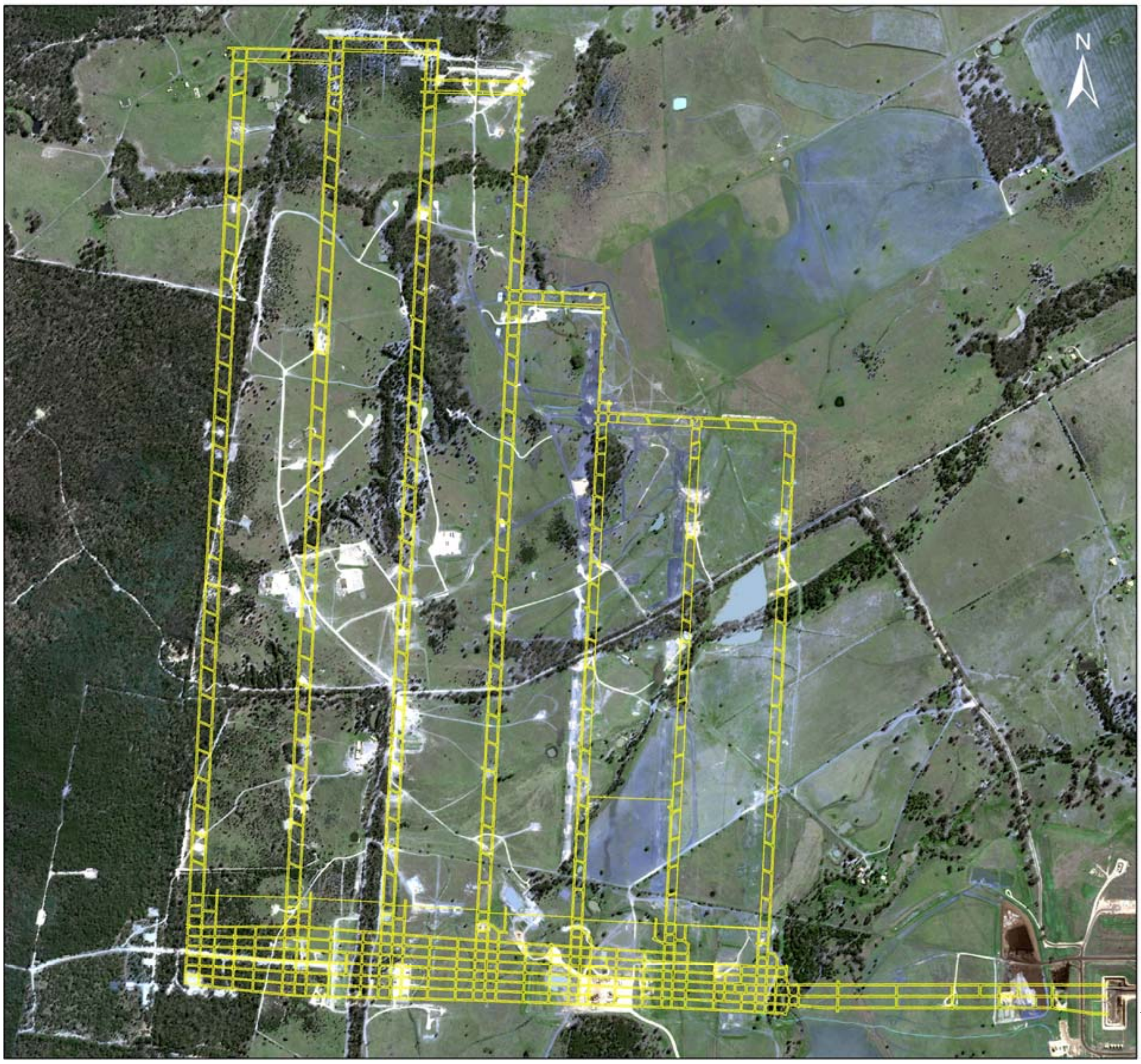
Narrabri Mine

Land Management Plan – Narrabri Coal (LW101 -106)

Prepared for
Narrabri Coal Operations Pty Ltd

18 May 2016



DOCUMENT TRACKING

Item	Detail
Project Name	Land Management Plan - Narrabri Mine (LW101 – 106)
Project Number	ARM1454
Project Manager	Nathalie van der Veer Phone: 02 8081 2684 92 Taylor St, Armidale, NSW 2350
Prepared by	Nathalie van der Veer
Reviewed by	Daniel Magdi
Approved by	Dr Paul Frazier
Status	Final
Version Number	1
Last saved on	18 May 2016

This report should be cited as 'Eco Logical Australia 2016. *Land Management Plan (LW101 – 106)*. Prepared for Narrabri Coal Operations Pty Ltd.'

ACKNOWLEDGEMENTS

This document has been prepared by Eco Logical Australia Pty Ltd with support from Narrabri Coal Operations Pty Ltd

Contents

List of figures

List of tables

Abbreviations

Abbreviation	Description
DGS	Ditton Geotechnical Services
DEM	Digital elevation model
DRE	Division of Resources and Energy
DP&E	Department of Planning and Environment
DPI	Department of Primary Industries
DPI Water	Department of Primary Industries – Water
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. LW104)
ML	Mining Lease
MOP	Mining Operations Plan
NCOPL	Narrabri Coal Operations Pty Ltd
NM	Narrabri Mine
OEH	Office of Environment and Heritage
PA	Project Approval
RMP	Rehabilitation Management Plan
TARP	Trigger Action Response Plan
WCL	Whitehaven Coal Limited
WMP	Water Management Plan

1 Introduction

The Narrabri Mine (NM) 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 NM under Section 75J 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 101 to 106 (herein referred to as LW 101-106) define the first of the secondary extraction mining within the approved underground mining areas and are the focus of this Land Management Plan (LMP).

Eco Logical Australia (ELA) prepared the initial LMP which covered LW 101 – 105 and was prepared as a component of the Narrabri Mine LW 101 – 105 Extraction Plan (EP) to manage the potential impacts and/or environmental consequences of the longwalls upon land in general as identified through the revised Mine Subsidence Effect Predictions and Impact Assessment prepared for the proposed LW 101-105 (DGS 2011), Landscape Management Plan (LSMP) (ELA 2011) and relevant approval documents, including the Environmental Assessment (EA) for Stage 2 of the Narrabri Mine (R.W. Corkery & Co. 2009).

1.1 Purpose & scope

This revision has been developed to incorporate LW 106 into the LMP.

As it is expected that subsidence impacts would be most evident within 12 months of each longwall, completion, this LMP has revised the time-frame for when monitoring can be scaled back or ceased. It is recommended that if no impacts associated with subsidence have been observed within 3 years after the completion of each longwall, that monitoring of some parameters can be scaled back or ceased. This will be done in consultation with the relevant government agencies.

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 LW 101-106
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	Content
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

