Field Soil Observations/Testing

The 1.4 m deep pit profiles were dug with a backhoe and trimmed with a geological pick to allow high resolution photography (4MB SLR images) and description of the undisturbed structure and root growth.

The following characteristics were assessed for the layers identified in each of the soil profiles:

- thickness of each layer (horizon);
- soil moisture status at the time of sampling;
- pH (using Raupach test kit);
- colour of moistened soil (using Munsell reference colours) and mottle characteristics;
- pedality of the soil aggregates;
- amount and type of coarse fragments (gravel, rock, manganese oxide nodules);
- texture (proportions of sand, silt and clay), estimated by hand;
- presence/absence of free lime and gypsum;
- root frequency; and
- dispersibility and the degree of slaking in deionised water (after 10 minutes).

Site factors noted included current land use, landform, slope (measured with a SUUNTO clinometer), aspect, and surface rock. The occurrence of outcropping bedrock was negligible[1] and no gilgai features were observed in the Gateway Certificate Application Area.

Field observations for each pit are presented in Attachments A, B and C.

The soil structure information (Attachment C) has been summarised to give SOILpak 'compaction severity' scores (McKenzie, 2001). This allows deep tillage recommendations to be made from the structure observations. The score is on a scale of 0.0 to 2.0, with a score of 0.0 indicating very poor structure for crop root growth and water entry/storage. Ideally, the SOILpak score of the root zone should be in the range 1.5 to 2.0.

Hand texturing (National Committee on Soil and Terrain, 2009) provides an approximation of the clay content of a soil. In conjunction with the estimation of coarse fragment (gravel) content, it provides a low-cost alternative to particle size analysis.

Total available water (TAW) for the upper 1 m of soil (Attachment A) has been estimated using texture, structural form and coarse fragment content data (McKenzie *et al*., 2008).

[1] No rock outcropping was observed at Sites 1 to 67.

Laboratory Soil Testing

All of the soil pits were sampled for laboratory analysis. The sampling intervals for laboratory analysis were as per the Interim Protocol, i.e. 0 to 5 cm; 5 to 15 cm; 15 to 30 cm; 30 to 60 cm; and 60 to 100 cm. Where important horizon boundaries did not coincide with these depth intervals, extra samples were taken to ensure that distinctive horizons (e.g. A2 horizons) were kept separate for analysis.

The soil was analysed by Incitec-Pivot Laboratory, Werribee Victoria for exchangeable cations, pH, EC, chlorides, nutrient status (nitrate-nitrogen, phosphorus, sulfur, zinc, copper, boron) and organic matter content (Attachment D). An ammonium acetate method was used for the extraction of exchangeable cations. The CEC values are the sum of exchangeable sodium, potassium, calcium, magnesium and aluminium; exchangeable sodium data are presented as exchangeable sodium percentage (ESP). Phosphorus was determined using the Colwell method, sulphur by the CPC method, boron by a calcium chloride ($CaCl_2$ extraction) and zinc/copper by a DTPA extraction (see Rayment and Lyons [2011] for further details). These methods are compatible with the key components of the Interim Protocol.

Soil dispersibility, as measured by the Aggregate Stability in Water (ASWAT) test (Field *et al.*, 1997), was assessed by Soil Management Designs in Orange, NSW. The results are presented in Attachment D. The ASWAT test has been related to the well-known Emerson aggregate stability test by Hazelton and Murphy (2007) – see Table 5. An advantage of the ASWAT test is that the results can be linked with management issues such as the need for gypsum application and avoidance of wet working (McKenzie, 2013) (Figure 9). The conversion factors of Slavich and Petterson (1993) allowed the electrical conductivity of saturated paste extracts (ECe) to be calculated from the EC of 1:5 soil:water suspensions ($EC_{1:5}$) and texture.

Table 5. The Relationship Between the Emerson Aggregate Stability Test and the ASWAT Test

Dispersibility	Emerson Aggregate Classes	Probable score for the ASWAT test (Field *et al.*, 1997)
Very high	1 and 2(3)	12-16
High	2(2)	10-12
High to moderate	2(1)	9-10
Moderate	3(4) and 3(3)	5-8
Slight	3(2), 3(1) and 5	0-4
Negligible/aggregated	4, 6, 7, 8	0

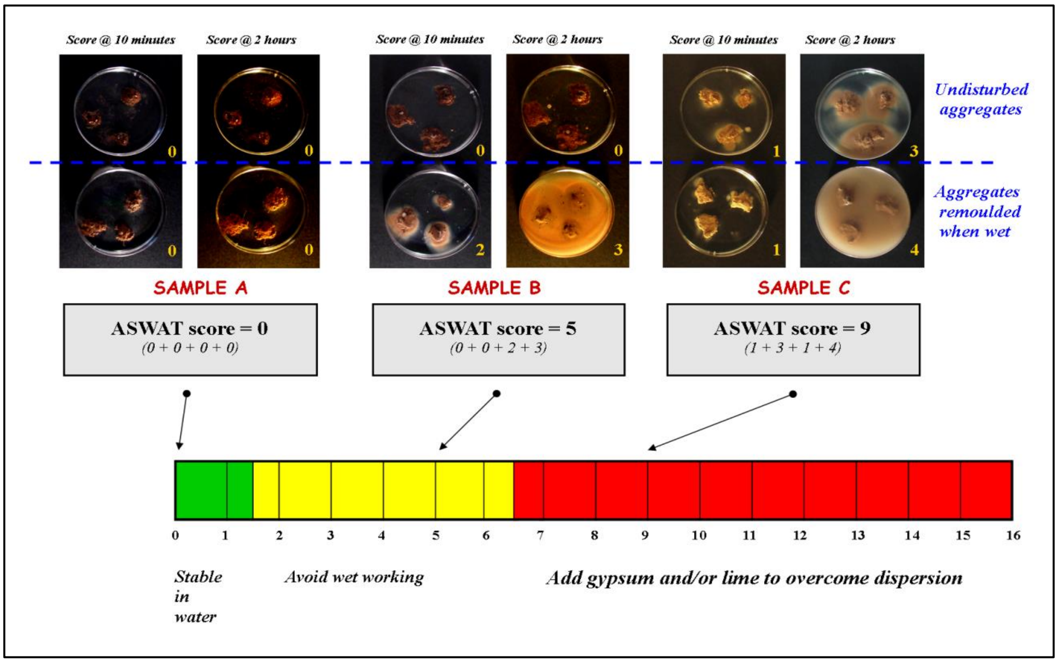


Figure 9. The Link Between ASWAT Results and Soil Management Options

The following key soil factors are attached in the form of colour coded maps:

Map 1a. Surface Contours.

Map 1b. Slope Mapping.

Map 2. Soil Types (Australian Soil Classification).

Map 3. Depth to Rock.

Map 4. Plant Available Water (TAW).

Map 5. Depth to Mottled Layer.

Map 6. Depth to Layer with Lime.

Map 7a. Dispersion (ASWAT score).

Map 7b. Dispersion (ESP Value).

Map 7c. Dispersion (ESI Value).

Map 8. Compaction Severity (SOILpak Score).

Map 9. Cation Exchange Capacity (CEC).

Map 10. Salinity (Electrical Conductivity [ECe]).

Map 11. pH ($CaCl_2$).

Map 12. Phosphorus (Colwell P).

Map 13. Organic Carbon (%).

5.3 Slope

The Interim Protocol notes that slope can be an impediment to farming as erosion potential rapidly increases once slope increases beyond 10%. Increased slope is also an impediment to the safe operation of machinery.

