sodic.
Ca:Mg ratio		>2	1.2 (1.0-1.3)	0.9 (0.5-1.1)	0.6 (0.2-0.8)	0.5 (0.2-0.7)	Unstable to strongly unstable.
Organic Carbon	%	>1.2	3.1 (2.4-5.0)	1.4 (0.6-1.9)	1.0 (<0.5-4.5)	0.9 (<0.5-1.1)	Very high to low.

Notes: *1. Sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).*

2. Values in brackets are the ranges measured.

** These values are an approximation based on calculations using the lowest measurable level.*

Table 3.19 Kandosolic Redoxic Hydrosol soil chemistry summary

Elements	Comments
pH_{water}	Varying from extremely to very strongly acidic throughout the profile. Outside of the desirable range for agriculture. Would restrict agriculture.
EC	Moderate to low soil salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
PAWC	A moderate PAWC, which would not restrict agriculture.

Table 3.19 Kandosolic Redoxic Hydrosol soil chemistry summary

Elements	Comments
Fertility	
Macronutrients	Very high to very low levels of nitrogen in the A horizons. Moderate to low levels of phosphorus and potassium extract in the A horizons. Mostly low levels of macronutrients in the B horizons. Would restrict agriculture.
Micronutrients	Variable levels of macronutrients in the A horizons, ranging from high to low depending on the parameter, and generally decreasing to moderate to very low levels in the B horizons. Would restrict agriculture.
CEC	Low CEC levels throughout the soil. Would restrict agriculture.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately low - Hydrosol (order), Redoxic (sub-order), any but some Sulfuric (Great Group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderately low (Group 2) **Explanation (Murphy et al. 2007):** Low fertilities that generally only support plants suited to grazing. Large inputs of fertiliser are required to make soil usable for arable purposes. Generally deficient in nitrogen, phosphorus and many other elements.
ESP	ESP indicating sodic soils. Would restrict agriculture.
Ca:Mg ratio	Unstable Ca:Mg ratio indicating soil instability.
Organic Carbon	Indicative of good structural condition and structural stability in the upper A horizon, but reducing with depth to low levels. Would not restrict agriculture.
Major limitations to agriculture	pH Macronutrients (eg phosphorus, potassium extract) Micronutrients (eg boron, calcium, potassium) Sodicity

3.3.6 Eutrophic Grey Dermosol

Eutrophic Grey Dermosol soils are moderately to well developed, depending on the landform element with which they are associated. The soil lacks strong texture contrast and has increasing clay content with depth. A horizons are typically greyish brown silty loam over grey medium to heavy clay B horizons. The soil surface is mostly without coarse fragments and of firm to cracked condition. Eutrophic Grey Dermosols generally have few or no coarse fragments in the lower A and upper B horizons with coarse fragments more common in the lower B horizon. Subsoils commonly have red and orange mottling with no segregations. A soil profile description for a typical Eutrophic Grey Dermosols is provided in Table 3.20.

Table 3.20 Eutrophic Grey Dermosol typical soil profile summary

ASC:	Horizon name and depth (m) (average)	Colour, mottles and bleach	Moisture, laboratory pH (median value) and drainage	Texture, structure and consistence	Coarse fragments, segregations and roots
	A1 0-0.18	Dark greyish brown, no mottles and no bleaching.	Moist, pH 4.9 and moderately well drained.	Silty loam, sub-angular blocky and moderately weak force.	No surface coarse fragments, no coarse fragments, no segregations and many roots.
	A2 0.18-0.30	Dark greyish brown, few red mottles and no bleaching.	Moderately moist, pH 4.8 and imperfectly drained.	Silty clay loam, sub-angular blocky and very firm force.	No coarse fragments, no segregations and common roots.
	B21 0.30-0.50	Greyish brown, common orange mottles and no bleaching.	Moderately moist, pH 5.1 and imperfectly drained.	Medium heavy clay, sub-angular blocky and very firm force.	Few coarse fragments, no segregations and few roots.
	B22 0.50-0.67	Grey, many orange mottles and no bleaching.	Dry, pH 6.8 and poorly drained.	Heavy clay, sub-angular blocky and moderately strong force.	Few coarse fragments, no segregations and few roots.

Note: 1. Description in accordance with the Australian Soil and Land Survey Field Handbook (NCST 2009).

