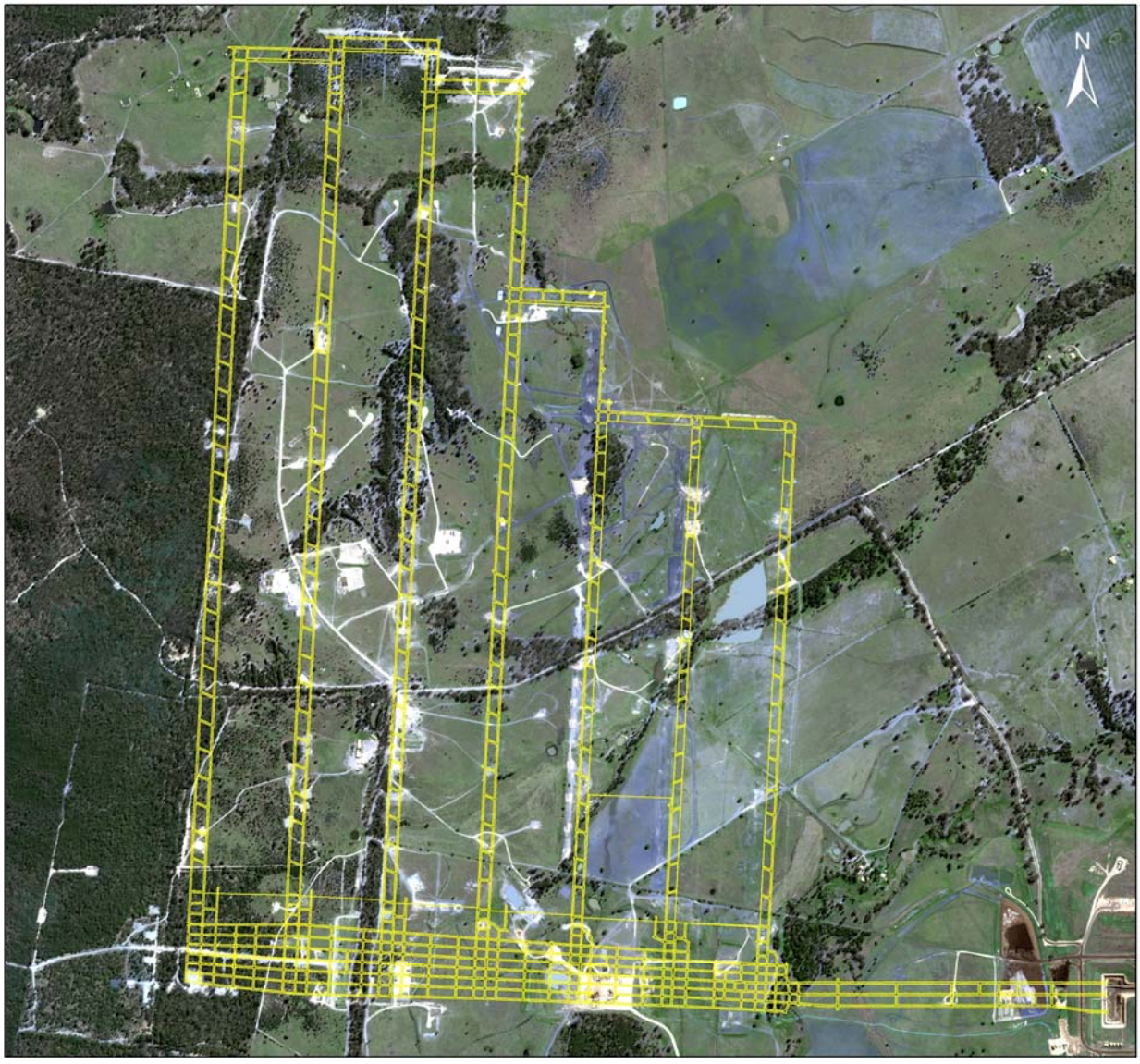
Narrabri Mine

Rehabilitation Management Plan (LW101 – 106)

Prepared for
Narrabri Coal Operations Pty Ltd

18 May 2016



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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
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Abbreviations

ABBREVIATION	DESCRIPTION
ACHMP	Aboriginal Cultural Heritage Management Plan
BFMP	Built Feature Management Plan
DP&E	Department of Planning and Environment
DPI	Department of Primary Industries
DPI Water	Department of Primary Industries – Water
EL	Exploration License
ELA	Eco Logical Australia Pty Ltd
EMS	Environmental Management System
GSSE	GSS Environmental Pty Ltd
LSMP	Landscape Management Plan
MCP	Mine Closure Plan
ML	Mining Lease
MOP	Mine Operations Plan
Mtpa	Million tonnes per annum
NCOPL	Narrabri Coal Operations Pty Ltd
NSC	Narrabri Shire Council
OEH	Office of Environment and Heritage
PA	Project Approval
RMP	Rehabilitation Management Plan
WCL	Whitehaven Coal Limited

1 Introduction

The Narrabri Mine is operated by Narrabri Coal Operations Pty Ltd (NCOPL), which is a majority owned subsidiary of Whitehaven Coal Limited (WCL). The site is located approximately 28 km south-east of Narrabri and approximately 10 km north-west of Baan Baa in north-western New South Wales (Figure 1). The mine site covers an area of approximately 5,298 ha within the Kurrajong and Pine Creek tributary catchments of the Namoi River Catchment. The mine is located within an area of mainly freehold agricultural and forested land, with small sections located within the Pilliga East and Jacks Creek State Forests.

Stage 1 (Project Approval for Stage 1 (PA 05_0102) was issued on 13 November 2007) involved the establishment of surface facilities to support the underground operations using underground continuous miner methods. As a requirement of PA 05_0102, a Landscape Management Plan (LSMP) was prepared for Stage 1 by Eco Logical Australia in 2009 (ELA 2009) and covers construction of surface infrastructure associated with the mine, a box cut and pit bottom area and infrastructure associated with the underground mining area. Stage 1 of the project has a surface area of 255 ha designated for all surface infrastructure associated with this mine. The mining operations approved under Stage 1 included the utilisation of continuous miners to produce at 2.5 million tonnes per annum (Mtpa) of Run-of-mine (ROM) coal for up to 21 years.

Stage 2 (Project Approval (PA) 08_0144, as modified, was originally issued on the 26 July 2010) involves converting the Stage1 mining operations to longwall mining of up to 20 longwall panels and increasing production to up to 11 Mtpa . As a requirement of the Project Approval (PA) for Stage 2 of the Narrabri Coal Mine operations, the existing LSMP for Stage 1 was revised to encompass all proposed mining activities and potential impacts associated with the landscape management for the site (Stages 1 and 2).

Schedule 5, Condition 3 of PA 08_0144 (as modified) required NCOPL (the proponent) to prepare a LSMP to the satisfaction of the Secretary and the Division of Resources and Energy (DRE). The two key components of the LSMP are:

- A Rehabilitation Management Plan (RMP)
- A Mine Closure Plan (MCP).

The revised RMP for Stage 2 was prepared to fulfil the requirements identified in the Project Approval for Stage 2 and to incorporate the detailed Mine Subsidence Effect Prediction and Impact Assessment prepared for the proposed Longwall 101 to 106 by Ditton Geotechnical Services Pty Ltd (DGS 2015).

The aim of this revised Stage 2 RMP is to incorporate LW106 and to direct ongoing activities that will create a final landform that is similar to the pre-mining landscape. The final land use of the mine site is conceptual at this stage as the closure of the mine is in excess of 25 years time (R.W. Corkery & Co Pty Ltd 2009). Currently, the aim is to return the mine site to productive agricultural land of the pre-mining land capability following the completion of the Narrabri Coal project (R.W. Corkery & Co Pty Ltd 2009). Cunningham (2007) indicates that the majority of the pre-MOP land capability was Class III agricultural lands with a small area of Class IV and the remaining areas as Class VI and Class VII near Jacks Creek State Forest and some Class VII agricultural lands adjacent to Kurrajong Creek (Table 1).

The final concept plan for the mine site has been described in the MOP and has been included in Appendix A.