Surface contour and slope information (Maps 1a and 1b) interpreted from detailed LiDAR data obtained by NCOPL was used to define BSAL exclusion zones in the Gateway Certificate Application Area. Approximately 224.8 ha of the Gateway Certificate Application Area had a slope greater than 10% and therefore cannot be BSAL in accordance with the Interim Protocol. The remaining 3,564.1 ha of the Gateway Certificate Application Area had a slope less than or equal to 10% and required further investigation.

Figure 10 shows the BSAL exclusion zones within the Gateway Certificate Application Area where slope is greater than 10%.

5.4 Rock Outcrops

Rocks hinder cultivation operations (e.g. damage to machinery). BSAL must have less than 30% rock outcrop.

None of the 69 sites in the Gateway Certificate Application Area had significant rock outcrops nearby.

5.5 Surface Rockiness

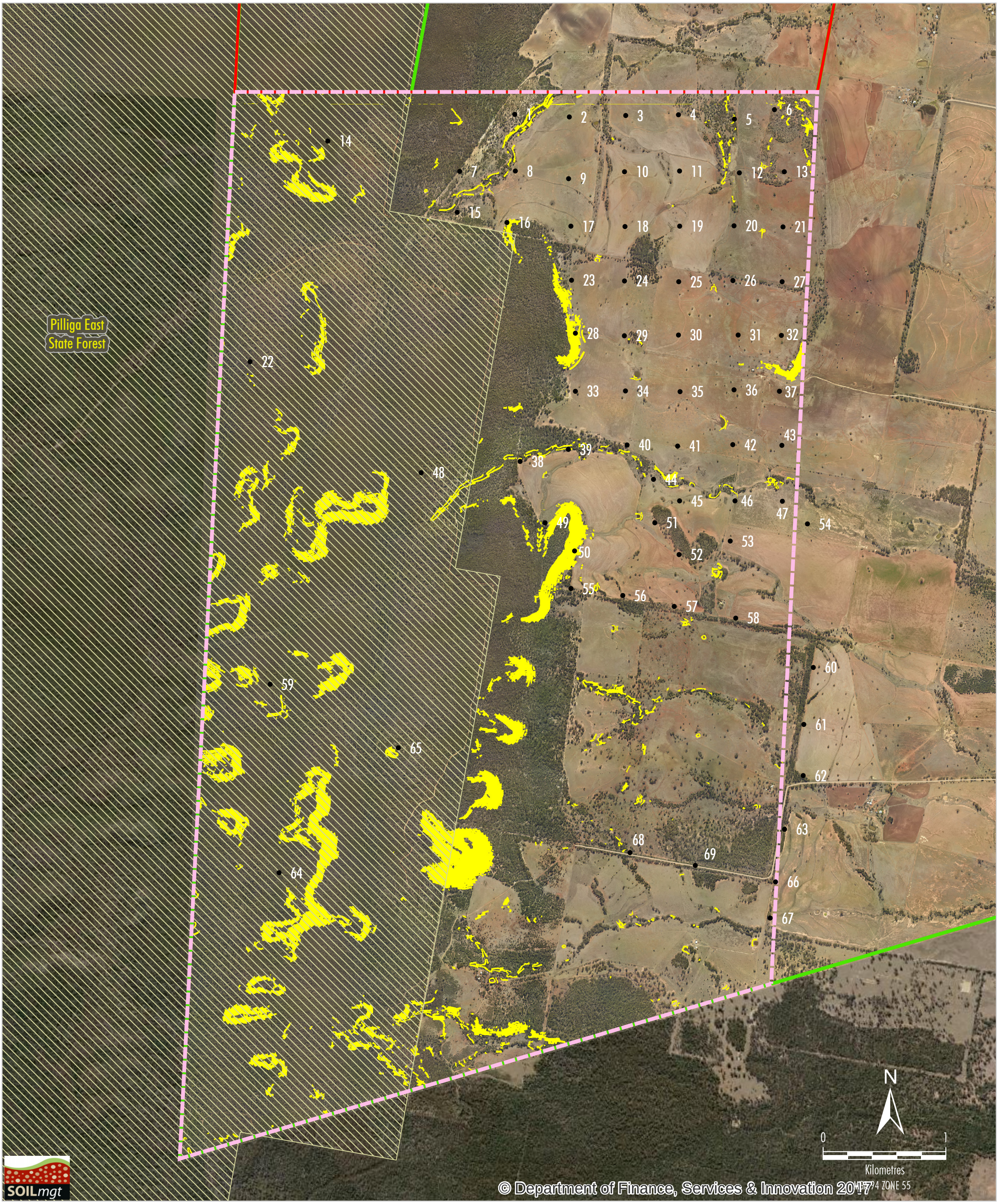
Rockiness refers to the presence of unattached coarse rock fragments on the soil surface.

Only one of the 69 sites in the Gateway Certificate Application Area (Site 25) had coarse rock fragments on the soil surface. The parent material was 'volcanic breccia'.

5.6 Gilgai

Gilgai microrelief is a natural soil feature of mounds and depressions commonly associated with cracking clays or Vertosols. Although gilgai microrelief can be ameliorated, gilgais will typically reform if deeper than 500 mm. If the average depth of gilgai depressions is deeper than 500 mm, and if the depressions occupy more than 50% of a mapped area of gilgai, then the area is not BSAL. Uneven surfaces interfere with cultivation, collect water following heavy rain, and often have elevated salinity and sodicity.

Although Vertosols were present, none of the 69 sites in the Gateway Certificate Application Area had gilgai limitations.



WHC-17-54_GCA_BSAL_AR_206A

LEGEND

- State Forest
- Mining Lease Boundary (ML 1609)
- Exploration Licence (EL 6243)
- Gateway Certificate Application Area
- Soil Test Pit
- Slope > 10%

Source: Orthophotos - Whitehaven Coal (July 2017); R.W. Corkery & Co Pty Ltd (2009), NSW Trade & Investment (2015); NCOPL (2017); McKenzie Soil Management (2017)

WHITEHAVEN COAL

NARRABRI STAGE 3 PROJECT

BSAL Exclusion Zone Where Slope > 10%

Figure 10

5.7 Soil Type

BSAL requires an ASC that is associated with naturally high, moderately high or moderate fertility. Appendix 2 in the Interim Protocol describes the relative fertility of the various ASC classes.

The ASC (Isbell, 2002) has been used to determine soil types at each of the 69 observation sites (Map 2). Photographs of representative soil profiles identified during the survey are presented in Figure 11 (for each Soil Landscape Unit and ASC soil type described below). All the sites have three photographs that record the following: a) Landscape view, b) Trimmed soil profile, and c) Close-up view of soil surface and associated vegetation where required. The Landscape view and Trimmed soil profile photographs for all sites are shown in Attachment E.

Total numbers of the contrasting ASC soil types, and the equivalent Great Soil Group (Stace *et al.*, 1968) terminologies, are shown in Table 6. ASC details for each site are shown in Table 7.