Eutrophic Grey Dermosols occur on gently to moderately inclined rolling low hills to rolling hills on small, randomly distributed, isolated basalt intrusions. Within the project area, land use on this soil type is for grazing of native and improved pastures (Photograph 3.5). Eutrophic Grey Dermosols appear to be limited to the small, randomly distributed, isolated basalt intrusions. They were not recorded away from these surface geology expressions.

Photograph 3.5 Eutrophic Grey Dermosol (site 632)

Eutrophic Grey Dermosols are of moderately high fertility, moderately permeable, poorly drained and have moderate to low salinity. They have sodic B horizons and very strongly acidic A horizons.

Soil chemistry results are given in Table 3.21, the soil chemistry constituent values highlighted in the 'soil sufficiency' column are agricultural industry benchmarks (Baker and Eldershaw 1993; Department of the Environment and Resource Management (DERM) 2011; Peverill, Sparrow and Reuter 1999) and have been referenced in interpreting the laboratory results. The outcomes are presented in the comments column, and are in reference to the median values with increasing depth. A summary of the agricultural potential of Eutrophic Grey Dermosols is given in Table 3.22.

Table 3.21 Eutrophic Grey Dermosol soil chemistry results – median values (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.18	A2 0.18-0.30	B21 0.30-0.50	B22 0.50-0.67	Comments on median values (in increasing depth)
pH_{water}	pH units	6.0-7.5	4.9 (4.5-5.4)	4.8 (4.7-4.9)	5.1 (4.8-7.4)	6.8 (5.2-8.3)	Very strong acidity (A1 to B21 horizons) to neutral (B22).
EC_{se}	dS/m	<1.9	1.51 (0.26-2.37)	0.56 (0.13-0.98)	0.22 (0.07-1.10)	1.21 (0.05-2.36)	Moderate to low soil salinity.
Cl^-	mg/kg	<800	10 (<10-10)	10 (10-10)	20 (10-140)	105 (30-200)	Not restrictive.
PAWC	mm	>80	10.8 (ZL-ZCL)	9.6 (ZL-ZCL)	24.0 (MC-HC)	20.4 (MC-HC)	Small (total of 64.8).

Table 3.21 Eutrophic Grey Dermosol soil chemistry results – median values (and ranges)

Constituents	Unit	Soil sufficiency[1]	A1 0-0.18	A2 0.18-0.30	B21 0.30-0.50	B22 0.50-0.67	Comments on median values (in increasing depth)
Macronutrients							
Nitrite + Nitrate as N (Sol.)	mg/kg	>15	104.70 (14-164)	36.60 (1.2-71.9)	1.60 (1.1-5.8)	0.35 (0.3-0.4)	Very high (A horizon) to very low (B horizon).
Total Nitrogen as N	mg/kg	>1500	3690 (1510-5650)	2645 (1240-4050)	990 (900-1330)	635 (560-710)	Sufficient (A) to deficient (B).
P (Colwell)	mg/kg	>10	12.0 (3.0-25.0)	8.5 (2.0-15.0)	<2.0 (<2.0-<2.0)	<2.0 (<2.0-<2.0)	Moderate (A1), low (A2) to very low (B).
K (Acid Extract)	mg/kg	>117	200 (100-400)	200 (<100-300)	<100 (<100-<100)	<100 (<100-100)	Moderate (A) to low - insufficient (B).
K (Total)	mg/kg	>150	595 (370-840)	515 (320-710)	570 (490-740)	570 (490-650)	Very high.
Micronutrients							
Cu	mg/kg	>0.3	1.51 (<1.00-1.71)	<1.00 (<1.00-<1.00)	<1.00 (<1.00-<1.00)	<1.00 (<1.00-<1.00)	Moderate (A1) to low -inconclusive (A2 horizon and below).
Zn	mg/kg	>0.5 (pH<7) >0.8 (pH>7)	<1.0 (<1.0-8.1)	<1.0 (<1.0-<0.1)	<1.0 (<1.0-<1.0)	<1.0 (<1.0-<1.0)	Low (inconclusive).
Mn	mg/kg	>2	45.10 (37.9-51.8)	31.30 (28.4-34.1)	1.23 (<1.0-1.46)	<1.00 (<1.0-<1.0)	Very high (A) to low (B21) to very low (B22).
B	mg/kg	>1	1.65 (0.8-2.4)	1.60 (1.2-2.0)	1.20 (0.7-1.7)	0.45 (0.4-0.5)	Moderate (A1 to B21) to very low (B22).
Exchangeable cations							
CEC	meq/ 100g	12-25	8.55 (6.9-10.4)	8.25 (6.6-9.9)	17.90 (12.0-21.0)	16.80 (12.6-21.0)	Low (A horizon) to moderate (B horizon).
Ca	meq/ 100g	>5	6.0 (5.0-6.9)	5.7 (4.4-6.9)	6.5 (5.4-7.1)	5.5 (4.7-6.2)	Moderate.
Mg	meq/ 100g	>1	2.1 (1.5-2.8)	2.1 (1.8-2.4)	10.6 (4.9-12.4)	9.9 (5.6-14.1)	Moderate (A horizon) to high (B horizon).
Na	meq/ 100g	<0.7	0.10 (<0.1-0.2)	0.15 (<0.1-0.2)	1.30 (0.4-1.4)	1.25 (0.4-2.1)	Low (A horizon) to moderate (B horizon).
K	meq/ 100g	>0.3	0.4 (0.2-0.6)	0.4 (0.2-0.6)	0.3 (0.2-0.5)	0.2 (0.1-0.3)	Moderate (A horizon) to low (B horizon).
ESP	%	<6	<1.20* (0.96-2.9)	2.00 (1.0-3.0)	6.19 (3.3-7.8)	6.60 (3.2-10.0)	Non-sodic (A horizon) to sodic (B horizon).
Ca:Mg ratio		>2	3.00 (2.5-3.4)	2.70 (2.4-2.9)	0.57 (0.5-1.3)	0.72 (0.3-1.1)	Stable (A horizon) to strongly unstable (B).
Organic Carbon	%	>1.2	3.75 (1.6-4.9)	2.80 (1.3-4.3)	1.00 (0.7-1.1)	<0.50 (<0.5-0.5)	Very high (A horizon) to very low (B).

