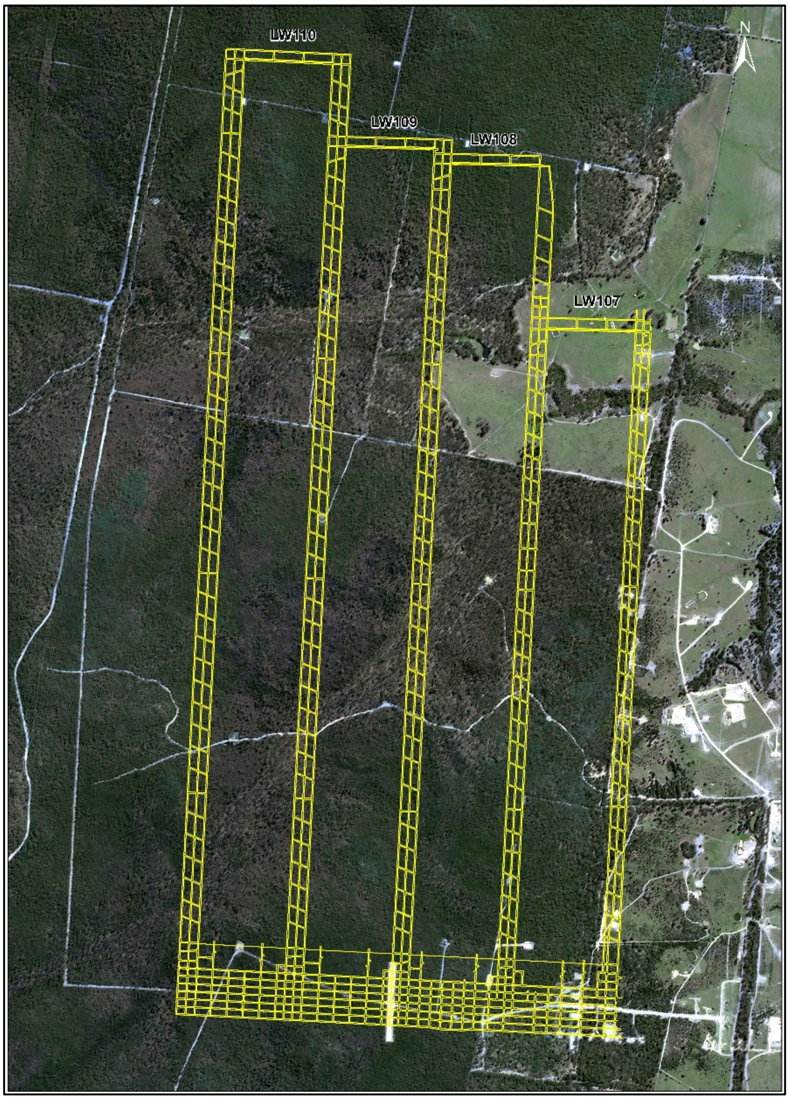
Narrabri Mine

Land Management Plan (LW107 to LW110)

Prepared for
Narrabri Coal Operations Pty Ltd

6 April 2017



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Abbreviations

Abbreviation	Description
DGS	Ditton Geotechnical Services
DEM	Digital elevation model
DRE	Division of Resources and Energy (part of the Department of Trade and Investment, Regional Infrastructure and Services)
DoPE	Department of Planning and Environment
DPI	Department of Primary Industries (part of the Department of Trade and Investment, Regional Infrastructure and Services)
DPI Water	Department of Primary Industries – Water
DTIRIS	Department of Trade and Investment, Regional Infrastructure and Services (formerly the Department of Industry & Investment NSW (I&I))
EA	Environmental Assessment
ELA	Eco Logical Australia Pty Ltd
EMP	Environmental Management Plan
EP	Extraction Plan
EP&A Act	*Environmental Planning and Assessment Act 1979* (NSW)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
EPL	Environmental Protection Licence
LMP	Land Management Plan
LSMP	Landscape Management Plan
LW	Longwall (eg. LW107)
ML	Mining Lease

Abbreviation	Description
MOP	Mining Operations Plan
NCOPL	Narrabri Coal Operations Pty Ltd
NSC	Narrabri Shire Council
OEH	Office of Environment and Heritage (formerly the Department of Environment, Climate Change and Water (DECCW))
PA	Project Approval
RMP	Rehabilitation Management Plan
SRP	Subsidence reduction potential
TARP	Trigger Action Response Plan
WCL	Whitehaven Coal Limited
WMP	Water Management Plan

1 Introduction

The Narrabri Mine is located approximately 28 km south-east of Narrabri and approximately 10 km north-west of Baan Baa in north-western New South Wales (NSW) (Figure 1). Narrabri Coal Operations Pty Ltd (NCOPL) was granted approval for Stage 2 of the Narrabri Mine under Part 3A of the NSW *Environmental Planning and Assessment Act, 1979* (EP&A Act) on the 26th July 2010 (PA 08_0144).

The Stage 2 project involves converting the existing mining operations to longwall extraction of 20 longwall panels. The approved underground mining layout is shown in Figure 2. Longwalls LW107 to LW110 define the second phase of the secondary extraction mining within the Approved Project underground mining areas and are the focus of this Land Management Plan (LMP).

1.1 Purpose & scope

In accordance with Schedule 3, Condition 4(h) of PA 08_0144, this LMP has been prepared as a component of the Narrabri Mine LW107 to LW110 Extraction Plan (EP) to manage the potential impacts and/or environmental consequences of the proposed second workings upon land. These impacts were identified within the Mine Subsidence Assessment completed for the Section 75W Modification to the Stage 2 Mining Layout (DGS 2015), the Landscape Management Plan (LSMP) (ELA 2016) and other relevant approval documents, including the Environmental Assessment (EA) for Stage 2 of the Narrabri Mine (R.W. Corkery & Co. 2009).

Land in general refers to the general landscape and features, and excludes built features and surface features which are addressed in (e.g. the Built Features Management Plan) and programs included in the EP.

1.2 Structure of the LMP

This LMP is structured according to Table 1.

Table 1: LMP structure

Section	Content
Section 2	Outlines the statutory requirements applicable to the LMP
Section 3	Outlines consultation that has been undertaken in the preparation of the LMP
Section 4	Provides baseline data collected during assessment of impacts for the Environmental Assessment (R.W. Corkery & Co. 2009)
Section 5	Provides an assessment of the potential subsidence impacts and environmental consequences for LW107 to LW110
Section 6	Details the performance measures and indicators that will be used to assess the LW project
Section 7	Describes the monitoring procedures required to detect impacts
Section 8	Describes the management measures that will be implemented
Section 9	Describes a Contingency Plan to manage any unpredicted impacts and their consequences, including a Trigger Action Response Plan (TARP)
Section 10	Lists the references cited in this LMP