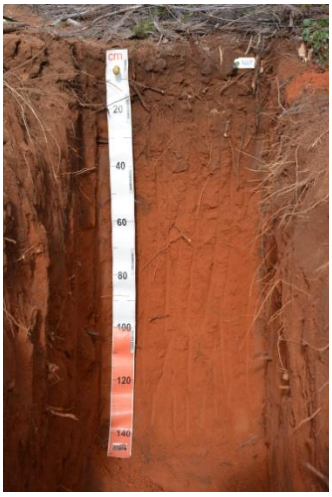
Table 6. Soil Types Identified; Classified According to the ASC and Great Soil Groups

ASC Soil Type	Number of Detailed Sites	Great Soil Group Equivalent	Relative Fertility[1]
Dermosol	17	Red and yellow podzolic soils	Mostly Moderate to High
Sodosol	15	Solodized solonetz and Solodic Soils	Moderately Low
Vertosol	10	Grey, Brown and Red Clays	Mostly Moderate to High
Orthic Tenosol	7	Lithosols	Moderately Low to Moderately High
Chromosol	6	Red-Brown Earths, Non-calcic brown soils	Moderately Low or Moderately High
Kandosol	6	Calcareous Red Earths	Moderately Low or Moderate
Leptic Tenosol	4	Lithosols	Low
Rudosol	2	Alluvial Soils	Low or Moderately Low
Calcarosol	2	Red calcareous soils	Low or Moderately Low

[1] In accordance with Appendix 2 of the Interim Protocol.

The soil types in Table 6 have the following characteristics (Isbell, 2002):

- Dermosols have structured B2 horizons and lack strong texture contrast between A and B horizons.
- Sodosols have strong texture contrast between the A and B horizons, and the B horizon is sodic (ESP of 6 or greater).
- Vertosols are clay soils with shrink-swell properties that exhibit strong cracking when dry.
- Tenosols have only weak pedological development; at this location they are either deep sandy soil (Orthic) or with hard rock close to the surface (Leptic).
- Chromosols have strong texture contrast between the A and B horizons, and a non-sodic subsoil with pH_{water} greater than 5.5.
- Kandosols lack strong textural contrast and have a massive or only weakly structured B horizon.
- Rudosols are derived from recently deposited materials that have only minimal profile development.
- Calcarosols are usually calcareous throughout the profile, often highly so.

Soil Landscape Unit	Dominant Soil Types	Landscape View
Pilliga Sandstone	Pit 22: Orthic Tenosol 	Site 22 
Garawilla Volcanics - Calcic	Pit 36: Vertosol 	Site 36 
Garawilla Volcanics - Intermediate	Pit 43: Dermosol 	Site 43 

Garawilla Volcanics - Sodic	Pit 47: Sodosol 	Site 47 
Garawilla Volcanics – Sodic/ Vertosols	Pit 19: Vertosol 	Site 19 
Napperby Siltstone	Pit 61: Sodosol 	Site 61 

Figure 11. Photographs of Representative Soil Types for each Soil Landscape Unit

5.8 Effective Rooting Depth to a Physical Barrier

Effective rooting depth refers to the depth of soil over which plant roots can function effectively. It is the depth of soil material from the surface to (i) a physical barrier and/or (ii) a chemical barrier (Section 5.12).

Physical barriers include bedrock, weathered rock, hard pans and continuous gravel layers. A "Physical barrier" (Step 8) was defined in this study as 'hard rock' or a layer with >90% coarse fragments.

BSAL soils cannot have impedance of root growth by a physical barrier within 750 mm of the soil surface.

Four of the 69 sites in the Gateway Certificate Application Area (Sites 16, 23, 29 and 69) had a physical barrier within 750 mm of the soil surface. Sites 16, 23 and 29 are adjacent to each other. All sites had a slope greater than or equal to 6% and, therefore, were steep enough to be very prone to water erosion, which reduces profile depth and water-holding capacity.

5.9 Drainage

Waterlogging can severely reduce crop productivity. It is caused by poor drainage that is generally associated with low-lying landscape positions, and/or by drainage restrictions such as shallow rock and sodic/compacted subsoil.

Poorly drained soils that have subsoil mottling within 750 mm of the soil surface are not BSAL (Step 9).

For the purpose of this report, poor drainage is determined by visual assessment of waterlogging indicators, i.e. the presence of distinct or prominent mottling (>10%) and/or black manganiferous nodules or concretions (>20%) within the depth interval 0-750 mm. The presence of grey and gley colours and/or the presence of a bleached horizon are indicators of poorly drained soil.

Twenty-five of the 69 sites in the Gateway Certificate Application Area had subsoil mottling (indicating poor drainage) within 750 mm of the soil surface. There was no evidence of an increase in subsoil mottling close to the drainage lines; some of the mottled sites were in upper slope positions. This suggests that variation in underlying geology is the main factor determining subsoil permeability in this area.

5.10 Soil pH

Soil pH refers to the acidity or alkalinity of a soil. pH influences the availability and behaviour of many soil elements which, in turn, affects the productivity of a range of plants.

BSAL soils have pH within the range 5.0 – 8.9 when measured in water, or 4.5 – 8.1 when measured in calcium chloride, within the uppermost 600 mm of the soil profile. Laboratory measurements of pH are more accurate than rapid field measurements.

In this study (Step 10) BSAL assessment is based exclusively on examination of pH (1:5 $CaCl_2$) data.

Laboratory testing identified that 25 of the 69 sites in the Gateway Certificate Application Area had a pH (1:5 $CaCl_2$) outside of the range 4.5 – 8.1 within 600 mm of the soil surface.

Soil acidity was a major limitation in the highly leached low-CEC sandy soil derived from sandstone in the Pilliga Forest. In contrast, subsoil alkalinity was a limiting factor in the clay-rich sodic Vertosols with lime accumulations (Garawilla Volcanics).

5.11 Soil Salinity

Soil salinity refers to the concentration of soluble salts in a soil. It adversely affects the ability of plants to extract water and nutrients.

BSAL soils have a low to moderate level of salinity; ECe is less than or equal to 4 dS/m or, if gypsum is present, chlorides less than 800 mg/kg. This applies to the uppermost 600 mm of the soil profile. Soil salinity has been measured in the laboratory as this is more accurate than field assessment.

Laboratory testing identified that nine of the 69 sites in the Gateway Certificate Application Area had an ECe greater than 4 dS/m within 600 mm of the soil surface. They were associated with Garrawilla Volcanics, where alkalinity and sodicity also were observed in the clay-rich subsoil.

5.12 Effective Rooting Depth to a Chemical Barrier

Chemical barriers to root growth, in addition to pH extremes and salinity, include dispersion associated with sodicity and low calcium to magnesium ratios.

BSAL soils cannot have a chemical barrier within 750 mm of the soil surface. BSAL soils must have an effective rooting depth to a chemical barrier greater or equal to 750 mm.

A "chemical barrier" (Step 12) is defined here as ESP>6 within 600 mm of the soil surface.

Laboratory testing identified that 31 of the 69 sites in the Gateway Certificate Application Area had a subsoil exchangeable sodium percentage of 6 or greater within 600 mm of the soil surface. Sodicity is associated with high amounts of dispersion, particularly where profile electrolyte concentrations are low. The Garawilla Volcanics contained most of the sodic soil. The sodium in the parent material may be present as a result of marine deposition of the volcanic eruption fragments.

5.13 Non-site criteria: Minimum area

BSAL soils must have a contiguous area equal to or greater than 20 ha. This is the minimum area considered necessary (by authors of the Interim Protocol) to commercially produce a high-value agricultural crop. The minimum area refers to the extent of the biophysical resource, not the size of the lot or holding.

Pits 6, 12, 20, 32, 36, 37 and 44 meet the criteria described in Sections 5.1 to 5.12. Of these sites, Pits 6, 12 and 20 and Pits 32, 36 and 37 form contiguous areas of greater than 20 ha. Pit 44 does not have a contiguous area of greater than 20 ha and is, therefore, not considered to be BSAL.