Notes: *1. Sources: Baker and Eldershaw (1993), DERM (2011) and Peverill, Sparrow and Reuter (1999).*

2. Values in brackets are the ranges measured.

** These values are an approximation based on calculations using the lowest measurable level.*

Table 3.22 Eutrophic Grey Dermosol soil chemistry summary

Elements	Comments
pH_{water}	Very strongly acidic at the surface grading to neutral in the subsoil. Outside of the desirable range for agriculture in the upper profile. Would restrict agriculture.
EC	Moderate to low soil salinity levels that would not restrict agriculture.
Cl	Acceptable chloride levels that would not restrict agriculture.
PAWC	A small PAWC, which would restrict agriculture.
Fertility	
Macronutrients	Moderate to high levels of macronutrients in the A horizon. Would not restrict agriculture. Note: there was evidence of recent cultivation at the detailed survey sites on this soil type and demonstrated field and laboratory signs of recent fertiliser application, including non-soil related white substance noted in the field and high nutrient levels in the A horizon.
Micronutrients	Moderate to low levels of micronutrients in the A horizon. Would not restrict agriculture.
CEC	Low CEC levels in the A horizon, which may present some fertility issues.
Fertility ranking	**Relative Fertility of ASC Classes (NSW Government 2013):** Moderately high - Dermosol (order), any (sub-order), Eutrophic (Great Group) **EMM applied Relative Fertility of ASC Classes (lab and field data applied to Murphy et al. 2007):** Moderate (Group 3) **Explanation (Murphy et al. 2007):** Soils have moderate fertility and usually require fertiliser and/or have some physical restrictions for arable use. Soils within this group are moderately deficient in nitrogen, phosphorus and some other elements. The grey, red and brown clays have a somewhat better chemical status than the other soils within this group. The high clay content and strongly coherent nature of some subsoils restrict water and root penetration. Note: The laboratory results class the soil as moderately high to high fertility, particularly with the very high nitrogen and total potassium levels recorded in the A horizon. However, the moderate to very low levels of most other macronutrients and micronutrients indicated by the laboratory results, particularly below 30 centimetres depth, suggest moderate natural fertility. Field and laboratory results suggest recent application of fertiliser.
ESP	ESP indicating a sodic subsoil that would restrict agriculture.
Ca:Mg ratio	Stable Ca:Mg ratio in the topsoil, but decreasing with depth to levels that suggest soil instability.
Organic Carbon	Indicative of good structural condition and structural stability in the A horizon, but reducing with depth to low levels. Would not restrict agriculture.
Major limitations to agriculture	Surface pH PAWC Subsoil sodicity

3.4 LSC assessment

The LSC classes of the project area were assessed in accordance with the requirements of the *Land and soil capability assessment scheme* (OEH 2012). The assessment used the information collected during the soil survey (EMM 2015) and information gathered during the desktop assessment for the current study.