Table 1: Land Capability Classes and descriptions

Land Capability Class	Description
Class III	Sloping land suitable for cropping on a rotational basis. 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 fertiliser and minimal cultivation for the establishment or re-establishment of permanent pasture.
Class VI	Land suitable for grazing with no cultivation. Soil conservation practices including limitation of stock, broadcasting of seed and fertiliser, prevention of fire and destruction of vermin are required along with some isolated structural works.
Class VII	Land best suited to green timber and generally comprises areas of steep slopes, shallow soils and/or rock outcrop. Adequate ground protection must be maintained by limiting grazing and minimising damage by fire.

1.1 Rehabilitation activities completed

Various rehabilitation activities within the ML have been undertaken to date, with a total of over 73.3 ha of land being rehabilitated to pasture and grasses and 1.5 ha being rehabilitated to native forest/ecosystems (NCOPL 2014). Furthermore, other rehabilitation activities comprise:

- Cover crop establishment in areas no longer required by operational activities, including the amenity bund, dam walls and drainage lines
- Planting of over 2,050 tube stock trees and shrubs along the perimeter amenity bund and in strategic locations across the site to improve the visual amenity for surrounding landholders and local road users
- Ongoing rehabilitation of areas disturbed by drilling activities (NCOPL 2011).

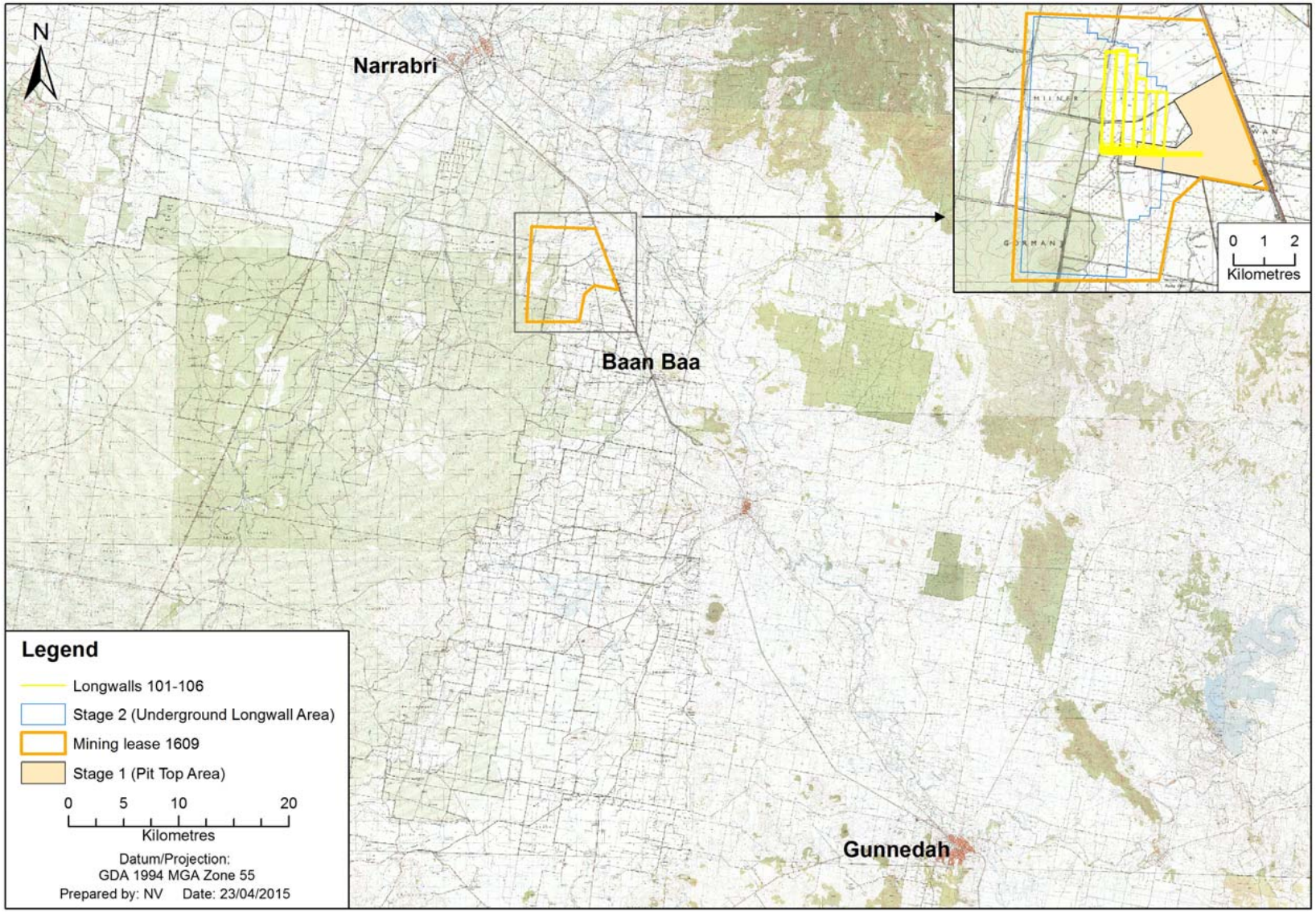


Figure 1: Location of the Narrabri Coal Mine.

2 Regulatory Requirements

2.1 Project Approval

PA 08_0144 was granted on the 26 July 2010 and included several conditions, including the revision of the existing RMP for Stage 1 of the Narrabri Coal Mine. The conditions of PA 08_0144 are shown in Table 2.

Table 2: Conditions of consent associated with the Narrabri Coal Project Stage 1 and Stage 2

Development Consent Condition Stage 2 (PA 08_0144)	Requirements for the RMP	Section of RMP
Schedule 5, Section 4 (a)	The rehabilitation objectives for the site	Section 3
Schedule 5, Section 4 (b)	A strategic description of how the rehabilitation of the site would be integrated with surrounding land use	Section 4
Schedule 5, Section 4 (c)	A general description of the short and long-term measures that would be implemented to rehabilitate the site	Section 3
Schedule 5, Section 4 (d)	A detailed description of the measures that would be implemented to remediate predicted subsidence impacts under individual Extraction Plans	Section 5
Schedule 5, Section 4 (e)	A detailed description of the measures that would be implemented to rehabilitate the site, including the measures to be implemented for: • Managing the remnant vegetation and habitat on site; • Minimising impacts on fauna; • Minimising visual impacts; • Conserving and reusing top soil; • Controlling weed, feral pests and access; • Managing bushfires; and • Managing potential conflicts between rehabilitation works and Aboriginal Cultural heritage.	Section 6.1 Section 6.2 Section 6.3 Section 5.4 Section 6.5 Section 6.6 Section 6.7
Schedule 5, Section 4 (f)	Detailed performance and completion criteria for the rehabilitation of the site	Section 7
Schedule 5, Section 4 (g)	A detailed description of how the performance of the rehabilitation works would be monitored over time to achieve the stated objectives and against the relevant performance and completion criteria	Section 8
Schedule 5, Section 4 (h)	Details of who is responsible for monitoring, reviewing and implementing the plan	Section 9

The purpose of this RMP is to identify the aims of the rehabilitation of the Narrabri Mine, including rehabilitation works, landscaping works and any other works required to address the consolidated conditions of approval now identified in PA 08_0144. The NCOPL Group Environmental Manager will be responsible for the implementation of this RMP. Information on rehabilitation progress will be provided in the Annual Environmental Management Report (AEMR).

2.2 Guidelines

Guidelines developed by the New South Wales Minerals Council Ltd (2007) and Australian and New Zealand Minerals and Energy Council (2000) have been followed in the development of this RMP. These guidelines have been used to provide a framework for rehabilitation outcomes and identify practical steps in the rehabilitation of the mine.

3 Rehabilitation Objectives

The rehabilitation objectives for the Narrabri Mine have been described in the Environmental Management Strategy (EMS) and Mining Operations Plan (MOP) for Stage 1 and Stage 2 of the mine. These rehabilitation objectives can be split into short-term and long-term objectives (NCOPL 2007a and NCOPL 2011). These objectives aim to address the conditions of consent identified in Table 2.