5.14 BSAL Sites within the Gateway Certificate Application Area

An assessment of each observation site within the Gateway Certificate Application Area has been conducted against the BSAL assessment criteria (Sections 5.3 to 5.13).

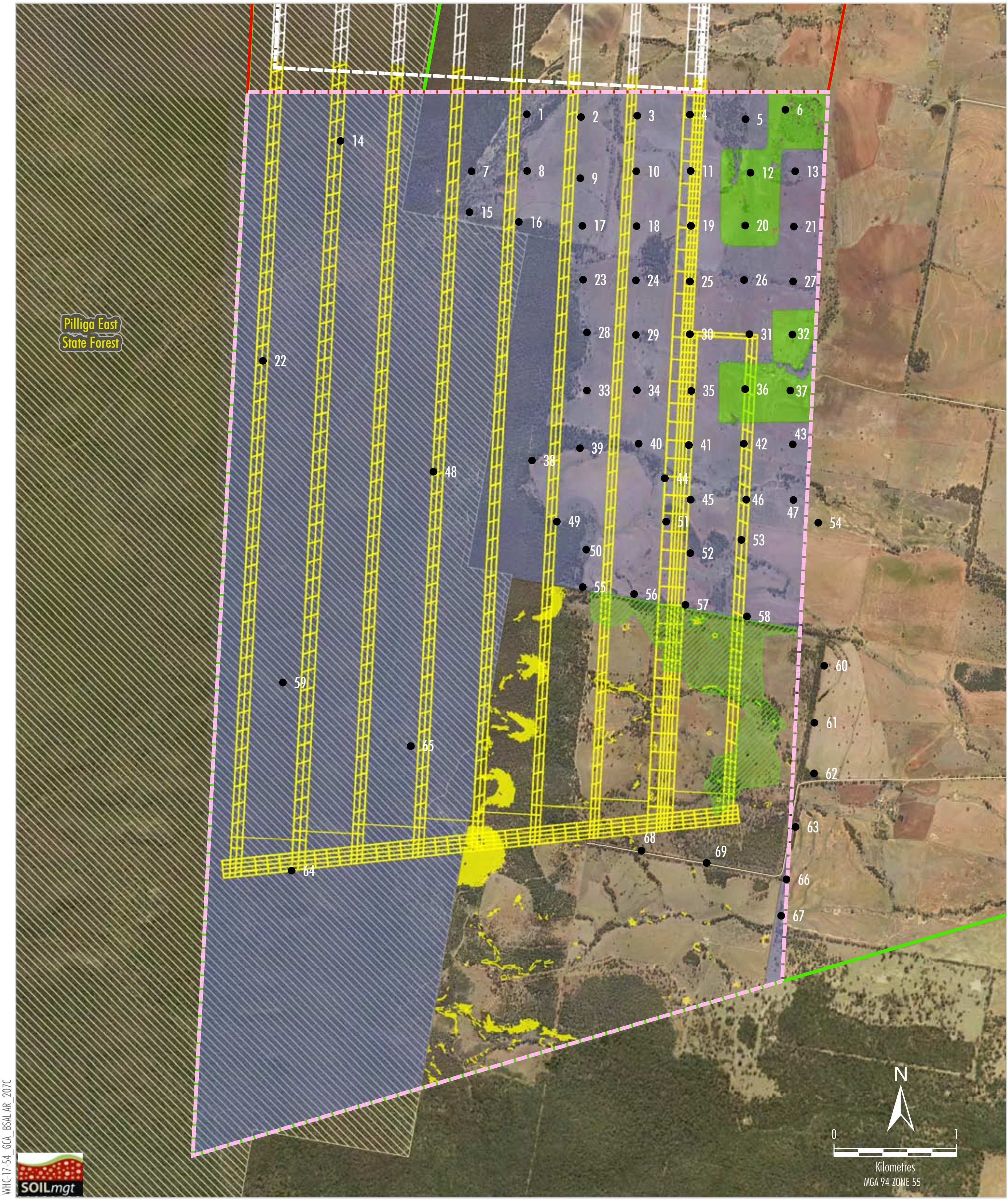
The limiting factors in the BSAL verification process are highlighted via a colour-coded matrix in Table 7. Soil sampling sites that are shown to be BSAL (green-coded) meet all relevant criteria.

Interim Protocol Verified BSAL within the Gateway Certificate Application Area is shown on Figure 12.

Table 7. BSAL Assessment Matrix for the Gateway Certificate Application Area (red shading indicates a BSAL limitation)