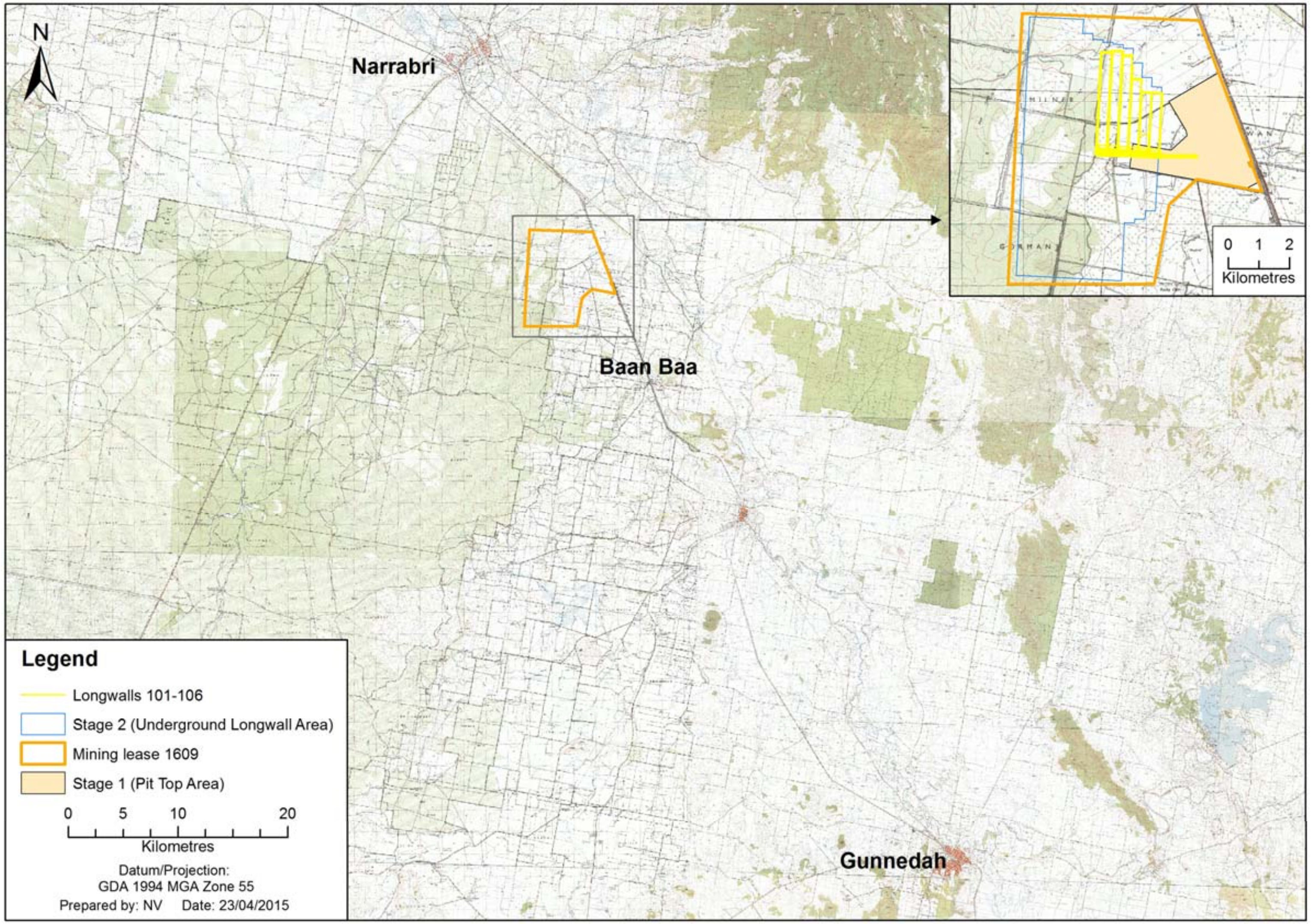


Figure 1: Mine site location

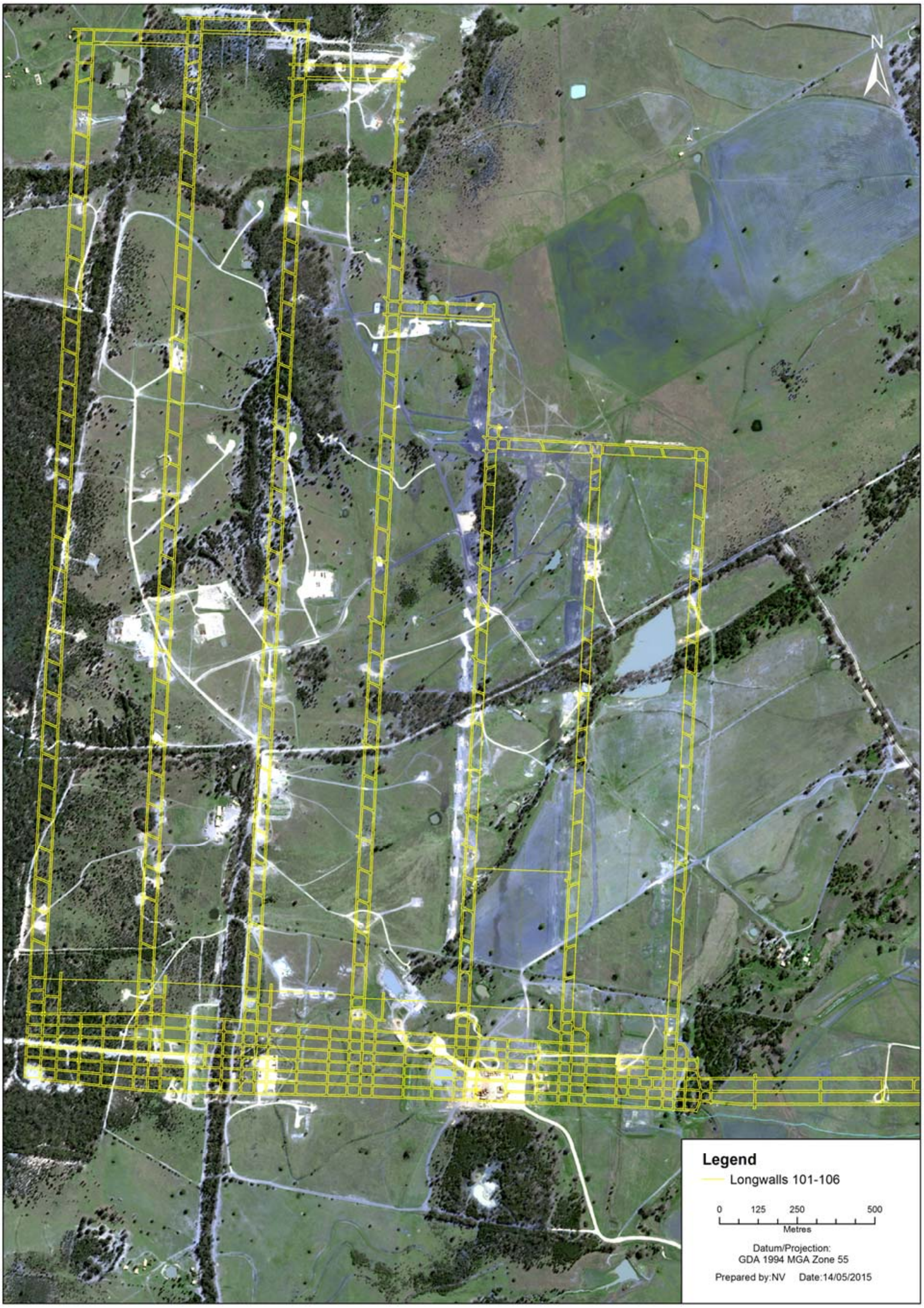


Figure 2: Underground mining layout

2 Statutory Requirements

NCOPL's statutory obligations are contained within:

- The conditions of the Project Approval (PA) 08_0144, as modified, under the NSW 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)
- Other relevant legislation.

These are described below.

2.1 EP&A Act approval

Condition 4(h) of Schedule 3 of the Project Approval (PA) 08_0144, as modified, under the EP&A Act requires the preparation of a LMP be included in the EP for second workings. Approval Condition 4(h) states:

Extraction Plan

4. The Proponent shall prepare and implement Extraction Plans for any second workings to be mined to the satisfaction of the Secretary. Each Extraction Plan must:

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.*

Under Condition 5 of Schedule 3, all management plans under Condition 4(h) of Schedule 3 of the Project Approval (PA) 08_0144 will 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.

In addition, Condition 2 of Schedule 6 outlines the management plan requirements that are applicable to the preparation of this LMP.

Table 2 indicates where each component of the Conditions is 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 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;	Section 4
	b) a description of:	
	• the relevant statutory requirements (including any relevant approval, license or lease conditions);	Section 2
	• any relevant limits or performance measures/criteria;	Section 8
	• 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;	Section 8
	c) a description of the measures that would be implemented to comply with the relevant statutory requirements, limits, or performance measures/criteria;	Section 10
	d) a program to monitor and report on the: • impacts and environmental performance of the project; • effectiveness of any management measures (see c above);	Section 9
	e) a contingency plan to manage any unpredicted impacts and their consequences;	Section 11
	f) a program to investigate and implement ways to improve the environmental performance of the project over time;	Overall EP
	g) a protocol for managing and reporting any; • incidents; • complaints; • non-compliances with statutory requirements; and • exceedances of the impact assessment criteria and/or performance criteria; and	Overall EP
	h) a protocol for periodic review of the plan.	Overall EP
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;	Overall LMP (this document) and Section 2
	i) include a program to collect sufficient baseline data for future Extraction Plans.	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;	Section 7

Condition number	Condition requirement	Relevant section of this report
	b) A detailed description of the measures that would be implemented to remediate predicted impacts; and	Section 10
	c) A contingency plan that expressly provides for adaptive management.	Section 11

2.2 EPBC Act approval

Condition 3 of the Approval (EPBC Ref 2009/5003) under the EPBC Act requires the incorporation of Commonwealth listed threatened species and communities within the LMP. Approval 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.*

2.3 Licenses, permits & leases

In addition to the Project Approval under the NSW EP&A Act and Commonwealth EPBC Act, all activities at or in association with the NM will be undertaken in accordance with the following licenses, permits and leases which have been issued or are in preparation:

- The conditions of the mining lease issued by the NSW Department of Resources and Energy (DRE), under the NSW Mining Act, 1992 (Mining Lease No.1609)
- 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 Environment Protection Authority (EPA) under the NSW Protection of the Environment Operations Act, 1997
- Water Access licence issued by the Department of Primary Industries – Water (DPI Water) in accordance with the Water Management Act 2000
- Mining and occupational health and safety related approvals granted by DRE and WorkCover NSW (R.W. Corkery & Co. 2009).

2.4 Other legislation

NCOPL will conduct the Project consistent with the Project Approval and any other legislation that is applicable to an approved Part 3A Project under the EP&A Act. The following Acts may be applicable to the conduct of the Project (R.W. Corkery & Co. 2009):

- Contaminated Land Management Act 1997
- Dangerous Goods Act 1975
- Mining Act 1992
- Noxious Weeds Act 1993

- Rail Safety Act 2002
- Road and Rail Transport (Dangerous Goods) Act 1997
- Roads Act 1993
- Protection of the Environment Operations Act 1997
- Threatened Species Conservation Act 1995 (TSC Act)
- Work Health and Safety Act 2011
- Work Health and Safety (Mines) Act 2013
- Crown Lands Act 1989
- Dams Safety Act 1978
- Energy and Utilities Administration Act 1987
- Fisheries Management Act 1994
- Water Management Act 2000.

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 and ML) from the following agencies:

- DoPI
- DRE.

Other relevant agencies, public authorities and affected landholders include:

- Narrabri Shire Council (landowner of Greylands Road).
- NSW Department of Primary Industries (DPI).
- Crown Lands Division.
- OEH.

Consultation of relevant agencies and stakeholders has been undertaken as part of the Extraction Plan preparation and assessment process. This consultation has included:

- Provision of draft copies of the Land Management Plan to Narrabri Shire Council (NSC), Essential Energy, Crown Lands Division, Namoi Valley Catchment Management Authority and State Forests NSW for comment
- Individual meetings with Narrabri Shire Council, Essential Energy and the Catchment Management Authority on site
- Submission of the full Extraction Plan to DP&E and DRE for assessment
- Presentation workshop on 18th January 2012 attended by DP&E, DRE and OEH.

Feedback received from these agencies 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)	Detailed baseline data (Condition 2, Schedule 6) needs to be provided and included in performance measures, performance indications and monitoring programs.	Section 4, 6 & 7
	Prepare Trigger Action Response Plan (TARP)	Section 8
	Lack of evidence of formal risk assessment	Section 5
	Demonstration that the Land MP has been prepared in consultation with affected public utilities (Condition 4(h)	Section 3 (this Section)

Further consultation was sought from DoPI, DRE and NSC for this revision of the LMP; responses from DRE and NSC with no further comments were received.

4 Baseline Information

Baseline data as relevant to land in general across LW 101-106 has been provided in this section. Baseline data incorporated into this LMP 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 (Geoff Cunningham Natural Resource Consultants Pty Ltd 2009). Other data included in the LMP has been sourced from site visits undertaken for the development of the Rehabilitation Management Plan (ELA 2011) and site reconnaissance undertaken in August 2011 specific to LW 101-105 and in April 2015 specific to LW 106.

The monitoring program outlined in Section 7 of this LMP indicates where additional baseline data specific to LW 101-106 are required and the relevant baseline monitoring report referenced (ELA 2012a; 2012b).

4.1 Landuse

There are 19 residences within and immediately surrounding the Mine Site, sixteen of which are owned by NCOPL or a related company. 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 LW 101-106 is owned by NCOPL (R.W. Corkery & Co. 2009). A public road reserve associated with the unsealed Greylands Road and a Crown Road Reserve occur above LW 101 – 106. These reserves are currently controlled by Narrabri Shire Council and the Crown Lands Division respectively.

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 LW106).

The land directly above LW 101-106 is largely used for grazing (R.W. Corkery & Co. 2009). Some soil conservation bank systems are in place and there are a number of small farm dams above LW 101-106.

4.2 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 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 between 2º to 5º. Maximum slopes of approximately 18º are located in the southwest of the Mine Site and minimum slopes of less than 1º occur in the northeast (R.W. Corkery & Co. 2009). Along the creeks and tributaries of Pine Creek slopes can increase to 10º-15º.

The elevation across LW 101-106 ranges from 320 m in the south-west corner to 270 m in the east. This area drains in an east to north-easterly direction (Pine Creek and Pine Creek Tributary 1). A small portion in the south-east corner drains to Kurrajong Creek.

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 3º, with two low parallel ridges oriented northeast to southwest across the Mine Site.

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

4.3 Soils

The broad geological formation underlying LW 101-103 are the Garrawilla Volcanics (western portion) and the Purlawaugh Formation. The Purlawaugh Formation dominates LW 104 and LW105, with a small portion of Pilliga Sandstone in the northern and southern extent of the western boundary of LW 105. Pilliga Sandstone extends out past LW 106, as does the Purlawaugh Formation (R.W. Corkery & Co. 2009) (Figure 3).

Across the area proposed for underground workings, 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 drainage lines and floodplains of the Garrawilla Volcanics and Purlawaugh Formation. Soil conservation works, such as contour banks and waterway systems indicate that soil erosion has been an issue in the past (GCNRC 2009).