The assessment classifies soils and landscape characteristics against eight decision tables that use landscape, soils and climate data on the various hazards or limitations to allocate land to an LSC class based on each hazard or limitation (OEH 2012). Each hazard is assigned one of eight LSC classes where Class 1 represents the least limitation and Class 8 represents the greatest limitation; each is assessed individually to develop a profile of hazards for the parcel of land being assessed. The final hazard assessment for a parcel of land is based on the highest hazard in that parcel of land (OEH 2012). A map has been produced that shows the spatial distribution of the LSC classes (Figure 3.7), and Table 3.23 shows the number of hectares of each land class.

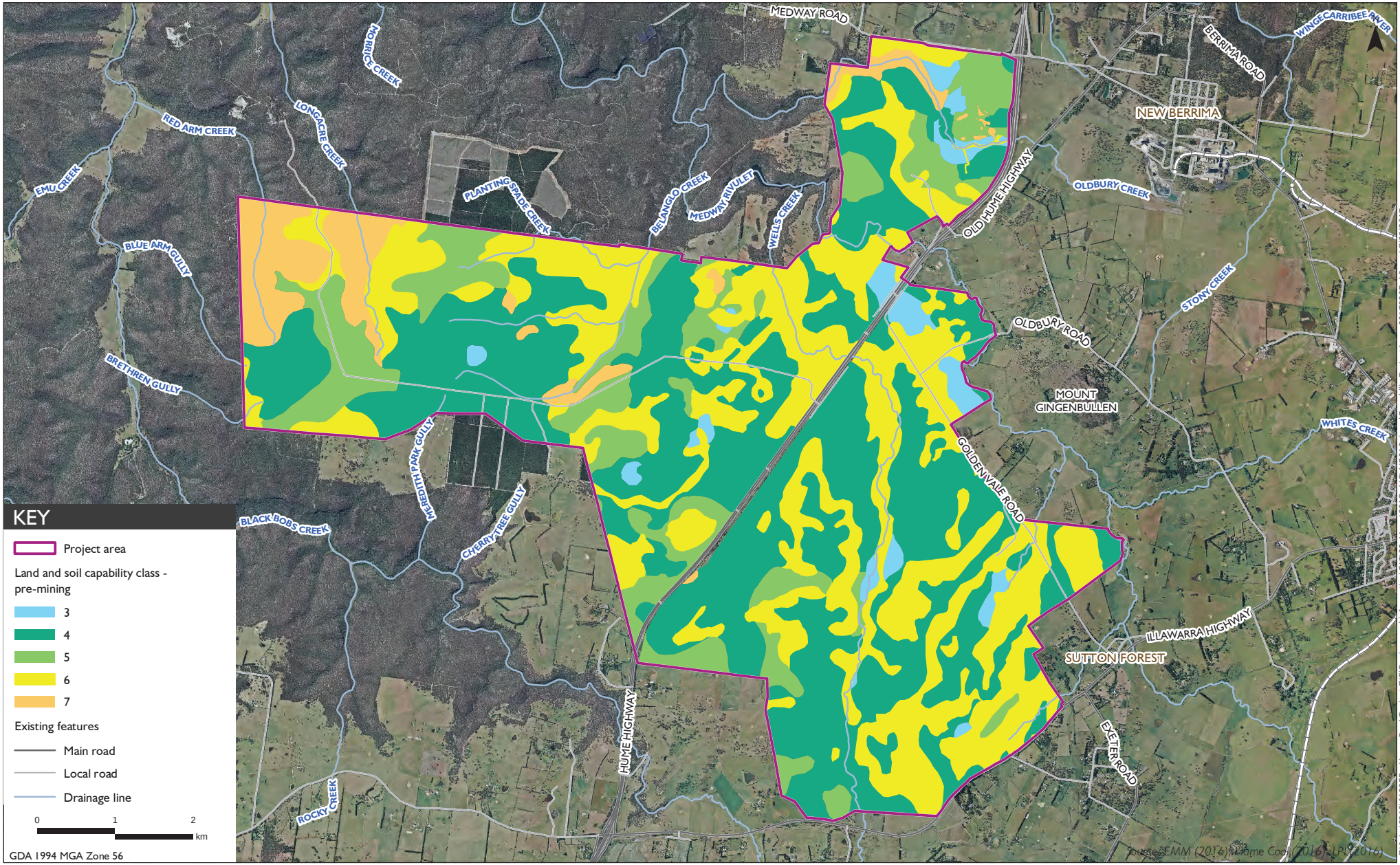
The LSC assessment has mapped 58% of the project area as moderate (Class 4 – 44%) to moderate-low (Class 5 – 14%) capability land. This means that the land has moderate to high limitations for high – impact land uses, which will restrict cropping, high intensity grazing and horticulture (OEH 2012). These limitations can only be managed with the implementation of suitable soil conservation measures.