BSAL Assessment Table

Map ID	Rock Outcrop	Surface Rock Fragments %	Surface Rock Fragments size (mm)	Gilgai	Physical Barrier: Depth to >90% Rock (cm)	Waterlogging: Depth to >10% Mottles (cm)	Waterlogging: Depth to >20% Mn (cm)	Waterlogging: Depth to water-logged layer	Chemical Barrier: pH $CaCl_2$ 0-5 cm	pH $CaCl_2$ 5-15 cm	pH $CaCl_2$ 15-30 cm	pH $CaCl_2$ 30-60 cm	ESP 0-5 cm	ESP 5-15 cm	ESP 15-30 cm	ESP 30-60 cm	Salinity (ECe, dS/m) 0-5 cm	Salinity 5-15 cm	Salinity 15-30 cm	Salinity 30-60 cm	Slope (%)	Australian Soil Classification: Great Group	Suborder	Order	Fertility Status	BSAL	part of BSAL cluster > 20ha	LSC Class: Salt Sensitive
1	0	0	-	0	140+	110	-	110	4.9	4.8	5.0	5.3	0.8	0.6	0.9	2.2	0.23	0.23	0.23	0.23	4	Regolithic	Grey-Orthic	Tenosol	Moderately Low	No	No	5
2	0	< 1	0	0	140+	80	-	80	5.4	5.3	6.5	7.5	3.6	4.8	9.0	14.3	0.60	0.43	0.52	0.81	2	Mottled-Subnatric	Red	Sodosol	Moderately Low	No	No	3
3	0	10	20-250	0	140+	90	-	90	6.2	6.6	8.0	8.5	3.4	6.1	11.6	17.0	0.38	0.50	1.73	5.19	3	Hypocalcic	Brown	Kandosol	Moderate	No	No	4
4	0	< 2	50-100	0	90	-	-	-	4.7	4.7	6.5	7.2	4.7	5.9	9.4	13.1	0.34	0.22	0.52	1.38	2	Hypocalcic	Red	Kandosol	Moderate	No	No	3
5	0	5-15	10-100	0	140+	80	-	80	5.0	4.5	5.6	6.3	3.2	8.8	17.5	37.4	0.52	0.95	2.24	6.79	9	Eutrophic	Brown	Dermosol	Moderately High	No	No	5
6	0	5	50-300	0	80	-	-	-	5.0	5.1	5.6	5.8	0.8	0.4	0.5	0.5	1.98	1.98	0.77	0.52	7	Eutrophic	Red	Dermosol	Moderately High	Yes	Yes	3
7	0	0	-	0	75	55	-	55	4.9	5.0	5.7	6.1	0.7	0.7	1.0	0.5	0.38	0.10	0.14	0.17	3	Mesotrophic	Brown	Dermosol	Moderately High	No	No	4
8	0	10	10-100	0	145+	90	-	90	6.3	7.4	7.9	8.2	0.6	1.0	1.3	4.1	0.34	1.29	1.29	1.55	4	Regolithic	Supracalcic	Calcarosol	Low	No	No	4
9	0	0	-	0	120+	-	-	-	5.9	5.6	6.5	7.3	1.3	1.0	3.3	6.8	0.77	0.25	0.30	0.47	6	Hypocalcic	Brown	Dermosol	Moderately High	No	No	3
10	0	5	50-250	0	140+	-	-	-	7.8	7.9	8.1	8.3	0.9	1.7	5.3	11.5	0.93	1.06	1.53	3.30	3	Self-mulching	Red	Vertosol	Moderately High	No	No	5
11	0	5	50-250	0	140+	90	-	90	7.1	6.0	6.9	8.2	6.7	4.5	5.7	9.7	2.63	0.42	0.60	4.39	3	Self-mulching	Brown	Vertosol	Moderately High	No	No	4
12	0	2	100-200	0	140+	-	-	-	5.9	5.3	5.5	6.1	1.2	1.0	1.5	4.7	0.52	0.26	0.17	0.34	2	Eutrophic	Red	Dermosol	Moderately High	Yes	Yes	3
13	0	< 2	50-200	0	90	70	-	70	5.6	6.0	7.2	7.0	0.3	0.2	0.1	0.6	0.43	0.34	1.38	0.60	6	Eutrophic	Red	Dermosol	Moderately High	No	No	4
14	0	0	-	0	100	-	-	-	3.8	3.8	3.9	4.0	0.4	0.5	0.4	0.5	2.04	1.36	1.14	0.45	4	Paralithic	Red-Orthic	Tenosol	Moderately Low	No	No	6
15	0	0	-	0	140+	75	-	75	4.7	4.5	4.8	5.1	0.7	0.8	2.6	2.5	0.45	0.45	0.23	0.23	4	Mottled-Subnatric	Brown	Sodosol	Moderately Low	No	No	5
16	0	40	0	0	35	-	-	0	4.2	3.9	3.9	3.7	2.7	3.1	2.6	3.0	3.44	3.87	1.38	0.69	9	Lithic	Leptic	Tenosol	Low	No	No	7
17	0	0	-	0	130+	-	-	-	5.9	5.6	6.4	7.8	0.4	0.4	0.3	0.4	0.69	0.43	0.40	1.13	6	Supracalcic	Brown	Kandosol	Moderately Low	No	No	3
18	0	< 2	0	0	130+	-	-	-	7.7	7.8	8.0	8.2	0.6	1.0	3.7	8.3	1.46	1.38	1.81	2.67	2	Epipedal	Red	Vertosol	Moderately High	No	No	4
19	0	< 2	0	0	140+	-	-	-	5.8	6.2	7.8	8.3	2.8	5.8	10.5	16.7	0.77	0.67	1.40	3.79	3	Epipedal	Brown	Vertosol	Moderately High	No	No	4
20	0	0	-	0	140+	-	-	-	5.6	5.3	5.7	6.3	0.8	0.5	0.4	1.3	0.52	0.26	0.17	0.26	3	Eutrophic	Red	Dermosol	Moderately High	Yes	Yes	3
21	0	< 1	0	0	90	25	-	25	5.2	5.6	6.0	6.6	1.1	1.2	2.2	5.4	0.26	0.17	0.17	0.29	2	Eutrophic	Brown	Chromosol	Moderately High	No	No	6
22	0	0	-	0	140+	-	-	-	3.7	3.8	3.9	4.1	1.7	0.5	0.6	0.7	0.91	0.68	0.45	0.45	3	Regolithic	Red-Orthic	Tenosol	Moderately Low	No	No	6
23	0	2	30	0	45	-	-	-	5.8	6.2	7.3	8.1	1.5	1.6	2.2	3.8	0.34	0.34	0.83	1.50	7	Lithic	Leptic	Tenosol	Low	No	No	6
24	0	0	-	0	140+	120	-	120	5.9	6.8	7.7	8.1	2.4	3.3	5.7	14.0	0.86	0.68	1.50	4.88	3	Epipedal	Brown	Vertosol	Moderately High	No	No	4
25	0	30	120	0	95	-	-	-	5.3	6.4	7.9	8.3	4.3	5.8	7.3	10.3	0.45	0.83	1.57	3.48	2	Hypocalcic	Red	Dermosol	Moderately High	No	No	4
26	0	0	-	0	140+	60	-	60	5.4	5.8	6.1	6.5	0.7	0.6	0.6	0.7	0.52	0.34	0.34	0.34	2	Eutrophic	Red	Dermosol	Moderately High	No	No	4
27	0	0	-	0	140+	40	-	40	5.4	5.4	6.7	7.4	0.7	0.7	0.8	1.2	0.60	0.43	0.43	0.43	2	Eutrophic	Red	Dermosol	Moderately High	No	No	6
28	0	60	15	0	100	-	-	-	6.0	7.2	7.8	8.0	0.9	1.2	1.8	5.0	0.60	1.29	2.41	4.99	14	Epipedal	Red	Vertosol	Moderately High	No	No	4
29	0	5	40	0	40	-	-	-	5.4	5.5	7.5	-	1.9	2.6	7.2	-	0.77	0.52	1.86	-	7	Lithic	Leptic	Tenosol	Low	No	No	6
30	0	0	-	0	140+	60	-	60	5.5	5.4	6.1	7.3	1.2	1.2	1.7	2.9	0.34	0.26	0.23	0.53	4	Supracalcic	Red	Kandosol	Moderately Low	No	No	4
31	0	0	-	0	140+	-	90	90	4.9	5.6	6.8	8.3	4.7	8.0	9.2	11.8	0.34	0.52	1.03	3.53	2	Subnatric	Red	Sodosol	Moderately Low	No	No	4
32	0	0	-	0	80	-	-	-	5.2	5.0	6.2	6.8	1.3	1.5	1.8	2.6	0.60	0.32	0.38	0.69	1	Eutrophic	Red	Dermosol	Moderately High	Yes	Yes	3