During the EA development, a range of soil attributes associated with land degradation following subsidence after longwall mining were examined (Table 4). These attributes were generally associated with soil erodibility and dispersibility.

Typical soil attributes associated with the geological formations and landform units about LW 101-106 identified in the EA are provided in Table 5 (R.W. Corkery & Co. 2009, GCNRC 2009). More detailed information from each of the soil pits references is provided in Appendix A.

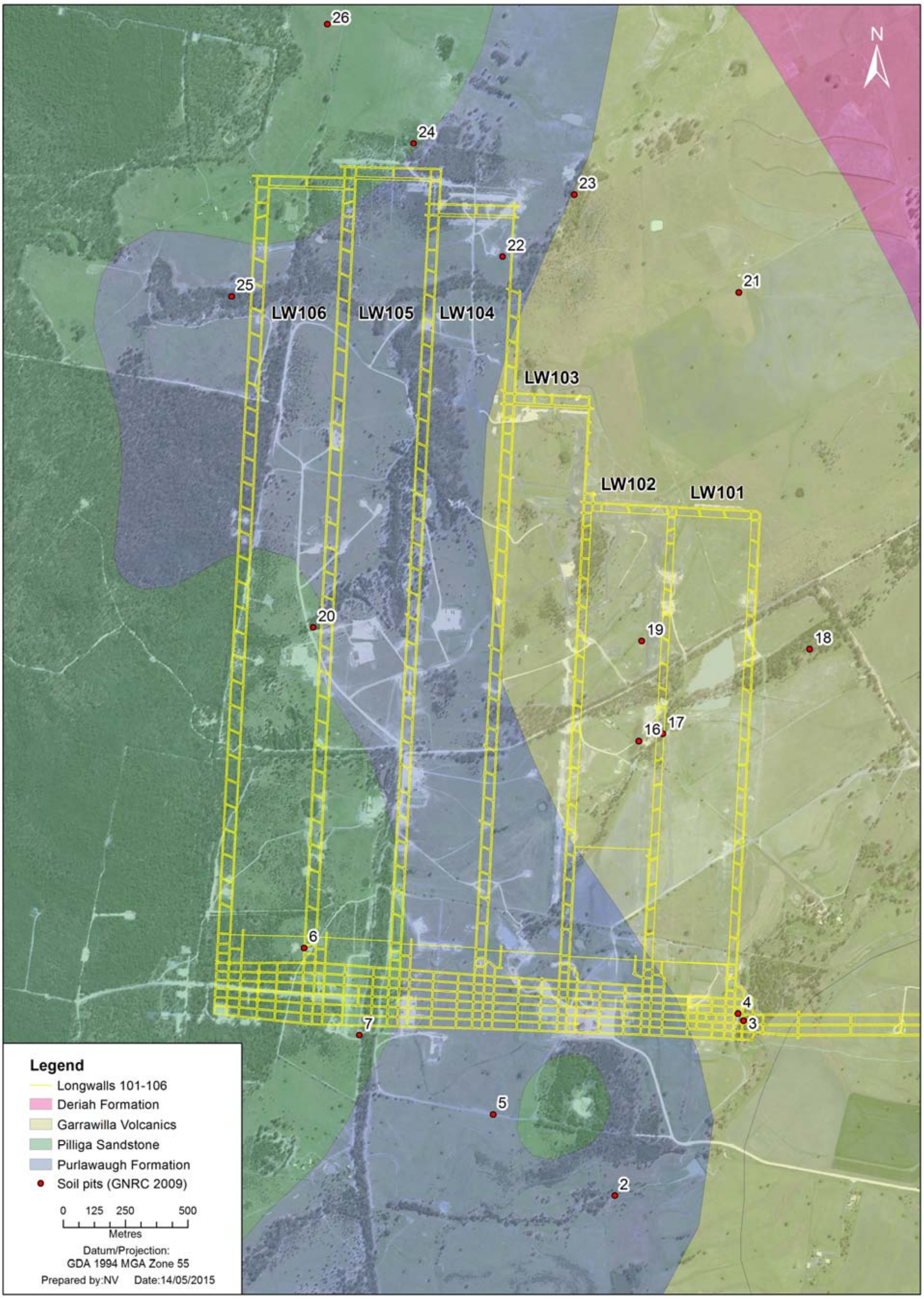


Figure 3: Geological formations underlying LW 101-106

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

Soil attribute	Surface geology								
	Garrawilla volcanics			Purlawaugh formation				Pilliga sandstone	
Soil Depth	Generally quite deep profiles on slopes, floodplains and in drainage lines; more likely to be shallower on upper slopes and crests **Not limiting**			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	Floodplain	Crests	Drainage lines	Floodplains	Slopes	Upper slopes	Upper slopes	Mid slopes
Topsoil	0-0.30 m	0~0.40 m	0~0.25 m	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	0.30-2.5 m	0.4-2.50 m	0.25-1.30 m	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	Usually finer textured (more clayey) **Not limiting**			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 usually absent, but noted on upper slopes; surface sometimes self-mulching; not hydrophobic **Not limiting**			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 **Not limiting**			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	Some limitations where subsidence results in slope increases **Low to moderate limitations**			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		
	Garrawilla volcanics	Purlawaugh formation	Pilliga sandstone
Topsoil Dispersibility	Topsoils generally not or only slightly dispersible **Not limiting**	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	Variable but often moderate to high **Limitation in vicinity of subsidence cracks**	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	Salinity not recorded **Not limiting**	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	Garrawilla volcanics		
Landform	Drainage line (18)*	Floodplain (3, 4, 15)	Upper slopes (21)
Surface condition	Firm, surface stone absent	Loose to firm, surface stone absent or sometimes medium amounts (angular) to 15 cm	Loose or self mulching, some angular surface gravel and stone (1-15 cm) in upper layers
Topsoil	Up to 30 cm Medium to heavy clay pH 6.5 Well structured Slightly dispersible (D% and EAT)** Non-saline	Up to 46 cm Light sandy clay loam to sandy clay loam pH 5.5-6.0 Well structured Slightly dispersible (D% & EAT) Non-saline	Up to 36 cm Medium to heavy clay or heavy clay pH 6.0-9.0 Well structured Slightly dispersible (D%) Not or slightly dispersible (EAT) Non-saline
Subsoil	3 horizons (to 250 cm) Medium clay or medium to heavy clay pH 8.0-9.0 Well structured Very high dispersibility (D%) High or high to moderate dispersibility (EAT) Non-saline	3 horizons (to 250 cm) Light to medium clay to heavy clay pH 6.0-7.5 (sometimes 8.0-9.0 at depth) Well structured Slight to moderate dispersibility (D%) Slight to very high dispersibility (EAT) Non-saline	Up to 4 horizons (to 250 cm) Light to medium clay to heavy clay pH 7.0-9.0 Well structured Slight dispersibility (D%) Not or slightly dispersible (EAT) Non-saline

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

The following guides were used to interpret and classify results of dispersion percentage and Emerson Aggregate Tests (EAT) (Table 6 and Table 7).

Table 6: Classification of dispersion percentage values and dispersibility

D%	Dispersibility
< 6	Negligible
6 – 30	Slight
30 – 50	Moderate
50 - 65	High
> 65	Very high

Source: Hazelton & Murphy (2007)

Table 7: Classification of Emerson Aggregate Classes and dispersibility

Eat	Dispersibility
4, 6, 7, 8	Negligible / aggregated
$3^{(2)}$, $3^{(1)}$, 5	Slight
$3^{(4)}$, $3^{(3)}$	Moderate
$2^{(1)}$	High to moderate
$2^{(2)}$	High
1, $2^{(3)}$	Very high

Source: Hazelton & Murphy (2007)

It is also noted that the tunnelling susceptibility of a soil is determined primarily by the dispersion percentage. A dispersion percentage value that exceeds 30% has a moderate or greater risk of tunnelling failure (Hazelton & Murphy 2007).

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 LW 101-106 is largely classified as Class III land; drainage lines are mapped as Class IV (Figure 4). There is a small area of Class VII in the very west and south-west portion of LW 106 (Table 8) which is an area of woodland vegetation.

Table 8: 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

The ML area has also been classified according to its agricultural suitability (Cunningham 2009). Most of the mine site can be classified as Class 3 with some minor areas of Classes 2 and 5 (R.W. Corkery & Co. 2009) (Table 9).

Table 9: 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

5.3 Agricultural production areas

Baseline agricultural monitoring was undertaken on agricultural land management areas, assessing attributes that relate to pasture productivity and soil nutrient status.

Baseline data were collected for attributes that relate to pasture productivity and soil nutrient status (ELA 2012b). Field survey included:

- Pasture biomass (kg green dry matter/ha)
- Pasture species composition
- Weed cover (%)
- Weed species composition
- Soil character (pH, EC, organic matter, nitrogen and phosphorus).

In addition to field surveys baseline data collection will include remotely sensed data that will provide for quantitative comparison of key land surface condition parameters in agricultural production areas across time. The normalised difference vegetation index (NDVI) of agricultural production areas will be determined across the site using multi-spectral imagery (a surrogate of pasture biomass). An electromagnetic induction (EM) survey will also be undertaken to create a baseline soil conductivity map (ELA 2012b).