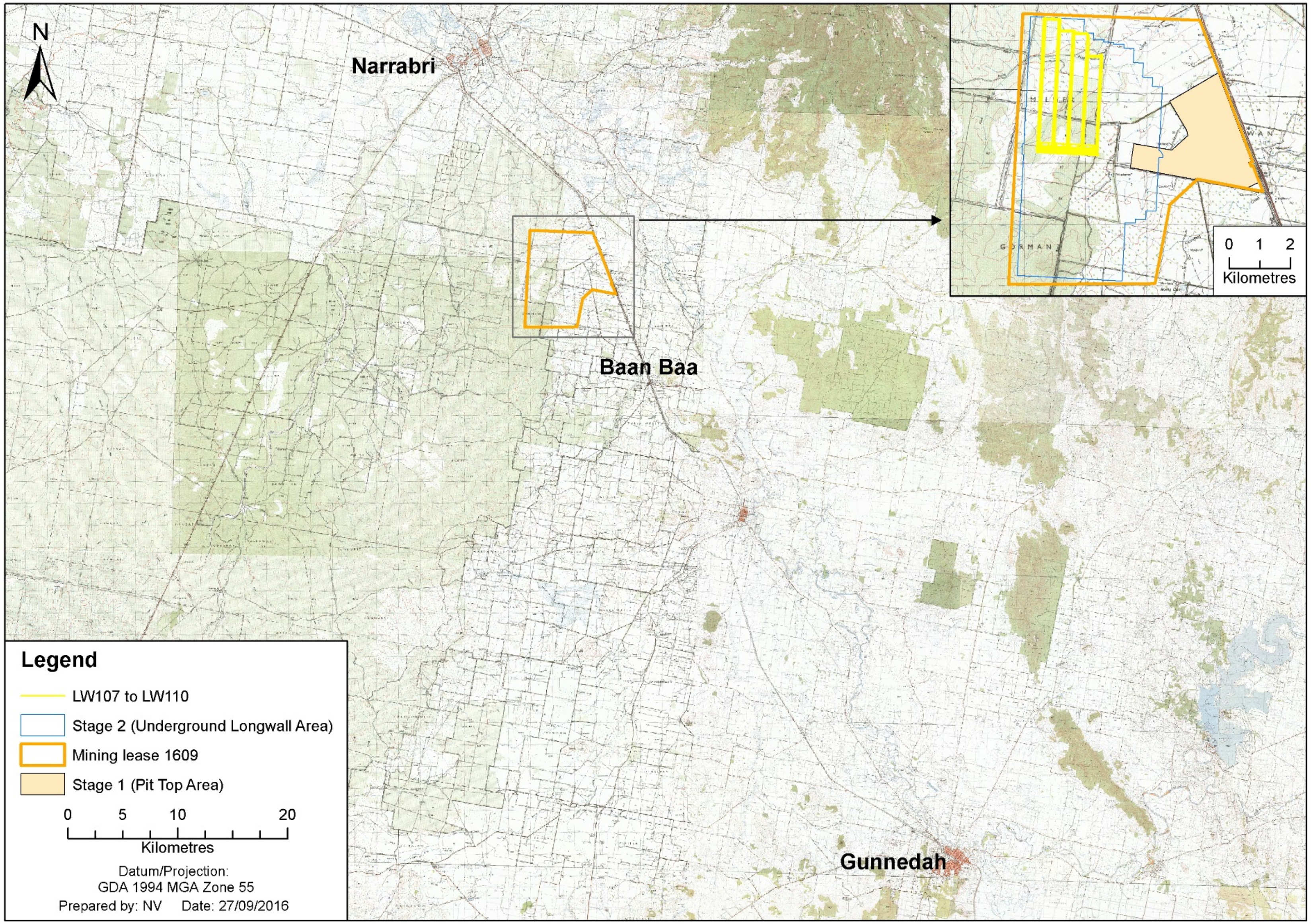

Figure 1: Mine site location

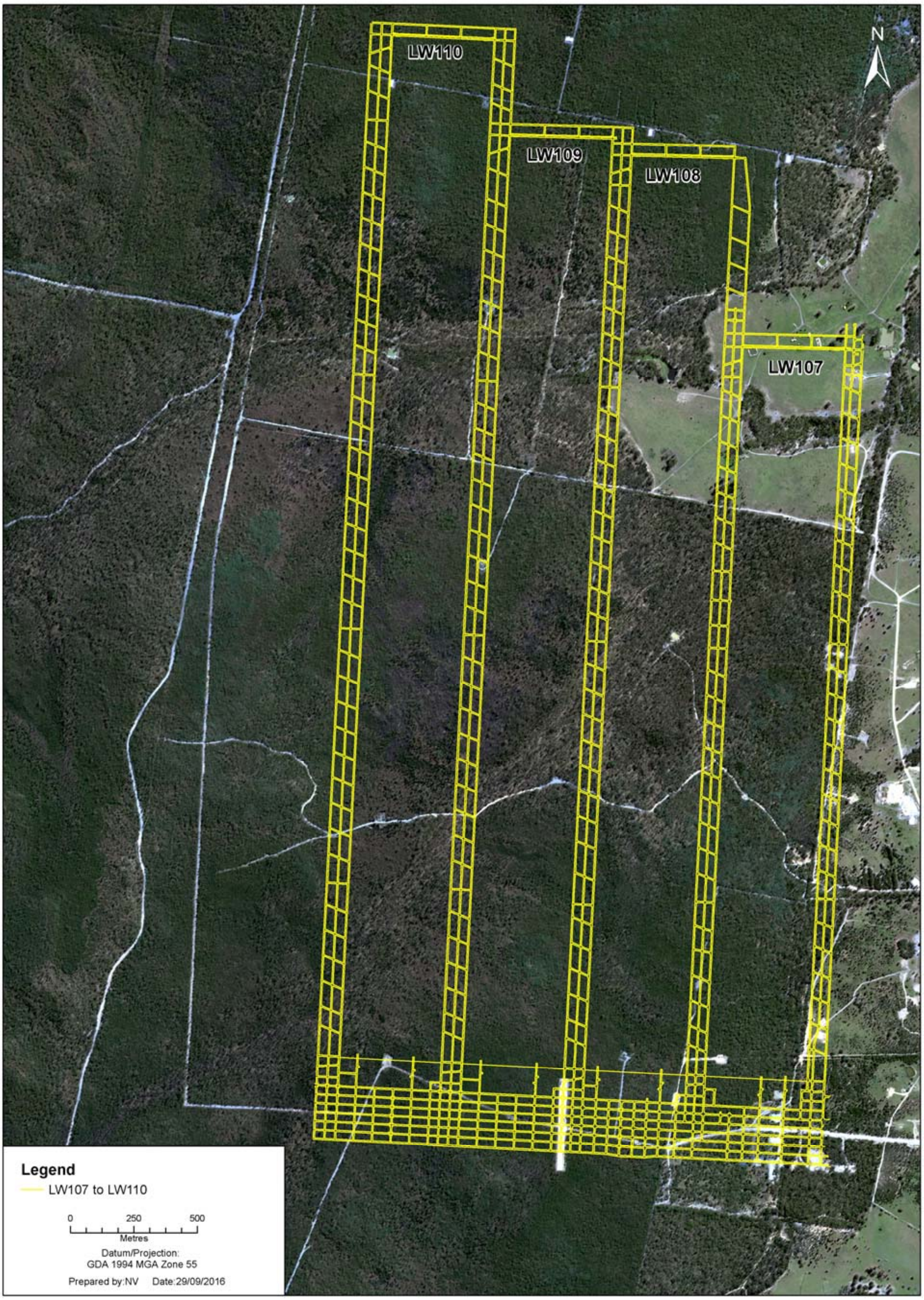

Figure 2: Underground mining layout for LW107 to LW110

2 Statutory Requirements

NCOPL's statutory obligations are contained within:

- the conditions of PA 08_0144 under the EP&A Act;
- the conditions of Approval (EPBC Ref 2009/5003) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act);
- relevant licenses and permits, including conditions attached to the mining lease (ML); and
- other relevant legislation.

These obligations are described in further detail below.

2.1 EP&A Act approval

Schedule 3, Condition 4(h) of PA 08_0144 requires the preparation of a LMP be included in the EP for second workings to be mined. Table 2 outlines the requirements of PA 08_0144 and indicates where each of the conditions have been addressed within this LMP.

Table 2: Conditions of approval (PA 08_0144) relevant to this LMP

Condition number	Condition requirement	Relevant section of this report
Schedule 3, Condition 4	h) include a: • Land Management Plan, which has been prepared in consultation with any affected public authorities, to manage the potential impacts and/or environmental consequences of the proposed second workings on land in general; i) include a program to collect sufficient baseline data for future Extraction Plans.	Overall LMP (this document) and Section 2 Overall LMP (this document)
Schedule 3, Condition 5	The proponent shall ensure that the management plans required under condition 4(h) include: a) An assessment of the potential environmental consequences of the Extraction Plan, incorporating any relevant information that has been obtained since this approval; b) A detailed description of the measures that would be implemented to remediate predicted impacts; and c) A contingency plan that expressly provides for adaptive management.	 Section 7 Section 10 Section 0
Schedule 6, Condition 2	***Management Plan Requirements*** The Proponent shall ensure that the management plans required under this approval are prepared in accordance with any relevant guidelines, and include: a) detailed baseline data; b) a description of: • the relevant statutory requirements (including any relevant approval, license or lease conditions); • any relevant limits or performance measures/criteria; • the specific performance indicators that are proposed to be used to judge the performance of, or guide the implementation of, the project or any management measures; c) a description of the measures that would be implemented to comply with the relevant statutory requirements, limits, or performance measures/criteria; d) a program to monitor and report on the: • impacts and environmental performance of the project; • effectiveness of any management measures (see c above); e) a contingency plan to manage any unpredicted impacts and their consequences; f) a program to investigate and implement ways to improve the environmental performance of the project over time; g) a protocol for managing and reporting any; • incidents; • complaints; • non-compliances with statutory requirements; and	 Section 2 Section 2 Section 8 Section 8 Section 10 Section 9 Section 0 Overall EP Overall EP

Condition number	Condition requirement	Relevant section of this report
	• exceedances of the impact assessment criteria and/or performance criteria; and h) a protocol for periodic review of the plan.	Overall EP

2.2 EPBC Act approval

Condition 3 of the EPBC Approval (2009/5003) requires the development and implementation of an Extraction Plan in order to minimise potential impacts upon Commonwealth listed threatened species and communities. Condition 3 states:

- *In order to minimise potential impacts on EPBC Act listed threatened species and communities within the mine site, prior to any works commencing and in accordance with the NSW Director General's Assessment Report and approval conditions (26 July 2010), the person undertaking the action must develop and implement an Extraction Plan. The final version of this plan must be submitted to the Department.*
- This requirement is addressed in the BMP.

2.3 Licenses, permits & leases

In addition to PA 08_0144 and EPBC Approval (2009/5003), all activities at or in association with the Narrabri Mine will be undertaken in accordance with the following licenses, permits and leases which have been issued or are currently under preparation.

- The conditions of Mining Lease No.1609 issued by the NSW Department of Primary Industries – Mineral Resources (now Department of Trade and Investment (DTI)), under the *NSW Mining Act 1992*.
- The Stage 2 MOP approved for the period 1 July 2011 to 31 December 2017.
- The conditions of Environment Protection Licence (EPL) No. 12789 issued by the NSW Department of Environment and Climate Change (now EPA) under the NSW *Protection of the Environment Operations Act 1997*.
- Water Access licence issued by the NSW Department of Water and Energy (now DPI Water which is part of the Department of Primary Industries) in accordance with the *Water Management Act 2000*.
- Mining and occupational health and safety related approvals granted by the Division of Resources and Energy (part of the Department of Trade and Investment, Regional Infrastructure and Services) (DRE) and SafeWork NSW (R.W. Corkery & Co. 2009).

2.4 Other legislation

NCOPL will conduct all operations at Narrabri Mine to be consistent with PA 08_0144 and any other applicable legislation that is applicable. The following Acts may be applicable to the operations at Narrabri Mine (R.W. Corkery & Co. 2009):

- *Contaminated Land Management Act 1997*
- *Noxious Weeds Act 1993*
- *Rail Safety Act 2002*
- *Road and Rail Transport (Dangerous Goods) Act 1997*
- *Roads Act 1993*
- *Threatened Species Conservation Act 1995* (TSC Act)
- *Work Health and Safety Act 2011*
- *Work Health and Safety (Mines and Petroleum Sites) Act 2013*
- *Crown Lands Act 1989*
- *Dams Safety Act 1978*
- *Energy and Utilities Administration Act 1987*
- *Fisheries Management Act 1994*

3 Consultation

In accordance with Schedule 3, Condition 4 (h) of the project approval, the LMP is to be prepared in consultation with relevant affected public authorities to manage the potential impacts and/or environmental consequences of the proposed second workings on land in general.

Approval of this LMP (and any subsequent substantial amendments) is required under statutory approvals (PA 08_144) from the DoPE.

Department of Primary Industries (DPI Water) were also consulted.

Consultation of relevant agencies and stakeholders has been undertaken as part of the Extraction Plan preparation and assessment process. This consultation included submission of the full Extraction Plan to DoPl and DRE for assessment.

Feedback received to date has been incorporated into this plan. A summary of matters arising from this consultation (as relevant to this Land MP) and reference to where each matter is addressed within this Land MP, is provided in Table 3.