3.1 Short-term

Short-term rehabilitation objectives have been identified in the NCOPL EMS (NCOPL 2007a) and Stage 2 MOP (NCOPL 2011). These include stabilisation, erosion control and revegetation works. The short-term objectives are:

a) To minimise clearing / vegetation disturbance consistent with operational requirements

b) To rehabilitate areas of disturbance no longer required for mining related operations in accordance with the approved RMP

c) To apply soil (top soil / sub-soil) to the final landform based on material availability and post-mining land use

d) To stabilise all earthworks, drainage lines and disturbed areas required for mine-related activities to minimise erosion and sedimentation

e) To control vermin, feral animals and noxious weeds

f) Reduce the visibility of the activities from adjacent properties and the local road network.

3.2 Long-term

Rehabilitation activities identified to be completed in the long-term are defined in the Narrabri Mine EMS (NCOPL 2011) and Stage 2 MOP (NCOPL 2011). The long-term aim is to return the mine to the agricultural land productivity class and remnant vegetation communities of pre-mining levels. These long-term aims include:

a) To control vermin, feral animals and noxious weeds. Continuation and/or restoration of biodiversity and ecological integrity of areas affected by mining or agriculture within the mining lease

b) To establish a low maintenance, geotechnically stable, safe and vegetated landform which blends in with the surrounding natural landscape

c) To backfill the box cut and blend the final landform with the surrounding topography such that the visual impact of the post-mining landform is minimised

d) To provide habitat for fauna and corridors for fauna movement within the final landform

e) To monitor rehabilitation success in terms of physical and biological parameters

f) To decommission and remove all project-related infrastructure not required for the future use of the site

g) To remediate any land contaminated by accumulated salts or hydrocarbon spills/leaks

h) The re-establishment of agricultural land of comparable land capability to that of the pre-disturbance environment (ie. Class III).

4 Rehabilitation Management Strategy

Within the context of this revised RMP, rehabilitation actions apply to Stage 1 (Pit Top Area) and Stage 2 (Longwall Area) with rehabilitation actions defined for specific domains (Figure 2) within the Pit Top Area and Longwall Area. A summary of rehabilitation actions is given below, with further detail of rehabilitation actions in Section 5.

NCOPL has acquired fourteen rural properties covering an area of approximately 5,400 ha within or adjacent to the mining lease. These properties are specifically centred on and around the Pit Top Area and Longwall Area of the Mining Lease (Table 3; Figure 2).

Table 3: Properties owned by the NCOPL

Property	Total Area (ha)	Area (ha) Within Pit Top Area	Area (ha) Within Longwall Area
'Claremont'	382	218	97.5
'Turrabaa'	124	117	0
'Willarah'	218	0	124.2
'Matoppo'	395	115	0
'Omeo'	225	0	98.3
'Westhaven'	360	0	320.7
'Rosevale'	692	0	388.8
'Bungaree' subdivision	104	0	82.97
'Greylands'	298	0	191.1
'Mayfield'	823	0	397.1
'Barton Hedge'	128	0	127
'Desanti Property'	344	0	330.1
'Kurrajong'	397	0	87.6
Unnamed property	218	0	187.1
'Merrilong'	463	0	21
'Naroo'	220	0	0

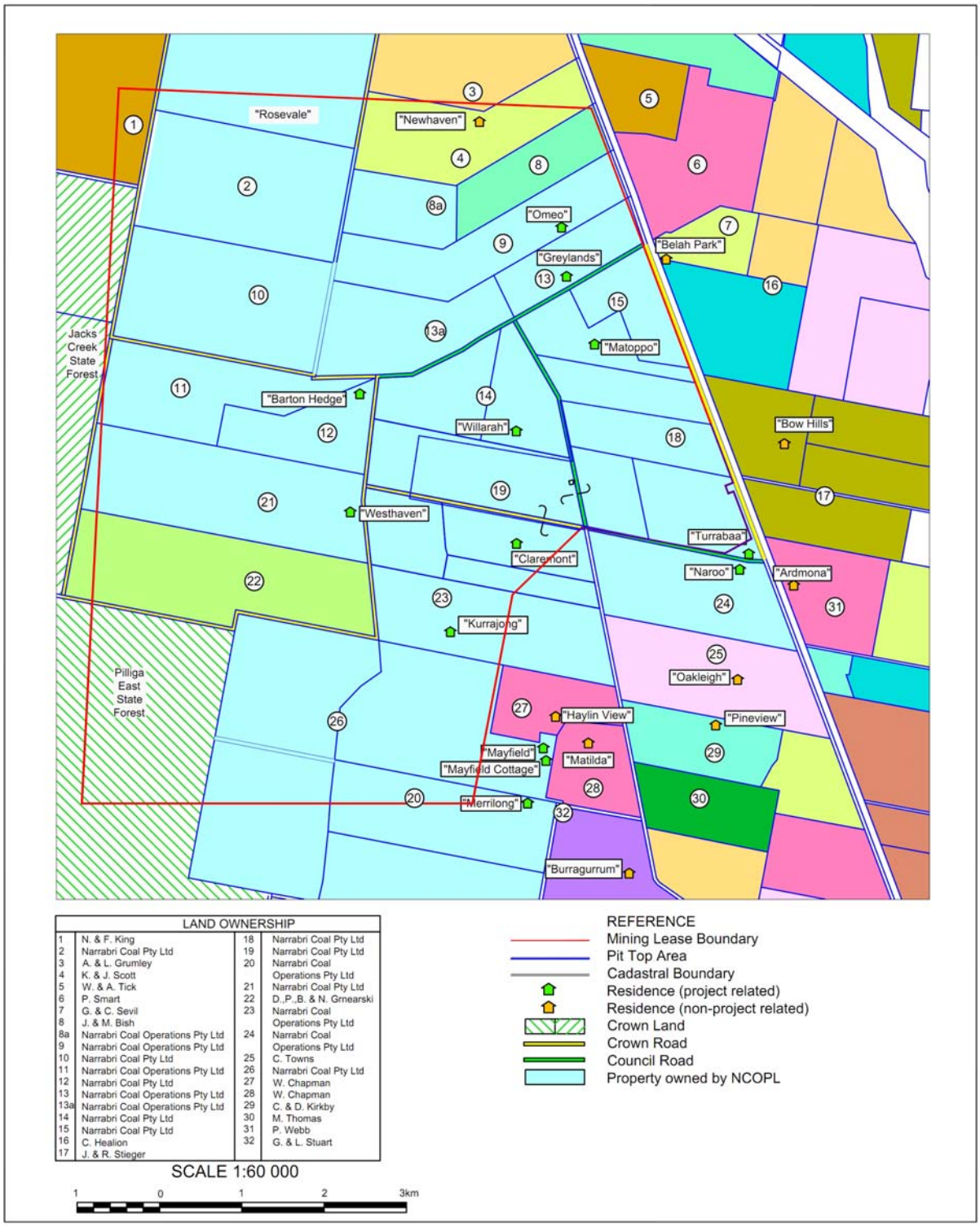


Figure 2: Land ownership on and adjacent to Narrabri Mine (Figure supplied by NCOPL)

4.1 Domains

The Pit Top Area (Stage 1) and Longwall Area (Stage 2) have been divided into 8 separate areas or domains, illustrated in Figure 2 and the domains are described below. These domains have been based on the 6 domains identified in the Stage 1 RMP with additional domains (Domains 7 and 8) needed for the Stage 2 operations.

- **Domain 1** Workshop, offices, bath house, staff car parking, access road, rail crossings, rail loop, and rail load out bin
- **Domain 2** Crushing and sizing equipment and coal stock piles
- **Domain 3** Box cut and transport, conveyor and ventilation drifts
- **Domain 4** Evaporation ponds and water storage dams
- **Domain 5** Other lands in the Pit Top Area (excluding Kurrajong Creek)
- **Domain 6** Surface of the Longwall Area and wider mining lease
- **Domain 7** Brine Storage Dams (BR1 – BR5)
- **Domain 8** Reject Emplacement Area and all weather unsealed road access.