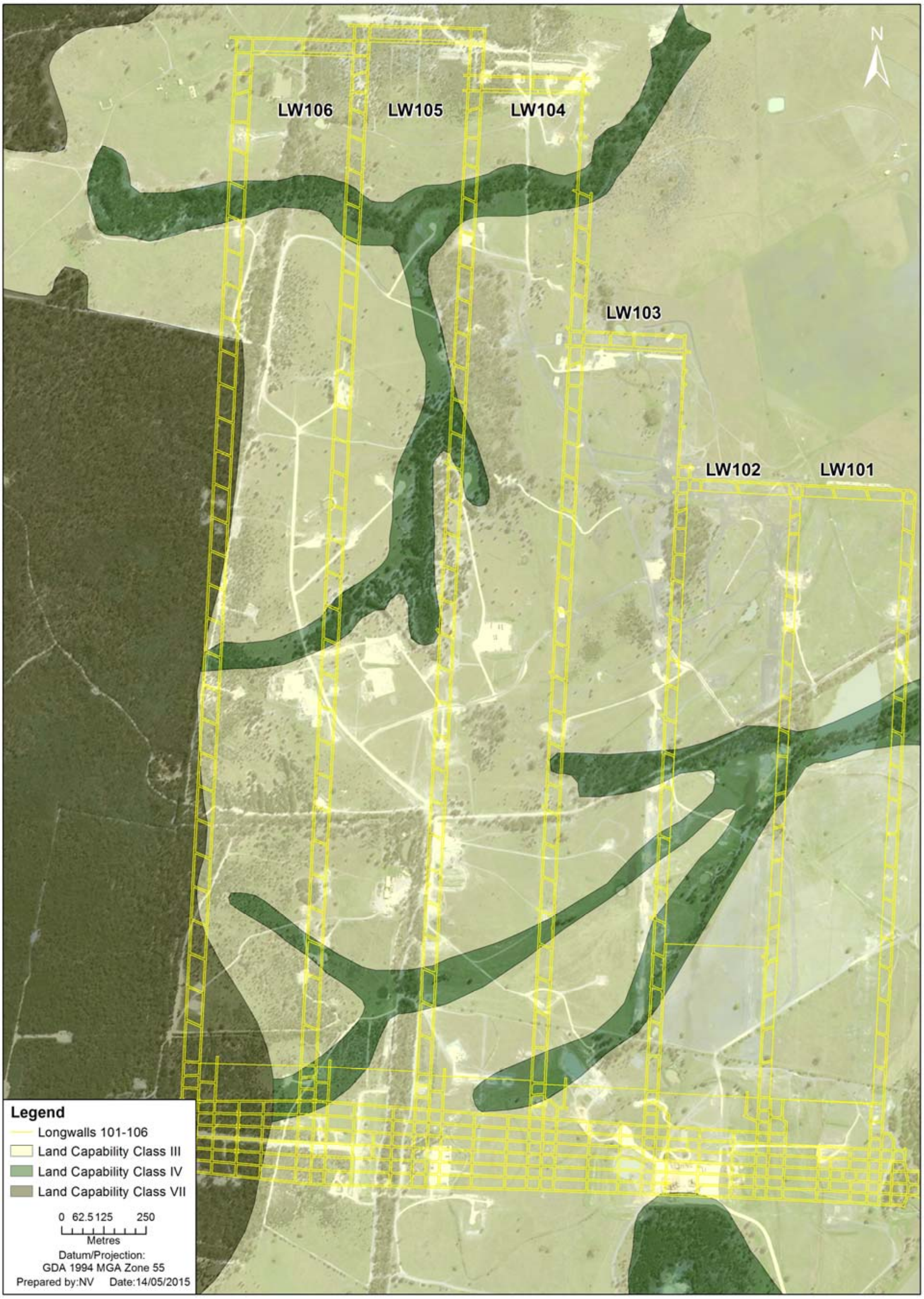


Figure 4: Land capability classification above LW 101-106

6 Surface water

6.1 Drainage

The Mine Site is located within the Tulla Mullen Sub-catchment of the Namoi River Catchment. The Namoi River is located some 3-5 km to the east of the eastern boundary of the ML. Tributary catchments in which LW 101-106 are directly located include Pine Creek (and Pine Creek Tributary 1) (Figure 6) and Kurrajong Creek in the south-east corner of LW 101. The Mine Site is generally drained in a north-easterly direction. The tributaries of Pine Creek and Kurrajong Creek are ephemeral with insignificant base flows and flow 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 sections and sandy alluvial deposits (up to 15 m deep) occur along the creek channels (R.W. Corkery & Co. 2009). Isolated sections of exposed bedrock along both Pine Creek and Pine Creek Tributary 1 were noted during field work in August 2011.

The reaches of Pine Creek and Pine Creek Tributary 1 within LW 101-106 range from first order water courses to third order under the Strahler stream ordering system (Figure 5) (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. Significant channel erosion is evident at points on Pine Creek Tributary 1. Bed material generally is the same as the surrounding soils (within the same horizon) with some sand deposits (WRM 2009). A large basalt outcrop has been exposed on the bed of a small gully draining into Pine Creek over LW105.

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 Water Management Plan for LW 101-106.

There are a number of farm dams located on the ML with storage capacities ranging from 0.5 ML to 22.5 ML with a combined storage capacity of 121.2ML (WRM 2009). 17 farm dams are located above LW 101-106 (DGS 2015).

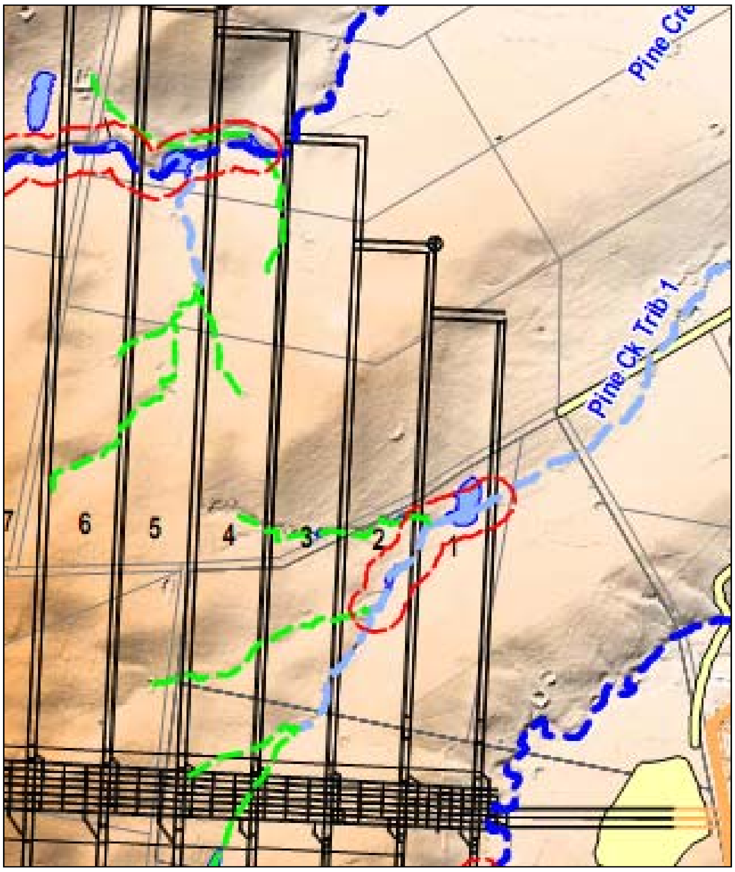


Figure 5: Strahler stream order

Source: WRM 2009

6.2 Weeds

Baseline surveys noted a high variability in vegetation condition throughout the overall longwall impact area. The land above LW 101-106 has been cleared for grazing and has a number of small patches of remnant vegetation. It is therefore assumed that the weeds identified for the purposes of the ecological assessment are highly likely to occur over this area (Ecotone Ecological Consultants 2009). This was confirmed during the site reconnaissance undertaken by ELA in August 2011 and April 2015, with a number of noxious weed species being recorded within the remnant vegetation above LW 101-106.

Three of the eight noxious weed species declared within Narrabri Shire Council control area that were identified in the ecological assessment undertaken by Ecotone Ecological Consultants (2009) were identified during the site reconnaissance of LW 101-106 including:

- *Lycium ferocissimum* (African boxthorn) – Class 4
- *Xanthium spinosum* (Bathurst burr) – Class 4
- *Opuntia stricta* (Prickly pear) – Class 4.

Most of the noxious weeds identified on the longwall impact area had a trace presence or were present in high numbers in very restricted areas. Common or established environmental weeds were also identified within the longwall impact area (Ecotone Ecological Consultants 2009). Class 4 weeds are

‘Locally Controlled Weeds’ and therefore must be controlled according to measures specified in a management plan published by the local control authority (Narrabri Shire Council).

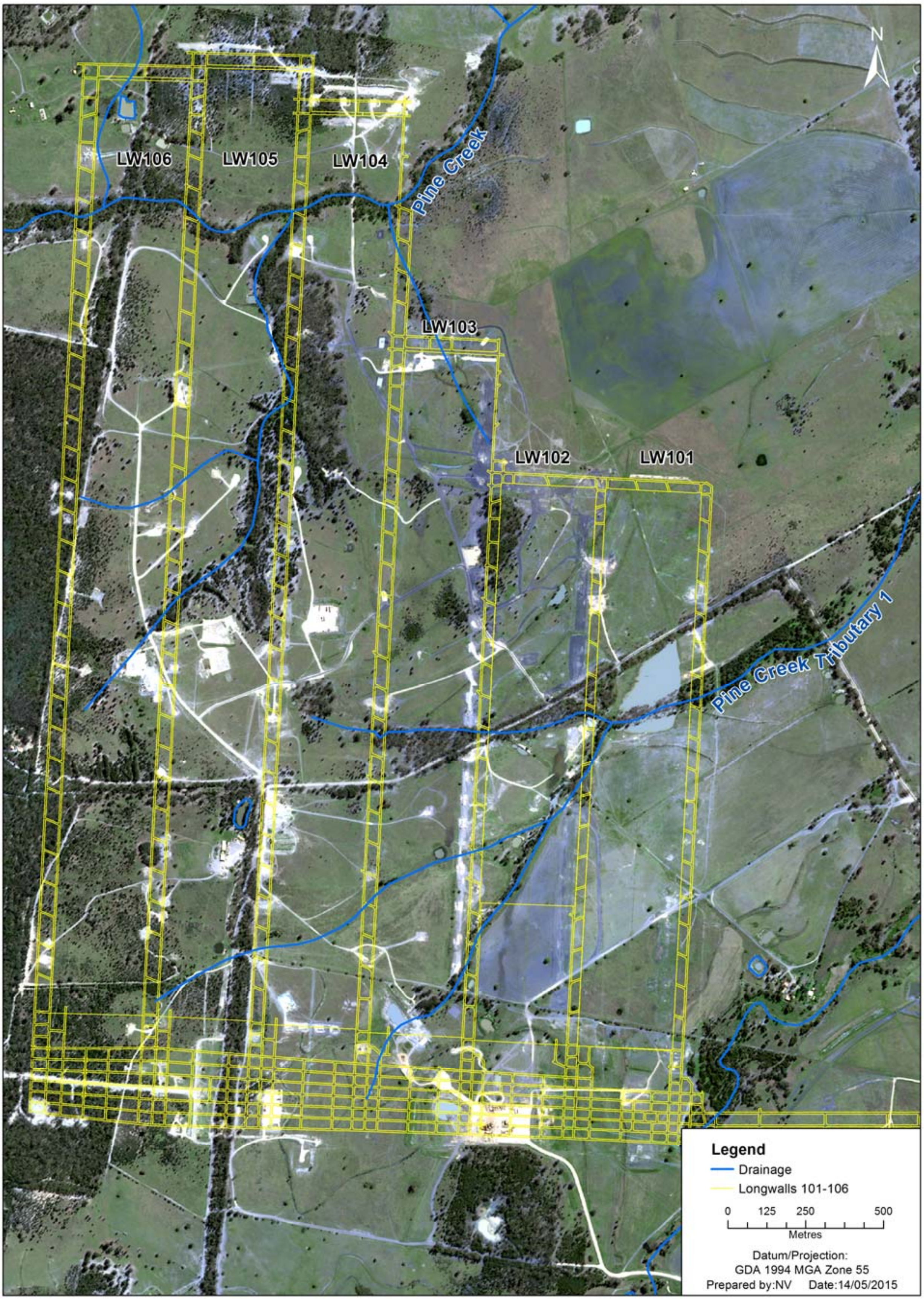


Figure 6: Drainage lines above LW 101-106

7 Assessment of Potential Environmental Consequences

A detailed Mine Subsidence Effect Prediction and Impact Assessment was prepared for the proposed LW 101-106 by Ditton Geotechnical Services Pty Ltd (DGS 2015) for incorporation into the EP. This study was undertaken to update the subsidence predictions and assessment of the impacts relating to the predicted subsidence over LW 101-106. 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 LW 101-106 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 Longwall 101 to 106 Layout

LW 101-106 lies immediately to the west of the Pit Top Area (Figure 2). The land surface is primarily used for livestock grazing with some cereal crop farming and remnant vegetation stands (predominantly along creek lines).