Table 3: Matters arising from consultation

Public authority	Issue raised	Relevant section of this report
DoPI (EP Review)	Describe frequency of monitoring in terms of period and event	Section 9.5, Table 14 Section 9.6, Table 15
	TARPS should reflect industry standard 'multi-level' documents that show clear escalation of the response measures and reporting based on escalating triggers	Section 11
DPI Water	Define how often the regular surveys of undermined creeks are to be undertaken (DPI Water)	Section 9.2, Table 13 Section 9.6, Table 16

4 Baseline Information

Baseline data as relevant to land in general across LW107 to 110 has been provided. Baseline data has been drawn from the EA undertaken by R.W. Corkery & Co for Stage 2 (2009) and specialist consultant studies, in particular the soils and land capability assessment (GCNRC 2009). Site experience gained from ecological monitoring has also been considered in the preparation of this LMP.

The monitoring program outlined in Section 8 of this LMP indicates where additional baseline data specific to LW107 to LW110 is required in addition to the relevant previous baseline monitoring report referenced (ELA 2012a; 2012b).

4.1 Land Ownership

There are 17 residences within and immediately surrounding the Mine Site, sixteen of which are owned by NCOPL. A portion of the Mine Site is located on Crown Land, Jacks Creek State Forest to the east and Pilliga East State Forest to the southeast. The land directly above LW107 to LW110 is owned by NCOPL.

4.2 Land Use

A large proportion of the Mine Site is currently cleared for grazing (cattle, sheep, horses) and some cereal crops. This area contains patches of remnant woodland vegetation (Cypress/Box Gum) and remnant stands of riparian vegetation. There is also a large continuous densely forested area which adjoins Jacks Creek State Forest and Pilliga East State Forest (located west of LW107 onwards).

The land directly above LW107 to LW110 is predominantly forested with woodlands dominated by cypress pines and box gum trees (R.W. Corkery & Co. 2009). A smaller proportion of land above LW107- LW110 is used for grazing and some cereal crop farming. Some soil conservation bank systems are in place and there are a number of small farm dams above LW107 to LW110.

4.3 Topography

The Mine Site is located in the Namoi Catchment in an area that transitions from the open plains in the Walgett and Coonamble areas to the west and the Nandewar Ranges to the northeast, and the Warrumbungle and Liverpool Ranges to the south. Locally, the topography is generally flat to undulating and the elevation ranges from 400 m AHD in Jacks Creek State Forest to the west, to approximately 230 m AHD toward the Namoi River in the east (R.W. Corkery & Co. 2009).

The surface terrain is generally flat with slopes ranging between 2° to 5°. Maximum slopes of approximately 18° are located in the southwest of the Mine Site and minimum slopes of less than 1° occur in the northeast (R.W. Corkery & Co. 2009). Along the creeks and tributaries of Pine Creek slopes can increase to 10°-15°.

The elevation across LW107 to LW110 ranges from 340 m in the south-west corner to 280 m in the east.

The topography of the site varies from areas that are comparatively flat in the east to gently undulating in the west. Average slopes across the Mine Site are 3°, with two low parallel ridges oriented northeast to southwest across the Mine Site. The surface terrain above LW107 to LW110 is generally flat with slopes of 2° – 5°. In several of the ephemeral creeks and tributaries, the slope increases to 10° – 15°. Above LW110, there are a few ridges with steep slopes ranging between 15° and 20° (DGS 2016).

LiDAR data captured in 2008 across the mine site provides a baseline land surface digital elevation model (DEM) (ELA 2012b).

4.4 Soils

The broad geological formations underlying LW107 and LW108 are the Purlawaugh and the Pilliga Sandstone. LW109 and LW110 are entirely underlain by the Pilliga Sandstone (R.W. Corkery & Co. 2009) (Figure 3).

Across the area proposed for secondary extraction, soils generally contain very low amounts of gravel. Soil horizons with higher levels of gravel were generally situated at depth within the profile. Generally, topsoils (up to 400 mm below surface with the exception of drainage lines) are slightly dispersive with subsoils displaying high to very high dispersibilty, particularly for areas above the Purlawaugh Formation (R.W. Corkery & Co. 2009).

Soils across the Mine Site have been variably affected by soil erosion, particularly within drainage lines and floodplains of the Purlawaugh Formation. The presence of soil conservation works, such as contour banks and waterway systems indicate that soil erosion has been an issue in the past (GCNRC 2009).

Table 4 shows the soil attributes associated with each geological formation present within LW107 toLW110. The limitations associated with each geological formation based upon the results of the soil attributes are described within this table.

Typical soil attributes associated with the geological formations and landform units above LW107 to LW110 identified in the EA are provided in Tables 4 and 5 (R.W. Corkery & Co. 2009, GCNRC 2009). More detailed information from each of the soil pit references is provided in Appendix A.

Figure 3: Geological formations underlying LW107 to LW110

Table 4: Soil attributes and limitations associated with land degradation following subsidence

Soil attribute	Surface geology					
	Purlawaugh formation				Pilliga sandstone	
Soil Depth	Usually very deep profiles on the crests where profiles tend to be more shallow **Not limiting**				Generally less than 250 cm; shallower on crests and slopes **Not limiting**	
Typical soil depths	Drainage lines	Floodplains	Slopes	Upper slopes	Upper slopes	Mid slopes
Topsoil	0<1.0 m	0~0.35 m	0~0.30 m	0 ~0.35 m	0~0.15 m	0~0.40 m
Subsoil	1.0-3.0 m	0.35-2.50 m	0.30-2.6 m	0.35-2.5 m	0.15-1.38 m	0.40~2.20 m
Soil Texture	A mix of often coarse texture topsoils and more clayey subsoils **Not limiting**				Generally the most sandy soils across the mine site **Not limiting**	
Soil Surface Characteristics	Surface stone often absent but noted on slopes; surface sometimes self-mulching; not hydrophobic **Not limiting**				Surface stone usually absent but noted on upper slopes; surface sometimes self-mulching; often hydrophobic **Not limiting**	
pH	Generally favourable to plant growth; usually increasing with depth but some lower horizons quite acidic **Not limiting**				Generally lower than in the other Geological Formations and not increasing much with depth **Not limiting**	
Erodibility	May be some limitations where subsidence results in slope increases and in drainage lines **Low to moderate limitations**				May be some limitations where subsidence results in slope increases and in drainage lines **Low limitations**	

Soil attribute	Surface geology	
	Purlawaugh formation	Pilliga sandstone
Topsoil Dispersibility	Topsoils usually slightly dispersible **Usually not limiting**	Topsoils usually slightly or moderately dispersible; may be limiting near subsidence cracks or where slope gradient increases following subsidence **Usually not limiting**
Subsoil Dispersibility	Often moderately to highly dispersible **May be limiting near subsidence cracks or where slope gradient increases following subsidence but may be an advantage in filling in cracks**	Slight to very highly dispersible, particularly in drainage lines **May be limiting near subsidence cracks or where slop gradient increases following subsidence but may be an advantage in filling in cracks**
Salinity	Slight to moderate salinity detected in drainage line, floodplain and some slopes areas **Limitation in areas associated with subsidence cracks where down slope saline areas may develop after erosion**	Salinity not recorded **Not limiting**

Source: R.W. Corkery & Co. 2009

Table 5: Soil attributes of geological formation/landform units

Geological formation	Purlawaugh formation		
Landform	Major drainage lines (17, 20, 23, 25)*	Crests (5, 24)*	Floodplains (2, 16, 22)*
Surface condition	Loose, soft or firm, surface stone absent	Loose to firm, surface stone absent or low to medium amounts of rounded angular surface stone (to 15 cm)	Loose to firm or hardsetting, surface stone absent
Topsoil	Up to 103 cm Sand, clayey sand to sandy light clay pH 6.0-7.5 Poorly structured (massive/single-grained), although sometimes well structured Slight dispersibility (D% and EAT) Non-saline	Up to 27 cm Clayey sand or sandy medium clay pH 5.0-5.5 Moderately to well structured Moderate dispersibility (D%) Slight dispersibility (EAT) Non-saline	Up to 39 cm Sandy loam to medium clay pH 6.0-6.5 Well structured Slight dispersibility (D% and EAT) Non-saline
Subsoil	Up to 3 horizons (to 300 cm) Sand to medium to heavy clay (sometimes sandy) pH 5.5-7.0, although sometimes 9.0-10 at depth Poorly structured (massive) or well-structured in more clayey horizons Very highly dispersible (D%) Slightly to high to moderately dispersible (EAT) Lowest horizon sometimes slightly saline	2 horizons (to 127 cm) Medium clay (sometimes sandy) pH 5.5-8.5 Well structured, although sometimes poorly structured Moderate dispersibility (D%) Slight dispersibility (EAT) Non-saline	Up to 4 horizons (to 255 cm) Sandy loam to medium (gritty) clay pH 6.5-7.54 sometimes 8.0-9.0 Well structured, occasionally massive Slight to very high dispersibility (D%) High to moderate and very high dispersibility (EAT) Lowest horizon slightly saline

Geological formation	Purlawaugh formation		Pilliga sandstone
Landform	Lower slopes (7)*	Midslopes (19, 26)*	Upper slopes (6)*
Surface condition	Loose, surface stone absent or some rounded surface stone (1-2 cm)	Firm, sometimes self mulching and cracked, surface stone absent or some angular surface stone (<1 cm) and some flat sandstone to 15cm present	Firm, surface stone absent
Topsoil	Up to 25 cm deep Sandy clay loam to light clay Well structured Slight dispersibility (D% and EAT) Non-saline	Up to 37 cm Silty clay to medium clay pH 6.0-7.5 Well structured Slight dispersibility (D% and EAT) Non-saline	Up to 21 cm Clayey sand to light to medium clay pH 4.5-6.5 Moderately to well structured Slight dispersibility (D%) Not or slightly dispersible (EAT) Non-saline
Subsoil	Up to 4 horizons (to 260 cm) Clay loam to heavy clay pH 6.5-7.5, sometimes 8.0-9.0 (4.0 recorded at lowest horizon) Well structured Negligible to very high dispersibility (D%) Very high dispersibility (EAT) Most subsoil horizons slightly to moderately saline	Up to 5 horizons (to 270 cm) Light to medium clay to heavy clay pH 7.5-9.9 (4.5 in some lowest horizons) Usually well structured, sometimes massive Slight to moderate dispersibility (D%) High to moderate or very high dispersibility (EAT) Lower horizons slightly to moderately saline	Up to 4 horizons (to 230 cm) Sandy clay loam to medium to heavy clay pH 4.5-6.5, up to 9.5 at depth Poorly structure (massive), at times well structured Slight dispersibility (D% and EAT) Non-saline

* Corresponding soil pit number/s ** Dispersion % and Emerson Aggregate Test
Source: GCNRC 2009

5 Land classification

Land capability is the ability of land to withstand a particular land use (considering use type, intensity and management regime) without permanent damage and without losing its productive capacity (Houghton and Charman 1986).