High capability land is mapped on 3% of the project area. There is no extremely high or very high capability land in the project area. It should be noted that none of the areas mapped as Class 3 were greater than 20 ha. OEH states that 20 ha is the minimum area required for commercial food production and therefore, use this as a requirement for defining BSAL in the interim protocol (DP&E 2015).

The project area has 32% (Class 6) mapped as low capability – suitable for a limited set of land uses such as grazing, forestry and nature conservation. Very low capability land (Class 7) is mapped for 6% of the project area, suitable for selective forestry and nature conservation.

Table 3.23 Land and soil capability classes in the project area – pre-mining

Class	Capability	Land in the project area	Hectares (ha)	%
Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation)				
1	Extremely high	None	0	
2	Very high	None	0	
3	High	Kandosols (areas restricted in size)	144	3%
Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, etc)				
4	Moderate	Kandosols	2221	44%
5	Moderate–low	Poorly drained Kandosols, slightly acidid tenosols and Kandosols	704	14%
Land capable for a limited set of land uses (grazing, forestry and nature conservation)				
6	Low	Hydrosols, Acidic Tenososls Soils with steep slopes or shallow soils	1641	32%
Land generally incapable of agricultural land use (selective forestry and nature conservation)				
7	Very low	Shallow soils (mostly Rudosols and Tenosols)	300	6%
8	Extremely low			
	None	Waterbody, Hume Highway, etc	41	1%



Land and soil capability of project area (EMM mapping)

Hume Coal Project

Agricultural Impact Statement

Figure 3.7

3.5 Biophysical strategic agricultural land assessment

EMM undertook a detailed biophysical strategic agricultural land assessment (BSAL) of the project area to determine if BSAL was present. The assessment was carried out in accordance with the Interim protocol. The BSAL assessment (EMM 2015) determined that no BSAL occurs within the project area. A Site Verification Certificate (SVC) was lodged on 17 August 2015 and issued on 22 April 2016.

For land to be classified as BSAL it must have access to a reliable water supply; meet all of the criterion; and be a contiguous area of at least 20 ha. Under the Interim Protocol if any individual criterion is not met, the site is not BSAL.

Each soil type identified in the project area was assessed against the specified BSAL verification criteria and no soil type was found to satisfy the criteria, with most failing multiple physical and chemical soil criterion. In addition, an analysis of slope in the project area determined that some land failed the slope criteria. There is no BSAL in the project area, a conclusion that is consistent with the results of the broader scale NSW Government's BSAL mapping (NSWDPE 2015).

The BSAL verification criteria have been evaluated for the project area, based on analysis of field, laboratory and remotely sensed data obtained during the soil survey assessment (Section 3.3). The evaluation is summarised below.

3.5.1 Slope

A slope assessment for the entire assessment area was conducted using a digital elevation model and site observations were made using a hand held clinometer. Areas with slopes greater than 10% were identified as BSAL exclusion areas. Slopes (greater than 10%) occupy much of the western part of the project area, mainly associated with ridgelines and watercourses. Lithic Leptic Rudosol was excluded based on slopes.

3.5.2 Rock outcrop

The area of rock outcrop at each site, estimated as a percentage of the site, was determined by visual inspection in the field. Sites with 30% or greater rock outcrop were identified as BSAL exclusion areas.