LW 101-106 will be mined at depths ranging from approximately 160 m to 250 m below the surface and each longwall panel will be 306.4 m wide. A row of chain pillars will be formed between each longwall panel, each pillar will be 3.5 m high and 97.25 m long (solid) with 5.4 m nominal roadway widths. Pillar widths are nominally:

- 30 m between LW 101-103
- 35 m between LW 103-105
- 39.5 m between LW 105-106 (DGS 2015).

Panel width to depth ratio will range from 1.23 to 1.92, indicating both critical and subcritical subsidence behaviour. The chain pillars are expected to have width to depth ratios of 8.6 to 11.3 and will be expected to strain-harden slowly and not crush out suddenly. The main headings pillars will be 27 m to 36 m wide and 30 m to 96 m long (DGS 2015).

7.2 Overall predicted subsidence

The predicted subsidence effects of secondary extraction (longwall mining) of LW 101-106 have been determined (DGS 2015). The predictions take into account the following factors:

- SRP of the overburden and the influence of the overburden and the influence of 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 2015).

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 10) (DGS 2015).

Table 10: Predicted mean and credible worst-case results for all of the cross-lines (DGS 2015)

<table>
<tr><th rowspan="2">Predicted subsidence</th><th colspan="2">Without spanning volcanics</th></tr>
<tr><th>Lower limit</th><th>Upper limit</th></tr>
<tr><td>First maximum panel subsidence after mining of LW 101-106</td><td>2.39 m</td><td>2.75 m</td></tr>
<tr><td>Final maximum panel subsidence after mining of LW 101-106</td><td>2.57 m</td><td>2.75 m</td></tr>
<tr><td>First maximum chain pillar subsidence after mining of LW 101-106</td><td>0.18 m</td><td>0.48 m</td></tr>
<tr><td>Final maximum chain pillar subsidence after mining of LW 101-106</td><td>0.21 m</td><td>0.54 m</td></tr>
<tr><td rowspan="2">Final maximum panel concave curvature after mining of LW 101-106</td><td>0.6/km</td><td>3.3/km</td></tr>
<tr><td colspan="2">Radii of curvature 1.66 km - 0.3 km</td></tr>
<tr><td rowspan="2">Final maximum panel concave curvature after mining of LW 101-106</td><td>0.40/km</td><td>2.6/km</td></tr>
<tr><td colspan="2">Radii of curvature 2.5 km - 0.38 km</td></tr>
<tr><td>Final maximum panel compressive strains after mining LW 101-106 (smooth profile behavior)</td><td>6 mm/m</td><td>13 mm/m</td></tr>
<tr><td>Final maximum panel compressive strains after mining LW 101-106 (discontinuous movements)</td><td>14 mm/m</td><td>33 mm/m</td></tr>
<tr><td>Final maximum panel tensile strains after mining LW 101-106 (smooth profile behavior)</td><td>4.0 mm/m</td><td>10.0 mm/m</td></tr>
<tr><td>Final maximum panel tensile strains after mining LW 101-106 (discontinuous movements)</td><td>11 mm/m</td><td>26 mm/m</td></tr>
</table>

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 12.8º to 24.6º for the proposed LW 101-106 and predicted goaf edge subsidence range of 0.08 to 0.31 mm (DGS 2015).

7.3 Predicted subsidence effects & impacts

The overall predicted subsidence effects and impacts upon land in general above LW 101-106 are summarised below.

Land in general refers to the general landscape and features and excludes built features and surface features which are addressed in other management plans and programs included in the EP.

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.

7.4 Surface cracking

Surface cracking widths of 40 mm to 260 mm are predicted based on the predicted range of maximum transverse and tensile and compressive strains for cover depths of 160 m to 260 m. Measured surface cracks above LW 101-104 have ranged from 50 to 100 mm wide, with some cracking of up to 200 mm. The largest cracks are predicted to occur over LW 101-104, with cracking over LW 106 expected to range between 40 to 110 mm (DGS 2015).

If there are adverse topographic or geological conditions, these crack widths may be exceeded by 5 % of incidences, this is unlikely to occur over the majority of LW 101-106. However, it may occur near steep creek banks along Pine Creek and its tributaries (DGS 2015).

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 a mine 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 2015).

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 2015).

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 2015).

7.5 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 Geometry 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 LW 101-106 (DGS 2015).

The Geometry Pi-Term Model predicts that discontinuous fracturing could interact with surface cracks where cover depths are <255 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 2015).

7.6 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 <10º 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 2015).

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 2015).

7.7 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 2015).

The occurrence of upsidence and closure along the creek beds above LW 101-106 is likely to be minimal as the valleys across the NM mining lease are not underlain by thick massive beds of conglomerate and/or sandstone and they are broad between crests (DGS 2015).

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 2015).

Ponding may develop above several of the longwalls and creeks in the flatter eastern areas at maximum depths of 0.25 to 2.1m after LW 101-106 are completed. It is expected that 18.4 ha in total with a combined volume of 122 ML will be affected by ponding (Table 11) (DGS 2015). 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 11: Potential worst-case ponding assessment for LW 101-106

Location	Longwall	Max depth h (m)	Pond area dimensions bxl (m)	Ponded area increase after mining# (m^2)	Ponded volume increase after mining# (ml)
Pine Creek	103	0.7	63 x 95	5463	1.92
	104	2.0	125 x 223	25862	25.8
	105	2.1	14 x 226	25214	26.47
	106	1.4	63 x 145	8996	6.3
Pine Creek Tributary 1	101	1.3	185 x 321	51567	33.52
	102	1.3	80 x 530	36695	23.85
	103	0.3	75 x 138	8388	1.258
	103	*1.9*	*75 x 183*	*12789*	*1.918*
	104	*0.3*	*27 x 120*	*4461*	*0.67*
	104	*0.25*	*53 x 81*	*4926*	*0.616*

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

Source: DGS 2015

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).

7.8 Potential environmental consequences on land in general

The predicted effects and impacts of surface subsidence may then trigger a number of environmental consequences that are related to land in general. These consequences and associated hazards are summarised in Table 12.

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.

In addition to these consequences there is potential to increase weed species numbers and cover through changes to site management and water movement. Short-term loss of riparian vegetation may also occur.

Other potential environmental consequences of surface cracking, including ‘trapping’ of ground dwelling fauna, risks to public safety and damage to infrastructure, are the subject of other management plans that form part of the EP.

Table 12: 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 (Pine Creek, Pine Creek Tributary 1 and Kurrajong Creek Tributary 1)
	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 drainage lines Altered drainage / erosion patterns, altered soil moisture and/or nutrient distribution patterns reducing vegetation condition

Subsidence impact	Subsidence consequence	Potential environmental hazard (to land in general)	Ecological/agricultural response (to land in general)
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, road users 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

The Project Approval requires NCOPL to manage the potential impacts and environmental consequences of the proposed second workings on land in general. Performance measures for the management of land that are relevant to the environmental consequences of subsidence impacts are listed in Table 13.

The overall performance measure for land in general 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 13: Performance measures and indicators for land management (LW 101-106)

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 each longwall pass
	Topographic form (LiDAR):	
	• Landscape morphology	Subsidence across landscape does not exceed subsidence predictions for LW 101-106
	• Creek lines	No identifiable change to overall drainage pattern
	Soil moisture and nutrient distribution (EM mapping)	Identified areas of EM mapping 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.
	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.
	Pasture:	
	• Pasture biomass	Less than 20% reduction in pasture biomass in impact zones in comparison to control zones.
	• Weed species	Weed species identified and managed according to the weed management measures provided in the Rehabilitation MP.
	• Weed cover	Less than 10% increase in weed cover in impact zones in

Objective	Performance measures	Performance criteria
		comparison to the control zone.
	Soil nutrient status:	
	• pH	pH remains within +/- 0.5 pH unit of baseline pH. If soil amelioration is undertaken, pH is to remain within recommended pH range for pasture (5.2-8.0).
	• EC	Less than 20% increase in EC in comparison to baseline values.
	• Organic matter	Less than 20% reduction in organic matter in comparison to baseline values.
	• Nitrogen	Less than 20% reduction in total nitrogen in comparison to baseline values.
	• Phosphorus	Less than 20% reduction in phosphorus in comparison to baseline values.
	Field survey of creek stability and condition	Less than 20% increase in creek erosion (bank and bed) in comparison to control Less than 20% increase in cross sectional area in comparison to control cross sectional area (unless stabilisation works have been undertaken)

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 14) has been developed to monitor the consequences of longwall mining on land in general above LW 101-106.

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, multi-spectral imaging and EM38) is proposed to monitor the entire target area including control areas followed by targeted field work to examine the causes of any change highlighted.

Where the monitoring schedule refers to the collection of baseline data, the reader is referred to the Narrabri Coal Mine LW 101 – 103 Baseline Monitoring Reports for Biodiversity and Land Management (ELA 2012a and ELA 2012b).

Table 14: Multi-scale monitoring program

Data source	Type	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
	EM38	Agricultural areas	Soil moisture and nutrient zones
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
Agricultural survey	Pasture survey	Within agricultural zones (soil type, paddock)	Pasture biomass and composition

Data source	Type	Scale	Purpose
	Soil Survey	Within agricultural zones (soil type, paddock)	Soil nutrient status
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 Surface cracking

Surface cracking is likely to occur rapidly (see Section 7.3) causing risk of erosion, creation of nick points and headcut initiation, consequences to flora and fauna as well as potentially hazardous occupational health and safety risks.

Monitoring of surface cracking will be undertaken during and post-mining. Visual inspections for surface cracking of areas immediately behind the longwall face passage should take place on a weekly basis to monitor for active subsidence (Table 15).

The location of surface cracking should be recorded using dGPS and the width, depth and length of cracks recorded. Cracks are considered permanent if they have not closed within one month of the longwall face passing and appropriate management measures undertaken (Section 8.1).

Opportunistic observations of any subsidence impacts (including surface cracking, ponding, landslips and erosion) noted by NCOPL employees and tenants during other routine monitoring and operations will be required to be reported to the Environment Officer.

Table 15: Surface cracking 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 rainfall events > 10mm until cracking disappears and then repeat inspection after a 12 month period Following rainfall events > 10mm
		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 rainfall events > 10mm

9.2 Remote sensing

It is proposed to use remote sensing data (LiDAR, multi-spectral imaging and EM38) to monitor the entire target area including control areas. The remotely sensed data will provide data that provide for quantitative comparison of key land surface condition parameters in agricultural and creek line environments. Repeat capture and analysis of the multi-spectral imagery will also highlight areas of changes in land cover beyond those found in control areas. Targeted field work will be implemented to examine the causes of any change highlighted.

The target area for this monitoring plan is the surface environment above and surrounding LW 101-106 within the predicted impact zone. Both modelled and empirical studies indicate that subsidence at the site will create a series of surface troughs on the landscape (MSEC 2007, DGS 2011). For impact monitoring it is considered that the surface zones (Table 16) can be classified as:

- Longwall - the zone of maximum subsidence
- Transition - the zone of maximum stress and tilt
- Pillar - the zone above the pillar with minimal subsidence.