There are two generally recognised systems of rural land classification in NSW (Cunningham et al, 1988):

- Soil Conservation Service's "Land Capability" defines eight classes (Class I to Class VIII) to delineate rural land on the basis its inherent physical characteristics and the resulting capability of the land to remain stable under particular land uses
- Department of Agriculture's "Agricultural Suitability" defines six classes (Class 1 to Class 5 and a Specialist Class) based on the land's suitability for general agricultural use and also includes evaluation of biophysical, social, and economic factors that may constrain land use.

5.1 Land capability

The area of land above LW107 to LW110 is largely classified as Class VII land which is an area of woodland vegetation (Table 6; Figure 4). There is a small area of Class III land in the northern portions of LW107 to LW109; with drainage lines mapped as Class IV (Table 6 and Figure 4).

Table 6: Land Capability Class Descriptions

Land capability class	Description
Class III	Sloping land suitable for rotational cropping. Structural soil conservation works such as graded banks, waterways and diversion banks, together with soil conservation practices such as conservation tillage and adequate crop rotations are required
Class IV	Land not capable of being regularly cultivated but suitable for grazing with occasional cultivation and requiring soil conservation practices such as pasture improvement, application of fertilizer and minimal cultivation for the establishment or re-establishment of permanent pasture
Class VII	Land best protected by green timber. It generally comprises of areas of steep slopes, shallow soils and/or rock outcrop. Adequate ground protection must be maintained by limiting grazing and minimising damage by fire

Source: R.W. Corkery & Co. 2009

5.2 Agricultural suitability

Land within the boundaries of ML 1609 has been classified according to its agricultural suitability (Cunningham 2009). The majority of the Mine Site can be classified as Class 3 with some minor areas of Classes 2 and 5 present (R.W. Corkery & Co. 2009) (Table 7).

Table 7: Agricultural Suitability Class Descriptions

Agricultural suitability class	Description
Class 2	Arable land suitable for regular cultivation for crops but not suitable for continuous cultivation. It has a moderate to high suitability for agriculture though soil and other environmental factors reduce the overall level of production and may limit the cropping phase to a rotation with sown pastures
Class 3	Grazing land or land well suited to pasture improvement that may be cultivated and cropped in rotation with pasture. Erosion hazard or soil structural breakdown limit the frequency of ground disturbance, and conservation works may be required
Class 4	Land suitable for grazing but not for cultivation. Agriculture is based on native pastures established using minimum tillage techniques
Class 5	Land unsuitable for agriculture or at best suited only to light grazing. Agricultural production is very low or zero due to severe constraints which preclude improvement

Source: R.W. Corkery & Co. 2009

Figure 4: Land capability classification above LW107 to LW110

6 Surface water

6.1 Drainage

The Mine Site is located within the Tulla Mullen and Pine Creek Sub-catchment of the Namoi River Catchment. The Namoi River is located approximately 3-5 km to the east of the eastern boundary of the ML. Tributary catchments in which LW107 to LW110 are directly located include Pine Creek (and Pine Creek Tributary 1) (Figure 5).

The Mine Site is generally drained in a north-easterly direction. The tributaries of Pine Creek are ephemeral with insignificant base flows and flow only after significant rainfall events or extended wet periods. The smaller tributaries often have poorly defined drainage paths (R.W. Corkery & Co. 2009). These catchments have undergone significant clearing for the purposes of grazing and wheat production. For example, 94% of the Pine Creek Tributary 1 catchment has been cleared.

The creeks are prone to high rates of erosion in some areas and sandy alluvial deposits (up to 15 m deep) occur along the creek channels, with no exposed bedrock evident (R.W. Corkery & Co. 2009; DGS 2016).

The reaches of Pine Creek and Pine Creek Tributary 2 within LW107 to LW110 range from first order water courses to third order as defined under the Strahler stream ordering system (WRM 2009). The channels of Pine Creek and its tributaries can be summarised as small, shallow and poorly defined. Subsequently, during flood events, the majority of the flows occur overbank at a shallow depth. Bed material generally is the same as the surrounding soils (within the same horizon) with some sand deposits (WRM 2009).

Although surface water flows on and around the Mine Site only provide a minor contribution to the overall flows within the Namoi Catchment, the water is important to local landowners who use the water for stock watering and irrigation. Surface water flows are also important to the ecological health of the catchment, in particular the local flora and fauna which rely on good quality water (R.W. Corkery & Co. 2009).

Water quality is addressed in the site Water Management Plan.

6.2 Water storages

There are a number of farm dams located within ML 1609 with storage capacities ranging from 0.5 ML to 22.5 ML, with a combined storage capacity of 121.2ML (WRM 2009). Five farm dams are located above LW107 to LW110 (DGS 2016).

Figure 5: Drainage lines above LW107 to LW110

7 Assessment of Potential Environmental Consequences

A detailed Mine Subsidence Assessment was prepared for LW107 to LW110 by Ditton Geotechnical Services Pty Ltd (DGS 2016) for incorporation into the EP. This study was undertaken to update subsidence predictions and assessment of the impacts relating to the subsidence over LW107 to LW110. A Subsidence Impacts Risk Assessment was also undertaken to identify potential hazards and controls.

Subsidence related impacts relating to land in general that have the potential to occur above LW107 to LW110 include:

- Surface cracking
- Subsurface fracture zones
- General slope instability and erosion potential
- Valley uplift and closure potential along creek beds
- Potential for ponding upon completion of mining.

7.1 LW107 to LW110 Layout

LW107 - LW110 lies to the west of the Pit Top Area (Figure 2). The land surface is primarily dense vegetation, with smaller areas used for livestock grazing with and remnant vegetation stands (predominantly along creek lines).

LW107 to LW110 will be mined at depths ranging from approximately 230 m to 350 m below the surface and each longwall panel will be 408.9 m wide. Panel width to depth ratio will range from 1.17 to 1.77, indicating both critical and subcritical subsidence behaviour.

7.2 Overall predicted subsidence

Likely subsidence resulting from secondary extraction of LW107 - LW110 has been determined (DGS 2016). The predictions take into account the following factors:

- Subsidence reduction potential (SRP) of the overburden and the influence of the overburden and the proposed mining geometry on single panel subsidence development.
- The behaviour of the chain pillars and immediate roof and floor system under double abutment load conditions when longwalls have been extracted along either side of the pillars.
- The combined effects of single and chain pillar subsidence to estimate final subsidence profiles and subsidence contours for subsequent environmental impact assessment (DGS 2016).

The mean and worst-case first and final maximum multiple panel subsidence values were predicted based on the predicted maximum single panel, chain pillar and goaf edge subsidence values (Table 8) (DGS 2016).

Table 8: Predicted mean and credible worst-case results for all of the cross-lines (DGS 2016)

Predicted subsidence	Without spanning volcanics	
	Lower limit	Upper limit
First maximum panel subsidence after mining of LW 107 to LW 110	2.53 m	2.71 m
Final maximum panel subsidence after mining of LW107 to LW110	2.58 m	2.75 m
First maximum chain pillar subsidence after mining of LW107 to LW110	0.28 m	0.69 m
Final maximum chain pillar subsidence after mining of LW107 to LW110	0.28 m	0.71 m
Final maximum panel concave curvature after mining of LW107 to LW110	0.3 km^{-1}	1.6 km^{-1}
	Radii of curvature 1.66 km - 0.3 km	
Final maximum panel convex curvature after mining of LW107 to LW110	0.3 km^{-1}	1.3 km^{-1}
	Radii of curvature 2.5 km - 0.38 km	
Final maximum panel compressive strains after mining LW107 to LW110 (smooth profile behavior)	3 mm/m	6 mm/m
Final maximum panel compressive strains after mining LW107 to LW110 (discontinuous movements)	8 mm/m	16 mm/m
Final maximum panel tensile strains after mining LW107 to LW110 (smooth profile behavior)	3 mm/m	5 mm/m
Final maximum panel tensile strains after mining LW107 to LW110 (discontinuous movements)	7 mm/m	13 mm/m

Goaf edge subsidence predictions have been used to predict angle of draw to the 20 mm subsidence contour. It is therefore estimated that the Angle of Draw Prediction (AoD) will range from 18.5° to 32.1° for the proposed LW107 to LW110 and predicted goaf edge subsidence range of 0.05 mm to 0.32 mm (DGS 2016).

7.3 Predicted subsidence effects & impacts

Figure 6 shows the current mine plan superimposed by subsidence contours based on predictions by DGS (2016). These predictions were based on a superseded mine plan. The length of the longwall blocks under the current mine plan have been subsequently shortened due to geological constraints, and therefore the extent of subsidence impacts, as predicted by DGS (2016), have been reduced. The management and monitoring identified under this plan are based on the current mine plan and reduced extent of subsidence.

The primary effect of longwall mining to the land surface is the vertical subsidence, tilts and strains. There are several resulting impacts of subsidence, including: surface cracking, subsurface cracking, slope instability and erosion, valley closure and uplift, and ponding. These impacts may then trigger a number of environmental consequences related to land in general. Predicted subsidence impacts are summarised below.