3.5.3 Surface rockiness

Rockiness refers to the presence of unattached coarse rock fragments and/or rock outcrops at the soil surface. The area of surface rockiness, estimated as a percentage of each survey site, as well as the physical characteristics and size of rock fragments, was determined in the field. Sites with greater than 20% coverage of unattached rock fragments, with diameters larger than 60 mm, were identified as BSAL exclusion areas.

3.5.4 Gilgai

Under the Interim Protocol, sites with average gilgai depressions deeper than 500 mm over more than 50% of the area are identified as BSAL exclusion areas. However, in the project area no significant areas of gilgai were identified and thus no areas were excluded as BSAL on this basis.

3.5.5 Soil fertility

Soil types with fertility less than 'moderate', based on the relative fertility of ASC classes presented in Appendix 2 of the Interim Protocol, were identified as BSAL exclusion areas. This was based on the soil type distribution map presented as Figure 3.6, and supported by laboratory analysis (Section 3.3).

The soils that were excluded based on fertility were:

- Dystrophic Yellow Kandosol which was excluded because of moderately low soil fertility;
- Kandosolic Redoxic Hydrosol which was excluded because of moderately low soil fertility;
- Paralithic Leptic Tenosol which was excluded because of low soil fertility; and
- Lithic Leptic Rudosol which was excluded because of low fertility.

3.5.6 Effective rooting depth

Effective rooting depth refers to the depth of soil in which roots can function effectively. That is, above any physical or chemical barrier. Physical and chemical barriers were identified in the field, and/or by laboratory analysis. In the context of BSAL, the depth of soil from the surface to a physical barrier such as bedrock, weathered rock, hard pans or continuous gravel layers was noted during field surveys. Chemical barriers were identified based on laboratory analysis of soil profile samples, being where limiting values of soil pH, chloride content, electrical conductivity, exchangeable sodium percentage and/or the Ca:Mg ratio exist. Survey sites with a physical or chemical barrier to rooting depth at less than 750 mm were identified as BSAL exclusion areas.

3.5.7 Drainage

The hydrology at the soil survey sites was observed in the field and recorded on *Soil and Land Information System* (SALIS) data cards. Poorly drained sites were identified as BSAL exclusion areas. Poorly drained sites were defined as those in low-lying landscapes with drainage restrictions and potential for waterlogging and comprised the below:

- Eutrophic Grey Dermosol was excluded because of poor drainage; and
- Kandosolic Redoxic Hydrosol was mostly excluded because of poor drainage.

