3 PROJECT ASSESSMENT AREA AGRICULTURAL ANALYSIS

Following is a summary of detailed technical investigations of existing or current agricultural land uses and productivities, and agricultural resources including soils, BSAL and groundwater, within the Project assessment areas. These technical investigations are reproduced as Appendices A through D.

3.1 Land use, production systems and productivity

There are 26 agribusinesses or enterprises wholly or partially within the Project assessment area footprints of 11,863 ha in total (Table 3.01 and Figure 3.01). A detailed description of available information concerning agricultural land use, operations, production systems and resources for each enterprise is provided (Appendix A). In addition to these agribusinesses that are affected by the Project assessment areas, detailed descriptions of two enterprises in close proximity to the Project assessment areas are also included (Table 3.02).

With regard to agricultural land use, production systems and productivity, two methods of description were performed. The first was *description by engagement and inspection,* where access to the land and interview of the land manager was possible (Figure 3.01). However, where engagement and inspection was not possible due to the relevant landholder declining to participate, a significantly less detailed *description by reconnaissance* method was used. Analyses were performed on a *per-farm management unit basis* and reveal an old maxim: *'there is no one way to farm, there are many'*, and no two production systems described are the same.

Agricultural land uses and productivities within the Project assessment areas can be summarised as follows.

- Dryland cropping and beef cattle grazing are dominant land uses;
- Irrigated cropping associated with properties described is typically on land outside of the Project assessment areas;
- Cropping systems are highly productive. For example, extensive areas of dryland wheat were harvested in the Project assessment areas in late 2013 with yields anecdotally greater than 4 t/ha and well in excess of the December 2013 forecast average yield of 1.7 t/ha for NSW (ABARES, 2013);
- One enterprise is the Caroona Feedlot, a cattle lot-feeding operation owned and managed by JBS Australia (land Reference #4). This facility finishes about 75,000 head of cattle each year on feed rations grown on-farm or sourced locally. This feedlot is likely a major contributor to the gross economic value of agricultural production on the Liverpool Plains; and,
- Another enterprise is the Doona State Forest (land reference 166 and 2001), a White Cypress Pine dominant native forest used for commercial harvesting of logs for milling. As a component of the Northern Cypress District, the Forestry Corporation of NSW manages the forest. It is a multi-use forest with ancillary land uses including recreational hunting, grazing agistment of cattle and apiary (honey bees).

Table 3.01 Landholders affected by the Project assessment areas

Count	Land reference #	Management	Production system
1	70, 71, 75, 166, 2001	Mr. J Fuller & Mr. S Fuller	Cropping, beef cattle
2	4	Mr. R Nicholls	Beef cattle lot feeding
3	38	Mr. M Cudmore	Cropping, beef cattle
4	57	Mr. B Evans	Beef cattle

Count	Land reference #	Management	Production system
5	5	Mr. A and Mrs. J Thompson	Cropping, beef cattle
6	166, 2001	Mr. C Rossler	Forestry
7	48, 49, 50, 135	Mr. A Duddy & Ms. J Burt	Cropping, beef cattle
8	161, 162, 172	Mr. S and Mrs. R Willis	Cropping, beef cattle
9	163	Mr. B and Ms. E Wilson	Beef cattle
10	160	Mr. K and Mrs. R Dugan	Cropping, beef cattle
11	19, 20	Mr. C and Mrs. S Charters Mr. C and Mrs. A Charters	Cropping, beef cattle
12	59, 113, 158a, 158b	Mr. A and Mrs. M Grant, Mr. R and Mrs. K Grant	Cropping, beef cattle
13	131, 150	Mr. D and Mrs. K Blomfield	Beef cattle
14	104	Mr. M and Mrs. N Bradfield	Cropping, beef cattle
15	11, 27	Mr. G and Mrs. M Clift, Mr. A Clift & Mr. S Clift	Cropping
16	52, 132, 152	N/A	Cropping, beef cattle
17	2, 3	Mr. L and Mrs. M Alcorn	Cropping, beef cattle
18	33, 34, 35, 36, 39, 170	Mr. G (Gary) and Mr. D Cohen	Cropping, beef cattle
19	32, 74	Mr. G (George) Cohen	Cropping, beef cattle
20	83	Mr. J Kim	Cropping, beef cattle
21	126	Mr. J and Mrs. C Priestley	Cropping, beef cattle
22	21, 22	Mr. K Charters	Cropping
23	29	Mr. M and Mrs. K Clift	Cropping
24	31	Mr. R Clift	Cropping
25	124	Mr. C. Pike	Cropping
26	125	Mr. S and Mrs. M Piper	Cropping, beef cattle

Table 3.02 Landholders outside of the Project assessment areas

Count	Land reference #	Management	Production system
1	23, 93, 111, 127, 128, 129, 130	Mr. A and Mrs. C Pursehouse	Cropping, beef cattle
2	101, 143	Mr. J Hockey & Mr. M Hockey	Cropping, beef cattle

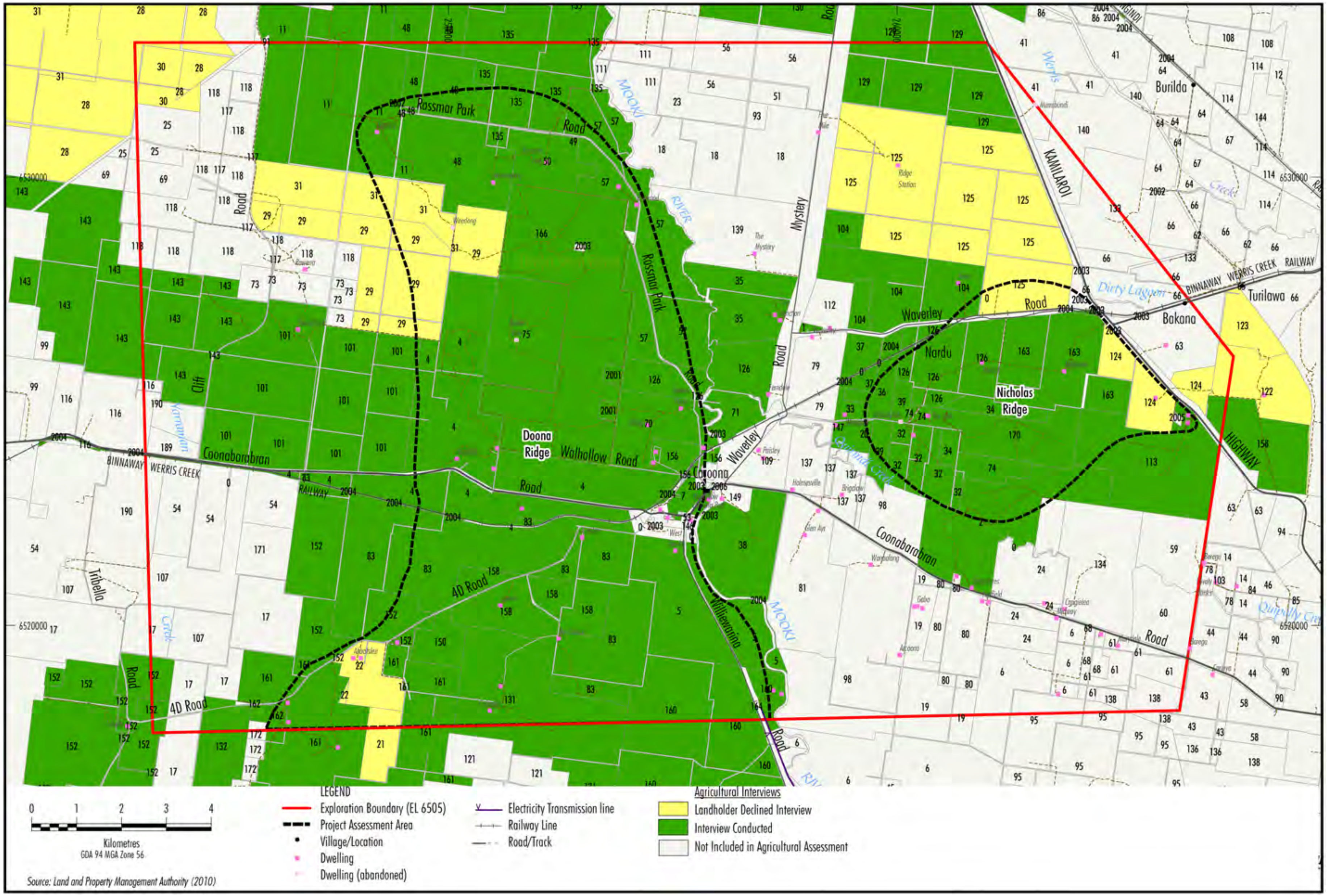

Figure 3.01 Land reference numbers relative to the Project assessment areas

3.2 Agricultural resource assessment

Intensive investigations of agricultural resources within the Project assessment area have been completed. Soils, land and soil capability, and BSAL verification by McKenzie (2014) and a preliminary assessment of groundwater resources by Nicol et al. (2014) have been finalised recently. These reports are reproduced as appendices to this report, and the key agricultural resources defined in these important investigations are summarised as follows.

3.2.1 Soils and land capability

Soils within the Project assessment areas were described at each of 404 pit locations and classified according to the Australian Soil Classification (Isbell, 2002) and the defunct Great Soil Group Scheme (Stace et al. 1968) (Table 3.03). Soil types were found by McKenzie (2014) to have the following characteristics:

- Vertosols are shrink-swell soils with a clay-field texture containing 35% or more clay; when dry they often crack to considerable depth (McKenzie et al. 2004).
- Chromosols have strong texture contrast between the A and B horizons, and a non-sodic subsoil with pH_{water} greater than 5.5.
- Dermosols lack a strong texture contrast between the A and B horizons and have moderately to strongly structured B2 horizons.
- Rudosols are derived from recently deposited alluvial/colluvial materials that have only minimal profile development.
- Tenosols at this location are shallow and have only weak pedological development.
- Kandosols lack strong textural contrast and have a massive or only weakly structured B horizon.
- Sodosols have strong texture contrast between topsoil and subsoil, and the B horizon is sodic (ESP of 6 or greater).
- Kurosols have strong texture contrast between topsoil and subsoil, and the B horizon is strongly acidic (pH_{water} less than 5.5).
- Ferrosols lack strong texture contrast between A and B horizons and have B2 horizons which are high in free iron oxide (and, for the purpose of this report, having subplastic field textures).
- Calcarosols lack strong texture contrast between A and B horizons and are dominated throughout profiles by the presence of calcium carbonate.

Soils were arranged into nine logical Soil Landscape Units (Table 3.04) and mapped across the Project assessment areas (Figure 3.02). McKenzie (2014) also contains useful commentary on existing soil-limitations to plant growth and productivity. Widespread subsoil salinity is, perhaps, the most significant of these limitations, affecting and limiting productivity of alluvial floodplain soils.