7.3.1 Surface cracking

Surface cracking widths of 30 mm to 130 mm are predicted based on the predicted range of maximum transverse tensile strains of 3 to mm/m. These crack widths may double to 60 mm and 260 mm due to strain concentrations in near surface rock. Measured surface cracks above LW101 to LW105 have ranged from 50 mm to 100 mm wide, with some cracking of up to 200 mm present. Surface crack widths are expected to decrease as cover depth increases over LW107 to LW110 (DGS 2016). Therefore, the revised cracking width range of 30 mm to 130 mm above LW107 to LW110 are considered conservative (DGS 2016).

If there are adverse topographic or geological conditions, these crack widths may be exceeded by 5% however, this is unlikely to occur over the majority of LW107 to LW110. Predicted crack widths are most likely to be exceeded near steep creek banks along Pine Creek and its tributaries (DGS 2016).

Cracks are expected to develop by the time the longwall face has retreated past a given location for a distance equal to 1 to 2 times the cover depth. Cracks will generally develop within several days after the longwall has retreated beneath a given location, with some cracks closing in the compression zone in the middle of the fully developed subsidence trough, together with new cracks developing in the tensile zones along and inside the panel sides several weeks later (DGS 2016).

Tensile strain zone cracks are likely to be tapered and extend to depths of 5 to 15 m, and possibly deeper in near surface rock exposures. Tensile type cracks can also occur as a result of buckling and uplift of near surface rock. Compressive strain zone cracks are usually low-angle shear cracks resulting from failure and shoving of near surface strata (DGS 2016).

Crack widths are likely to be wider on ridges than along sandy-bottomed creek beds. Undermining ridges can result in the migration of surface cracks up-slope and outside the limits of extraction for significant distances due to rigid block rotations. This is dependent on the slope angle, vertical jointing and the subsidence at the toe of the slope (DGS 2016).

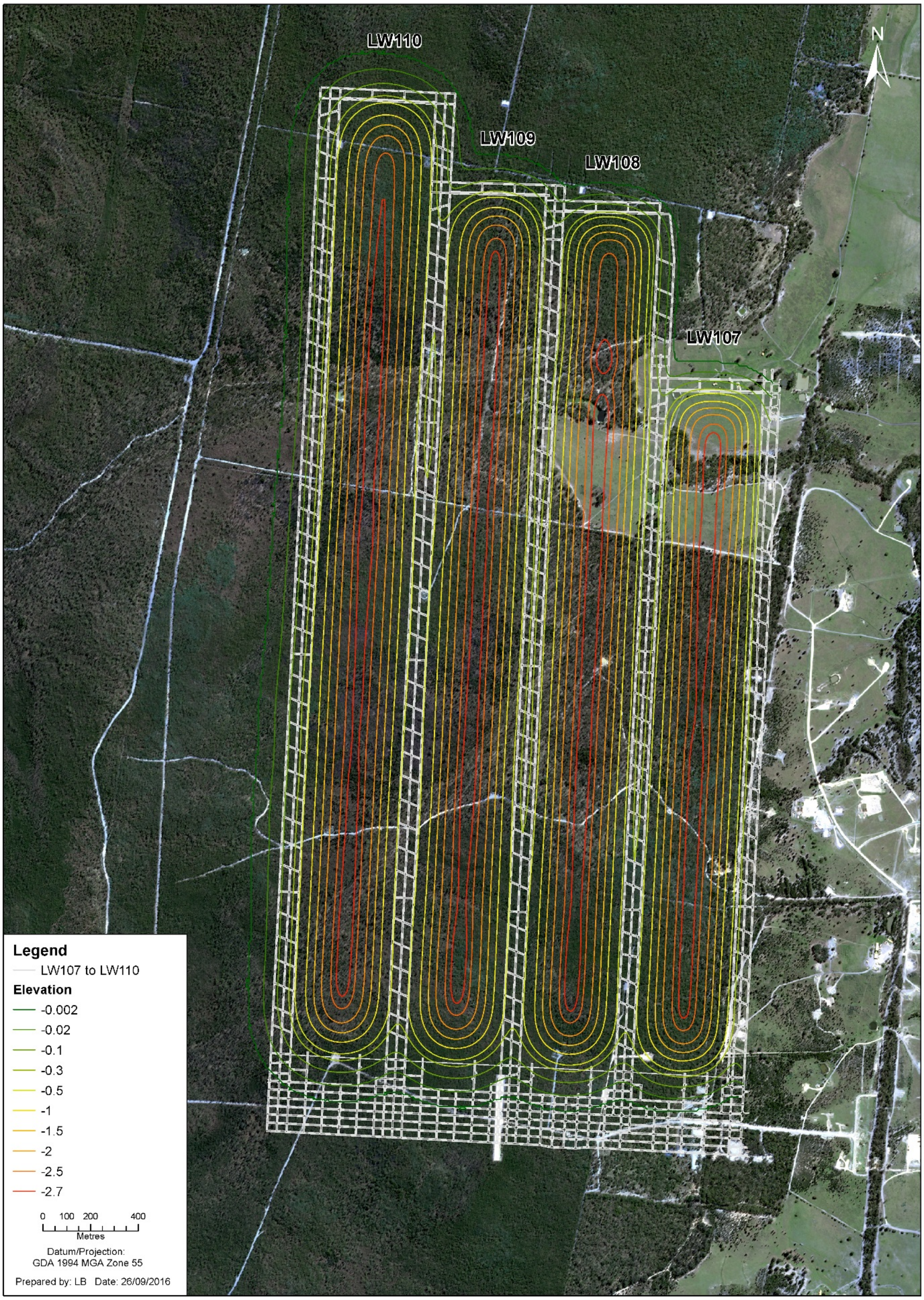

Figure 6: Predicted subsidence LW107 to LW110

7.3.2 Subsurface cracking

Subsurface fracturing can either be continuous or discontinuous. Continuous fracturing refers to cracking above a longwall panel which would create a hydraulic connection to the workings if a subsurface aquifer were intersected. This would result in increased water at seam level during longwall extraction.

Discontinuous fracturing refers to an increase in horizontal and vertical permeability, due to bending or curvature deformation of the rock mass. This type of fracturing can result in surface and subsurface flowpaths being altered, and rock mass conductivity and storage magnitudes being altered, however, groundwater or surface water resources may not undergo significant long-term change (DGS 2011).

The Geology Pi-Term Model was used to determine continuous fracture heights. Results from this modelling indicate that it is very unlikely that the continuous fracture zone will encroach within the surface cracking zone (i.e. within 10 m below the surface) for the range of cover depths above LW107 to LW110 (DGS 2016).

The Geometry Pi-Term Model predicts that discontinuous fracturing could interact with surface cracks where cover depths are < 335 m. Where this is the case, creek flows could be re-routed to below-surface pathways and resurfacing down-stream of the mining extraction limits. Tree stress above extracted longwalls has been found to be due to root sheer, indicating that B-Zone interaction has occurred with tree root systems (DGS 2016).

7.3.3 Slope instability

It is highly unlikely that landslip of the surface terrain over basal siltstone beds tilted by subsidence will occur. In areas where the soils are exposed and dispersive/reactive, the rate of soil erosion is expected to increase and slopes of <10° are expected to have low erosion rate increases. Creek channels are an exception where they would be expected to re-adjust to any changes in gradient (DGS 2016).

Headcuts are expected to develop above chain pillars between the panels and on the side where the gradients increase. Sediments are expected to accumulate where gradients decrease (DGS 2016).

7.3.4 Valley closure and uplift

Valley closure typically occurs along cliffs and sides of deep valleys when longwalls are mined beneath them and across broader drainage gullies where there is shallow surface rock. Compressive stress generated by surface deformation can cause the floor rocks of a valley to buckle upwards, resulting in less subsidence taking place in river or creek beds than would be expected in flat terrain. This ‘upsidence’ has been known to extend outside steep sided valleys and included immediate cliff lines and the ground beyond them. There are a number of factors which influence the occurrence and extent of valley closure and uplift movements, including: the level of ‘locked-in’ horizontal stress directly below the gully floors; bedding thickness of floor strata; and, aspect ratio (valley width/depth) with narrow valleys having greater upsidence than broad, round ones (DGS 2016).

The occurrence of upsidence and closure along the creek beds above LW107 - LW110 is likely to be minimal as the valleys across the Narrabri Mine mining lease are very broad between crests and are not underlain by thick massive beds of conglomerate and/or sandstone and they are broad between crests (DGS 2016).

In the unlikely event of upsidence occurring, minor localised deviation of surface flows along ephemeral creek beds into subsurface routes above the longwall panels may result. Tensile bending or compressive/shear strains resulting in failure and cracking of near surface rocks will also contribute to the deviation of surface flows. It is expected that re-routed surface flows will resurface downstream of the damaged area (DGS 2016).

7.3.5 Ponding

Ponding may develop above several of the longwalls and creeks in the flatter eastern areas at maximum depths of 0.1 to 2.6 m after secondary extraction of LW107 - LW110 is completed. It is expected that 3.7 ha, with a combined volume of 19 ML will be affected by ponding (Table 9) (DGS 2016). In-stream and over-bank ponding is predicted (WRM 2009), with in-stream ponding most likely to occur where channels are perpendicular to the LW panels.

Table 9: Potential worst-case ponding assessment for LW107 to LW110

Location	Longwall	Max depth (m)	Ponded area increase after mining# (m^2)	Ponded volume increase after mining# (ML)
Pine Creek	107	1.0	9,805	4.90
	108	2.6	7,096	9.23
		0.5	2,682	0.67
		0.1	7,502	0.38
	109	0.8	3,503	1.40
	110	0.7	6,126	2.14
Pine Creek Tributary 2	108	0.4	622	0.12

# denotes pre-mining pond areas and volumes assumed to be nil; *italics* denotes ponding on different branch of Tributary 1
Source: DGS 2016

Factors influencing ponding depths and volumes include rain duration, surface cracking, effective percolation rates of the surface soils and fractured rock bars/outcrops along the creeks (DGS 2012).

7.4 Potential environmental consequences on land in general

The predicted effects and impacts of surface subsidence may trigger a number of environmental consequences related to land. These consequences and associated hazards are summarised in Table 9.