Domain 6 is a large area consisting of both the longwall subsidence areas and other areas of the ML. Given this, Domain 6 has been further divided into management units (Figure 3), consisting of:

- Remnant vegetation
- Agricultural land
- Riparian
- Infrastructure
- Other areas of ML.

4.2 Rehabilitation assessment

In the short and long-term, the following strategies will be implemented in the rehabilitation of the Narrabri Mine:

- No clearance of native vegetation without pre-clearance approval from the Environmental Officer
- The control of noxious weeds and feral animals across all Domains
- The implementation of bushfire management strategies across all Domains
- The conservation and reuse of top soil (for Domains 2, 3, 4, 7 and 8)
- The ripping and contouring of the disturbed surface area to resemble the surrounding landscape (for Domains 2, 3, 4, 7 and 8)

- Cleared vegetation for the purposes of drilling and gas drainage sites should be placed in stockpiles and respread over impact area upon completion of removal and backfilling
- Subsidence management within Domain 6 should be undertaken in agreement with the Extraction Plan
- The sowing of appropriate pasture species to provide protection to disturbed areas of top soil from soil erosion for Domains 2, 3, 4, 7 and 8; and Domain 6 upon completion of ripping surface cracks and rehabilitation of gas drainage sites
- If high levels of soil erosion occur, areas will be battered, contoured and sown with appropriate pasture species to provide further soil stabilisation and prevent further soil erosion (most likely in Domains 2, 3, 4, 7 and 8)
- Native tree species endemic to the area will be planted as paddock trees at low densities outside of the infrastructure foot print of the Pit Top Area and in areas within Domain 6 that are agricultural management areas
- The sowing of long lived perennial pasture grasses to produce a vegetation regime compatible with the final land use landscape and surrounding landscape (entire Pit Top Area and agricultural management unit and ventilation shaft bunds within Domain 6)
- Native woodland species, including overstorey, midstorey and understorey species, which are endemic to the area will be planted around the perimeter of the Pit Top Area at the base of the amenity perimeter bund on the external boundary to provide visual amenity during the mines operation
- Native woodland species, including overstorey, midstorey and understorey species, which are endemic to the area will be planted within the drilling and gas drainage sites of the remnant vegetation and riparian management areas of Domain 6. These native plantings are to reflect the dominant species of the surrounding or pre-mining vegetation communities.

4.3 Assessing completion criteria

Completion criteria will reference the short-term and long-term rehabilitation objectives (Section 3.1 and 3.2 respectively) and will require NSW Trade and Investment satisfaction that NCOPL have met rehabilitation objectives provided in this RMP and rehabilitation has achieved a standard whereby rehabilitation bonds can be released.