Table 3.03 Soil classification (after McKenzie, 2014)

Australian Soil Classification	Pit count	Great Soil Groups
Chromosol	93	Red-brown Earths, Non-calcic brown soils
Black Vertosol	93	Black Earths
Vertosol	83	Grey, Brown and Red Clays

Australian Soil Classification	Pit count	Great Soil Groups
Dermosol	73	Chocolate Soils, Red Podzolics
Rudosol	20	Alluvial Soils
Tenosol	14	Lithosols
Kandosol	10	Calcareous red earths
Sodosol	7	Solodic Soils
Kurosol	7	Podzolic soils and Soloths
Ferrosol	3	Kraznozems, Euchrozems
Calcarosol	1	Solonised Brown Soil

Table 3.04 Soil landscape units and soil types (after McKenzie, 2014)

Soil landscape unit	Number of sites	Map code	Dominant soil type	Sub-dominant soil types	Comments
Alluvial	90	A	Black Vertosol, other Vertosols	Chromosol	Subsoil saline/ alkaline/sodic
Volcanic: Parent material (PM) Transferral Zone /Lower Slope	37	VO-LS	Black Vertosol	Vertosol, Chromosol	Subsoil relatively free of subsoil constraints
Volcanic PM Mid/Upper Slope (Vertosols)	39	VO-MUS/V	Black Vertosol, other Vertosols	Dermosol	Subsoil relatively free of subsoil constraints
Volcanic PM Mid/Upper Slope (Chromosols, Dermosols, Ferrosols)	17	VO-MUS/CDF	Chromosol	Dermosol, Ferrosol	Subsoil relatively free of subsoil constraints
Volcanic PM Ridge (Acidic Ferrosol)	1	VO-MUS/RAF	Ferrosol	-	Strongly acidic subsoil
Sedimentary PM Steep Upper Slope	16	S-SUS	Dermosol	Chromosol, Tenosol, Vertosol, Kandosol, Kurosol	Shallow soil; slope >10%
Sedimentary PM Mid Slope	165	S-MS	Chromosol, Dermosol	Rudosol, Tenosol, Kandosol, Sodosol, Vertosol, Kurosol	Soil Landscape Unit with the greatest number of sampling sites (165)
Sedimentary PM Lower Slope	29	S-LS	Chromosol	Vertosol, Dermosol, Rudosol, Black Vertosol, Sodosol, Kandosol, Kurosol	-
Mixed Origin Transferral Zone	10	M	Rudosol, Chromosol, Dermosol	Vertosol, Ferrosol, Calcarosol	-

Soil and land capability (LSC) was determined in accordance with *The Land and Soil Capability Assessment Scheme – Second Approximation* (OEH, 2012) (Table 3.05 and Figure 3.03). LSC Class >5 on the alluvial plain have severe limitations associated with subsoil salinity, sodicity and alkalinity. Limitations on elevated land include soil acidification and waterlogging.

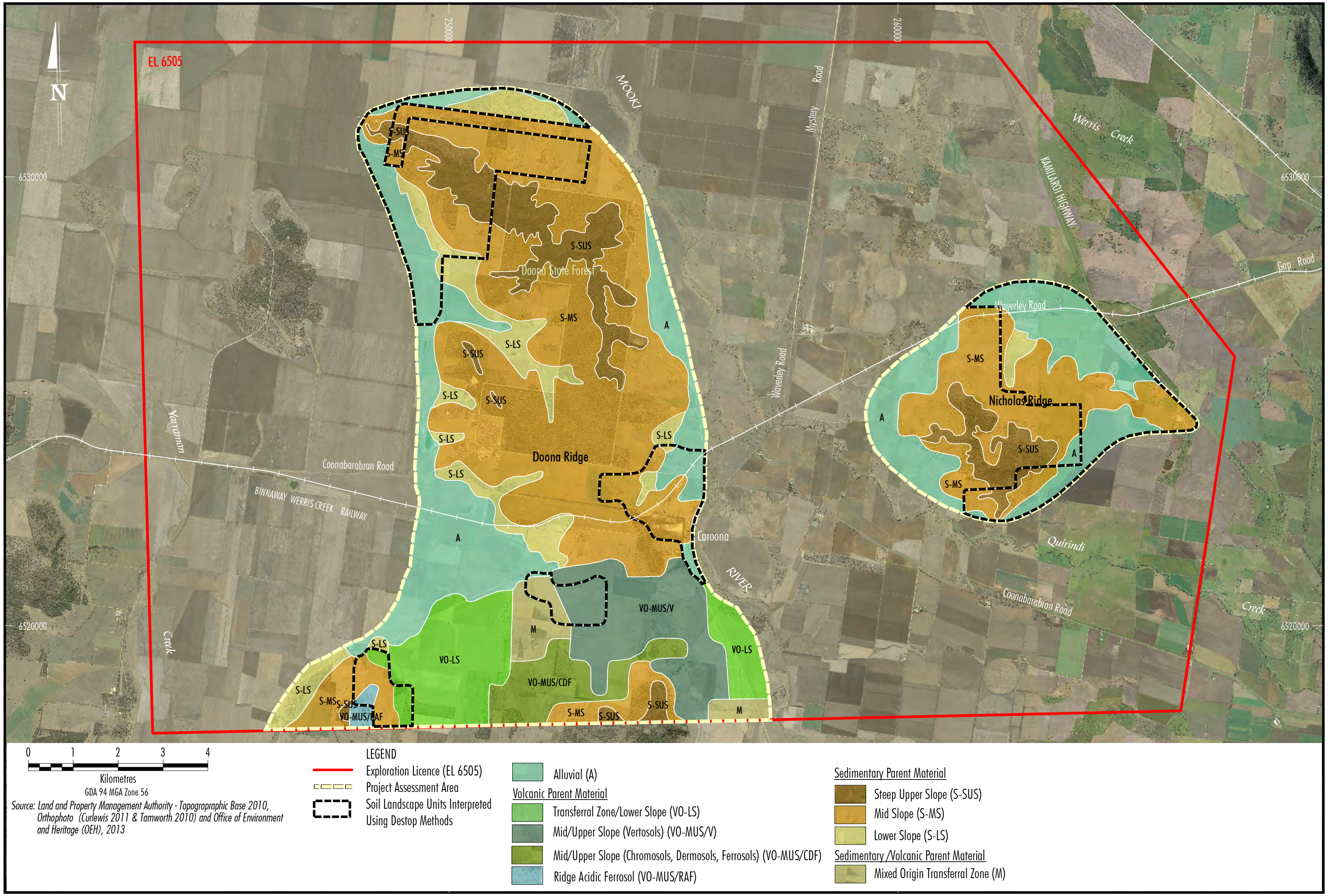

Figure 3.02 Soil landscape units within the Project assessment areas (from McKenzie, 2014)

Table 3.05 Land and soil capability within the Project assessment areas

Land & soil capability class	Extent within Project assessment areas (ha)	Description[1]
Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation)		
1	0, (0)[2]	Extremely high capability land: Land has no limitations. No special land management practices required. Land capable of all rural land uses and land management practices.
2	535, (1,239)	Very high capability land: Land has slight limitations. These can be managed by readily available, easily implemented management practices. Land is capable of most land uses and land management practices, including intensive cropping with cultivation.
3	2,174, (2,098)	High capability land: Land has moderate limitations and is capable of sustaining high-impact land uses, such as cropping with cultivation, using more intensive, readily available and widely accepted management practices. However, careful management of limitations is required for cropping and intensive grazing to avoid land and environmental degradation.
Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, some horticulture, forestry, nature conservation).		
4	4,287, (4,379)	Moderate capability land: Land has moderate to high limitations for high-impact land uses. Will restrict land management options for regular 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.
5	2,385, (2,244)	Moderate–low capability land: Land has high limitations for high-impact land uses. Will largely 5 restrict land use to grazing, some horticulture (orchards), forestry and nature conservation. The limitations need to be carefully managed to prevent long-term degradation.
Class 6: Land capable for a limited set of land uses (grazing, forestry and nature conservation, some horticulture). Classes 7 and 8: Land generally incapable of agricultural land use (selective forestry and nature conservation).		
>5	2,464, (1,885)	Class 6: Low capability land: Land has very high limitations for high-impact land uses. Land use restricted to low-impact land uses such as grazing, forestry and nature conservation. Careful management of limitations is required to prevent severe land and environmental degradation Class 7: Very low capability land: Land has severe limitations that restrict most land uses and generally cannot be overcome. On-site and off-site impacts of land management practices can be extremely severe if limitations not managed. There should be minimal disturbance of native vegetation. Class 8: Extremely low capability land: Limitations are so severe that the land is incapable of sustaining any land use apart from nature conservation. There should be no disturbance of native vegetation.
TOTAL	**11,845[3]**	

[1] From OEH (2012)

[2] Brackets indicate values for salt-tolerant crop species (McKenzie, 2014)

[3] Total is 18 ha less than the total Project assessment area as it excludes Disturbed Terrain, e.g. Caroona township area

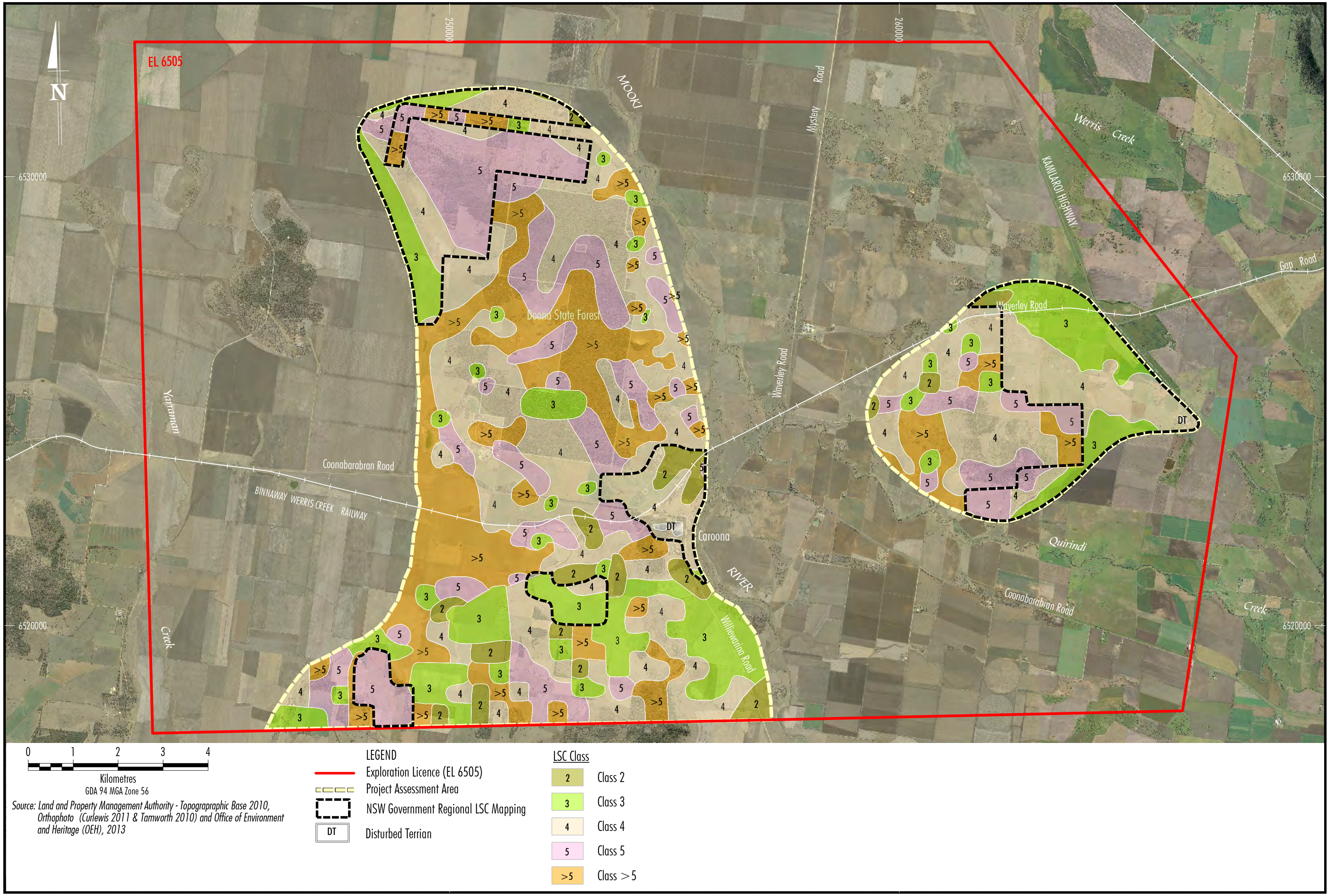

Figure 3.03 Soil and land capability within the Project assessment areas (from McKenzie, 2014)

3.2.2 BSAL

McKenzie (2014) verifies the presence of 2,215 ha of BSAL soils within the Project assessment areas (Figure 3.04). According to McKenzie (2014), the total area of verified BSAL is comprised of 2,069 ha confirmed by application of the verification protocol (OEH and OAS&FS, 2013) plus an additional 146 ha interpreted by a desktop method that recognised adjacent verified BSAL and the continuity of the relevant soil landscape unit (refer to Figure 3.02).