The assessment of the predicted impacts and potential consequences on land in general includes:

- Agricultural consequences:
    - soil erosion and deposition
    - altered soil moisture and nutrient distribution
    - reduced pasture productivity
- Creek line consequences:

- in-stream ponding
- over-bank ponding
- alteration of overland flow paths
- localised bank and channel erosion and scouring
- increased in-stream sedimentation.

Table 10: Environmental consequences associated with land subsidence

Subsidence impact	Subsidence consequence	Potential environmental hazard (to land in general)	Ecological/agricultural response (to land in general)
Surface subsidence troughs	Altered surface and subsurface flow	Re-routed surface flows into areas not currently subject to concentrated flows leading to redirection of soil moisture and material/chemicals transported by flow, and increased risk of erosion	Altered drainage / erosion patterns, altered soil moisture and/or nutrient distribution patterns reducing vegetation condition Soil loss, bank instability, loss of agricultural land, decrease of water quality (elevated turbidity and total suspended solids (TSS)) of flows during rainfall events Decreased land and agricultural capability
	Damage to contour banks	Increased erosion	Soil loss, bank instability, loss of agricultural land, decreased land and agricultural capability
	Ponding (in-stream and overbank)	Drainage channel re-alignment Localised water logging of pasture Potential decrease in water quality (elevated EC) of receiving catchment (where ponding occurs over saline soils) Increased surface infiltration	Altered soil moisture or nutrient distribution patterns Reduced land and agricultural capability, loss of agricultural land Reduction in water quality in Pine Creek
	Landslip of surface terrain	Increased erosion	Soil loss and exposure of sub-soils, sedimentation of drainage lines, loss of agricultural land
	Altered ground surface, including sequence of troughs and ridges akin to chain-of-ponds (corresponding with subsidence troughs and chain pillars respectively	Altered overbank surface gradients Altered channel gradients and/or alignments Headcuts associated with increased land surface slope	Increase or decrease in surface flow velocity, including deposition of suspended solids Increased erosion of creek bed / banks leading to loss of riparian vegetation, loss of soils, loss of agricultural land, increased sedimentation of

Subsidence impact	Subsidence consequence	Potential environmental hazard (to land in general)	Ecological/agricultural response (to land in general)
			drainage lines Altered drainage / erosion patterns, altered soil moisture and/or nutrient distribution patterns reducing vegetation condition
Surface and subsurface cracking	Exposure of dispersive subsoils	Increased erosion	Soil loss, bank instability, loss of agricultural land, decreased land and agricultural capability
	Interconnection from seam to surface and near surface cracking (increase in infiltration)	Altered surface and subsurface flow - reduction in surface and stream flows	Changes to both surface and groundwater availability Redirection/loss of soil moisture and material/chemicals transported by flow Decreased land and agricultural capability
	Redeveloped cracking	Risk to livestock, stock handlers as well as personal safety Increased erosion	Risk to safety of stock, mine personnel Soil loss, loss of agricultural land
Valley closure and uplift	Localised deviation/re-routing of surface flows	Localised loss of surface flows	Redirection/loss of soil moisture and material/chemicals transported by flow Decreased land and agricultural capability

8 Performance Measures and Indicators

Performance measures to enable the management of subsidence impacts upon land are listed in Table 11.

The overall performance measure for land is to maintain and/or re-establish agricultural land of comparable land capability to that of the pre-disturbance environment (i.e. Class III land suitable for cropping on a rotational basis) that provides a stable landform with comparable functionality.

Table 11: Performance measures and indicators for land management (LW107 to LW110)

Objective	Performance measures	Performance criteria
To maintain the pre-mining land and agricultural capability of the site	Surface cracking	Permanent cracks (which do not self-close within one month of longwall face passing) are remediated as soon as practicably possible (and safe to do so).
		Surface cracking is remediated to prevent erosion and slope instability issues within 6 months of mining of each longwall.
	Topographic form (LiDAR):	
	Landscape morphology	Subsidence across landscape does not exceed subsidence predictions for LW107 to LW110.
	Creek lines	Change to overall drainage pattern is not more than predicted.
	Groundcover (multi-spectral images – erosion and pasture cover)	Identified areas of NDVI change (greater than 1 standard deviation from the mean change) investigated in the field to determine the source of the change.
		Site specific management report prepared and recommendations implemented where necessary.

9 Monitoring

Given the size of the target area and the multiple land uses and key environments, a multi-scale, multi-data source monitoring approach (Table 12) has been developed to monitor the consequences of longwall mining on land in general above LW107 to LW110.

At the local scale, a program of field survey based on a stratified random and targeted design will be implemented for agricultural and creek line areas. Surveys will be directed into 'control' and 'impact' areas to allow direct comparison between these areas through time and space.

Whole-of-site monitoring using remote sensing data (LiDAR and multi-spectral imaging) is proposed to monitor the entire target area including control areas followed by targeted field work to examine the causes of any change highlighted.

Table 12: Multi-scale monitoring program

Data source	Method	Scale	Purpose
Visual Inspection	Visual assessment	Area immediately behind longwall face (i.e. panel width x 160-480 m)	Immediate consequences of subsidence particularly surface cracking, landslip and erosion
Remote sensing	LiDAR	Entire site	Topographic form and change
	Multi-spectral imaging	Entire site	Agricultural pasture cover / biomass Erosion monitoring
Direct field survey	Field inspection and sampling/testing as required	Areas of change[1] identified using remote sensing techniques	Confirm changes in pasture, biomass or soil characteristics and areas of erosion to identify cause and management requirements
Creek line survey	Geomorphic survey	Along creek lines	Creek stability and condition.
	Cross-sections	Targeted pools	Bank and bed stability.

[1] Compared to control sites and/or over time (not related to seasonal or broad scale variation).

9.1 Baseline monitoring

Baseline monitoring will be undertaken to understand current conditions above LW107 to LW110. A site traverse over each longwall panel will also be undertaken to describe current condition. Measurement collected and analysed shall include remote sensing data.

Multi-spectral image capture will also occur prior to undermining to detect any changes as a result of subsidence.

9.2 Visual inspections

Visual inspection of the surface environment above each of the longwalls will be undertaken by NCOPL personnel. The methods and frequency of routine inspections to be undertaken is shown in Table 13.

Cracks are considered permanent if they have not closed within one month of the longwall face passing. Where this occurs, appropriate management measures will be implemented (Section 8.1).

Opportunistic observations of any subsidence impacts (including surface cracking, ponding, landslips and erosion) noted by NCOPL employees and tenants will be reported to the Environment Superintendent as they are identified, and management measures implemented where necessary.

Table 13: Routine inspection monitoring program

Data source	Parameters	Analysis	Purpose	Sampling frequency
Visual inspections of areas immediately behind the longwall face passage	Crack location and size	Identify areas of surface cracking Document cracking locations, depth and width using GPS	Determine appropriate management response (see Section 10)	Prior to the commencement of each longwall Visually inspect following subsidence as soon as practically possible and safe to do so Repeat at least weekly and following significant rainfall events until cracking disappears and then repeat inspection after a 12 month period Following a significant rainfall event (defined as a rainfall event > 38.4 mm over 5 consecutive days).
		Identify erosion/potential erosion		
	Evidence of erosion (e.g. nick points, headcuts)	Identify erosion Record nature and extent of sedimentation (location, extent, depth, sediment calibre)	Determine appropriate management response (see Section 10) Record nature and extent of sedimentation (location, extent, depth, sediment calibre)	
Visual inspections of drainage lines	Bed and bank stability	Identify erosion/potential erosion	Determine appropriate management response (see Section 10)	Following a significant rainfall event (defined as a rainfall event > 38.4 mm over 5 consecutive days).

9.3 Remote sensing

It is proposed to use remote sensing data (LiDAR and multi-spectral imaging) to monitor the entire target area (including control areas). The remotely sensed data will allow quantitative comparison of key land surface condition parameters in agricultural and creek line environments. Repeat capture and analysis of the multi-spectral imagery will highlight areas of changes in land cover beyond those found in control areas. Field work will then be undertaken to examine the causes of any change highlighted.

The target area for this monitoring plan is the surface environment above and surrounding LW107 to LW110 within the predicted impact zone. Table 14 shows the surface zones to be used for impact monitoring. Control sites will be selected from zones where no subsidence impacts have been predicted. These control sites will have similar characteristics and biological condition to the target area.

Table 14: Surface zones for monitoring

Surface zone	Definition	
Longwall	Zone of maximum subsidence	>2 m predicted subsidence
Transition	Zone of maximum stress and tilt	0.1 – 1.5 m predicted subsidence
Pillar	Zone above the pillar with minimal subsidence	
Control	Zones of no impact located outside of any predicted subsidence zone	

Whole of site monitoring will be conducted using LiDAR and multi-spectral data sources (Table 15).

At the local scale a program of field survey based on a stratified random and targeted design will be implemented for agricultural and creek line areas. Surveys will be directed into control and impact areas and will allow direct comparison between these areas through time and space.

9.3.1 LiDAR processing and analysis

LiDAR processing and analysis will be undertaken at baseline and then every three years. LiDAR data will be captured across the target area and identified control areas. The data will be processed into a land surface digital elevation model (DEM) across the entire landscape. Subsequent LiDAR captures will be processed similarly (i.e. DEM products) and each new dataset will be subtracted from those produced from earlier captures creating a series of DEM change images.

LiDAR datasets are capable of describing channel width and depth, especially where the creek has formed a distinct channel (>1 m depth and 2 m wide). These datasets will enable the long-profile and volume of the creek to be documented and changes in creek slope, width and depth quantified.

The best results will be derived from repeat data capture and image to image comparison. These comparisons may provide accurate reach length assessment of erosion and deposition.

Each dataset produced will be used to create a map for visual interpretation and analysis and for communication of results.

9.3.2 Multi-spectral image processing and analysis

Multi-spectral image processing and analysis will be undertaken at baseline and then annually during spring. The high-resolution multi-spectral imagery (World View, Geoeye, Quickbird or similar) will be processed into a normalised difference vegetation index (NDVI). The initial data capture will be stratified into the 4 zones (Longwall, Transition, Pillar, Control) and compared using ANOVA to determine if data in any of the zones are significantly different from each other.