33	0	0	-	0	105	30	-	30	5.4	5.7	5.9	7.1	1.4	2.1	1.9	15.3	0.41	0.37	0.45	0.77	3	Mottled-Mesonatric	Brown	Sodosol	Moderately Low	No	No	6
34	0	0	-	0	140+	-	-	-	5.5	6.1	8.0	8.4	2.0	3.2	4.6	14.4	0.34	0.43	1.81	4.13	3	Regolithic	Supracalcic	Calcarosol	Low	No	No	4
35	0	<1	40	0	140+	-	-	-	5.9	5.9	6.1	8.3	1.0	1.2	4.2	9.0	0.43	0.34	0.27	3.27	4	Supracalcic	Red	Dermosol	Moderate	No	No	4
36	0	0	-	0	140+	-	-	-	5.3	5.5	6.2	6.8	0.4	0.2	0.2	0.5	0.60	0.43	0.43	0.43	2	Epipedal	Red	Vertosol	Moderately High	Yes	Yes	2
37	0	0	-	0	140+	-	-	-	6.4	6.0	6.7	7.2	1.5	0.5	0.4	0.6	2.13	0.73	0.67	0.83	4	Self-mulching	Brown	Vertosol	Moderately High	Yes	Yes	3
38	0	0	-	0	140+	60	-	60	5.6	4.8	5.3	7.0	0.6	0.6	1.3	2.6	0.29	0.19	0.15	0.38	2	Eutrophic	Red	Chromosol	Moderately High	No	No	6
39	0	0	-	0	130+	70	-	70	5.3	5.4	5.4	5.3	0.4	0.3	0.2	0.2	0.26	0.17	0.28	0.14	3	Eutrophic	Red	Kandosol	Moderate	No	No	4
40	0	0	-	0	105+	70	-	70	5.1	4.8	4.9	6.7	1.8	3.1	2.9	12.8	0.67	0.67	0.55	0.52	2	Mottled-Subnatric	Red	Sodosol	Moderately Low	No	No	4
41	no	< 1	0	0	140+	90	-	90	5.3	6.7	7.9	8.3	1.6	3.3	4.1	14.1	1.12	1.20	1.98	6.36	1	Supracalcic	Red	Dermosol	Moderate	No	No	5
42	0	0	-	0	140+	85	-	85	6.5	4.7	4.7	6.6	5.6	1.1	1.7	7.7	1.81	0.26	0.17	0.33	4	Mottled-Subnatric	Red	Sodosol	Modertately Low	No	No	3
43	0	0	-	0	100	65	-	65	5.6	5.4	5.7	6.9	0.2	0.4	0.3	0.6	0.43	0.26	0.20	0.45	4	Eutrophic	Red	Dermosol	Moderately High	No	No	4
44	0	4	25	0	135+	-	-	-	7.6	7.4	7.7	7.8	0.3	0.5	0.7	3.3	1.03	0.60	0.80	0.67	2	Eutrophic	Red	Chromosol	Moderately High	Yes	No	3
45	0	0	-	0	140+	60	-	60	6.2	6.3	6.6	6.8	0.5	0.5	1.4	3.9	0.77	0.52	0.34	0.34	1	-	Stratic	Rudosol	Moderately Low	No	No	4
46	0	0	-	0	130+	40	-	40	5.3	5.2	5.2	6.4	0.3	0.3	1.0	1.5	0.26	0.26	0.17	0.27	3	Eutrophic	Red	Chromosol	Moderately High	No	No	6
47	0	0	-	0	140+	28	-	28	4.5	4.8	5.8	7.8	2.2	5.4	11.9	38.8	0.28	0.28	0.45	1.89	1	Mottled-Hypernatric	Brown	Sodosol	Moderately Low	No	No	6
48	0	0	-	0	130+	-	-	-	4.0	4.0	4.0	4.1	1.6	1.6	2.0	0.7	0.68	0.68	0.91	0.68	4	Regolithic	Red-Orthic	Tenosol	Moderately Low	No	No	5
49	0	0	-	0	140+	30	-	30	5.2	5.2	5.7	7.3	0.2	0.2	0.2	0.6	0.28	0.28	0.17	0.46	6	Eutrophic	Brown	Chromosol	Moderately High	No	No	6
50	0	0	-	0	140+	70	-	8	7.0	7.6	7.9	8.4	0.4	0.8	2.1	9.4	0.90	1.04	1.10	2.59	12	Self-mulching	Grey	Vertosol	Moderately High	No	No	7
51	0	0	-	0	140+	-	-	-	5.8	6.3	7.5	8.3	5.2	8.4	10.0	13.1	0.34	0.46	1.33	4.65	3	Supracalcic	Red	Kandosol	Moderately Low	No	No	4
52	0	0	-	0	125+	-	-	-	6.4	6.8	6.9	7.6	1.6	2.2	8.5	19.7	0.30	0.43	0.52	1.58	2	Epipedal	Red	Vertosol	Moderately High	No	No	4
53	0	0	-	0	140+	60	-	60	4.6	4.9	6.7	7.0	1.7	1.0	1.5	2.4	0.29	0.29	0.27	0.33	2	Supracalcic	Red	Chromosol	Moderately Low	No	No	4
54	0	0	-	0	140+	42	-	35	4.5	4.6	5.3	7.1	3.3	3.6	4.2	31.9	0.45	0.45	0.45	0.86	2	Mottled-Hypernatric	Brown	Sodosol	Moderately Low	No	No	6
55	0	0	-	0	140+	-	-	-	4.9	5.4	6.6	8.1	1.4	3.2	4.8	10.1	0.29	0.31	0.41	2.03	6	Mottled-Mesonatric	Brown	Sodosol	Moderately Low	No	No	4
56	0	0	-	0	140+	30	-	30	4.8	4.7	5.1	6.9	2.3	1.3	1.5	11.8	0.28	0.28	0.19	0.43	4	Mottled-Mesonatric	Red	Sodosol	Moderately Low	No	No	6
57	0	0	-	0	140+	95	-	95	5.7	6.9	7.9	8.2	1.4	1.2	1.3	4.1	0.34	1.03	1.00	1.22	3	Hypocalcic	Red	Dermosol	Moderately High	No	No	3
58	0	0	-	0	-	60	-	60	6.1	6.0	6.2	7.5	0.3	0.1	0.1	0.2	0.26	0.26	0.26	0.86	1	Eutrophic	Red	Dermosol	Moderately High	No	No	4
59	0	0	0	0	120	-	-	-	3.9	4.0	4.2	4.2	2.8	3.9	5.4	5.3	1.36	1.14	0.68	0.45	4	Lithic	Brown-Orthic	Tenosol	Moderately Low	No	No	6
60	0	<1	20	0	75	42	-	42	4.2	4.1	4.5	6.6	1.1	1.8	1.6	12.3	0.19	0.29	0.17	0.67	1	Mottled-Subnatric	Brown	Sodosol	Moderately Low	No	No	6
61	0	2	30	0	140+	65	-	65	4.2	5.2	7.1	7.9	2.3	8.3	10.2	15.7	0.28	0.34	0.60	1.55	2	Mottled-Mesonatric	Red	Sodosol	Moderately Low	No	No	5
62	0	0	-	0	140+	65	-	65	5.4	5.9	6.0	6.5	0.3	0.7	1.3	3.1	0.26	0.26	0.34	0.26	3	-	Stratic	Rudosol	Moderately Low	No	No	4
63	0	0	-	0	88	58	-	58	4.5	4.5	5.1	6.8	1.0	1.8	2.8	13.1	0.29	0.29	0.29	0.95	3	Mottled-Mesonatric	Red	Sodosol	Moderately Low	No	No	5
64	0	0	0	0	140+	-	-	-	3.7	3.8	3.9	4.0	0.4	1.0	2.1	1.4	1.36	1.59	1.14	0.45	2	Regolithic	Red-Orthic	Tenosol	Moderately Low	No	No	6
65	0	0	0	0	140+	-	-	-	3.9	4.0	4.1	4.2	3.9	1.5	0.8	1.9	0.68	0.45	0.45	0.23	3	Regolithic	Red-Orthic	Tenosol	Moderately Low	No	No	6
66	0	0	-	0	125+	45	-	45	4.7	4.7	4.8	5.7	2.3	6.0	11.7	19.4	0.41	0.19	0.29	0.95	6	Mottled-Hypernatric	Brown	Sodosol	Moderately Low	No	No	6
67	0	50	15	0	140+	105	-	105	4.7	5.3	7.4	7.8	9.7	13.4	16.9	24.2	0.57	1.05	1.46	4.99	4	Mottled-Hypernatric	Red	Sodosol	Moderately Low	No	No	4
68	0	0	-	0	140+	-	-	-	4.6	4.1	4.8	6.8	0.2	1.1	1.6	1.8	0.17	0.17	0.17	0.34	3	Eutrophic	Red	Dermosol	Moderately High	No	No	4
69	0	0	-	0	60	-	-	-	4.1	3.9	4.0	-	2.6	2.2	1.6	-	1.36	0.73	0.41	-	6	Lithic	Leptic	Tenosol	Low	No	No	5