There is discrepancy between the location and extent of potential BSAL, 3,423 ha (Mining SEPP, Sheet STA_09), and the location and extent of BSAL verified by this investigation. The most significant difference is associated with the Alluvial soil landscape unit, in the central-western portion of the Doona Ridge assessment area. These Vertosol soils have strongly saline (chloride), sodic (sodium) and alkaline (high pH) subsoils, to the extent that these parameters exceed the threshold limits for verification as BSAL (McKenzie, 2014).

Verified BSAL within the Project assessment areas represents 0.54% of potential BSAL on the Liverpool Plains and 0.14% of BSAL in the New England North West Region (Table 3.06).

Table 3.06 Location and extent of BSAL

Location	Total extent (ha)	Potential BSAL (ha)	Verified BSAL (ha)
New England North West Region	9,970,426	1,541,694	
Southern Plains	1,007,602	384,051	
Namoi Catchment	4,206,932	576,232	
Liverpool Plains Catchment	1,224,431	409,704	
Project assessment areas	11,863	3,423	2,215
Doona Ridge assessment area	9,447	3,261	2,143
Nicholas Ridge assessment area	2,416	162	72

It must be noted that access to several properties within the Project assessment areas was not available for soil investigations conducted between May and December 2013. Within these properties there is 459 ha of potential BSAL (Figure 3.04). Most of this potential BSAL is within the Alluvial soil landscape unit (refer to Figure 3.02), which has been demonstrated by McKenzie (2014) to have subsoil limitations that exceed BSAL verification criteria threshold limits. The Applicant will endeavour to gain access to these remaining properties such that soil survey and BSAL verification can be completed. Results of any additional soil assessment work will be presented in the EIS, if the relevant landholder provides land access. If land access is not permitted, then desktop assessment methods will continue to be relied upon.

3.2.3 Groundwater systems

Nicol et al. (2014) investigated groundwater systems in a 6,790 km^2 area centred on the Project assessment areas. Of these groundwater systems (Figure 3.05), it is the aquifers contained in the alluvium-derived Narrabri and Gunnedah formations that are the most important to agriculture. The Narrabri formation, where present, is typically above the Gunnedah formation. Deeper aquifers rapidly trend to highly saline conditions making them unsuitable for irrigation or other agricultural use.

Interpolated alluvial watertables are shallow, ranging from about two to ten metres in some areas, particularly to the west and south of the Project assessment area, and ten to 25 m over large areas of the

Mooki floodplain. Very shallow watertables exist in the central-western part of the Doona Ridge assessment area and in the north-east of the Nicholas Ridge assessment area. This may explain, to some extent, subsoil salinity identified by McKenzie (2014) in overlying soils.

The watertable is shallow at Breeza, to the north, where the alluvials thin and become clay dominant. This area acts as a 'choke' to alluvial groundwater flow, which is generally from the south to the north. On the regolith areas of the Doona and Nicholas Ridge Project assessment areas, estimated watertable depths are much greater, ranging from ten to 100 m, suggesting low recharge rates to outcropping bedrock. There is inter-connectivity between alluvial aquifers and surface watercourses, e.g. Mooki River.

The Gunnedah Formation is the primary (highest yielding, most utilised) aquifer in the region. Groundwater from the Gunnedah Formation is used extensively for irrigation, stock and domestic use and for the town water supply at Gunnedah, Breeza, Curlewis, Quirindi and Caroona/Walhallow. There are 5,279 registered bores and wells within the investigation area of 6,790 km^2, and more than 4,000 bores are known to be privately owned.

Groundwater extraction from the alluvial aquifers is anecdotally thought to have commenced in about the early 1970's. An estimated peak extraction rate of more than 400 mega-litres (ML) per day occurred in 2002 (146,000 ML annualized), after which time usage has declined significantly to approximate <25% of peak, i.e. <100 ML/day (Nicol et al. 2014).

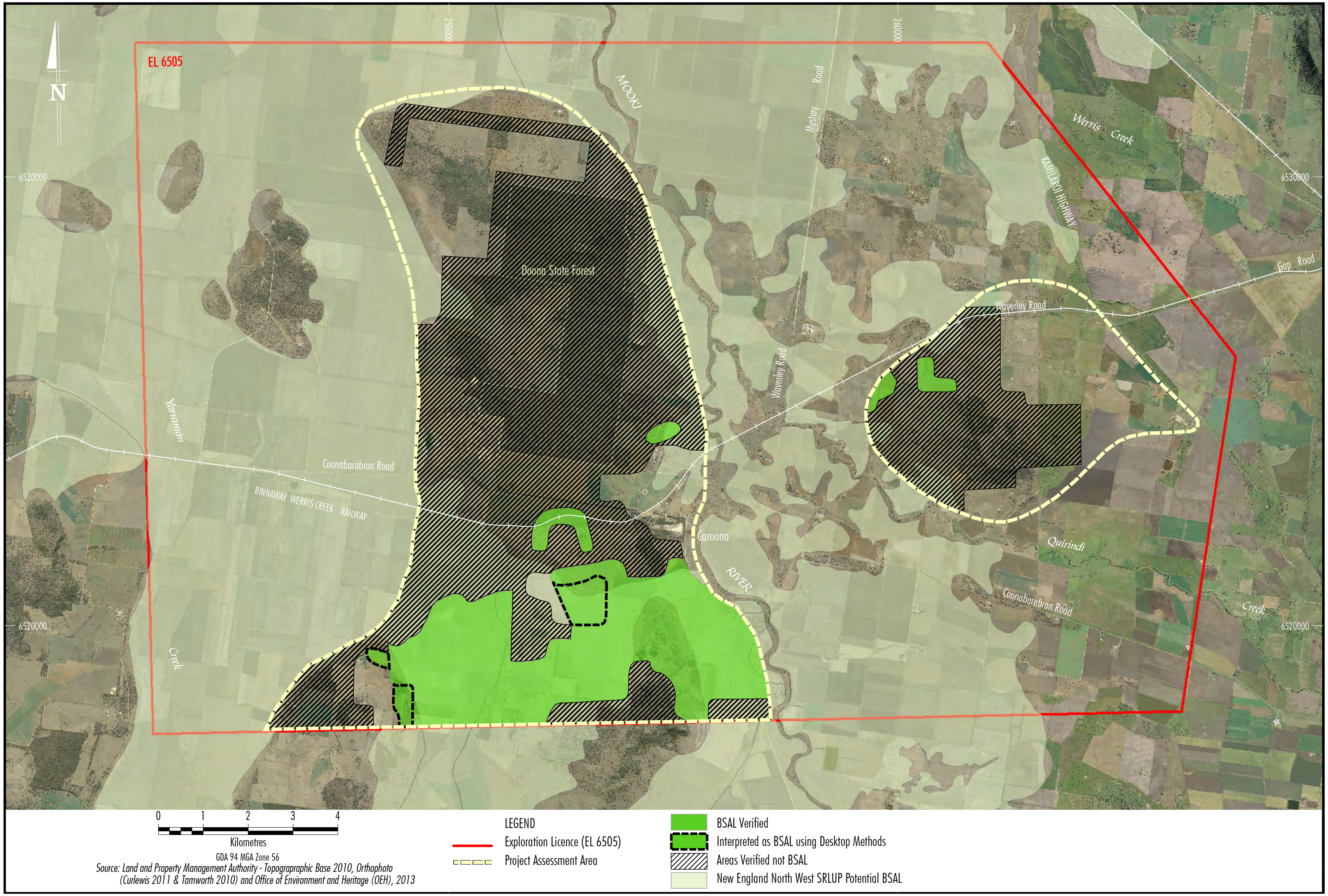

Figure 3.04 Verified BSAL soils within the Project assessment areas (from McKenzie, 2014)

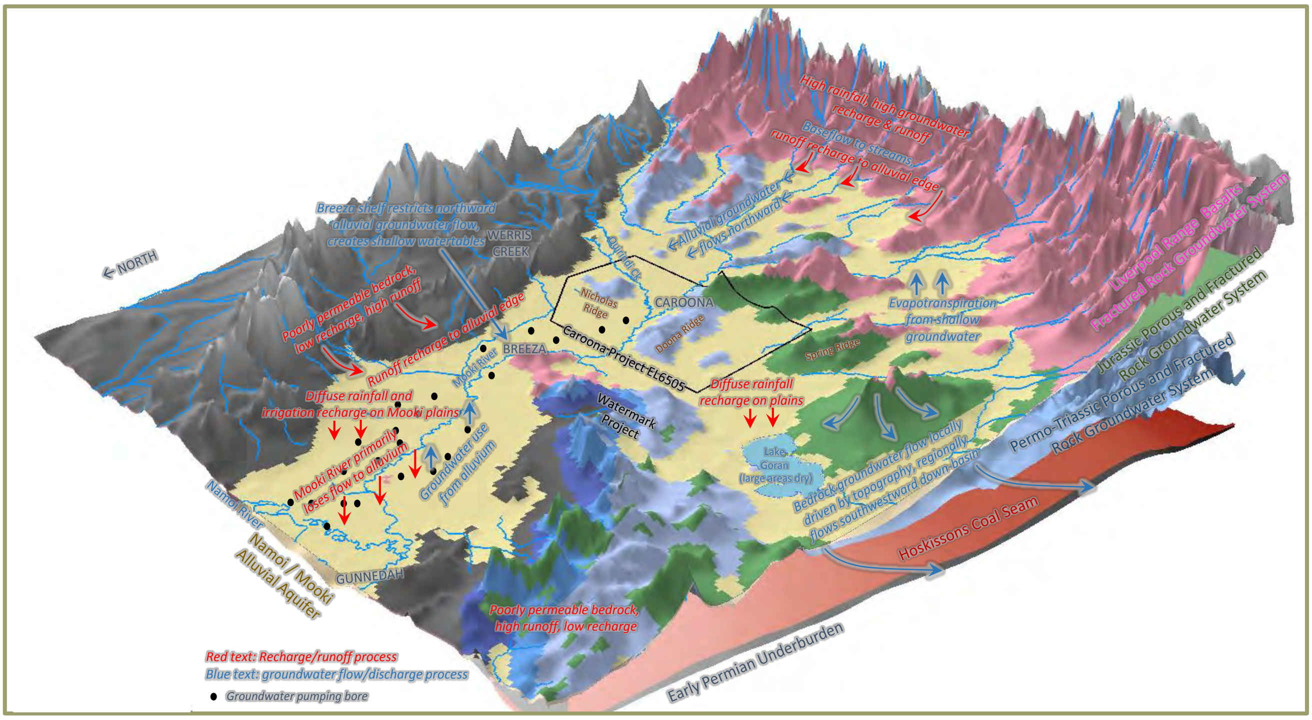

Figure 3.05 Groundwater systems associated with the Project (adapted from Nicol et al. 2014)

4 ASSESSMENT OF AGRICULTURAL IMPACTS

Following is a process-based identification and description of potential impacts of the Project on strategic agricultural land, specifically BSAL and its associated highly productive groundwater systems.

4.1 Nature of Proposed Mining Impacts

The Project proposes underground longwall coal mining methods in the Hoskissons Seam. The conceptual mine layout design (Figure 4.01) indicates seven proposed 'Mining areas'. The extent of verified BSAL within each of these Mining areas has been calculated (Table 4.01).