Control sites will be selected from control zones (zones of no impact located outside of any predicted subsidence zone) with similar characteristics and biological condition that lie beyond the predicted impact zone.

Figure 7 shows the current mine plan superimposed by subsidence contours based on predictions by DGS (2015). 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 (2015), have been reduced. The management and monitoring identified under this plan are based on the current mine plan and reduced extent of subsidence.

Table 16: 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	

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.

Whole of site monitoring will be conducted using LiDAR, multi-spectral and EM38 data sources (Table 17).

9.3 LiDAR processing and analysis

LiDAR data will be captured across the entire target area and 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.

9.4 Multi-spectral image processing and analysis

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 impact 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.

9.5 EM38 survey

EM38 survey is widely used in the agricultural industry to assist with soil mapping. EM38 provides information of variability in surface soil conductivity which relates strongly to soil moisture, soil ion and soil texture variations.

The EM38 data will be processed into a soil conductivity map. The initial data capture will be stratified into the 4 impact zones (Longwall, Transition, Pillar, Control) and compared using ANOVA to determine if data in any of the zones is significantly different from each other.

Subsequent EM38 will be processed into conductivity maps and each dataset will be subtracted from those produced from earlier captures creating a series of change images. Both the newly created map and the change image will be stratified into the 4 impact zones and analysed using ANOVA.

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

Table 17: 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
	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
EM38* survey	Soil electrical conductivity	Comparative statistics Visual assessment	Document baseline variability in surface soil conductivity, relates to water, ions and texture Document changes in soil surface conductivity	Baseline Repeat every 3-5 years *Best results achieved after saturating rainfall

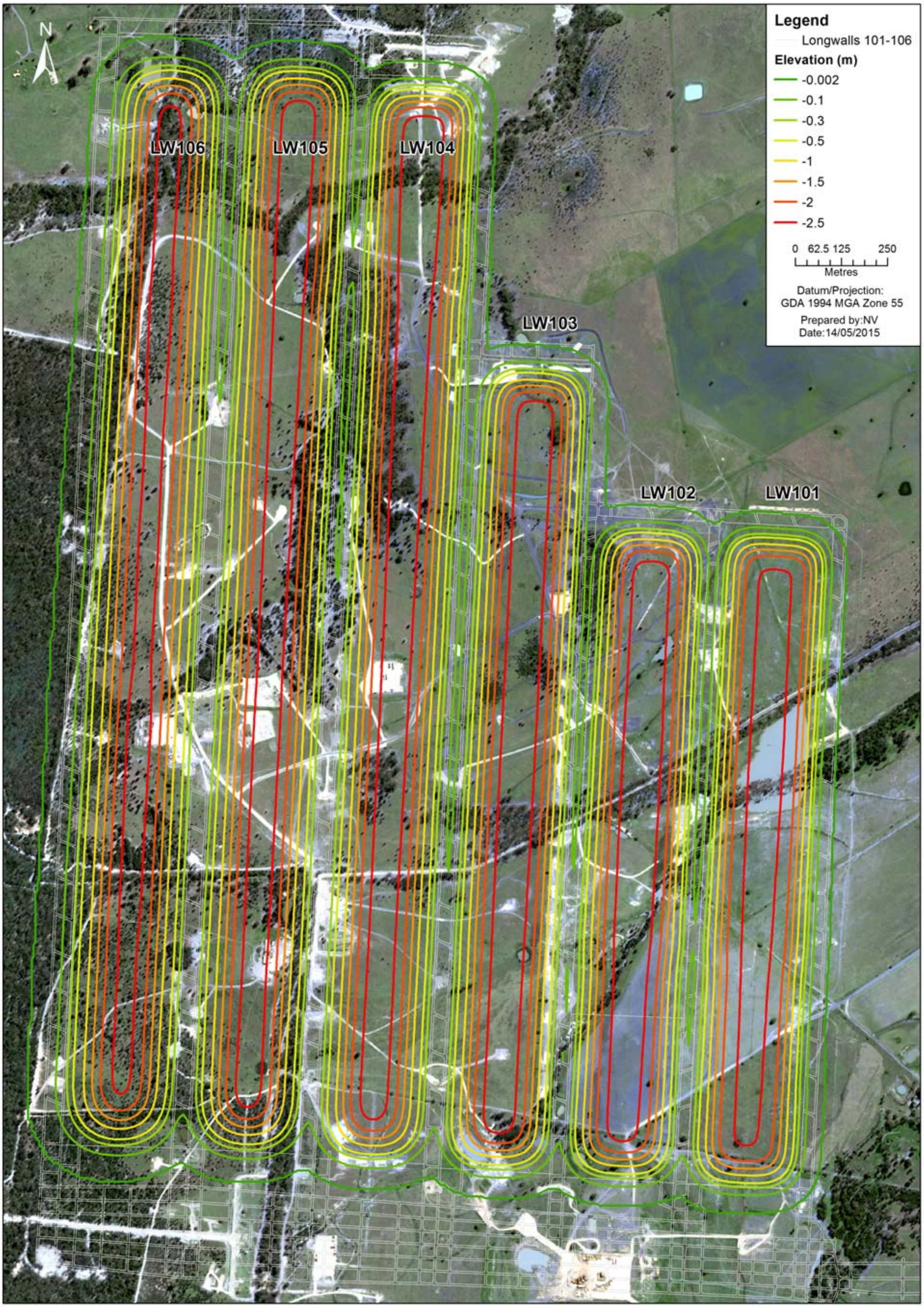


Figure 7: Predicted subsidence LW 101-106

9.6 Agricultural area surveys

Agricultural monitoring will focus on the agricultural land management areas, assessing attributes that relate to pasture productivity and soil nutrient status. The area will be stratified into each of the 4 impact zones overlying each individual management unit (i.e. paddocks and underlying geology - Purlawaugh Formation and Garrawilla Volcanics). It is important to keep variability from existing soil types and management as controlled as possible to reduce the influence of non-mining related activities on sample variability.

Within each zone a minimum of 8 sample locations will be selected using a random design. At each site a 1 m by 1 m quadrat will be placed and assessed for pasture biomass and composition. Following pasture survey a soil sample to 150 mm will be taken from the centre of each quadrat location. The soil sample will be bagged, stored appropriately for laboratory analysis of pH, EC, N, P and organic matter (Table 18).

Incidental observations of weeds and erosion should also be recorded during these surveys and the necessary management procedures undertaken (see Section 10).

Table 18: Agricultural monitoring program

Data source	Parameters	Analysis	Purpose	Sampling frequency
Pasture biomass cuts (1 m x 1m quadrat)	Pasture biomass	Comparative statistics	Give baseline variability in pasture biomass BACI comparisons	Baseline Every year – early spring
Pasture composition (1 m x 1m quadrat)	Pasture species	Descriptive statistics Species list	Establish baseline pasture composition BACI comparisons	Baseline Every year – early spring
Weed survey (1 m x 1m quadrat)	Weed species and cover	Descriptive statistics Species list	Establish baseline weed species and % cover BACI comparisons	Baseline Every year – early spring
Soil character (top 150 mm from centre of quadrat)	pH, EC, Organic matter, N, P	Comparative statistics	Give baseline variability in key soil parameters BACI comparisons	Baseline Every 3 years

9.7 Geomorphic (creek line) surveys

Change in the channel form of the creek lines that flow across the target area has been identified as a key potential impact of LWMS. In addition the creek banks and bed have already been noted as being in relatively poor condition with active erosion and sedimentation occurring currently. 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 19). 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 LW 101-106 are mining-induced by comparing for example, changes to channel area and bed slope, erosion of channel banks and bed or sediment deposition.

Permanent survey 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 one which results in continuous overbank surface flow at surface water monitoring locations PC and PC1.

In addition to specific surveys to understand the geomorphic change in creek lines the subsidence monitoring program includes longitudinal survey along both Pine Creek and Pine Creek Tributary 1 to document total subsidence along the entire reach.

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

Table 19: 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 survey markers for on-going monitoring	Baseline At least annual, in late winter/spring or following a significant run-off event

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 20. 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 20: 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 sub-soil 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. • Grout or other suitable self-cementing materials which do not require compaction can also be used in agricultural areas • Install deep sub-surface drainage trenches and construct catch drains along slope crests to control surface run-off around significant areas of cracking, if required • 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 such as installation of deep sub-surface drainage trenches or construction of strategic catch drains along slope crests – 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	Implement suitable erosion and sediment control measures identified in the Erosion and Sediment Control Plan for the Longwall Project and the EP, such as:

Trigger	Management
subsidence identified	• 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 8).

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 21). The second tier of response is triggered if changes are confirmed or discovered on-ground (Table 22). These triggers instigate the development of site specific management responses and remedial actions.

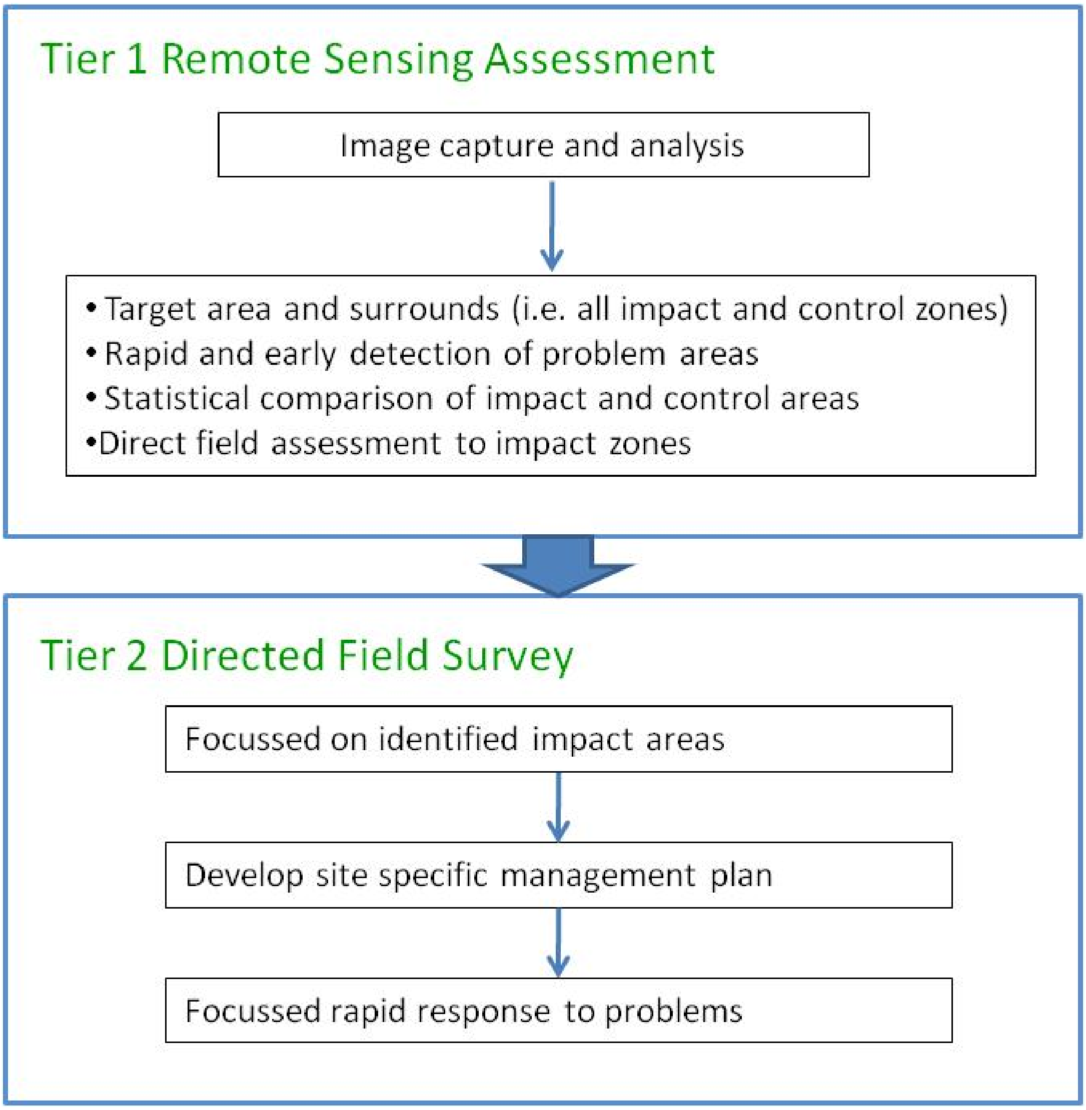


Figure 8: Two-tiered remote sensing monitoring and management approach

Table 21: Remote sensing monitoring triggers 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 (Table 22) 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 22)