LEGEND

State Forest
Mining Lease Boundary (ML 1609)
Exploration Licence (EL 6243)
Project Underground Mine Development
Approved Narrabri Mine
Underground Mine Footprint
Underground Mine Development

Gateway Certificate Application Area
Soil Test Pit
Interim Protocol Verified BSAL
Interim Protocol Verified Non-BSAL
Mining SEPP Potential BSAL in Unmapped Areas
Interpreted as Interim Protocol Verified Non-BSAL Using Desktop Method

Source: Orthophotos - Whitehaven Coal (July 2017); R.W. Corkery & Co Pty Ltd (2009), NSW Trade & Investment (2015); NCOPL (2018); McKenzie Soil Management (2017) Department of Planning and Environment (2015)

WHITEHAVEN COAL

NARRABRI STAGE 3 PROJECT

BSAL within the Gateway Certificate Application Area

Figure 12

6 LAND AND SOIL CAPABILITY CLASSES

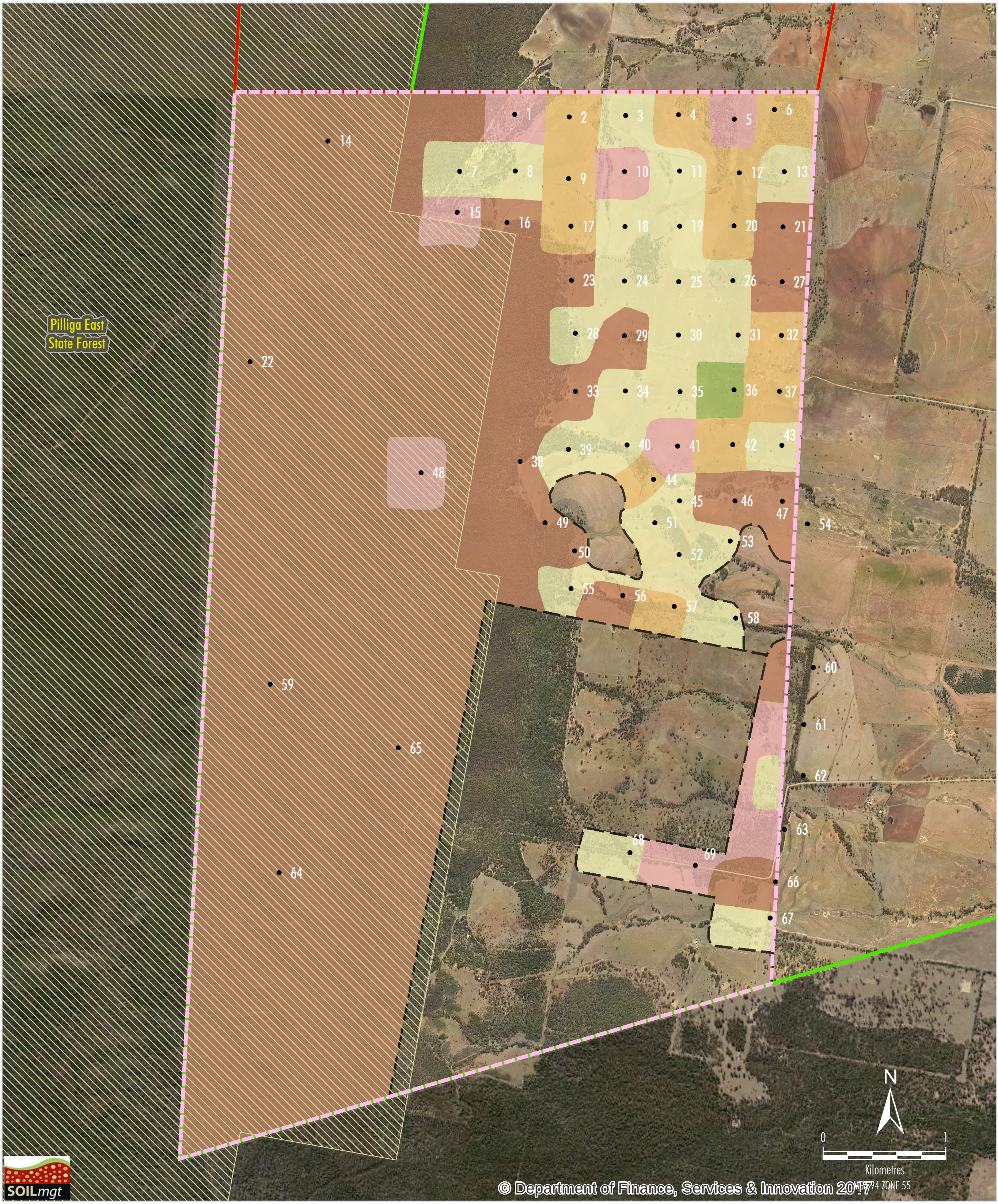
LSC mapping was prepared for the Gateway Certificate Application Area based on the results of the soil survey conducted by McKenzie Soil Management in accordance with *The Land and Soil Capability Assessment Scheme – Second Approximation* (OEH, 2012). LSC mapping is shown on Figure 13. A detailed description of each of the LSC classes is provided in Section 2.2.

Essential adaptations to the methodology are described in Attachment F. It is noted on page 28 of the LSC assessment scheme (OEH, 2012) that, when an initial LSC determination does not match known or indicative conditions of the landscape or soils, expert knowledge is used to record a modified LSC class that overrides the original assessment. The original value and reasons for the change are documented. This provides a mechanism to refine the logic/decision tables based on applied usage and feedback in a process of continual improvement.

LSC Class 6/7 has severe erosion hazards associated with the steep slopes. The small area with Class 5 land is considered to have limited agricultural potential because of topsoil with acidity and poor buffering capacity.

LSC Class 4 dominates the Project area. It is 'moderate capability land' that has moderate to high limitations for high-impact land uses such as cropping, high-intensity grazing and horticulture. These limitations can only be managed by specialised management practices with a high level of knowledge, expertise, inputs, investment and technology (OEH, 2012).

Zones with LSC Classes 2 and 3 are considered to be capable of a wide variety of land uses, including cropping, grazing, horticulture, forestry and nature conservation. Areas categorised as these classes (Figure 13) generally coincide with the BSAL areas shown in Figure 12.



WHC-17-54_GCA_BSAL AR_212A

LEGEND

- State Forest
- Mining Lease Boundary (ML 1609)
- Exploration Licence (EL 6243)
- Gateway Certificate Application Area
- Soil Test Pit

Land and Soil Capability

- 2 Slight but Significant Limitations
- 3 Moderate Limitations
- 4 Moderate to Severe Limitations
- 5 Severe Limitations
- >5 Very Severe Limitations
- Undetermined

Source: Orthophotos - Whitehaven Coal (July 2017); R.W. Corkery & Co Pty Ltd (2009), NSW Trade & Investment (2015); NCOPL (2017); McKenzie Soil Management (2017)

WHITEHAVEN COAL

NARRABRI STAGE 3 PROJECT

Land and Soil Capability Classes within the Gateway Certificate Application Area

Figure 13

7 POTENTIAL IMPACTS ON SOIL RESOURCES

Possible impacts to agricultural productivity as a result of the Project would be associated with temporary loss of land due to construction of mine infrastructure (e.g. surface facilities) and potential subsidence impacts. Potential impacts on agricultural activities associated with subsidence could include:

- Low points with possible waterlogging problems, and adjacent increases in slope and erosion risk, along the outside boundaries of subsided longwall panels.
- Injury to livestock caused by ground cracking.
- Loss of integrity of stock fences and water pipelines.
- Possible injury to persons undertaking agricultural activities.