Table 4.01 Extent of verified BSAL within each Mining area and Project assessment areas

Mining area	Extent of mining area (ha)	Extent of verified BSAL (ha)
1	873	9
2A	1,436	0
2B	1,126	0
2S	229	1
3	989	23
4	2,166	1,242
5	1,173	711
Balance in Project assessment areas	n/a	229
TOTAL	**7,992**	**2,215**

Undoubtedly, for the mining of any coal resource, the underground longwall mining method has lower-order potential impacts on agriculture than does open-cut mining. The foremost agricultural impacts of underground longwall mining are the nature, extent and timing of surface subsidence, and the location and lifespan of surface infrastructure. The focus of this report is the potential impacts of subsidence and infrastructure on strategic agricultural land, i.e. BSAL and highly productive aquifers associated with those soils.

4.1.1 Subsidence

Surface subsidence refers to the vertical and horizontal movement of the land surface and is the inevitable consequence of underground longwall coal mining. The extent and nature of subsidence is defined by several key parameters, i.e. vertical movement, tilt (change in slope), curvature (rate of change of tilt), and strain (relative differential horizontal movement). Engineering calculation and modelling can reliably predict each of these parameters.

Barbato (2014) (reproduced here as Appendix C) provides a thorough description of predicted subsidence parameters and surface impacts for the Project. Predicted maximum subsidence parameters are as follows:

- Vertical subsidence of 1,600 to 3,100 mm;

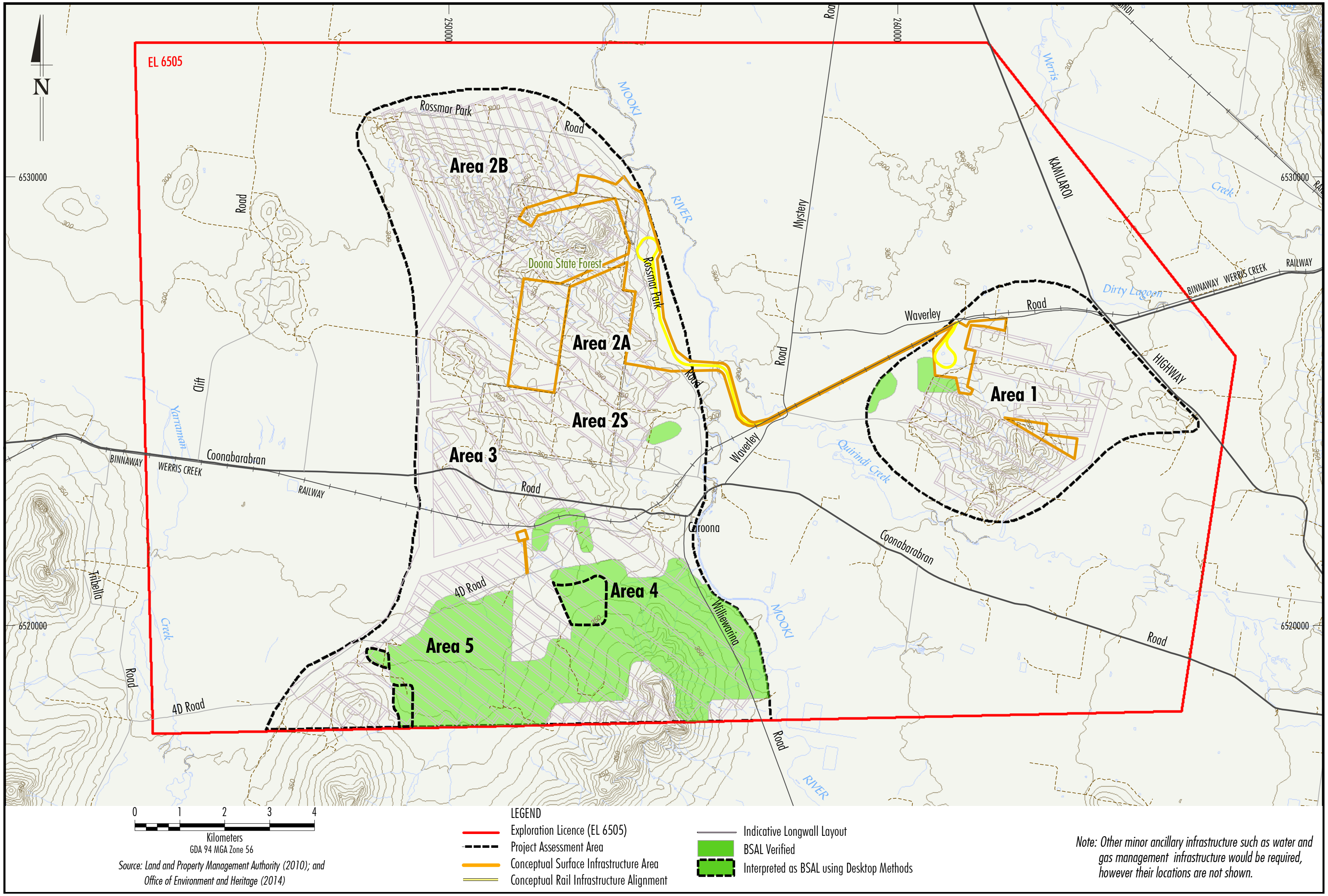

Figure 4.01 Conceptual mine layout design, 'Mining Areas' and verified BSAL

- Tilt of 10 to 70 mm/m;
- Hogging and sagging curvatures of 0.1 to 3.0 km-1 (i.e. 100 m to 3 km radius of curvature); and
- Strains typically up to 20 mm/m, with isolated strains greater than 20 mm/m.

Barbato (2014) considers the potential impacts on BSAL as a result of subsidence may include surface cracking, changes in surface water drainage, changes to surface water resources, changes to groundwater resources, and effects on built features.

4.1.1.1 Surface cracking and land deformation

As subsidence occurs, surface cracks will generally appear in the tensile zone, i.e. within 0.1 to 0.4 times the depth of cover from the longwall extents, mostly within a radius of approximately 0.1 times the depth of cover from the longwall perimeters. The cracks will generally be parallel to the longitudinal edges or the ends of the longwalls. Surface cracking normally develops behind the extraction face up to a horizontal distance equal to around half the depth of cover and, hence, cracking normally develops over a period of around two to four weeks.

Barbato (2014) provides a summary of the estimated maximum crack widths within each of the proposed mining areas (Table 4.02). Importantly, widths of actual cracks will generally be less than maximum widths shown here.

Table 4.02 Predicted maximum crack width for each mining area (after Barbato, 2014)

Mining area	Depth of cover (m)	Longwall width to depth ratio	Extraction height (m)	Typical maximum crack widths
Areas 1 and 2A	130 ~ 360 250 mean	0.9 ~ 2.9 1.5 mean	4.8	Typically between 50 and 100 mm, with isolated cracks greater than 300 mm
Area 2B	135 ~ 275 200 mean	0.8 ~ 1.5 1.1 mean	2.5	Typically between 25 and 50 mm, with isolated cracks greater than 200 mm
Areas 2S and 3	330 ~ 420 390 mean	0.5 ~ 1.2 0.9 mean	4.8 typical 2.5 in SCZ[1]	Typically between 25 and 75 mm, with isolated cracks greater than 200 mm
Areas 4 and 5 outside of SCZ	395 ~ 710 570 mean	0.6 ~ 1.0 0.7 mean	4.8	Typically between 10 and 25 mm, with isolated cracks greater than 100 mm
Areas 4 and 5 inside of SCZ	425 ~ 570 520 mean	0.3 ~ 0.5 0.4 mean	2.5	Typically less than 10 mm, with isolated cracks greater than 25 mm

[1] SCZ is a Subsidence Control Zone where extraction height and block width has been reduced to lessen subsidence.

There is no verified BSAL located in Mining areas 2A or 2B (McKenzie, 2014).

There is verified BSAL in Mining areas 1, 2S, 3, 4 and 5 (McKenzie, 2014) and in these areas, BSAL is reasonably expected to experience surface cracking due to subsidence. In Mining Area 1, cracks will generally be 50 to 100 mm width, with isolated cracks to 300 mm. In Mining Areas 4 and 5, and outside of subsidence control zones (SCZ), cracks will be ten to 25 mm, with isolated cracks to 100 mm width. Crack width within the SCZ will be significantly reduced to about ten mm typically, but up to 25 mm.

4.1.1.2 Changes in surface water drainage

Barbato (2014) has analysed predicted post-mining topography and identified likely changes in surface water drainage, including areas where topographic depressions may lead to surface water ponding. Prolonged submersion can reduce the chemical and physical fertility of soils. Whilst ponding is likely in some locations within the Project assessment areas, none is predicted to occur on verified BSAL. This is due to the existing topography, the orientation of longwall blocks relative to this topography, and the location of SCZs where extraction height and block width is reduced specifically to limit surface subsidence deformation impacts including the extent and depth of potential ponding.

4.1.1.3 Changes to surface water resources

The Project does not propose to undermine the Mooki River or Quirindi Creek. At its closest points, proposed underground mining will be 250 m from the Mooki River, and 500 m from Quirindi Creek. Barbato (2014) states that neither watercourse will be impacted by subsidence. On this basis, there is no risk to stream bank stability due to the proposed mining activities.

In contrast, unnamed drainage lines that traverse the Mining Areas will experience subsidence up to the predicted maximum effects described previously (see Section 4.1.1.1). Barbato (2014) describes these drainage lines as first or second order ephemeral streams with shallow incisions in the natural surface soils. The maximum predicted tilts for the drainage lines are around 70 mm/m (i.e. 7 %, or 1 in 14) in Areas 1 and 2A, 40 mm/m (i.e. 4 %, or 1 in 25) in Area 2B, between 20 mm/m (i.e. 2 %, or 1 in 50) to 30 mm/m (i.e. 3 %, or 1 in 33) in Areas 2S, 3 and 4 and 10 mm/m (i.e. 1 %, or 1 in 100) in Area 5 (Barbato, 2014).

The predicted increased gradients of drainage lines that traverse verified BSAL in Mining Areas 1, 4 and 5, have the potential to cause accelerated scouring of the stream bed, particularly in times of high flow, when stream velocities exceed 1 m/s (Barbato, 2014). This may be further exacerbated where channel incisions expose structurally weak (e.g. saline) and/or dispersive (e.g. sodic) subsoils. Cracking is also anticipated in beds of drainage lines (Barbato, 2014).

Nicol et al. (2014) discuss groundwater and surface water interactions, highlighting the Mooki River between Caroona and Breeza is a "losing system", where water is generally 'lost' from the river to underlying groundwater systems, particularly during periods of low stream flow. In this area, depth to the watertable is about 10 m below the bed of the river. It is concluded that the Project will cause a reduction in river base flow of 0.7 ML/day peak, and with the proposed Shenhua Watermark mine, may cause a cumulative peak base flow reduction as high as 0.9 ML/day (Nicol et al. 2014).

4.1.1.4 Changes to groundwater resources

Groundwater modelling by Nicol et al. (2014) indicates the Project will have a negligible effect on the Narrabri, Gunnedah or Tertiary (Liverpool Range) Volcanic formation groundwater sources with no areas of modelled maximum drawdown greater than 2 m. Most groundwater pumping bores in the area screen the Gunnedah formation (Nicol et al. 2014).

Where these bores are located above the proposed Mining areas, there is potential they will be impacted by subsidence. These impacts are thought to include lowering of the water level, blockage of the bore due to differential horizontal displacements at different horizons within the strata and changes to groundwater quality (Barbato, 2014).

Nicol et al. (2014) have determined the potential impacts on groundwater resources to be as follows.