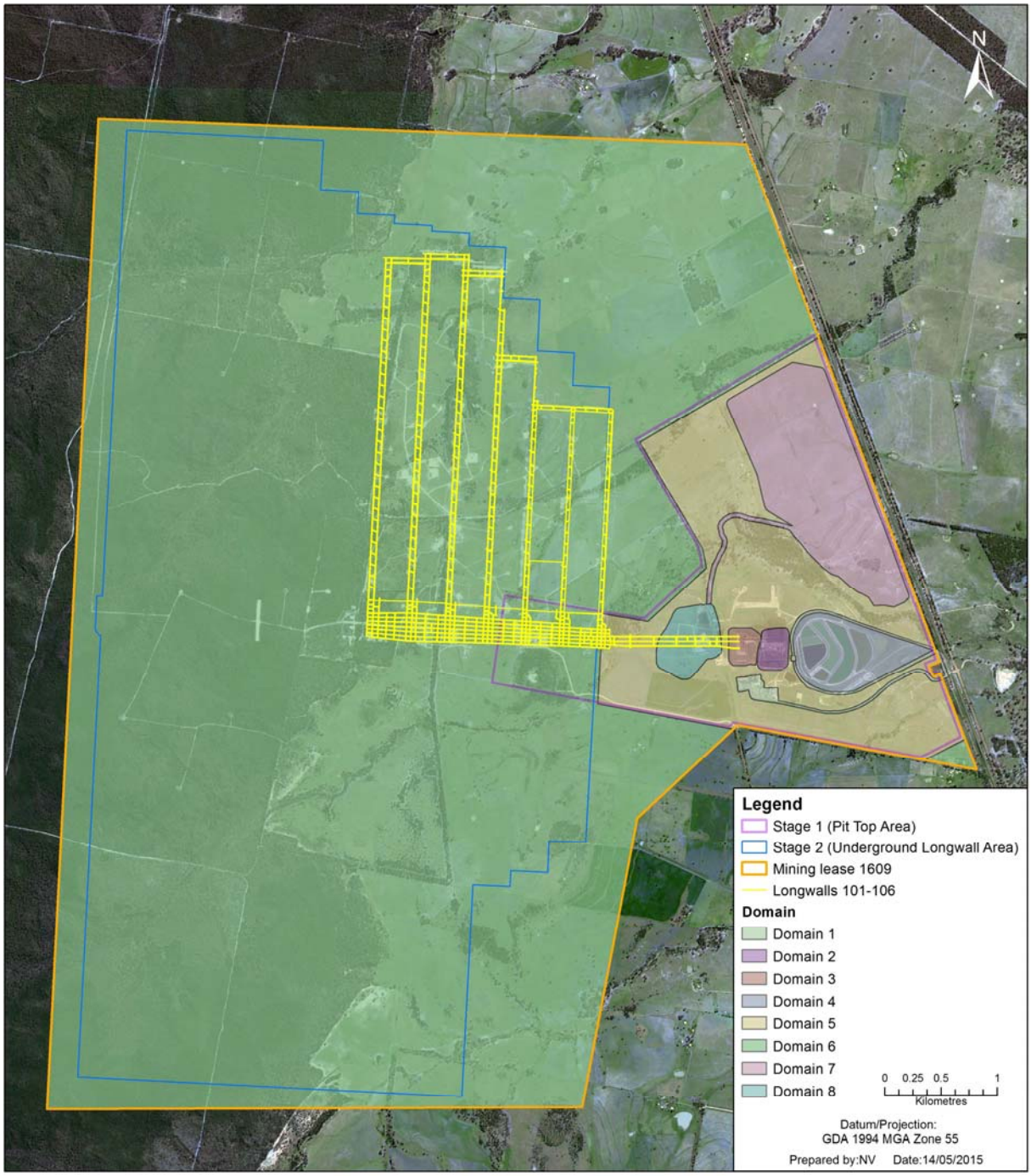


Figure 3: Domains of the Narrabri Coal Mine

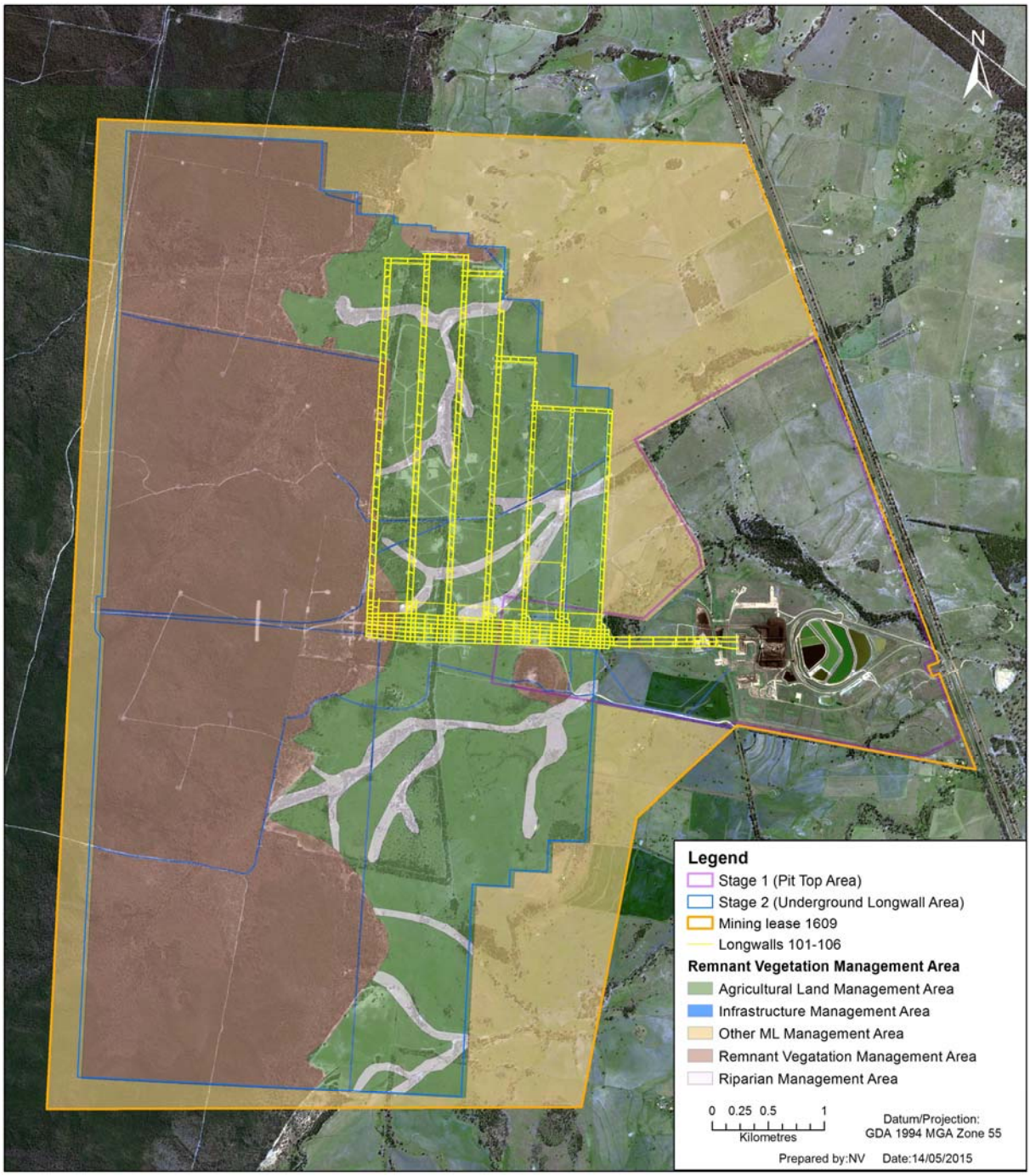


Figure 4: Management Areas within Domain 6

5 Subsidence Impacts and Remediation

This section is based upon the following reports prepared for NCOPL:

- Environmental Assessment for the Narrabri Coal Mine Stage 2 Longwall Project (R.W. Corkery & Co. 2009)
- Mine Subsidence Assessment for the Proposed Addition of Longwall 106 to the Longwall 101 to 106 Extraction Plan at the Narrabri Coal Mine, Narrabri (DGS 2015).

5.1 Preliminary subsidence impacts & remediation

5.1.1 Potential subsidence impacts

The longwall mining method to be employed during Stage 2 of the Narrabri Coal Mine is predicted to cause subsidence of lands directly above and surrounding the longwall panel area. Generally, primary impacts caused by longwall mining subsidence (LMS) can include a reduced topographic elevation of land surface above longwall panels (crest and trough formations), fracturing of groundwater aquifers and disturbance or damage to infrastructure or heritage sites and artefacts (R.W. Corkery & Co. 2009).

These primary impacts can result in secondary impacts that are outlined within the Environmental Assessment (EA) for Stage 2 of the Narrabri Coal Mine, and may include:

- Damage of infrastructure
- Change in grade or alignment of localised drainage lines which could cause ponding or loss of flow, or initiation of knick points (erosion)
- Surface cracking and subsequent erosion resulting in a reduction in water quality
- Subsurface fracturing causing hydrogeological flow paths to be altered, loss of base flow in surface streams, and resulting in a reduction in the availability of groundwater
- Altered vegetation community structure or composition resulting in changed fauna habitat; and
- Damage or movement of Aboriginal artefacts (R.W. Corkery & Co. 2009).

As a result of these primary and secondary impacts, a set of potential impacts and their extent, specific to the Narrabri Mine have been identified within the EA and will be addressed in further detail within individual Extraction Plans being developed for the Narrabri Mine. The potential impacts and their extent identified include:

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 in 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. Crack widths are likely to be wider on ridges than along sandy-bottomed creek beds (DGS 2015).

These surface cracks have the potential to cause some ecological impacts as identified in R.W. Corkery & Co. (2009), including:

- Small terrestrial fauna may fall into the cracks and subsequently perish
- Vegetation communities may be impacted by a reduction in the amount of groundwater availability due to an accelerated vertical flow of water
- Surface cracks which are aligned down slope could also initiate a rill which could develop into a gully line, however, this risk is not deemed significant
- Tunnel erosion could also be triggered by down slope aligned subsidence cracks, in particular where dispersible subsoils occur

In addition cracking may result in the physical shear of plant roots particularly larger trees and shrubs with a concomitant impact on plant health.

- **Slope instability & erosion –** most likely to be restricted to the subsidence areas of Domain 6, slope instability and erosion can result from a change in slope inclination caused by subsidence. Although the top soil layers of the soil types on the ML are not generally prone to erosion, there is potential for erosion to occur along creek channels due to increased bed gradient. The resulting impact from slope instability and erosion is altered or reduced habitat value for flora and fauna (R.W. Corkery & Co. 2009);
- **Ponding & flow re-direction –** based upon the Stage 2 Subsidence Assessment for Stage 2, it has been predicted that ponding at maximum depths of 0.25 to 2.1 m will occur along the tributaries of Kurrajong and Pine Creeks above LW 101-106 (DGS 2015). Ponding is not expected to occur outside of existing channel banks except for along one tributary of Kurrajong creek where the potential for overbank ponding has been identified. Areas that undergo ponding could experience a change in riparian vegetation which will alter the vegetation structure and therefore habitat value. Flow re-direction could result from contour banks no longer running along the contour as a result of variable subsidence across retained chain pillars. Further impacts associated with ponding include:
  - Increased in-stream sedimentation on the eastern (downstream) side of the longwall panels as a result of channel erosion upstream
  - Potential inundation of Aboriginal sites both identified and unidentified
  - Potential increase of saline water discharge from the ML if ponding should occur on saline soils within the ML (R.W. Corkery & Co. 2009)
- **Damage to infrastructure –** based upon the Stage 2 Subsidence Assessment for Stage 2, a number of predicted impacts to infrastructure above the longwall panels may occur, including:

- Unsealed gravel access roads and tracks above the longwall panels are likely to experience cracks ranging between 40 and 260 mm at tensile and compressive strain zones. Surface 'steps' or humps due to compressive shear failures are estimated to range between 60 and 330 mm.
- Farm dams and water storages which are not sufficiently engineered will be impacted by subsidence depending on construction materials and methods and foundation type
- Contour banks or dam walls may be breached and water loss through the dam floor may result due to phases of tensile and compressive strain development
- Tilting of the land surface may increase or reduce storage areas and windmills and fences around the dams may be damaged
- There are several buildings above the proposed longwall panels which may be subject to subsidence of up to 2.75 m. It is predicted that these buildings will incur severe damage which may result in structural instability, rendering them uninhabitable. These buildings are on land owned by NCOPL, with only two being occupied. These dwellings will be vacated prior to subsidence occurring
- Fences may also be damaged as a result of subsidence (DGS 2015).

- **Damage or movement of aboriginal artefacts –** There are 46 known Aboriginal Archaeological Sites above LW 101-106. The Project Approval conditions require sites of 'high' archaeological significance to be protected from mine subsidence related impact, Sites of 'high' archaeological significance include:
  - Five scattered artefact sites above LW104
  - Two grinding groove sites which comprises grooves in separate sandstone floaters above LW102 and LW105
  - An open camp site is located to the south and outside of the extraction limits for LW105
  - Two scarred trees above LW101 and 106

  Site cracking and loss into cracks are determined to be likely for the five scattered artefact sites above LW104. Erosion damage is deemed possible for the grinding grooves. It is understood that there had been no impacts to sites as a result of subsidence effects above LW101 to 104 (DGS 2015).