Table 22: Rapid field checking protocol and management

Parameter	Method	Management
Weed invasion	Document key weed species, estimate of % of weed cover in defined impact area Determine if invasive environmental or declared weed Enter location and extent of infestation (within limits of inspection) into GIS database	Weed management will be implemented to limit the spread and colonisation of noxious and environmental weeds. Weed management should be in line with the Narrabri Coal Rehabilitation Management Plan and be targeted at noxious weeds initially. All noxious weeds currently recorded are Category 4 noxious weeds, which must be controlled by the landowner according to the measures specified in a management plan published by the local control authority (NSC). Noxious weed management plans have been produced by the NSC for all noxious weed species. Follow-up inspections to assess the effectiveness of the weed management measures implemented and the requirement for any additional management measures.
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 (GPS) and refer to Table 20

10.3 Agricultural areas

The agricultural monitoring program has been designed to provide quantitative data on key pasture and soil attributes as they relate to land agricultural capability. Statistical analysis is proposed to identify significant changes in any of these parameters which will trigger management actions (Table 23).

Table 23: Agricultural areas monitoring triggers for management

Trigger	Management
Statistically significant change detected between impact and control sites in either: • pasture biomass • pasture species composition • weed cover • soil character (pH, EC, OM, N or P)	Verify with infield assessment and determine appropriate response, including sowing of appropriate pasture species

10.4 Creek lines

Creek line surveys have been designed to provide quantitative information to document changes in channel cross-section, bed erosion and deposition. Management measures (Table 24) 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 24: 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 Where ponding alters flow path of 2^{nd} or 3^{rd} order streams and there is a visible impact on riparian vegetation, advice will be sought from a qualified geomorphologist so that the most effective way of re-establishing more natural flow patterns is identified (NCOPL 2011). Remedial measures would be determined based on the extent and degree of impacts but should aim to provide long-term stability of creek channel and banks

10.5 Reporting and review

Reporting of all monitoring results and comparative analysis should take place annually in summer following the spring survey and subsequent analysis.

Review of the entire program should be undertaken after the initial survey and every 3 years to examine the trends in the data, investigation sampling effort in terms or redundancy or shortfall and to incorporate new monitoring technologies or techniques if appropriate.

The review should include consultation with key government agencies to ensure continued acceptance of the methodology and results.

11 Contingency Response

The ongoing monitoring outlined in this LMP aims to identify the consequences of longwall mining on land in general above LW 101-106. 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 20-24.

In the event the subsidence effects and consequences on land in general exceed those predicted in the EA and/or the performance indicators nominated in this LMP (Section 8) are exceeded (or are considered likely to be exceeded based on observed trends), Narrabri Mine will implement the contingency responses nominated in the EP and the Trigger Action Response Plan (TARP) below. Contingency measures as identified in other plans including the Subsidence Monitoring Program shall also be adhered to.

Table 25: 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 rainfall events > 10 mm 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	Surface cracks have not self-repaired within one month of the longwall face passing Erosion as a result of surface cracking and subsidence identified (i.e. nick points) Surface cracking prevents functioning of contour banks Persistent cracking identified (even after remediation)	Rip surface cracks within agricultural areas. Grout or other suitable self-cementing materials can also be used in agricultural areas For remnant vegetated areas and for larger cracks for which surface ripping will not completely fill, fill crack with suitable sub-soil material (sourced from nearby stockpiles for from within the footprint of the Reject Emplacement Area) Temporary fencing is to be maintained until all remediation works have been completed. Implement appropriate erosion and sediment control measures as nominated in the Erosion and Sediment Control Plan.	NCOPL Environmental Officer

Aspect	Monitoring		Response		
	Methodology	Purpose	Trigger	Action	Responsibility
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 **Analysis:** Comparison to baseline DEM **Frequency:** Every 3 years	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 To identify changes creek line drainage path/s and creek line slope and volumes	If subsidence detected from DEM exceeds the predicted / modelled subsidence. Deviation of drainage from baseline mapped drainage path. An increase of more than 20% in the length of eroding creek banks	The General Manager will be informed and the necessary reporting to authorities undertaken. The Subsidence MP and overall EP should be referred to. Gemorphologist (or other appropriately qualified and experienced specialist) should be engaged to undertake a review of DEM and site investigation to assess the identified changes and provide recommendations and actions (which may include re-establishing drainage path ways with earthworks or the do nothing approach), with consideration given to the predicted subsidence model and LW progression. Agencies will be informed before any in-stream works are undertaken Undertake physical inspection of the affected creek length to verify changes and determine appropriate erosion control works. Agencies will be informed before any in-stream works are undertaken	NCOPL Environmental Officer

Aspect	Monitoring		Response		
	Methodology	Purpose	Trigger	Action	Responsibility
Soil moisture and nutrient distribution (EM38 survey)	**Sites:** Affected longwall panels and control zones outside of subsidence impact zone **Parameters:** Soil electrical conductivity (EC_a) derived from EM38 survey **Analysis:** Comparison to baseline soil surface conductivity mapping **Frequency:** Every 3-5 years (best results achieved after saturating rainfall)	To document baseline variability in surface soil conductivity (surrogate for below ground water, ion and texture) To identify and document changes in soil surface conductivity	Areas of EM mapping change (greater than 1 standard deviation from the mean change) identified.	Areas of change investigated by a suitably qualified consultant to determine the source of the change. A site specific management report is to be prepared and recommendations implemented where necessary	NCOPL Environmental Officer

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	Remote sensing change detection identifies area of significant change (> +/- 1 std dev from average) in an area that exceeds 0.1ha.	Investigate source of change via desktop assessment if possible (e.g. fire etc). Corroborate statistical analysis with site specific rapid assessment to determine cause of change (for example, weed invasion, erosion, sedimentation, surface cracking) and appropriate management response (refer Table 22). If necessary a suitably qualified consultant should be engaged to prepare a site specific management report is to be prepared and recommendations implemented where necessary.	NCOPL Environmental Officer

Aspect	Monitoring		Response		
	Methodology	Purpose	Trigger	Action	Responsibility
Pasture biomass and composition	**Sites:** Affected longwall panels (and their respective surface zones include longwall, transition and pillar zones) and control zones outside of subsidence impact zone **Parameters:** Pasture biomass (kg green dry matter/ha) Pasture species composition Weeds species composition Weed cover **Analysis:** Comparison to baseline values for each parameter BACI comparisons Comparison against trends documented in control zones **Frequency:** Annually (spring)	To establish baseline variability in pasture biomass To establish baseline pasture composition, weed composition and weed cover To identify and quantity changes to baseline parameters	**Pasture biomass:** More than 20% reduction in pasture biomass in impact zones in comparison to control zones **Weeds species composition:** New weed species identified. **Weed cover:** More than 10% increase in weed cover in impact zones in comparison to the control zone.	Areas of change investigated by a suitably qualified consultant to determine the cause of the change. A site specific management report is to be prepared with recommended treatment measures implemented where necessary. Weed species are managed according to the weed management measures provided in the Rehabilitation MP.	NCOPL Environmental Officer

Aspect	Monitoring		Response		
	Methodology	Purpose	Trigger	Action	Responsibility
Soil nutrient status	**Sites:** Affected longwall panels (and their respective surface zones include longwall, transition and pillar zones) and control zones outside of subsidence impact zone **Parameters:** pH, EC, Organic matter, N, P **Analysis:** Comparison to baseline values BACI comparisons Comparison against trends documented in control zones **Frequency:** Every 3 years	To establish baseline variability in key soil parameters To identify and quantity changes to baseline parameters	**pH:** pH exceeds +/- 0.5 pH unit of baseline pH After soil amelioration, pH is outside of recommended pH range for pasture (5.2-8.0) **EC**: More than 20% increase in EC in comparison to baseline values **Organic carbon**: More than 20% reduction in organic matter in comparison to baseline values **N:** More than 20% reduction in total nitrogen in comparison to baseline values. **P (Colwell) :** More than 20% reduction in P (Colwell) in comparison to baseline values	Verify changes and extent of changes via field investigation (including further soil testing if required) and review of all available data including cropping/pasture history, fertiliser/soil ameliorant applications, climatic data. If necessary, a suitably qualified specialist shall be consulted to determine causes and/or contributing factors and appropriate remediation measures.	NCOPL Environmental Officer

Aspect	Monitoring		Response		
	Methodology	Purpose	Trigger	Action	Responsibility
Creek stability and condition	**Sites:** Representative reaches within affected LW panels and control reaches **Parameters:** Geomorphic characteristics **Analysis:** Geomorphic survey (field survey) **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)	To define geomorphic zones of drainage lines To establish the baseline status of each zone To document ongoing status of each zone	More than 20% increase in length of eroding creek line Identifiable change to overall drainage pattern	An investigation shall be undertaken by a suitably qualified geomorphologist to determine the extent of the impact, identify contributing factors and determine the most appropriate remediation measures. Remedial measures would be determined based on the extent and degree of impacts but should aim to provide long-term stability of creek channel and banks. It is noted that while creek systems are dynamic and natural morphological recovery occurs, active rehabilitation may need to be considered. The development and implementation of remediation measures along creek lines will be undertaken in consultation with and approval of relevant agencies. Contingency measures as identified in other plans including the Subsidence Monitoring Program shall also be adhered to.	NCOPL Environmental Officer

Aspect	Monitoring		Response		
	Methodology	Purpose	Trigger	Action	Responsibility
Creek bank and bed stability	**Sites:** Selected cross sections within representative reaches of LW panels and control reaches **Parameters:** Channel width, depth via cross sectional surveys **Analysis:** **C**omparison of cross sectional surveys to determine any change in cross section **Frequency:** Field survey to be undertaken 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	To document baseline creek slope, width and depth (impact areas and control reaches) To document and quantify changes in creek slope, width and depth (impact areas and control reaches)	More than 20% increase in creek erosion (bank and bed) in comparison to control More than 20% increase in cross sectional area in comparison to control cross sectional area (unless stabilisation works have been undertaken)	Where significant change to channel cross sections has been identified, relevant agencies will be notified. An investigation shall be undertaken by a suitably qualified geomorphologist to determine the extent of the impact, identify contributing factors and determine the most appropriate remediation measures. Remedial measures would be determined based on the extent and degree of impacts but should aim to provide long-term stability of creek channel and banks. It is noted that while creek systems are dynamic and natural morphological recovery occurs, active rehabilitation may need to be considered. The development and implementation of remediation measures along creek lines will be undertaken in consultation with and approval of relevant agencies. Contingency measures as identified in other plans including the Subsidence Monitoring Program shall also be adhered to.	NCOPL Environmental Officer

12 References

Cunningham G.M., Higginson F.R., Riddler A.H.M. & Emery K.A. (1988) Systems used to classify rural lands in New South Wales Department of Land and Water Conservation: http://www.environment.nsw.gov.au/resources/soils/systemsclassifylands.pdf.