- 27 privately owned bores with drawdowns in excess of 2 m, in the highly productive Jurassic (Spring Ridge) porous rock unit (see Nicol et al. 2014, Tables 27 and 28). None of these bores are allocated water under any Water Sharing Plan, and none are screened in the Narrabri, Gunnedah or Liverpool Range formations. These bores are thought to be used for stock and domestic supply purposes;
- No significant impacts with respect to the quality of any groundwater resources;

- The post-mining average total water take from the Namoi Alluvium is 167 ML/year. The maximum extraction rate at any point in time from this source is 487 ML/year. Throughout simulated mining operations, the average take from this source is 363 ML/year;
- The average total water take from the Liverpool Ranges Basalt (fractured rock) aquifer during operational mining is 9 ML/year. The maximum extraction rate from this source is 10 ML/year. Post-mining, the simulated take from this source averages 4 ML/year, with a maximum of 9 ML/year;
- The average total water take from the Jurassic porous rock unit (Spring Ridge) during operational mining is 2 ML/year. The maximum depletion rate at any point in time from this source is 11 ML/year. Post-mining, the simulated take from this source averages 6 ML/year, with a maximum of 11 ML/year;
- The average total water take from the Permo-Triassic porous rock groundwater system (Other) during operational mining is 1,033 ML/year. The maximum depletion rate at any point in time from this source is 2,301 ML/year. Post-mining, the simulated take from this source averages 88 ML/year, with a maximum of 254 ML/year;
- The risk of reduced beneficial uses of any groundwater source or the Mooki River as a result of water quality effects due to the Project would not occur.

Potential impacts on highly productive aquifers within the meaning of the Aquifer Interference Policy are discussed in Section 4.2.4 of this report.

4.1.1.5 Effects on built features

In addition to groundwater bores, built features identified by Barbato (2014) to be directly above longwall blocks include the following.

- 23 houses;
- Approximately 100 rural building structures located directly above the proposed longwalls, which includes sheds, garages and other non-residential building structures;
- 52 farm dams located directly above the proposed longwalls, which have been established along the natural drainage lines;
- The Caroona Feedlot and associated infrastructure;
- The Binnaway Werris Creek Railway;
- Local roads including sections of Woodlands Road, Rossmar Park Road, Coonabarabran Road, 4D Road, Willewarina Road and Mooki Road. There are also a number of unsealed tracks within the Doona State Forest;
- Electrical infrastructure comprising aerial 33 kV, 11 kV and low voltage powerlines supported by timber poles. A zone substation is also located south of the proposed longwalls in Area 4;
- An optical fibre, which follows the alignment of the railway, which is located above the proposed longwalls in Area 3. A second optical fibre cable is also located in the vicinity of Areas 2S and 3. Copper telecommunications cables are located across each of the mining areas, which service the rural properties. A telecommunications station is also located south of the proposed longwalls in Area 4;
- A water pipeline which follows the alignment of Coonabarabran Road above the proposed longwalls in Area 3. The pipeline provides potable water to the township of Caroona; and,
- The Central Ranges natural gas pipeline.

Built features will potentially incur some impact from subsidence and this will require further and careful consideration in the EIS, including interventional management to limit impacts.

4.1.1.6 Changes to agricultural land use

Subsidence will cause surface cracking and land deformation, changes to groundwater resources, impacts to built features and has the potential to affect localised water drainage patterns. For the period of active subsidence and subsidence remediation, it may be necessary to remove areas of cultivated BSAL from agricultural production or modify the type/methods of agricultural production, e.g. change in crop. On cultivated BSAL, it may also be necessary to ensure a high-percentage of groundcover during active subsidence to reduce the risk of erosion. Generally, grazing will continue above areas of active subsidence with regular monitoring for cracking and installation of additional temporary fencing, e.g. additional electric fences. Livestock access to active subsidence areas may be limited in areas where larger cracks are predicted, e.g. on sloping ground, in the interest of animal safety. Access by landholders and other people would be restricted in areas that may become unsafe, such as near cliff lines or near structures that an engineering inspection has determined may be unstable. These short-term and temporary impacts are discussed further herein (see section 4.2.5).

4.1.2 Surface infrastructure and other disturbance

Surface infrastructure is required to support underground longwall coal mining and includes the following.

- Buildings - offices, bathhouse, warehouse, underground control room, fuel storage;
- Electrical infrastructure - overhead transmission lines, switchyard;
- Ventilation infrastructure - exhausting fan assemblies;
- CPP - coal stockpiles, coal-washing plant;
- Fine and coarse reject emplacement - dump and/or dam;
- Gas management infrastructure - flares; and
- Roads - internal and external access routes.

None of the above Project infrastructure is proposed on verified BSAL. It is proposed that only limited surface infrastructure and minor disturbance, other than subsidence, for water and gas management infrastructure and exploration activities, will be sited on verified BSAL.

4.1.3 Summary of impacts on agribusinesses within the Project assessment areas

The BSAL status and summary mining impacts, including impacts on groundwater resources, for each of the agribusinesses described in detail within the Project assessment areas (refer to Appendix A) is provided (Table 4.03 and Figure 4.02).

Table 4.03 Summary BSAL status and mining impacts on agribusinesses within the Project assessment areas

Land reference	Surname	Verified BSAL (ha)		Remaining Potential BSAL (ha)		Groundwater	
		Extent occurring	Extent to be subsided	Extent occurring	Extent to be subsided	Bore ID	Drawdown (m)
70 71 75	Fuller	24.17 -- 0.00	5.04 -- 0.00			54961[3] (70)	-22.22
4	JBS	18.13	18.13	13.80	0.00		
38	Cudmore	N/A[1]	--				
57	Evans	0.00	0.00	11.40	0.00		
5	Thompson	384.95	359.00	6.00	0.40		

Land reference	Surname	Verified BSAL (ha)		Remaining Potential BSAL (ha)		Groundwater	
		Extent occurring	Extent to be subsided	Extent occurring	Extent to be subsided	Bore ID	Drawdown (m)
166 2001	NSW Forestry	0.00 0.00	0.00 0.00				
48 49 50 135	Duddy	N/A[1]	--	45.20 7.20	0.50 0.00		
161 162 172	Willis	193.88 -- --	193.88 -- --			17099[2] (161) 15671[2] (161) 38273[2] (161) 20446[2] (161) 22576[2] (161)	-12.19 -9.91 -7.79 -4.56 -4.01
163	Wilson	0.00	0.00				
160	Dugan	207.26	198.76			44769[3]	-163.19
19, 20	Charters (Craig)	N/A[1]	0.00				
59 113 158a 158b	Grant	-- 0.00 214.13 N/A	-- 0.00 214.13 0.00	 46.40	 45.90	04845[3] (158a) 38808[3] (158a)	-184.58 -165.79
23, 93, 111, 127, 128, 129, 130	Pursehouse	N/A[1]	0.00				
131 150	Blomfield	394.32 107.95	394.32 107.95				
104	Bradfield	N/A[1]	--	5.40	0.00		
11 27	Clift	N/A[1] N/A[1]	-- --	40.10	1.50		
52 132 152	Not disclosed	N/A[1] N/A[1] 11.38	-- -- 11.38			14626[2] (152) 22213[2] (152)	-2.73 -2.71
2 3	Alcorn	N/A[1] N/A[1]	0.00 0.00				
7 33 34 35 36 37 39 170	Cohen (Gary)	N/A[1] 0.66 0.00 0.00 26.46 0.79 0.08 0.00	-- 0.00 0.00 0.00 0.00 0.00 0.00 0.00	18.1	0.00		

Land reference	Surname	Verified BSAL (ha)		Remaining Potential BSAL (ha)		Groundwater	
		Extent occurring	Extent to be subsided	Extent occurring	Extent to be subsided	Bore ID	Drawdown (m)
32 74	Cohen (George)	0.00 0.00	0.00 0.00				
83	Kim	497.14	497.14	4.00	4.00	48250[3]	-185.58
126	Priestley	42.49	15.45				
101, 143	Hockey	N/A[1]	0.00				
21 22	Charters (Ken)	2.39 28.12	2.39 28.12			48614[2] 68004[2] 15673[3] (all on 22)	-13.77 -8.24 -108.18
29 31	Clift	N/A[1] N/A[1]	-- --	136.7 35.8	0.00 0.00		
124	Pike	N/A[1]	--				
125	Piper	N/A[1]	--	20.80	0.00		
Subtotal landholders within PAAs		**2,154**	**2,045**				
2002	Not known	--	--				
2003	Dept. of Lands	N/A	--	3.50	0.00		
2004	State Rail Authority	0.00	0.00				
156	Walhallow Local Aboriginal Land Council	2.13	0.00	49.20	0.00		
Other	Road reserves	58.60	57.58	15.30	3.30		
TOTAL		**2,215**	**2,103**	**459**	**56**	--	

[1] N/A means not assessed by McKenzie (2014); [2] indicates 'highly productive' water source (after Nicol et al. 2014); [3] indicates 'less productive' water source on verified BSAL (after Nicol et al. 2014); and, [4] verified BSAL includes interpreted BSAL (refer to Section 3.2.2)

4.2 Identification and Assessment of Impacts against the Relevant Criteria

The Mining SEPP provides the relevant criteria to be used in determining potential impacts to strategic agricultural land. With reference to these criteria and the Guideline (DP&I, 2013), the Project's potential impacts on BSAL are considered as follows.

4.2.1 Any impacts on the land through surface area disturbance and subsidence

Within the Project assessment areas of 11,863 ha total, there are 2,215 ha of verified BSAL (McKenzie, 2014). In total, the Project will result in about 8,500 ha of land subsidence, including subsidence of 2,103 ha of verified BSAL (to the 20 mm predicted subsidence contour). The majority of verified BSAL is located in the southern portion of the Doona Ridge assessment area, above Mining areas 4 and 5. Smaller areas of BSAL are located above Mining areas 1 (9 ha), 2S (1 ha) and 3 (23 ha). Predicted maximum subsidence impacts have been determined for these mining areas (Table 4.04), excluding Mining area 2S as it only contains a single hectare of verified BSAL. Some temporary mine infrastructure for ventilation and gas management may be located on up to 30 ha of verified BSAL.