Subsequent multi-spectral image captures will be processed into a NDVI. Each dataset will be subtracted from those produced from earlier captures creating a series of change images. Both the newly created models and the change models will be stratified into the four impact zones and analysed using ANOVA.

In addition, areas of significant change in NDVI will be highlighted and a targeted reconnaissance survey directed to investigate the source of the change and implement any planning, management action or change in management procedures required (see Section 10).

Each dataset produced will be used to create a map for visual interpretation and analysis and for communication of results.

Although the primary purpose of this monitoring is to detect changes in pasture cover the design of the program is such that other impacts such as weed infestations and disturbance caused by erosion and sedimentation will also be detected. Significant weed infestations are likely to be detected as changes in image derived vegetation density information. Erosion and sedimentation can result in loss and/or smothering of vegetation, which would also register in imagery, and would be targeted for direct field survey.

Table 15: Remote sensing monitoring program

Data source	Parameters	Analysis	Purpose	Sampling frequency
LiDAR	High resolution topography	Comparative statistics Visual assessment	Document baseline landscape morphology Quantify topographic change	Baseline Repeat every 3 years For a period of up to four years following mining of each longwall to enable capture of two images per longwall
	Creek line slope and volumes	Description of long-profile and creek volume	Document baseline creek slope, width and depth Document changes in creek slope, width and depth	
High resolution imagery	NDVI – relative plant biomass and cover	Comparative statistics Visual assessment	Document baseline variability in vegetative cover (pasture) Direct targeted field survey	Baseline Repeat every year – early spring For a period of up to two years following mining of each longwall to enable capture of two images per longwall

9.4 Geomorphic (creek line) surveys

Creek line surveys have been designed to identify the main geomorphic zones and hence overall nature of the channel morphology and to provide quantitative information that can document changes in channel cross-section, bed erosion and deposition (Table 16). Geomorphic zones will be defined during the baseline survey based on stream order, dominant channel bed material, bed stability, channel geometry etc.

Locations for cross-sections should be determined during the baseline survey to determine channel parameters (channel width, depth, area, bankfull level). A reach of at least 100 m in length shall be surveyed from each geomorphic zone and at least four cross sections recorded at equal intervals along the reach.

Two to three reaches each at least 100 m long within a control zone should also be surveyed to provide information on natural channel variability between survey periods. These control surveys will provide an indication of natural variability across time due to rainfall events that can be used to determine if channel changes above LW107 to LW110 are mining-induced by comparing for example, changes to channel area and bed slope, erosion of channel banks and bed or sediment deposition.

Permanent pegs will be established at each cross-section to ensure comparability of cross-section sequences.

Channel activity is driven by rainfall events that cause significant overbank runoff. Creek line surveys should be undertaken annually either in winter/spring or after significant rainfall/runoff events. Prior to detailed analysis, a significant rainfall/runoff event can be defined as one which results in continuous overbank surface flow at PC and PC1 (Narrabri Mine Extraction Plan – Water Management Plan LW101 to Lw106 surface water monitoring locations).

The final location of on-going monitoring reaches and cross-sections will be determined following the completion of the baseline survey.

Table 16: Creek line survey procedures

Data source	Parameters	Analysis	Purpose	Sampling frequency
Geomorphic survey	Representative geomorphic zones	Mapping and description Survey (100 m reach)	Define geomorphic zones Establish baseline status of each zone	Baseline At least annual, in late winter/spring or following a significant run-off event For a period of up to two years following mining of each longwall
Channel cross-sections	Channel width, depth, area	Cross-section diagrams Channel parameters	Establish baseline status Establish permanent markers for on-going monitoring	Baseline At least annual, in late winter/spring or following a significant run-off event For a period of up to two years following mining of each longwall

10 Management Procedures

10.1 Surface cracking

Surface cracking that appears as the longwall face passes is to be monitored and remediated as per the management measures outlined in Table 17. Large surface cracks are to be repaired, if required, after subsidence development for a given longwall (i.e. permanent cracks which have not collapsed within one month of the longwall face passing). Temporary fencing is necessary during the interim period between the longwall face passing and when remediation measures are undertaken.

Where erosion along drainage lines has been identified from visual inspections, appropriate control measures as identified in the Erosion and Sediment Control Plan and Water Management Plan shall be implemented. If necessary, advice should be sought from a qualified geomorphologist or other suitably qualified professional.

Table 17: Surface cracking monitoring and management responses

Trigger	Management
Surface cracking identified	• Rip surface cracks not filled in by natural processes • For larger cracks, or persistent cracking within important vegetated areas and/or the vicinity of Aboriginal archaeological sites, fill with material sourced from nearby stockpiles, or from within the footprint of the Reject Emplacement Area. Any such works will be in consistent with the Heritage Management Plan. • Develop and implement an erosion control management plan to address any erosion issues that are not addressed in the Erosion and Sediment Control Plan • Retain soil conservation structures or, if disturbed, reinstate these structures to maintain pre-mining condition (refer to Built Features Management Plan) • Mitigation works such as re-grading, installation of new contour banks and revegetation (sowing of cover crops) of exposed areas in areas that are significantly affected by erosion after mining • Assess if additional management plans or works are required to minimise likelihood of long term degradation and seek expert advice • In the event of large scale slope instability, undertake appropriate stabilisation works – expert advice should be sought • Assess whether repairs to cracking caused by upsidence of gully stabilisation works are required to prevent long-term degradation and reduce risks to personnel and the general public All measures implemented must align with the Erosion and Sediment Control Plan for the Longwall Project and the EP.
Areas of erosion as a consequence of subsidence identified	Implement suitable erosion and sediment control measures identified in the Erosion and Sediment Control Plan for the Longwall Project and the EP, such as: • Installation of sediment fences downslope of erosion areas. • Stabilisation of erosion areas using rock or other appropriate materials. • Other erosion and sediment control measures consistent with relevant guidelines such as Landcom (2004) *Managing Urban Stormwater: Soils and Construction Volume 1*

10.2 Remote sensing

A two-tiered system of triggers for management is proposed in response to changes identified via remote sensing (Figure 7).

The first tier of response is triggered by changes detected in the remote sensing time series analysis which instigates further investigation including targeted rapid on-ground assessments (Table 18). The second tier of response is triggered if changes are confirmed or discovered on-ground (Table 19). These triggers instigate the development of site specific management responses and remedial actions.

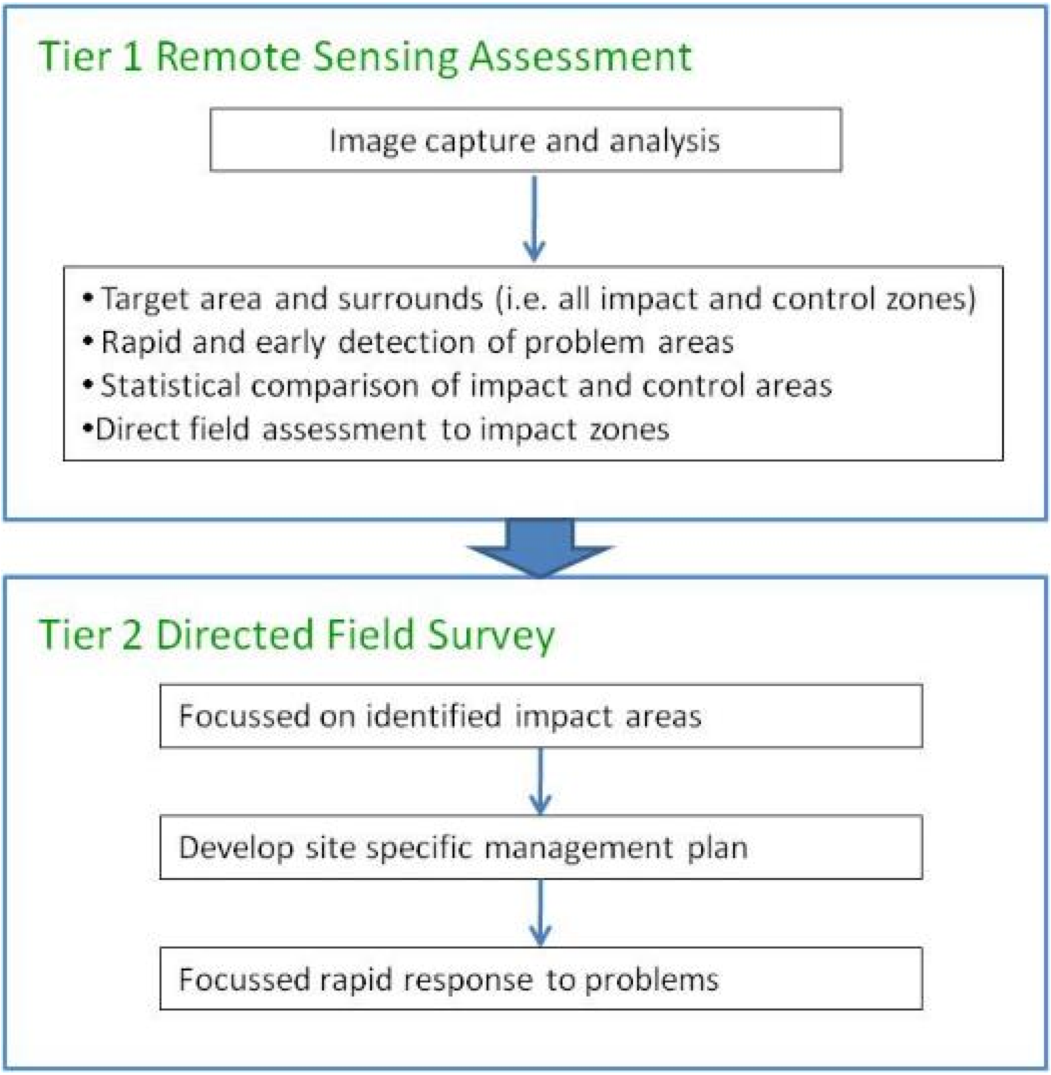

Figure 7: Two-tiered remote sensing monitoring and management approach

Table 18: Remote sensing monitoring for management

Trigger	Investigation	Management
Remote sensing time series analysis - statistical change in a region not consistent with regional patterns	Corroborate statistical analysis with visual image inspection	Investigate via site specific rapid assessment based on the impacting factor and on-ground effect and determine what further action is required. The need for this field assessment and the direction for where it is to be undertaken will arise from the specific changes observed in the remote sensing.
Remote sensing change detection identifies area of change (> +/-1 std dev from average) in area greater than 0.1 ha	Investigate sources of change via desktop assessment: 1. Obvious external influence e.g. fire, major storm, or unrelated development) 2. Potentially due to altered sheet flow, significant weed infestation and/or erosion / sedimentation	Respond to change based on likely source of impact: 1. Identify region of change and tag it as non-project specific impact 2. Undertake directed field investigation via rapid field checking protocol

Table 19: Rapid field checking protocol and management

Parameter	Method	Management
Erosion or sedimentation	On ground inspection record nature and extent of erosion (location, erosion type, depth of soil loss)	Identify cause / source and refer to the Erosion and Sediment Control Plan for the Longwall Project or seek expert advice to develop site specific management of erosion.
Sedimentation (deposition)	On ground inspection record nature and extent of sedimentation (location, extent, depth, sediment calibre)	
Surface Cracking	Visual assessment	Record cracking locations (e.g. GPS) and refer to Table 16.