5.1.2 Subsidence remediation

The subsidence that is likely to occur within the Underground Longwall Area (Domain 6) will require the implementation of measures to remediate the predicted subsidence impacts. These measures have been briefly described below and in detail within **Section 6** (Rehabilitation Actions), and will be further defined within individual Extraction Plan's for the Narrabri Coal Mine. Such remediation measures include:

- **Surface cracking -** It is expected that natural processes such as wind, water and soil movement will infill many of the cracks that develop as subsidence occurs. As part of the

Statement of Commitments for Site Operations and Management for Stage 2 (DoP 2010), the following additional remediation actions will occur:

- Inspections within the cracking zones are to occur during and for a period of two years following the mining of each longwall panel to identify the occurrence of cracks
- Where natural processes have not completely filled each crack, ripping or grading to infill the crack will be undertaken where necessary
- Significant surface cracks which may occur and cannot be filled with surface ripping or grading will be filled using subsoil stockpile material from stockpiles maintained at nearby gas drainage or ventilation sites or material from within the footprint of the Reject Emplacement Area (R.W. Corkery & Co. 2009).

- **Slope instability & erosion -** Stabilisation actions to remediate slope instability and erosion will be undertaken in the unlikely event of large-scale slope instability or erosion. Such actions would include:
  - Infilling of surface cracking to prevent excessive ingress of runoff into the slopes (DGS 2015)
  - Installation of deep sub-surface drainage trenches and the construction of catch drains along slope crests so that surface run-off is controlled
  - Stabilisation works will be undertaken along sections of bank which are damaged or steeply eroded. These works would be conducted in accordance with the Erosion and Sediment Control Plan which forms part of the Site Water Management Plan for the site.

- **Ponding & flow re-direction -** Local drainage patterns may be impacted by surface subsidence with ponding or redirection of channels within local creeks and tributaries possible. In the event that ponding or flow re-direction occurs, the following actions will be undertaken, including:
  - If ponding occurs, no further work will be undertaken unless the ponding significantly affects downstream flows and vegetation
  - Should ponding significantly affect flow or 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).

- **Damage to infrastructure –** Remediation actions for the infrastructure occurring above the longwall panel subsidence areas includes:
  - Regular inspection and maintenance of roads and tracks is proposed to be undertaken after each longwall panel has been mined or when impacts occur
  - Damage to water storage dams is mostly confined to properties owned by NCOPL, any damaged structures could be remediated or replaced;

- Should impacts to dams, contour banks or windmills occur on properties not owned by NCOPL these structures would be repaired or replaced by NCOPL
- Should water supply be disrupted as a result of damage an alternative supply would be provided in the interim. Structures not owned by NCOPL, that are within the angle of draw (<200 m from the edge of the longwall blocks), will have a dilapidation survey and inspection carried out on them prior to and after mine subsidence
- Fair and reasonable outcomes between land owners and NCOPL would be ensured by referral of these reports to the Built Feature Management Plan (BFMP). The BFMP will address the following:
  - The timing of mining impacts and the expected damage to property structures;
  - The property monitoring plan for the mining duration and a safety/hazard plan;
  - Timing of disconnection of utilities
  - Post-mining inspection and reporting of property damage and repair works options (R.W. Corkery & Co. 2009).

5.2 Longwall Panels 101 to 106 subsidence effect prediction & impact

The mine subsidence effect predictions were developed by DGS (2015) and involved reviewing site geotechnical and geological data and assessing the massive strata Subsidence Reduction Potential (SRP) for land above LW 101-106. The DGS report also took into consideration measured subsidence effects and their impacts for LWs 101-104. This information was then used to predict the maximum subsidence over the longwall panels, subsidence over the chain pillars between the longwall panels, key subsidence profile parameters (such as goaf edge subsidence, inflection point and maximum convex and concave curvature locations), credible worst-case subsidence, and tilt and strain profiles across representative sections using a modified version of the ACARP 2003 model (DGS 2015).

The impact assessment component of the study involved determining the subsidence related impacts that have the potential to occur above the LW 101-106, including:

- Surface crack widths and their likely locations
- Subsurface fracture zones
- General slope instability and erosion potential
- Valley uplift and closure potential along creek beds
- Potential for ponding upon completion of mining
- Subsidence impact parameter predictions for existing developments and archaeological sites
- A review of the differences (if any) between the subsidence impact predictions made in the EA and the current mining layout (DGS 2015).

5.2.1 Longwall 101 to 106

LW 101-106 will occur immediately to the west of the Pit Top Area (Figure 5). The land in this area is primarily used for livestock grazing with some cereal crop farming and remnant vegetation stands (predominantly along creek lines), most of which is owned by WCL.

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 will nominally be:

- 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).

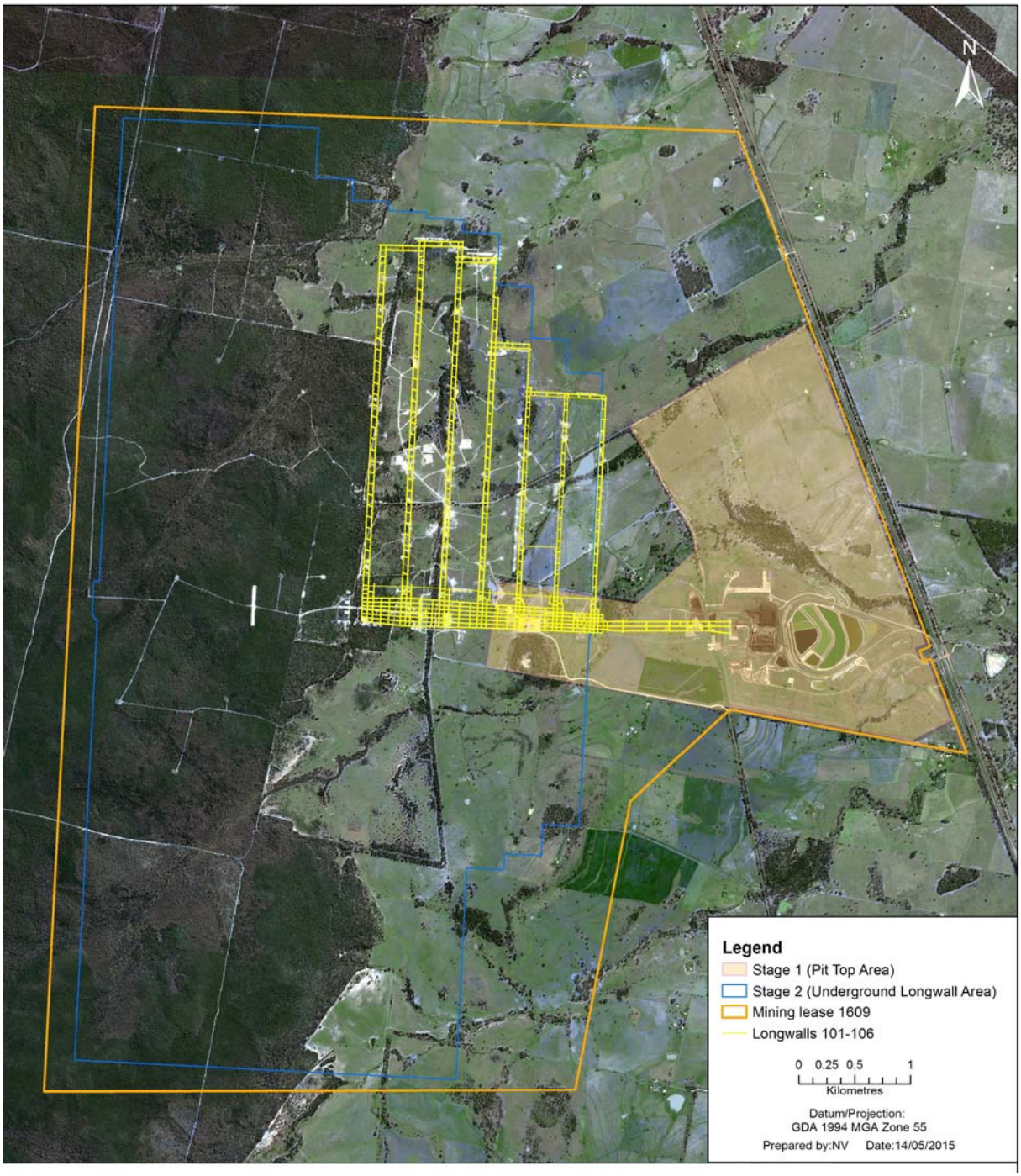


Figure 5: Longwalls 101 - 106

The LW 101-106 will be <1% wider than the panels previously proposed within the Environmental Assessment for the Narrabri Coal Mine Stage 2 Longwall Project (R.W. Corkery & Co Pty Ltd 2009) and the chain pillars are up to 10.2 m wider (DGS 2015).