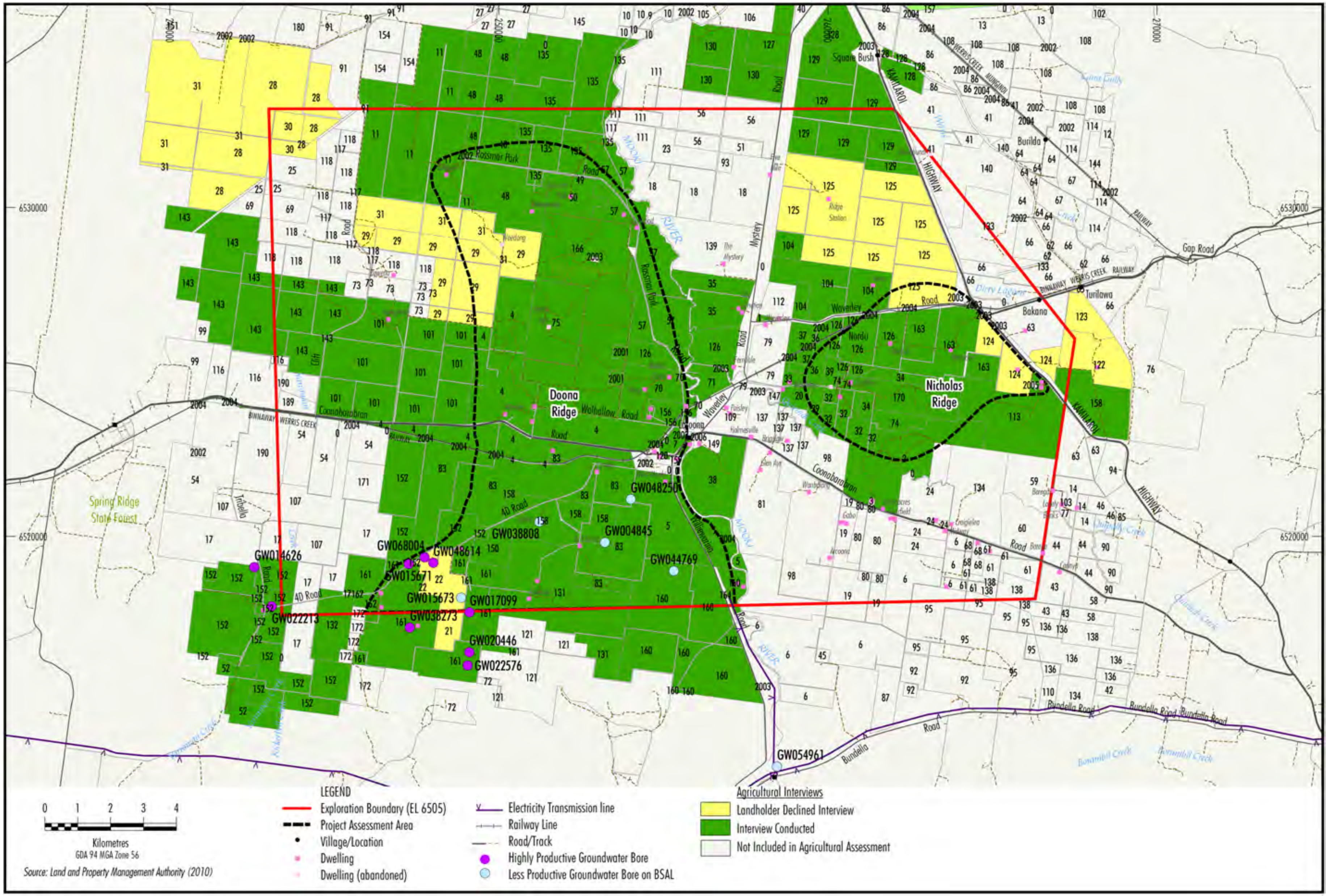

Figure 4.02 Bores within the Project assessment areas and immediate surrounds with a predicted >2m drawdown

At the time of mine closure and following the cessation of mining, the decommissioning and removal of all plant, infrastructure and equipment, and the completion of all necessary rehabilitation activities, the impacts of all these mining activities will cause minor changes to land and soil capability (Table 4.05). The main impact on land and soil capability is due to surface emplacement of CPP rejects materials (on verified non-BSAL land). McKenzie (2014) anticipates that the planned coal rejects emplacement could be remediated to LSC Class 4 land. Importantly, no significant mine infrastructure and no rejects emplacements will be sited on verified BSAL.

Table 4.04 Predicted maximum subsidence effects in Mining areas containing verified BSAL (after Barbato, 2014)

Mining area	Verified BSAL (ha)	Void width[1] (m)	Vertical sub. (mm)	Tilt (mm/m)	Hogging & sagging (km-1)	Strain (mm/m)	Typical maximum crack widths
Area 1	9	410	3,100	70	3.00	4 – 20	Typically between 50 and 100 mm, with isolated cracks greater than 300 mm
Area 3	23	410	2,900	25	0.45	2 – 12	Typically between 25 – 75 mm, with isolated cracks greater than 200 mm
Area 4	1,242	410 (210 in SCZ)	2,750	20	0.35	2 – 6	Outside SCZ, typically between 10 and 25 mm, with isolated cracks greater than 100 mm
Area 5	711	410 (210 in SCZ)	2,400	10	0.20	0.5 – 2.5	Inside SCZ, typically less than 10 mm, with isolated cracks greater than 25 mm

[1] Void width accounts for 200 or 400 m longwall block and roadways on each side

As recommended by McKenzie (2014), a *Rehabilitation Management Plan* should be developed. Amongst other things, this plan would contain detail concerning the stripping, storage and management of soil resources for rehabilitation of emplacement and mine infrastructure sites, and strategies to mitigate the effects of subsidence, e.g. infilling of surface cracks.

Table 4.05 Pre- and post-mining land and soil capability classes (after McKenzie, 2014)

Land & soil capability class	Pre-mining (ha)	Post-mining (ha)	Percentage change (%)
1	0, (0)[1]	0, (0)	0
2	535, (1,239)	535, (1,239)	0
3	2,174, (2,098)	2171, (2,088)	-0.2, (-0.5)
4	4,287, (4,379)	4,518, (4,619)	5.4, (5.5)
5	2,385, (2,244)	2,283, (2,140)	-4.3, (-4.6)
>5	2,464, (1,885)	2,339, (1,759)	-5.1, (-6.7)
TOTAL	11,845[2]	11,845	--

[1] Brackets indicate values for salt-tolerant crop species (after McKenzie, 2014)
[2] Total is 18 ha less than the total Project assessment area as it excludes Disturbed Terrain, e.g. Caroona township area

With subsidence, surface deformation occurs and cracks may develop, usually in a zone parallel and proximate to the longwall block limits (refer to Barbato, 2014). Deformation is typically complete within months of the longwall face advancing past a given point, and regular monitoring by survey methods is used to determine a deformation process endpoint. At this time remediation works are conducted and once complete, the land is returned to agricultural production.

Subsidence should not affect the parameters and threshold limits that are used to define BSAL. Hinchcliffe et al. (2003) reports the effects of subsidence on certain soil properties and crop yields for non-irrigated Vertosol soils in central Queensland. This time and budget constrained study adopted a 'must sow' strategy, which led to successive crop failures that ultimately obfuscated overall results. However, when crops were sown in adequate soil-moisture conditions, and enough in-crop rainfall was received to allow harvest, the study demonstrated that subsidence did not significantly affect crop yield for two wheat crops. Soil characteristics analysed were not affected by subsidence. The land on which this study was conducted was later designated as Strategic Cropping Land, that State's equivalent to BSAL.

Prior to causing any subsidence, the Project will be required to prepare and submit a *Subsidence Management Plan* (SMP) for approval by NSW Trade & Investment, Division of Resources & Energy (DRE). This is a standard approval required by condition of mining lease for an underground coal mine in NSW (under the Mining Act 1992).

In general, DMR (2003) requires SMPs describe the following.

- Area that may be affected;
- Process of subsidence prediction employed;
- Prediction and assessment of subsidence impacts on the area affected;
- Consultation process undertaken with government agencies and the community;
- Results of that consultation; and
- Proposals to prevent, mitigate or rehabilitate subsidence impacts.

By requirement, SMPs contain considerable detail including the monitoring and assessment of actual subsidence impacts on affected land. Without pre-empting this detail, and with respect to agricultural land in general, a monitoring schedule and methodologies is proposed here (Table 4.06). Application of such monitoring will allow comparison of actual versus predicted subsidence impacts, and inform decisions on how to best management subsidence impacts on agricultural land and verified BSAL.

Table 4.06 Subsidence monitoring methodologies and schedule for agricultural land and verified BSAL

Parameter	Method	Unit	Schedule
Ground deformation	Traverse survey (centre-line and x- sections)	mm (x,y,z)	Monthly
	Aerial survey (LIDAR)	mm (x,y,z)	Annual
Surface cracking	Visual inspection with GPS locations	Inspection	Monthly
	Length and width measurements	mm	Monthly
	Photography	count	Monthly

Monitoring should also include pre- and post-subsidence assessments of key soil characteristics of chemical and physical fertility and plant productivity, e.g. yield.

4.2.1.1 Non-cultivated land

Non-cultivated lands within the Project assessment areas are typically used for grazing, forestry and agricultural infrastructure, both public and private. Impacts on agricultural infrastructure, e.g. roads, houses, sheds and other farm buildings, will be managed via the Mine Subsidence Board in accordance with the *Mine Subsidence Compensation Act 1961*. Impacts on grazing and forestry land uses include risks associated with potential surface movement, deformation and cracking, e.g.

- Risk of injury to humans and livestock, particularly associated with surface cracking; and,
- Potential tree health impacts due to hydrologic alterations and root shearing during land deformation.

These risks should be considered on a case-by-case basis, with management strategies to be determined in property-based SMPs. Generally, grazing and forestry land uses will be able to continue uninterrupted during active subsidence with the implementation of the following management strategies.

- Regular visual monitoring of the surface in the active subsidence zone to identify any surface cracking and deformation which could potentially injure stock or people. Where large cracking is identified, this area would be isolated with temporary fencing.
- Consider, in consultation with the landholder, the installation of temporary fencing, e.g. additional electric fences at paddock boundaries, where there is a reasonable risk of damage to existing fences from subsidence.
- Consider, in consultation with the landholder, the temporary relocation of stock to areas outside the active subsidence zone in areas where larger cracks are predicted, e.g. on slopes or areas of low depth of cover. The stock would then be re-introduced to the paddock following subsidence and any required remediation, e.g. infilling of surface cracks.
- Establish methods of remediation, which could include infilling of surface cracks with soil or other suitable materials, or by locally re-grading and re-compacting the surface.
- Develop property-based SMPs incorporating the agreed management strategies.

The rehabilitation of non-cultivated land affected by subsidence should focus on the removal of any surface cracking and earthworks to limit or prevent water ponding in subsidence induced depressions. This will be achieved using conventional earthmoving equipment to:

- In-fill minor surface cracks by cultivation of the ground surface; or,
- In-fill larger surface cracks with suitable soil or other material; and,
- Localised reshaping to limit the potential for water ponding; and,
- Stabilisation of disturbed areas with temporary erosion controls, e.g. silt fences, and long-term measures, e.g. vegetation planting.

These rehabilitation methodologies are standard mining industry practice throughout Australia and a common inclusion in SMP approvals in NSW.

4.2.1.2 Cultivated land

Cultivated land within the Project assessment areas are used for irrigated and dryland farming. Subsidence impacts on cultivated land are considered to include the following.

- Surface movement, deformation and cracking;
- Changes to surface water drainage pathways; and,
- Potential water ponding.

The rehabilitation of farming or cultivated land affected by subsidence should also focus on the removal of any surface cracking and earthworks to limit or prevent water ponding in subsidence induced depressions. Similar conventional earthworks should be applied to those described above. Where contour banks or similar existed prior to subsidence, these should be reinstated post-subsidence and prior to the resumption of cultivation or other soil disturbance. Post-subsidence, the soil condition should be monitored for trends of increasing salinity, particularly in areas where the watertable is known to be very shallow, i.e. ≤2 m of the soil surface.

4.2.2 Any impacts on soil fertility, effective rooting depth or soil drainage

McKenzie (2014) reports existing soil conditions for the growth of plants. Mining impacts on verified BSAL soils are largely restricted to subsidence. Subsidence of verified BSAL soils should not affect soil fertility, effective rooting depth or soil drainage.

Notwithstanding, existing subsoil salinity was considered by McKenzie (2014) to be a widespread limitation to plant growth on non-BSAL alluvial Vertosol soils. Whilst not a Gateway consideration, the potential impacts of subsidence on agricultural productivities of these non-BSAL soils will require careful consideration in the EIS.

4.2.3 Increases in land surface micro-relief, soil salinity, rock outcrop, slope and surface rockiness or significant changes to soil pH

Subsidence will cause changes to the land surface micro-relief and slope, including areas of verified BSAL. As discussed previously (refer to section 4.2.1), these changes are not anticipated to diminish inherent soil properties that verify BSAL.

The prevalence of dryland salinity on the Liverpool Plains is well documented, e.g. URS (2001) and Walker et al. (1999). Scott and Farquharson (2002) attribute dryland salinity on the Liverpool Plains to vegetation clearing and long-fallow cropping systems. Walker et al. (1999) add the farming of some inappropriate soil types with low water holding capacities to the factors causing dryland salinity and recommend these areas be permanently vegetated.