DGS (2015) *Mine Subsidence Effect Predictions and Impact Assessment for the Proposed Addition of Longwall 106 to the Longwall 101 to 105 Extraction Plan at the Narrabri Coal Mine, Narrabri*. Prepared by Ditton Geotechnical Services, Charlestown.

DGS (2011) *Mine Subsidence Effect Predictions and Impact Assessment for the Proposed Longwalls 1 to 5 at the Narrabri Coal Mine, Narrabri*. Prepared by Ditton Geotechnical Services, Charlestown.

Ecotone Ecological Consultants. (2009) *Narrabri Coal Mine Stage 2 Longwall Project – Flora and Fauna Impact Assessment*, Specialist Consultant Studies Compendium.

ELA (2011) *Narrabri Coal Mine Rehabilitation Management Plan*. Prepared for Narrabri Coal Operations Pty Ltd.

ELA (2012a) *Narrabri Coal Mine LW 101 – 103: Biodiversity – Baseline Monitoring*. Prepared for Whitehaven Coal Ltd.

ELA (2012b) *Narrabri Coal Mine LW101 – 103: Land Management – Baseline Monitoring*. Prepared for Whitehaven Coal Ltd.

Geoff Cunningham Natural Resource Consultants (2009) *Narrabri Coal Mine Stage 2 Longwall Project – Soils and Land Capability Assessment of the Mining Area*, Specialist Consultants Studies Compendium.

Hazelton, P.A. & Murphy, B.W. [Eds] (2007) *What Do All the Numbers Mean? A Guide for the Interpretation of Soil Test Results,* NSW Department of Natural Resources and University of Technology, Sydney.

Houghton P.D. & Charman P.E.V. (1986) Glossary of Terms used in Soil Conservation, Soil Conservation Service of NSW: http://www.lpma.nsw.gov.au/__data/assets/pdf_file/0004/157558/Glossary_of_Terms_Used_In_Soil_Conservation.pdf.

MSEC (2007) Introduction to longwall mining and subsidence, Revision A, August 2007, Mine Subsidence Engineering Consultants, Sydney: http://www.minesubsidence.com/index_files/files/Intro_Longwall_Mining_and_Subs.pdf.

R.W. Corkery & Co P/L (2009) *Environmental Assessment for the Narrabri Coal Mine Stage 2 Longwall Project, Project Application No: MP08_0144.*

WRM Water & Environment Pty Ltd (2009) *Surface Water Assessment, Narrabri Coal Mine – Stage 2 Longwall Project*, Specialist Consultant Studies Compendium Vol. 1, Part 3.

Appendix A - Soil Pit Summaries

Pit #	Location	Geological formation / landform unit	Profile							
			Topsoil	pH	D% (DISPERSIBILITY)	EAT (DISPERSIBILITY)	SUBSOILS	pH	D% (DISPERSIBILITY)	EAT (DISPERSIBILITY)
3	Eastern boundary of LW 101	Garrawilla - Floodplain	0-39 cm Light sandy clay loam	pH 6.0			3 horizons (to 250 cm) Light to medium to heavy clay			
4	Eastern boundary of LW 101	Garrawilla - Floodplain	0-25 cm Sandy loam	pH 5.5	25 (slight)	3(2) (slight)	3 horizons (to 250 cm) Medium to heavy clay	pH 6.0-7.5	9-40 (slight to moderate)	3(2)-2(3) (Slight to very high) Possibly sodic
5	South of LW 103-104	Purlawaugh - Crest	0-14 cm Light clay	pH 5.5			2 horizons (to 70 cm) Sandy medium clay to medium clay over decomposing rock	pH 6.0-8.5		
6	LW 106	Pilliga - Upper Slope	0-21 cm Light to medium clay	pH 6.5			3 horizons (to 230 cm) Medium to heavy clay	pH 4.5-9.5		
15	East of LW 101	Garrawilla - Floodplain	0-46 cm Light sandy clay loam	pH 5.5			3 horizons (to 230 cm)	pH 7.0-9.0		
16	LW 102 Creekline (Pine Creek Trib 1)	Purlawaugh - Floodplain	0-39cm Sandy clay loam	pH 6.0	29 (slight)	3(2) (slight)	4 horizons to 255 cm Sandy clay loam to light to medium clay	pH 7.0-9.0	12-94 (slight to very high)	2(1) to 2(3) high to

Pit #	Location	Geological formation / landform unit	Profile							
			Topsoil	pH	D% (DISPERSIBILITY)	EAT (DISPERSIBILITY)	SUBSOILS	pH	D% (DISPERSIBILITY)	EAT (DISPERSIBILITY)
							Slightly saline at depth (>170 cm) EC_e > 3.35 dS/m)		High risk of tunnelling failure	moderate to very high Possibly sodic
17	LW 102 Creekline (Pine Creek Trib 1)	Purlawaugh – Drainage Line	0-103 cm Sand	pH 7.0-7.5			2 horizons (to 250 cm) Medium to heavy clay	pH 9.0		
18	East of LW 101	Garrawilla – Drainage Line	0-30 cm Medium to heavy clay	pH 6.5	17 (slight)	3(2) (slight)	3 horizons (to 250 cm) Gritty medium clay to heavy clay	pH 8.0-9.0	78-91 (very high) High risk of tunnelling failure	2(1)-2(2) High to moderate to high Possibly sodic
19	LW 102	Purlawaugh – Midslope	0-37 cm Silty clay	pH 6.0			3 horizons (to 270 cm) Light to heavy clay	pH 9.0		
20	LW 106 (Pasture)	Purlawaugh – Drainage Line	0-30 cm Sandy light clay	pH 6.5	18 (slight)	3(2) (slight)	2 horizons (to 260 cm) Sandy light to heavy clay Slightly saline at depth (> 92 cm)	pH 6.5-7.0	74-92 (very high) High risk of tunnelling failure	2(1)-2(2) (high to moderate to high) Possibly sodic

Pit #	Location	Geological formation / landform unit	Profile							
			Topsoil	pH	D% (DISPERSIBILITY)	EAT (DISPERSIBILITY)	SUBSOILS	pH	D% (DISPERSIBILITY)	EAT (DISPERSIBILITY)
							EC_e 2.5 dS/m)			
21	North of LW 101 (Pasture)	Garrawilla – Upper Slope	0-36 cm Heavy clay	pH 6.0	8 (slight)	3(2) (slight)	3 horizons (to 210 cm) Light to heavy clay	pH 7.0-8.5	10-15 (slight)	4-5 (negligible)
22	LW 104	Purlawaugh – Floodplain	0-28 cm Fine sandy clay loam	pH 6.5			3 horizons (to 250 cm) Light to medium clay	pH 8.0-9.0		
23	North of LW 103	Purlawaugh – Drainage Line	0-40 cm Clayey sand	pH 6.0			2 horizons (to 300 cm) Sand to sandy medium clay	pH 6.5-10.0		
24	LW 105	Purlawaugh – Crest	0-24 cm Sand	pH 5.0	38 (moderate)	3(1) (slight)	2 horizons to 127 cm Clayey sand to medium clay	pH 5.5-6.0	24-40 (slight to moderate)	3(1) (slight)
25	West of LW 106	Purlawaugh – Drainage Line	0- 60 cm Sand	pH 6.5	21 (slight)	3(1) (slight)	2 horizons (to 270 cm) Sandy clay loam to clayey sand	pH 5.5-6.5	33-67 (moderate to very high)	3(1)-2(1) (high to moderate) Possibly sodic
26	North-east of LW 105	Purlawaugh – Mid Slope	0-30 cm Light to medium clay	pH 7.5	24 (slight)	3(2) (slight)	3 horizons (to 204 cm) Light to heavy clay	pH 8.0-4.5	25-48 (slight to moderate)	4-1 (negligible to very

Pit #	Location	Geological formation / landform unit	Profile							
			Topsoil	pH	D% (DISPERSIBILITY)	EAT (DISPERSIBILITY)	SUBSOILS	pH	D% (DISPERSIBILITY)	EAT (DISPERSIBILITY)
							Subsoils slightly to moderately saline (EC_e > 2.1 dS/m)			high)

eco logical AUSTRALIA

HEAD OFFICE
Suite 2, Level 3
668-672 Old Princes Highway
Sutherland NSW 2232
T 02 8536 8600
F 02 9542 5622

SYDNEY
Level 6
299 Sussex Street
Sydney NSW 2000
T 02 8536 8650
F 02 9264 0717

HUSKISSON
Unit 1 51 Owen Street
Huskisson NSW 2540
T 02 4201 2264
F 02 4443 6655

CANBERRA
Level 2
11 London Circuit
Canberra ACT 2601
T 02 6103 0145
F 02 6103 0148

NEWCASTLE
Suites 28 & 29, Level 7
19 Bolton Street
Newcastle NSW 2300
T 02 4910 0125
F 02 4910 0126

NAROOMA
5/20 Canty Street
Narooma NSW 2546
T 02 4476 1151
F 02 4476 1161

COFFS HARBOUR
35 Orlando Street
Coffs Harbour Jetty NSW 2450
T 02 6651 5484
F 02 6651 6890

ARMIDALE
92 Taylor Street
Armidale NSW 2350
T 02 8081 2681
F 02 6772 1279

MUDGEE
Unit 1, Level 1
79 Market Street
Mudgee NSW 2850
T 02 4302 1230
F 02 6372 9230

PERTH
Suite 1 & 2
49 Ord Street
West Perth WA 6005
T 08 9227 1070
F 08 9322 1358

WOLLONGONG
Suite 204, Level 2
62 Moore Street
Austinmer NSW 2515
T 02 4201 2200
F 02 4268 4361

GOSFORD
Suite 5, Baker One
1-5 Baker Street
Gosford NSW 2250
T 02 4302 1220
F 02 4322 2897

DARWIN
16/56 Marina Boulevard
Cullen Bay NT 0820
T 08 8989 5601
F 08 8941 1220

BRISBANE
Suite 1 Level 3
471 Adelaide Street
Brisbane QLD 4000
T 07 3503 7191
F 07 3854 0310

1300 646 131
www.ecoaus.com.au