10.3 Creek lines

Management measures (Table 20) are to be adopted as per the Erosion and Sediment Control Plan and Water Management Plan. If necessary, advice should be sought from a qualified geomorphologist or other suitably qualified professional.

Table 20: Creek lines monitoring triggers for management

Trigger	Management
Detected change in surface drainage paths Detected change in surface vegetation in areas of ponding Detected alteration in channel dimensions or channel processes outside of normal range or in comparison to the control site (statistically significant compared to baseline and/or control sites)	Stabilise the damaged or eroded banks in accordance with the Erosion and Sediment Control Plan for the Longwall Project and/or Water Management Plan Management actions for ponding should be undertaken in accordance with the Ponding Management Plan (with DoPE for approval).

10.4 Reporting and review

Reporting of all monitoring results and comparative analysis should occur following completion of the annual walkover inspection and subsequent analysis.

PA_08_0144 requires a protocol for periodic review of the plan, refer to Section 5.3 of the EP.

11 Contingency Response

The monitoring program outlined in this LMP aims to identify the impacts that longwall mining has had on land above LW107 to LW110.

In the event that subsidence impacts on land exceed those predicted in the EA and/or the performance measures and indicators nominated in this LMP (Section 8) are exceeded (or are considered likely to be exceeded based on observed trends), NCOPL will implement contingency responses within the Trigger Action Response Plan (TARP) below.

Contingency measures must consider the specific issue and an assessment of environmental consequences. Relevant actions may include the implementation of management measures identified in Tables 21.

Table 21: Land management Trigger Action Response Plan (TARP)

Aspect	Monitoring		Response		
	Methodology	Purpose	Trigger	Action	Responsibility
Surface cracking	**Sites:** Affected longwall panel/s, including drainage lines within affected longwall panels **Parameters:** Crack width and location Evidence of erosion (e.g. nick points etc) **Analysis:** Appearance of new surface cracks after longwall face has passed Permanency of cracking **Frequency:** At least weekly and following a significant rainfall event until cracking disappears and the repeat after a 12 month period	Identify area/s of surface cracking as a result of subsidence To determine appropriate management response and remediation measure/s	Level 1 • Surface cracks <50 mm remain present within one month of the longwall face passing	Level 1 • Document occurrence of surface cracks • Continue monitoring • Summarise occurrence in relevant reports	NCOPL Environmental Superintendent
			Level 2 • Surface cracks >50 mm and <330 mm remain within one month of the longwall face passing • Erosion as a result of cracking identified (i.e. nick points)	Level 2 • *As for Level 1* • Provide safety fencing and signage if required • Advise relevant stakeholders • Implement remediation measures as appropriate – these may include ripping of surface cracks; filling of cracks with grout, spoil or other self-cementing material • Implement appropriate control measures as outlined in the Erosion and Sediment Control Plan • Review monitoring program as required	

Aspect	Monitoring		Response		
	Methodology	Purpose	Trigger	Action	Responsibility
			Level 3 • Surface cracks >330 mm remain present within one month of the longwall face passing • Surface cracking prevents functioning of contour banks	Level 3 • *As for Level 2* • Make area safe • Investigate the reasons for exceedance of predictions • Review and update predictions and assessment of potential impacts	
Topographic form	**Sites:** Affected longwall panel/s **Parameters:** Digital elevation model (DEM) derived from LiDAR Creek line drainage path/s and creek line slope and volumes	To document baseline landscape morphology To identify and quantify topographic change To document baseline creek line drainage path/s and creek line slope and volumes	Level 1 • Surface gradient change as detected by LiDAR is >1.5% and <3% • Length of eroding streambank increases more than 10% compared to baseline	Level 1 • Document observed changes • Continue monitoring • Summarise occurrence in relevant reports	NCOPL Environmental Superintendent

Aspect	Monitoring		Response		
	Methodology	Purpose	Trigger	Action	Responsibility
	Analysis: Comparison to baseline DEM **Frequency:** Every 3 years	To identify changes in creek line drainage path/s and creek line slope and volumes	Level 2 • Surface gradient change as detected by LiDAR is >3% and <5% • Length of eroding streambank increases more than 15% compared to baseline	Level 2 • *As for Level 1* • Consult geomorphologist or other appropriately qualified and experienced specialist to review DEM and conduct site investigation to assess changes and provide recommendations for remediation which may include – re-establishing drainage pathways with earthworks and implementation of erosion control measures • Notify relevant agencies if in-stream works are to be undertaken	
			Level 3 • Surface gradient change as detected by LiDAR is >5% • Length of eroding streambank increases more than 20% compared to baseline	Level 3 • *As for Level 2* • Make area safe (if applicable) • Investigate the reasons for exceedance of predictions • Review and update predictions and assessment of potential impacts	

Aspect	Monitoring		Response		
	Methodology	Purpose	Trigger	Action	Responsibility
Groundcover (multi-spectral images – erosion and pasture cover)	**Sites:** Affected longwall panels and control zones outside of subsidence impact zone **Parameters:** Multi-spectral imaging - NDVI (relative plant biomass and cover) **Analysis:** Comparison to baseline NDVI values and maps Comparison against trends documented in control zones **Frequency:** Annually (early spring)	To document baseline variability in vegetative cover To document ongoing variability in vegetative cover To guide direct targeted field survey and subsequent management responses	Level 1 • Remote sensing change detection identifies no change (i.e. within +/- 1 std dev from average) in an area that exceeds 0.1ha	Level 1 • No action required, continue monitoring	NCOPL Environmental Superintendent
			Level 2 • Remote sensing change detection identifies change > > +/- 2 std dev from average in an area that exceeds 0.1ha which is not related to surface activities (e.g. ripping for sowing, installation of infrastructure)	Level 2 • *As for Level 1* • Conduct site investigation to determine the cause of change (e.g. weed invasion, erosion, sedimentation, surface cracking) and appropriate management response (refer Table 18) • Review monitoring program as required	
Creek stability and condition Creek bank and bed stability	**Sites:** Representative reaches within affected LW panels and control reaches Selected cross sections within representative reaches of LW panels and control reaches	To define geomorphic zones of drainage lines To establish the baseline status of each zone To document ongoing status of each zone	Level 1 • Field survey indicates <20% increase in length of eroding creek line • Surface drainage pattern is unchanged	Level 1 • Document observed changes • Continue monitoring • Summarise occurrence in relevant reports	NCOPL Environmental Superintendent

Aspect	Monitoring		Response		
	Methodology	Purpose	Trigger	Action	Responsibility
	Parameters: Geomorphic characteristics Channel width, depth via cross sectional surveys **Analysis:** Geomorphic survey (field survey) Comparison of cross sectional surveys to determine any change in cross section **Frequency:** At least annual (ideally in late winter/spring or following a significant rainfall event (i.e. an event which results in continuous overbank surface flow at surface water monitoring locations PC and PC1) LiDAR survey every 3 years		Level 2 • Field survey indicates >20% increase in length of eroding creek line • Surface drainage pattern is significantly altered	Level 2 • *As for Level 1* • Consult geomorphologist or other appropriately qualified and experienced specialist to determine the extent of the impact, identify contributing factors and determine appropriate remediation measures • Implement contingency measures as identified in other plans as relevant (e.g. Subsidence Monitoring Program) • Consult with relevant agencies and stakeholders prior to remediation works being undertaken • Review monitoring program as required	

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Appendix A Soil Pit Summaries

Pit #	Location	Geological formation / landform unit	Profile							
			Topsoil	pH	D% (DISPERSIBILITY)	EAT (DISPERSIBILITY)	SUBSOILS	pH	D% (DISPERSIBILITY)	EAT (DISPERSIBILITY)
25	LW107	Purlawaugh – Drainage Line	0 - 60 cm Sand	6.5	21 (slight)	3(1) (slight)	2 horizons (to 270 cm) Sandy clay loam to clayey sand	5.5 - 6.5	33 - 67 (moderate to very high)	3(1) - 2(1) (high to moderate) Possibly sodic
27	LW108	Purlawaugh – Drainage Line	0 - 20 cm Sand	6.5	17 (slight)	8/3(1) negligible to slight)	3 horizons (to 223 cm) Sand to sandy clay loam	6.5 - 7	0 - 69 (negligible to very high)	3(1) - 2 (3) (slight to very high)
28	LW109	Pilliga – Upper Slope	0 - 15 cm Sandy loam	4.5	8 (slight)	8/3(1) negligible to slight)	3 horizons (to 180 cm) Sandy loam to sandy clay loam	4.5 - 6	8 - 14 (slight)	3(1) - 5 (slight)
29	LW109	Pilliga – Lower Slope	0 - 23 cm Loamy sand	5.5 to 6.5	31 (moderate)	3(1) (slight)	3 horizons (to 220 cm) Sandy loam to clay	5.5 - 6.5, 4.5	5011 (slight to moderate)	3(1) - 3(2) (slight)
30	LW108	Pilliga - Crest	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

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