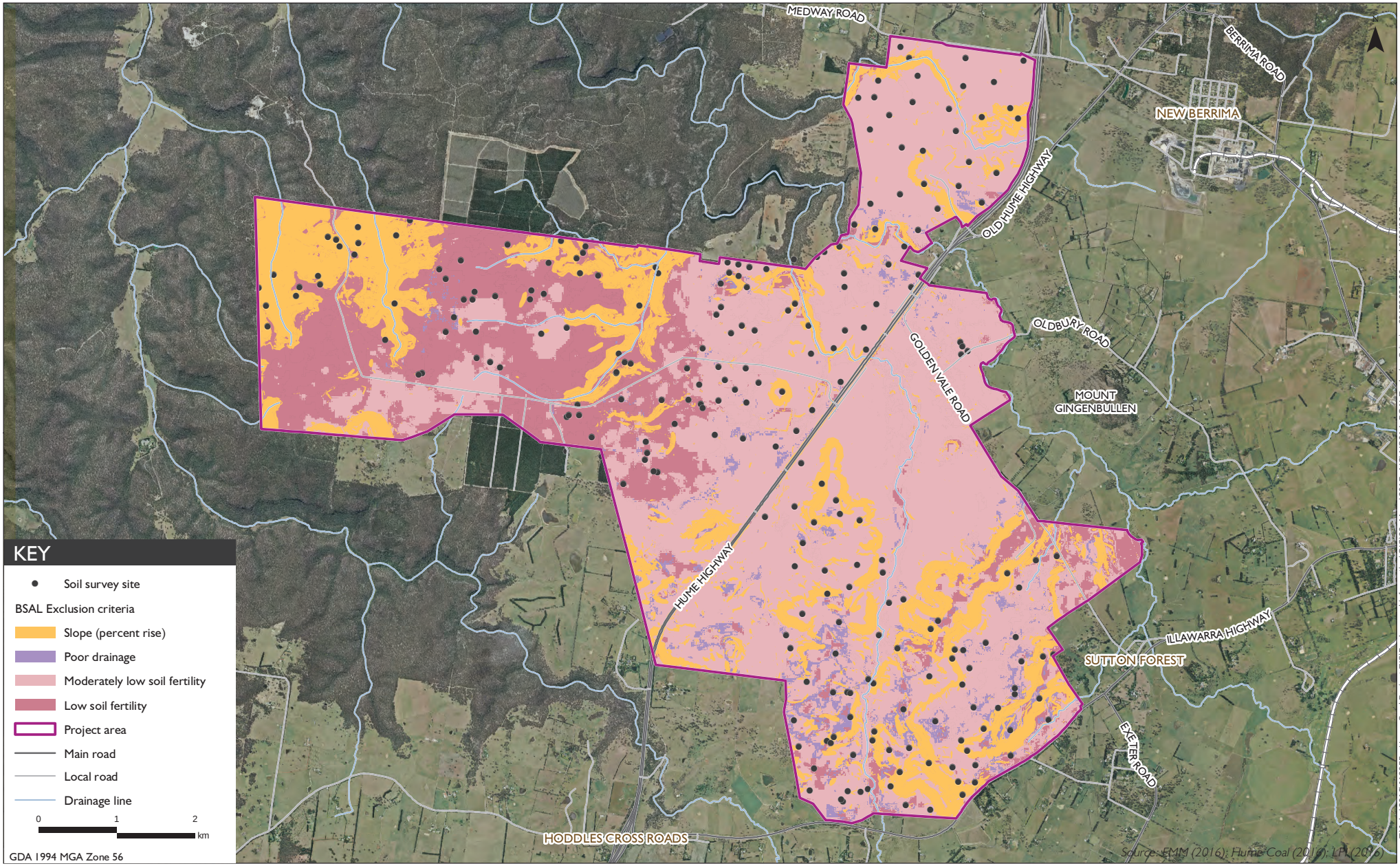
3.5.8 Soil pH

Soil pH was measured in the laboratory and occasionally in the field. Sites where the pH in the uppermost 600 mm of the soil profile was outside of the range 5.0-8.9, measured in water, were identified as BSAL exclusion areas. Many of the sites were excluded based on pH.

3.5.9 Soil salinity

Soil salinity was measured in the laboratory. Sites where soil salinity in the uppermost 600 mm of the soil profile had EC > 4 deciSiemens per metre (dS/m); or the presence of chlorides at 800 milligrams/kilogram (mg/kg) or more, with gypsum present.

The results for each criterion for the individual soil sites, grouped by soil type, are presented in Table 3.24. There are at least three representative detailed sites for each soil type. A BSAL exclusion map (Figure 3.8) shows the areas excluded by slope, waterlogging, and low fertility.



BSAL exclusion map, EMM mapping

Hume Coal Project

Agricultural Impact Statement

Figure 3.8

Table 3.24 BSAL verification assessment by soil survey site

Site[1]	ASC soil type (to Great Group)	BSAL verification criteria															Is the site BSAL?
		Water	1	2	3	4	5	6	7a	7b	8	9	10	11	12	Area	
		Access to reliable water supply?	Slope ≤ 10%?	< 30% rock outcrop?	≤ 20% of area has unattached rock fragments > 60 mm diameter?	≤ 50% of the area has gilgais > 500 mm deep?	Slope < 5 %?	Nil rock outcrops?	Moderate soil fertility?	Moderately high or high soil fertility?	Effective rooting depth to physical barrier is ≥750 mm?	Soil drainage is better than poor?	pH 5-8.9 if measured in water or 4.5-8.1 if measured in calcium chloride, within the uppermost 600 mm of the soil profile?	Salinity is ≤ 4 dS/m or chlorides < 800 mg/kg when gypsum is present, within the uppermost 600 mm of the soil profile?	Effective rooting depth to a chemical barrier is ≥750 mm?	Is the contiguous area ≥20 ha?	
Dystrophic Yellow Kandosol																	
15	Acidic-Mottled Dystrophic Grey Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	N	Y	No
32	Acidic Dystrophic Brown Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	Y	N	Y	No
44	Bleached Mesotrophic Yellow Kandosol	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	No
133	Acidic-Mottled Dystrophic Yellow Kandosol	Y	N	Y	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	No
183	Palic-Acidic Paralithic Leptic Tenosol	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	Y	No
267	Acidic-Sodic Dystrophic Yellow Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	N	Y	N	Y	No
388	Bleached-Mottled Dystrophic Yellow Kandosol	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	No
404	Acidic-Mottled Dystrophic Brown Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	No
472	Acidic-Sodic Dystrophic Yellow Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	N	N	N	Y	No
481	Acidic-Mottled Dystrophic Yellow Kandosol	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	No
502	Mottled Dystrophic Yellow Kandosol	Y	Y	Y	Y	Y	N	Y	N	N	N	Y	N	Y	N	Y	No
592	Haplic Dystrophic Red Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	N	No
594	Mottled Dystrophic Yellow Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	No
595	Haplic Dystrophic Red Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	N	No
596	Mottled Dystrophic Yellow Kandosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	No