5.2.2 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 4; Figure 6) (DGS 2015).

Table 4: Predicted mean and credible worst-case results for all of the cross-lines (DGS 2015)

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

Predicted subsidence	Without spanning volcanics	
	Lower limit	Upper limit
Final maximum panel tensile strains after mining LW 101-106 (discontinuous movements)	11 mm/m	26 mm/m

Goaf edge subsidence predictions have been used to predict angle of draw to the 20 mm subsidence contour, it is therefore estimated that the Angle of Draw Prediction (AoD) will range from 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).

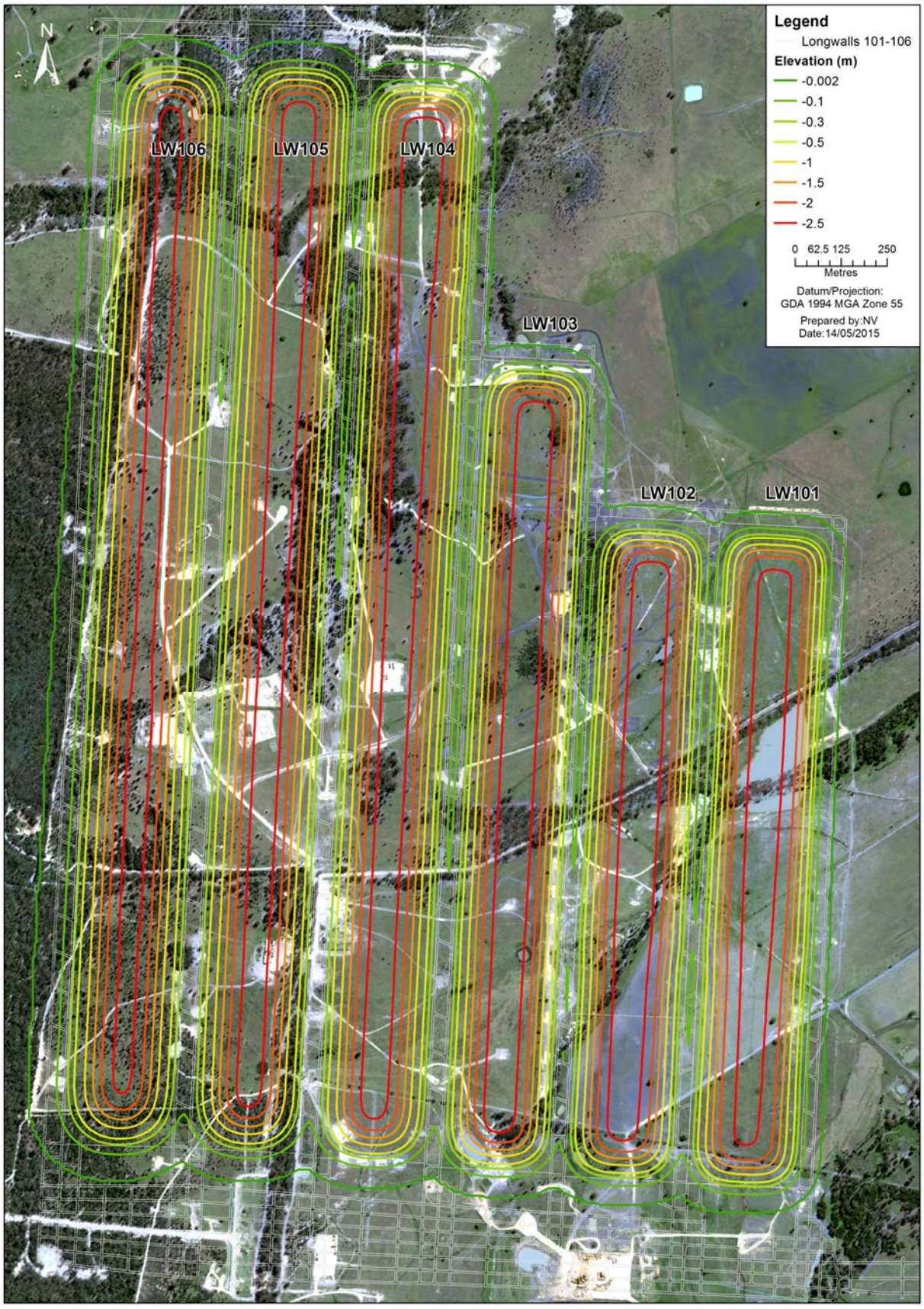


Figure 6: Predicted subsidence effects across LW 101-106

5.2.3 Predicted subsidence effects, impacts & management

The overall predicted effects and impacts and recommended management strategies associated with the subsidence upon land above LW 101-106 are summarised below and presented in further detail within the Extraction Plan being developed to include LW 101-106. The subsidence that is likely to occur will require the implementation of measures to remediate the predicted effects and impacts. These measures have been briefly described below and within Section 6 (Rehabilitation Actions), and will be further defined within the individual Extraction Plan.

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 in 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).

To manage surface cracking, Narrabri Mine will:

- Conduct regular inspections of the surface during subsidence development above a given panel and map the crack locations
- Repair large surface cracks, usually after subsidence development for a given longwall. Temporary fencing may be required before repairs can be made
- Limit subsidence and hence tensile strains by decreasing mining height and/or panel width
- Leave a barrier pillar beneath a sensitive area or limit mining to first workings (DGS 2015)

Areas of the lease, in particular access roads and ephemeral watercourses, which are affected by surface cracking, may need to undergo repair works such as ripping and re-compacting soil material or pouring gravel or grout into large, deep cracks. Grout or other suitable self-cementing materials which

do not require compaction to gain strength are recommended for livestock grazing areas. 'Piping' or erosion failures can develop if dispersive or poorly compacted spoil materials are used in backfilling cracks or trenches (DGS 2015).

Subsurface fracturing

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 flow paths 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).

To manage subsurface fracturing, Narrabri Mine will consider the following options:

- Repair surface cracks when they occur
- Decrease mining height and/or panel width to limit continuous fracture heights
- Leave a barrier pillar beneath sensitive areas or limit mining to first workings (DGS 2015).

The installation of deep borehole piezometers and extensometers in the overburden above the first one or two longwall panels will provide data invaluable to resolving uncertainty associated with the above prediction models (DGS 2015).

Slope stability & erosion

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).

To manage slope instability from increased erosion due to cracking or changes to drainage patterns after extraction, Narrabri mine will:

- Monitor surface slope displacement along subsidence cross lines

- Infill surface cracking to prevent excessive ingress of runoff into the slopes
- Conduct mitigation works such as re-grading, installation of new contour banks and revegetation of exposed areas in areas that are significantly affected by erosion after mining
- Regularly review and appraise any significant changes to surface slopes after each longwall is extracted (DGS 2015).

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 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).

To manage the impact of upsidence and valley bending effects, Narrabri mine will:

- Install and monitor survey lines along ephemeral drainage gullies and along valley crests during and after mining activities and carry out visual inspections to locate damage
- Review predictions of upsidence and valley crest movements after mining of each longwall
- 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 (DGS 2015).

Ponding

If the predicted maximum subsidence of 2.75 m occurs and closed-form depressions form in the central panels natural drainage to water courses may be disrupted if (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 5) (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 5: Potential worst-case ponding assessment for longwalls 101-106 (DGS 2015)

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

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 2015).