Potential impacts to agricultural enterprises associated with the Project are discussed in detail in the Agricultural Impact Assessment (Ecological Australia Pty Ltd, 2018).

7.1 Post-mining Land and Soil Capability Assessment

The Project would temporarily remove land from agricultural uses in the Gateway Certificate Application Area for the duration of the Project (i.e. until 2045). Following completion of mining activities, infrastructure would be removed and the land rehabilitated to a condition consistent with the pre-mining land use. Where necessary, topsoil would be stripped and managed in accordance with the measures described in Section 7.2 so that it could be replaced following removal of surface infrastructure and remediation of soil compaction would be undertaken where necessary (e.g. through shallow ripping and re-grading). It is anticipated that the existing LSC classes could be re-established following remediation.

7.2 Soil Resource Management Measures

Surface development associated with the Project is proposed within the Gateway Certificate Application Area. General soil resource management practices should be applied prior to any mine-related disturbance (except for vegetation clearing) and these practices should involve the stripping and stockpiling of soil resources. The general strategy should be for those disturbance areas to be rehabilitated progressively. The objectives of soil resource management for the Project are to:

- Identify and quantify potential soil resources for rehabilitation.
- Optimise the recovery of useable topsoil and subsoil during stripping operations.
- Manage topsoil and subsoil reserves so as not to degrade the resource when stockpiled.
- Establish effective soil amelioration procedures to maximise the availability of soil reserves for future rehabilitation works.
- Take into account the need to provide soil conditions that minimise the risk of soil loss via wind and water erosion during and after rehabilitation.

Stripping

The following management measures should be implemented during the stripping of soils at the Project:

- Areas of disturbance requiring soil stripping are to be clearly defined following vegetation clearing.
- Topsoil and subsoil stripping during periods of high soil moisture content (i.e. following heavy rain) is to be avoided to reduce the likelihood of damage to soil structure.

The degree of success of a stripping and stockpiling program is strongly influenced by soil water content. Attempts to strip soil under moist conditions with inappropriate machinery settings can aggravate structural degradation problems. Excessive compaction and/or remoulding of the soil by heavy machinery under wet conditions can limit the potential of the soil for use in rehabilitation.

Stockpile Management

The following management measures should be implemented during the stockpiling/storage of soils at the Project:

- Topsoil and subsoil stockpiles should be retained at a height of no more than 2 m, with slopes no greater than 1:2 (vertical to horizontal) and a slightly roughened surface to minimise erosion.
- Construct topsoil stockpiles in a way that minimises erosion, encourages drainage and promotes revegetation.
- Where amendments such as lime, gypsum and fertiliser are needed to improve the condition of cut soil, they should be spread on the soil prior to scraping.
- Wherever practicable, soil should not be trafficked, deeply ripped or removed in wet conditions to avoid breakdown in soil structure.
- All topsoil and subsoil stockpiles should be seeded with a non-persistent cover crop to reduce erosion potential as soon as practicable after completion of stockpiling. Where seasonal conditions preclude adequate development of a cover crop, stockpiles should be treated with a straw/vegetative mulch to improve stability.
- Grow deep-rooting vegetation to encourage organic matter accumulation and maintain microbial activity. Stockpile height should be kept as low as possible. This maximises the chances of plenty of plant roots reaching the base of the stockpile as it awaits redistribution.
- There should be no vehicle access on soil stockpiles, except when soil quality monitoring is required.
- Soil stockpiles should be located in positions to avoid surface water flows. Silt-stop fencing would be placed immediately down-slope of stockpiles until stable vegetation cover is established.
- In the event that unacceptable weed generation is observed on soil stockpiles, a weed eradication program should be implemented.
- An inventory of soil resources (available and stripped) on the Project site should be maintained and regularly reconciled with rehabilitation requirements.

Application of Soil on Rehabilitated Landforms

The following management measures should be implemented during the application of soils on rehabilitated landforms at the Project:

- Topsoil and subsoil placement is to be undertaken from the top of slopes or top of sub-drainage catchment to minimise erosion damage created by storm runoff from bare upslope areas.
- Topsoil and subsoil placement is to be conducted along the general run of the contour to minimise the incidence of erosion.
- Topsoil and subsoil is not to be placed in the invert of drainage lines or drainage works.
- Spread topsoil/subsoil profile thickness and quality is to be evaluated prior to sowing.

Remediation of Potential Soil Contamination and Compaction Beneath Infrastructure Areas

Following removal of infrastructure during mine closure, soil profile inspections are recommended to quantify any contamination and the depth and severity of soil compaction damage. In the event that land contamination is identified, a more detailed investigation would be undertaken to develop appropriate remediation measures. Where soil compaction is identified, deep ripping will be carried out under dry conditions to de-compact the identified hard layers and provide a favourable root zone.

Rehabilitation Management Plan

It is recommended that the existing Rehabilitation Management Plan for the Narrabri Mine be reviewed and, if necessary, updated to detail the soil resource management measures for the Gateway Certificate Application Area as outlined in the sections above. The Rehabilitation Management Plan should continue to be progressively updated to cater for the site-specific management requirements of soils as the Project progresses.

7.3 Remediation Strategies for Subsidence Impacts

Remediation of surface cracks and/or low point development / slope steepening would continue to be undertaken as described in the Narrabri Mine Land Management Plan and Rehabilitation Management Plan.

If necessary, treatment of surface cracking would include ripping or grouting of surface cracks within agricultural areas and filling of cracks with suitable subsoil material (particularly in vegetated areas). Minor cracks (i.e. less than 50 mm) that develop are not expected to require remediation as geomorphological processes would result in these cracks filling naturally over time.

It is noted that Frazier *et al.* (2010) found no significant effect of longwall mining subsidence on agricultural production, including cattle grazing, in the Hunter Valley region.

8 CONCLUSION

This assessment has identified that approximately 106.5 ha of Interim Protocol Verified BSAL is located within the approximately 3,789 ha Gateway Certificate Application Area. An additional 95.3 ha has been interpreted as Interim Protocol Verified BSAL using desktop methods where access was not available for soil surveys. The remainder of the Gateway Certificate Application Area has a broad range of constraints which preclude the land from being classified as BSAL, including physical barriers, chemical barriers, subsoil with salinity, alkalinity and sodicity problems and excessive slope (>10%).

The Project would not result in subsidence to the majority of the Interim Protocol Verified BSAL identified within the Gateway Certificate Application Area (Figure 12).

Possible impacts to agricultural productivity as a result of the Project would be associated with temporary loss of land due to construction of mine infrastructure (e.g. surface facilities) and potential subsidence impacts.

With the implementation of subsidence management measures for surface cracking, topographical depressions and localised slope changes, and the remediation of land disturbed by surface infrastructure, it is considered that there would be no significant change to the long-term agricultural productivity of the Gateway Certificate Application Area as a result of subsidence impacts on agricultural land.

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SOIL MAPS 1 TO 13

LEGEND

- State Forest
- Mining Lease Boundary (ML 1609)
- Exploration Licence (EL 6243)
- Contour (2m Interval)
- Gateway Certificate Application Area
- Soil Test Pit

Source: Orthophotos - Whitehaven Coal (July 2017); R.W. Corkery & Co Pty Ltd (2009), NSW Trade & Investment (2015); NCOPL (2017); McKenzie Soil Management (2017)

WHITEHAVEN COAL

NARRABRI STAGE 3 PROJECT

Surface Contours

Map 1a