McKenzie (2014) identifies subsoil salinity as a widespread limitation to plant growth on non-BSAL alluvial Vertosol soils, particularly in the central-western portion of the Doona Ridge assessment area. Nicol et al. (2014) confirm the presence of a very shallow, i.e. ≤2 m depth, watertable in this area. This is most likely an induced salinity hazard, whereby long-fallow cropping systems have increased 'deep drainage', mobilising salts present in subsoil layers and raising the watertable, bringing the salts closer to the surface. These effects, i.e. rising watertables, may be spatially removed from their causes, i.e. increased infiltration. The salinity hazard present in the Doona Ridge assessment area is the primary reason for disparity between mapping of potential BSAL and the extent of verified BSAL by McKenzie (2014), possibly indicating a loss of BSAL due to farming practices. The nature of this soil salinity hazard and the potential implications of subsidence on agricultural productivities of these soils will require careful consideration in the EIS.

Proposed mining activities will not lead to increased soil surface rockiness, rock outcrops or changes to soil pH.

4.2.4 Any impacts on highly productive groundwater (within the meaning of the Aquifer Interference Policy)

Nicol et al. (2014) have determined potential impacts on groundwater systems, including highly productive groundwaters within the meaning of the Aquifer Interference Policy (Tables 4.07, 4.08 and 4.09). Assessments are made for the highly productive Namoi Alluvial aquifer (Narrabri and Gunnedah formations), Liverpool

Range Basalt fractured rock aquifer and Jurassic (Spring Ridge) porous rock aquifer, in addition to the less productive Permo-Triassic porous rock aquifer. Simulation indicates the Aquifer Interference Policy criteria are not triggered for the highly productive aquifers of the Namoi Alluvium or the water bearing rocks of the Liverpool Range Basalt. No minimal impact considerations other than exceeding the 2 m drawdown criteria at existing bores screened in the Jurassic and Permo-Triassic strata were identified (Nicol et al. 2014).

Table 4.07 Summary of Aquifer Interference Policy assessment for Namoi Alluvial (after Nicol et al. 2014)

Aquifer	Upper and Lower Namoi Groundwater Sources
Category	Highly productive
Level 1 minimal impact consideration	**Assessment**
Water Table	Level 1 minimal impact consideration classification
Water pressure	Level 1 minimal impact consideration classification
Water quality	Level 1 minimal impact consideration classification

Table 4.08 Summary of Aquifer Interference Policy assessment for Liverpool Range basalt (after Nicol et al. 2014)

Aquifer	NSW Murray Darling Basin Fractured Rock Groundwater Sources (Liverpool Ranges Basalt MDB)
Category	Highly productive
Level 1 minimal impact consideration	**Assessment**
Water Table	Level 1 minimal impact consideration classification
Water pressure	Level 1 minimal impact consideration classification
Water quality	Level 1 minimal impact consideration classification

Table 4.09 Summary of Aquifer Interference Policy assessment for Jurassic porous rock (after Nicol et al. 2014)

Aquifer	NSW Murray Darling Basin Porous Rock Groundwater Sources (Gunnedah-Oxley Basin MDB (Spring Ridge))
Category	Highly productive
Level 1 minimal impact consideration	**Assessment**
Water Table	Level 2 minimal impact consideration classification
Water pressure	Level 2 minimal impact consideration classification
Water quality	Level 1 minimal impact consideration classification

4.2.5 Any fragmentation of agricultural land uses

Considering the extent of verified BSAL and existing land uses on verified BSAL (refer to section 3 of this report), the proposed mining activities should not cause the long-term or permanent fragmentation of agricultural land uses on this area. Rather, fragmentation should be temporary and short-term, associated with suspension of agricultural production on verified BSAL only for the period of time needed to manage that land with regard to subsidence. This time period may be some years at a paddock level, to allow appropriate management measures to be implemented, actual subsidence to occur, and remediation works to be effected as needed and across sensibly-scaled areas.

An estimated 2,103 ha of verified BSAL will be subsided. This will not occur simultaneously, but sequentially, on a longwall block-by-block basis over a period of about 15 years (in Mining Areas 4 and 5).

Successful anecdotal management practices at Kestrel (Rio Tinto) and Crinum (BHP Billiton Mitsubishi Alliance) mines in central Queensland, have required a suspension of agricultural production activities on the affected land for a period of time ahead of subsidence. Exact timing is typically dependant on soil, climatic and other constraints, but enough time is needed to establish a high-percentage groundcover on the land. This is particularly important where soils are cultivated or otherwise prone to erosion, and a cover crop or pasture ley is needed to protect soil resources from the risk of erosion during deformation by subsidence. If contour banks exist, these are typically removed at this time also, to eliminate the risk of gully erosion by uncontrolled channelling of water if contour banks otherwise remain and fail during deformation.

Following establishment of a protective groundcover, the land is subsided and the land condition monitored. Surface deformation occurs and cracks may develop, usually in a zone parallel and proximate to the longwall block limits (refer to Barbato, 2014). Surface cracks may pose a risk to humans and livestock, and for this reason access by both may be restricted during active subsidence. Deformation is typically complete within months of the longwall face advancing past a given point, and regular monitoring by survey methods is used to determine a deformation process endpoint. At this time remediation works are conducted and once complete, the land is returned to agricultural production.

The management strategies for subsidence impacts on cultivated land will be developed in consultation with the landholder on a paddock basis as part of property-based SMPs, and will be highly dependent on the nature of the cultivation activities and the predicted subsidence. If the landholder and miner agree to implement subsidence mitigation or management strategies on a property, e.g. temporary modification or removal of contour banks, exclusion of stock from areas, or change in agricultural practice, the Applicant would compensate the landholder for this temporary loss of production resulting from these subsidence management activities.

Whilst not a Gateway consideration, further consideration of this temporary suspension of agricultural production should be included in the EIS. It is reasonably anticipated that any loss in economic contribution may be material at a farm-level, but immaterial from a catchment or regional perspective.

4.2.6 Any reduction in the area of biophysical strategic agricultural land

Although longwall mining and subsidence of agricultural land is a worldwide occurrence, there are few published quantitative studies of the impacts on soils and plant productivity. As with surface mining rehabilitation of agricultural lands, most work on subsidence impacts has occurred in Illinois, USA. Darmody et al. (1988 and 1989) studied the effects of longwall subsidence on corn yields in southern Illinois and concluded the impacts are minor, generally. There is some work from China that shows substantial crop yield impacts but conclusions are not supported by data. Regardless, much caution is needed when extrapolating the results of foreign studies, particularly when considering high-clay content Australian Vertosol soils.

Hinchcliffe et al. (2003) report subsidence of Vertosol soils in central Queensland caused no discernible impacts on soil physical properties measured, i.e. soil strength, bulk density, and soil moisture content and matric potential. This two-year quantitative study also concluded no significant effects on the yield of successive wheat crops grown under 'organic' conditions, with no chemical fertiliser additions, perhaps also demonstrating no impact on inherent chemical fertility.

More recent qualitative assessments are contradictory. Bacon (2013) predicted that even minor subsidence deformations would have catastrophic consequences for irrigated cotton production due to waterlogging, soil compaction, irregular crop ripening and potential salinization. In contrast, Hamilton (2013), drawing broad conclusions from observations in Illinois, *"could see no reason why full productivity would not be restored after mining. Clearly, this observation needs confirmation for the different soil types, topography, farming systems and climate of Central Queensland."*

Although not subject to quantitative study, it is known that Vertosol soils subsided by BMA Crinum Mine continue to be commercially cropped post-subsidence. This mine site was one of two studied by Hinchcliffe et al. (2003) but no quantitative evaluation has been continued at either site.

Within the Project assessment areas, McKenzie (2014) determines that subsidence will have no adverse effect on the chemical fertility of verified BSAL soils.

It is considered that the proposed mining activities will not cause any reduction in the area of verified BSAL. Whilst not a Gateway consideration, where ponding is predicted on certain areas of non-BSAL soils, and particularly if the period of inundation extends due to wet conditions or restricted access to perform remediation works, it may cause changes to soil chemical and physical fertility. The likelihood of these impacts and consequential impacts on agricultural productivity in these areas will require careful consideration in the EIS.

5 CONSULTATION WITH STAKEHOLDERS

In developing this Agricultural Impact Assessment, La Tierra has conducted extensive engagement with stakeholders including potentially affected landholders within the Project assessment areas (refer to Table 3.01), and also interested parties, industry organisations and Government agencies (Table 5.1). Engagement has been via remote communication, e.g. email, and also face-to-face interview and delivery of presentations at selected forums.

5.1 Direct engagement with potential affected landholders

A proper and contemporary analysis of agricultural resources, enterprises and production systems can never be made without engaging with land managers, i.e. farmers. La Tierra has sought to engage directly with all landholders potentially affected by the Project assessment areas. A total of 23 landholder interviews and property inspections were undertaken throughout an eight-month period ending in February 2014 (Figure 5.01). Ultimately, five landholders partially affected by the assessment areas declined to participate. The results of this engagement have been presented herein (refer to Section 3 and Appendix A of this report).

Figure 5.01 Mr. Craig Charters (Gabo Pastoral Co.) and Ms. Tiffany Thomson (La Tierra) discuss farming systems and groundwater during the wheat harvest on "Spring Ridge" in November 2013

Initially, in about June 2013, many landholders were reluctant to be interviewed or allow inspection of their properties for this agricultural impact assessment. However, following communication from the Applicant, a presentation by La Tierra (and others) to the Caroona Coal Action Group (CCAG) on 8 August 2014 and the *Soils Field Day* in September 2013 (discussed subsequently), most agreed to participate. La Tierra conducted its engagement with landholders on-farm during the following periods.

1. Round 1: 17 to 21 June 2013;
2. Round 2: 5 to 9 August 2013;
3. Round 3: 19 to 22 November 2013; and,
4. Round 4: 29 to 31 January 2014.

5.2 Direct engagement with interested parties, industry organisations and Government agencies

In the course of developing this agricultural impact assessment and in addition to the direct engagement of potentially affected landholders, La Tierra has engaged with a range of interested parties, industry organisation and Government agencies (Table 5.01).

Table 5.01 List of interested parties, industry organizations and Government Agencies engaged by La Tierra (presented chronological order)

Organisation	Representative	Engagement details		
		Type	Date	Location
Gunnedah Shire Council	Mr. Mike Silver Mr. Wayne Kerr	Interview	18 June 2013	Council Chambers, Gunnedah
Liverpool Plains Land Management Inc.	Mr. David Walker	Interview	19 June 2013	LPLM office, Gunnedah
Namoi Catchment Management Authority	Mr. Bruce Brown Mr. Matt Davidson	Interview	20 June 2013	CMA office, Tamworth
Liverpool Plains Shire Council	Mr. Ron van Katwyk	Interview	21 June 2013	Council Chambers, Quirindi
NSW Farmers' Association	Ms. Fiona Simpson Ms. Danica Leys	Interview	8 August 2013	Coffee Pot Café, Quirindi
CCAG	Members	Address	8 August 2013	Caroona Hall
AMPS	Mr. Nigel Herring	Interview	9 August 2013	AMPS office, Tamworth
Department of Primary Industries	Mr. Andrew Scott Mr. Graham Carter	Interview	9 August 2013	DPI office, Tamworth
Walhallow Aboriginal Corporation	Mr. Jason Allan	Interview	20 November 2013	Impact Café, Quirindi

By invitation of the CCAG, La Tierra's Mr. Terry Short delivered a presentation to the Group following their Annual General Meeting in the Caroona Hall on 8 August 2013. The presentation outlined the following.

1. La Tierra introduction
2. Project scope
3. Gateway agricultural assessment and EIS interaction
4. Gateway agricultural assessment requirements
5. Gateway process
6. Caroona assessment update
    a. Work commenced
    b. Work to be completed

The presentation, coupled with addresses by the Applicant, invoked significant discussion.