Table 3.24 BSAL verification assessment by soil survey site

Site[1]	ASC soil type (to Great Group)	BSAL verification criteria															Is the site BSAL?
		Water	1	2	3	4	5	6	7a	7b	8	9	10	11	12	Area	
		Access to reliable water supply?	Slope ≤ 10%?	< 30% rock outcrop?	≤ 20% of area has unattached rock fragments > 60 mm diameter?	≤ 50% of the area has gilgais > 500 mm deep?	Slope < 5 %?	Nil rock outcrops?	Moderate soil fertility?	Moderately high or high soil fertility?	Effective rooting depth to physical barrier is ≥750 mm?	Soil drainage is better than poor?	pH 5-8.9 if measured in water or 4.5-8.1 if measured in calcium chloride, within the uppermost 600 mm of the soil profile?	Salinity is ≤ 4 dS/m or chlorides < 800 mg/kg when gypsum is present, within the uppermost 600 mm of the soil profile?	Effective rooting depth to a chemical barrier is ≥750 mm?	Is the contiguous area ≥20 ha?	
Paralithic Leptic Tenosol																	
73	Palic-Acidic Paralithic Leptic Tenosol	Y	N	Y	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	No
83	Palic-Acidic Paralithic Leptic Tenosol	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	No
126	Palic-Acidic Paralithic Leptic Tenosol	Y	N	Y	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	No
263	Palic-Acidic Paralithic Leptic Tenosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	No
287	Palic-Acidic Paralithic Leptic Tenosol	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	Y	Y	N	Y	No
300	Palic-Acidic Paralithic Leptic Tenosol	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	N	Y	N	Y	No
Kandosolic Redoxic Hydrosol																	
4	Acidic-Sodic Dermosolic Redoxic Hydrosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	N	N	Y	No
10	Acidic-Sodic Tenosolic Oxyaquic Hydrosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	Y	No
92	Acidic-Sodic Kandosolic Redoxic Hydrosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	N	Y	N	Y	No
238	Acidic-Sodic Kandosolic Redoxic Hydrosol	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	Y	N	Y	No
454	Acidic-Sodic Kandosolic Redoxic Hydrosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	Y	Y	No
524	Acidic-Sodic Kandosolic Redoxic Hydrosol	Y	Y	Y	Y	Y	Y	Y	N	N	Y	N	N	Y	N	Y	No

Table 3.24 BSAL verification assessment by soil survey site

Site[1]	ASC soil type (to Great Group)	BSAL verification criteria															Is the site BSAL?
		Water	1	2	3	4	5	6	7a	7b	8	9	10	11	12	Area	
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Lithic Leptic Rudosol																	
264	Acidic Lithic Leptic Rudosol	Y	N	Y	N	Y	N	N	N	N	N	Y	N	N	N	Y	No
414	Acidic Lithic Leptic Rudosol	Y	N	N	N	Y	N	N	N	N	N	Y	N	Y	N	Y	No
474	Acidic Lithic Leptic Rudosol	Y	N	Y	Y	Y	N	N	N	N	N	Y	Y	Y	Y	Y	No
Eutrophic Grey Dermosol																	
152	Mottled-Sodic Eutrophic Grey Dermosol	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	N	No
181	Acidic-Sodic Eutrophic Brown Dermosol	Y	Y	Y	Y	Y	N	Y	Y	N	Y	N	N	Y	N	N	No
278	Acidic- Mottled Mesotrophic Grey Dermosol	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	N	No

Note: 1. Refer to Figure 2.1 for the locations of survey sites.