Engagement with interested parties, industry organisation and Government agencies was useful, however, the dialogue was mainly concerned with the Gateway process and broader regional issues, and did not add materially to the identification of impacts on strategic agricultural land by the proposed Project. For this reason, the detailed notes of these discussions are not presented in this report.

5.3 Soils Field Day

Throughout 2013, there was a general reluctance from landholders within the Project assessment areas to grant the Applicant's consultants access to their land for the purpose of verifying BSAL for this agricultural impact assessment. This was thought to be due, at least in part, to the landholders not having a clear understanding of the methods and purpose of the work. In an attempt to overcome the impasse, the Applicant held an open *field day* on Thursday 19 September 2013 at "Burwood" (land reference #59), one of the properties it had recently acquired in the Doona Ridge assessment area. The purpose of the Field Day was to demonstrate the soil survey field-methods used to verified BSAL and also explain the context and purpose for this verification, i.e. strategic agricultural land assessment and the Gateway process. Although landholder numbers were low, the event attracted wide interest and drew attendees from across NSW (Table 5.02).

Table 5.02 Field Day attendees

Count	Name of attendee	Organisation
1	Ms. Prue Green	CCAG
2	Mr. Sandy Blomfield	Landholder
3	Mr. Struan Willis	Land holder
4	Mr. Tony Todman	Landholder
5	Mr. Angus Duddy	Landholder
6	Ms. Jamie Burt	Landholder
7	Mr. Les Alcorn	Landholder
8	Mr. Garry West	Chair, Caroona Coal Project Community Consultative Committee
9	Mr. Jock Laurie	NSW Land & Water Commissioner
10	Ms. Mary Kovac	NSW DPI
11	Ms. Julie Moloney	NSW DPI
12	Mr. Rob Williamson	NSW DPI
13	Ms. Liz Rogers	NSW DPI
14	Mr. Graham Carter	NSW DPI
15	Mr. Mick Lovely	BHP Billiton
16	Mr. Darren Swain	BHP Billiton
17	Mr. Andrew Garratt	BHP Billiton
18	Ms. Aleisa Priestley	BHP Billiton
19	Mr. Tom MacKillop	Resource Strategies
20	Dr. David McKenzie	McKenzie Soil Management
21	Ms. Tiffany Thomson	La Tierra
22	Mr. Terry Short	La Tierra

The key attraction of the day was the in-paddock demonstration of soil survey and BSAL verification techniques by Dr. David McKenzie of McKenzie Soil Management (Figure 5.02). In total, two soil pits were excavated and assessed in the presence of attendees and Dr. McKenzie gave a running account of his work processes and took questions. Importantly, the sequential backfilling of the excavated pits was also demonstrated, whereby soils were replaced in their original sequence and the site smoothed over to allow regeneration (Figure 5.03).

Figure 5.02 Dr. David McKenzie (McKenzie Soil Management) in a test pit, explains his soil survey and BSAL verification techniques at the Field Day

Figure 5.03 A backfilled soil survey pit at the Field Day

Also at the Field Day, Mr. Jock Laurie, NSW Land & Water Commissioner, addressed the group encouraging the Applicant's engagement with the community and introducing the need for a 'pilot study' to gauge the effectiveness of the Gateway process at Caroona. La Tierra's Mr. Terry Short also addressed the attendees and explained the importance of proper soil assessment and a thorough agricultural impact assessment to the Gateway process and, ultimately, NSW Government's consideration of mining proposals (Figure 5.04).

Figure 5.04 Mr. Terry Short (La Tierra) addresses the Field Day and explains why verification of BSAL is important to the agricultural impact assessment and the Gateway process

5.4 Pilot Study

Instigated by the CCAG in about September 2013 and with support from the NSW Land & Water Commissioner, Mr. Jock Laurie, the *Pilot Study* was set up by NSW Government to clarify the required technical methodology and identify any technical gaps in the Gateway process. It was intended that the outcomes of this pilot should inform this and future projects.

NSW Trade & Investment through DRE engaged independent consultants FPC Water Solutions (Mr. Geoff Fishburn and Ms. Margie Parmenter) to talk with landholders about the technical information that the Applicant was required to provide for the Gateway process, how this technical information should be gathered (by La Tierra and others) and landholder expectations of the type of technical information put forward in a Gateway Application.

Landholder participation was voluntary and open to all landholders regardless of their affiliations, i.e. CCAG members or not. It is understood that FPC Water Solutions engaged with some landholders over a two or three day period in October 2013. The consultants did not engage formally or to any significant extent with La Tierra.

A meeting concerning the *Pilot Study* was held in Quirindi on 25 October 2013. La Tierra provided a presentation about its scope and methods at this meeting and, using a whiteboard, categorized concerns raised by attendees as being either a matter for consideration in the Gateway stage or EIS or accompanying Agricultural Impact Statement.

It is known that FPC Water Solutions did provide Trade & Investment with a report. That report has not been made publicly available and therefore has not been able to be used to inform this report. Nonetheless, in late 2013 and early 2014 there was an increased willingness by landholders to engage with La Tierra for the purpose of contributing to this agricultural impact assessment.

5.5 Community Consultative Committee

Mr. Garry West is the independent Chair of the Project's Community Consultative Committee (the CCC). The CCC members include representation by the CCAG amongst other community interest groups, individuals and Government agencies, e.g. Liverpool Plains and Gunnedah Shire Council. The CCC meets regularly and disseminates information to the broader community by opening technical meetings to the broader community and via the internet, i.e. http://www.caroonacoalccc.com.au/site/index.cfm.

La Tierra's Mr. Terry Short was invited to deliver presentations to the CCC as follows:

- 5 August 2013 with respect to:
  - La Tierra introduction;
  - Project scope;
  - Gateway agricultural assessment and EIS interaction;
  - Gateway agricultural assessment requirements;
  - Gateway process; and,
  - Caroona assessment update.
- 26 March 2014 with respect to:
  - Summary findings of this agricultural impact assessment;
  - The Gateway process; and,
  - Further work to be conducted for the AIS as a component of the EIS in 2014.

6 CONCLUSIONS AND RECOMMENDATIONS

This report assessed the potential impacts of the Caroona Coal Project on BSAL and highly productive groundwater sources. In assessing the potential impacts on BSAL, this report has relied upon specialist technical studies to verify the existence of BSAL (McKenzie, 2014), assess impacts on highly productive groundwater sources (Nicol et al. 2014) and predict surface subsidence effects due to underground longwall mining (Barbato, 2014). These studies have enabled the potential impacts on BSAL to be identified. Stakeholder engagement and on-ground property inspection has allowed existing agricultural resources, land uses and production systems to be described.

Project assessment areas that encompass planned Development Application areas and buffer land were defined. In combination these areas have a total land area of 11,863 ha and contain 2,215 ha of verified BSAL. Regional mapping of potential BSAL indicated a larger area of 3,423 ha might exist within these areas. McKenzie (2014) found through applying the BSAL verification protocol (OEH and OAS&FS, 2013) that some potential BSAL soils did not meet BSAL verification criterion threshold limits. This was primarily due to some alluvial Vertosol soils having strongly saline (salt of chloride) and alkaline (high pH) subsoils, to the extent that these parameters exceed stipulated threshold limits for verification as BSAL.

Agriculture induced salinity is a well-documented soil and land management issue on the Liverpool Plains, e.g. URS (2001), Scott and Farquharson (2002) and Ringrose-Voase et al. (2003). The issue has manifested with the development of modern agricultural systems. Extensive clearing of native vegetation and long-fallow cropping systems, in a period of wetter than average conditions, has increased deep drainage through soil profiles, mobilising salts in the subsoil layers and raising watertables. These factors are thought to have induced significant dryland salinity issues across the Liverpool Plains.

Dryland cropping and beef cattle grazing are the dominant land uses in the Project assessment areas. Exceptions to this include a significant cattle feedlot, with 75,000 head capacity per annum, and a State Forest managed for commercial harvesting of White Cypress Pine. This mix of land use is broadly consistent with regional analyses of agricultural land uses.

In the Liverpool Plains the value of agricultural production is skewed towards livestock slaughtering, and undoubtedly this is due to the operation of large feedlots including the feedlot within the Project assessment area. Considered on a gross value of production per ha, the Liverpool Plains area is highly agriculturally productive. This agricultural productivity is entirely reliant on the existing rare combination of inherently fertile soils, reliable rainfall, moderate climate and availability of surface and groundwater.

Mining induced land subsidence will cause impacts to 2,103 ha of verified BSAL. These impacts include the following predicted maximum effects.

- In the Nicholas Ridge assessment area, vertical settling of 3,100 mm, ground tilt or increased gradients of 70 mm/m, hogging and sagging radius of curvatures to 3.0 km^{-1} and surface cracking typically between 50 and 100 mm with isolated cracking to 300 mm width; and,
- In the Doona Ridge assessment area, vertical settling of 2,450 to 2,900 mm, ground tilt or increased gradients of 25 mm/m, hogging and sagging radius of curvatures to 0.35 km^{-1} and surface cracking typically between 10 and 75 mm with isolated cracking to 200 mm width.

With regard to verified BSAL soil resources, subsidence induced impacts can be mitigated, at least to the extent that the soil resource retains BSAL characteristics post-mining. There are few precedents for the management and mitigation of subsidence effects on cropped Vertosol soils in Australia. Successful anecdotal management practices at Kestrel (Rio Tinto) and Crinum (BMA) mines in central Queensland, have required a suspension of agricultural production activities on the affected land for a period of time before, during and following subsidence. These practices ensure a high-percentage groundcover on the land pre-subsidence, monitoring of ground deformation during active subsidence, and the repair of surface cracks and drainage post-subsidence. A similar management strategy should be applied to the proposed Project.

Nicol et al. (2014) have determined the Projects potential impacts on highly productive groundwater within the meaning of the Aquifer Interference Policy. These impacts on highly productive groundwater are summarised as follows.

- For the highly productive Upper and Lower Namoi Groundwater Source, Project impacts satisfy Level 1 minimal impact considerations for water level, pressure and quality;
- For the highly productive NSW Murray Darling Basin Fractured Rock Groundwater Source, Project impacts satisfy Level 1 minimal impact considerations for water level, pressure and quality; and,
- For the NSW Murray Darling Basin Porous Rock Groundwater Source (Spring Ridge Management Zone), Project impacts satisfy Level 1 minimal impact considerations for water quality and Level 2 minimal impact considerations for water level and pressure.

The Project will cause up to 27 privately owned bores in highly productive groundwater sources to have drawdowns exceeding two metres. Nine of these are located on properties either partially or wholly affected by the Project assessment areas. No bores in the highly productive Namoi Alluvium (Narrabri and Gunnedah formations) or Liverpool Range Basalt aquifers are predicted to experience drawdowns of greater than two metres. The Applicant will commit to 'make good' provisions for any bores affected by the Project.

Whilst it is considered that the Project will not lead to a reduction in the area of verified BSAL or its associated highly productive groundwater, it is considered likely that the Project will have additional and mainly subsidence-induced impacts on agricultural resources, productivities and systems. These impacts are considered to include the following.

- Temporary suspension of agricultural production on non-BSAL cropping and grazing land affected by subsidence causing agro-economic loss at an enterprise-level;
- The effects of subsidence induced land deformation on 'workability' and 'farming efficiency' with respect to cropping practices;
- The effect of ground deformation on the health and longevity of key tree species in the Doona State Forest;
- Potential impacts on non-high yielding groundwater sources (within the meaning of the Aquifer Interference Policy); and,
- Any secondary effects of mining impacts, particularly subsidence-induced impacts, on existing land management issues on non-BSAL land, e.g. dryland salinity

Addressing these broader potential impacts is beyond the scope of this report. These important aspects will be considered in detail in the EIS.

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