After each longwall is extracted it has been recommended by DGS (2015) that on-going review and an appraisal of changes to surface drainage paths and surface vegetation in areas of ponding development is undertaken. It is expected that, due to the predicted post-mining surface levels, channel earthworks to the east of LW 104 and LW 105 along Pine Creek and LW 101 and LW 102 along Pine Creek Tributary 1 to the south may be required (DGS 2015).

Far-field horizontal displacements

Far-field horizontal displacements are when there are horizontal movements recorded beyond the angle of draw. This phenomenon is dependent on cover depth, distance from goaf edges, maximum subsidence over extracted area, topographic relief and the horizontal stress field characteristics. Previous models indicate that measurable far-field displacement (FFDs) movements usually occur in relatively flat terrain for distances up to 3 to 4 times the cover depth (DGS 2015).

Long, linear features such as pipelines, bridges, dam walls and railway lines are the only features likely to be damaged by FFDs. Movements which occur outside a distance equal to one cover depth from longwall extraction limits are unlikely to generate significant strain or movement to cause cracking or surface damage (DGS 2015).

Monitoring for FFD movements on features such as bridges and culverts within 5 times the cover depth during mining has been recommended by DGS (DGS 2015).

Aboriginal heritage sites

The general mine subsidence area contains several modified trees, grinding grooves and various scattered artefact sites which may be affected or damaged as a result of subsidence induced surface cracking or increased erosion rates (DGS 2015).

Artefacts of high archaeological significance will be fenced off and remediated as necessary after mining of LW 104 and 105. It is assumed that the grinding grooves are detached from the underlying bedrock and fully surrounded by unconsolidated soils (alluvium) as demonstrated for the grinding grooves identified above LW102 and 103. These grinding grooves were unaffected by the subsidence that occurred in the immediate vicinity (DGS 2015). It is understood that Aboriginal Stakeholder Groups have undertaken salvage exercises to gather and store artefacts that may have fallen into subsidence cracks (DGS 2015). Upon completion of subsidence rehabilitation works or disturbances have recovered due to natural geomorphic processes these artefacts may then be returned to their original resting place (DGS 2011). Less significant artefacts should be left in situ.

Unsealed gravel access roads and tracks

Unsealed gravel access roads and tracks located above the proposed longwall panels are likely to be damaged by cracking and 'shoving' at tensile and compressive strain zones. It is estimated that maximum tensile crack widths across or along roads will range between 40 mm and 260 mm. Surface 'steps' or humps due to compressive shear failures are estimated to range between 60 mm and 330 mm (DGS 2015).

It can be assumed that subsidence impacts will start to occur within a 26.5º angle of draw or 0.5 times the cover depth ahead of the retreating longwall face. Full subsidence development and impacts on the roads within the actively subsiding area is likely to be 90% complete when the longwall face has moved past the road of 1.5 times cover depth or 56º angle of draw (DGS 2015).

After each longwall has been extracted Narrabri Mine will inspect and maintain roads and access tracks on a daily basis. To ensure safe passage for all vehicles, repairs to road surface will be undertaken as required. Temporary warning signs will be erected near the limits of actively subsiding areas in combination with informing local residents and/or site personnel of when and where subsidence effects may occur (DGS 2015).

Water storage dams and soil conservation (contour) banks

There are 17 farm dams above LW 101-106. These will be susceptible to surface cracking and tilting as a result of mine subsidence. The levels of tilt and strain which can be endured by the dams are dependent on the materials from which the dam is constructed, methods of construction and foundation type (DGS 2015).

Tensile and compressive strain development could result in dam walls being breached or water loss through the dam floor. Predicted tilting may also result in loss or increase in storage areas. Estimated maximum tensile crack widths of between 40 mm and 260 mm could occur across dam wall or storage areas. Compressive shear failures resulting in surface 'steps' or humps of 60 mm to 330 mm could also occur (DGS 2015).

Windmills and dams which are within close proximity to the dams and soil conservation (contour) banks may also be damaged to subsidence impacts and therefore may require repairing (DGS 2015).

To manage water storage dams and soil conservation, Narrabri Mine will:

- Consult with stakeholders and regulatory authorities to develop a suitable monitoring and response plan of dams, windmills and fences so that safe conditions and access to water is maintained during and after the effects of mining
- Maintain the integrity of dams and prevent potential flooding or erosion damage downstream and/or provide an alternative water supply to affected stakeholders until dams are re-instated to pre-mining conditions
- Communicate threats to public/personnel/livestock safety
- Keep downstream areas clear until mining impacts to dams are restored or controlled
- Make allowance for response times so that impacts from cracking and tilting which can manifest rapidly, can be responded to in a controlled manner when it occurs
- Consider responses to subsidence including: draining the dam storage area prior to subsidence and then repairing the dam with an impermeable clay layer after mining; or, monitoring the dam wall during mining and having high capacity pumps on 24 hour stand-by during mining to draw down the storage area , if walls are significantly weakened by subsidence development (DGS 2015).

The extent of action required on dam restoration will be dependent upon land ownership and importance of the water storage in the area. If it is on mine owned property, and the dam is not required for ongoing stock watering purposes, infilling the dam may be undertaken in preference to restoring the dams water storage capability.

Property fences, livestock and orchards

Fence lines, orchards and grazing areas above LW 101-106 will be subject to subsidence effects and cracking. Ponding is not expected to affect grazing or pasture areas except near Pine Creek and its tributaries (DGS 2015).

Temporary fencing or re-location of livestock may be necessary during the repair of surface cracking and damaged fences which have occurred as a result of subsidence (DGS 2015).

Residential dwellings and machinery sheds

A residential dwelling, machinery shed and water storage tank are located above LW 105 and are likely to be subject to subsidence effects. All other buildings lie outside a 26.5º angle of draw to the longwall panels and are unlikely to be impacted.

Where tilts are >7 mm/m and tensile and/or compressive strains are >2 mm/m significant damage to buildings is likely, with the severity of the damage dependent on the type and geometry of each structure (DGS 2015).

The structures above LW 105 will need to be vacated before subsidence occurs and repaired upon completion of undermining. Mine subsidence will start to develop soon after longwall panel 5 retreats beneath the buildings and continue until the longwall face is 1 to 2 times the cover depth past the property. It is expected that primary subsidence movements will affect undermined properties for 3 to 6

weeks after undermining, with residual subsidence occurring for periods of another 1 to 2 years after primary subsidence is complete (DGS 2015).

Buildings will be repaired and deemed structurally sound by qualified building consultants prior to allowing residents to return to their dwellings (DGS 2015). In the case of dwellings/structures owned by Narrabri Coal, a determination will be made at the time to identify if the structure will be repaired or demolished in accordance with Council requirements.

Utilities

The existing properties within the mining lease are connected to buried Telstra copper cabling and Energy Australia domestic power supply (suspended 415V). The Telstra line within LW 101-106 connects to a company owned house which is occupied by a company person. The line has been disconnected and impacts of the proposed longwalls on the line have not been considered further as part of the assessment.

There are 15 timber power poles within the angle of draw above LW 101-106. The line supplies power to the residential dwelling and machinery shed adjacent to the orchard. The power poles will be subject to transient movements towards the retreating longwall face, and will generally start moving towards the north and then swing around (up to 90 degrees in bearing) to their final positions after subsidence is fully developed. The poles are also likely to be subject to tensile and compressive strains associated with the subsidence 'wave' as it passes underneath the poles (DGS 2015).

Conductor clearances are expected to decrease by a maximum of 1.87 m along the easement. The conductors are supported by ceramic insulators which, due to their lack of flexibility, will not be able to tolerate the predicted pole movement rates (DGS 2015).

To manage utility infrastructure, Narrabri Mine will:

- Develop a plan for LW 101-106 in consultation with Energy Australia to ensure that the predicted subsidence effects on the poles and powerlines do not result in unsafe conditions or loss of serviceability during or after mining
- Replace any damaged poles and/or carry out mitigation works to conductors as mine subsidence develops
- Consider management options in the event an exceedence occurs, including the erection of temporary fencing in critical areas before subsidence develops.

Narrabri Coal Mine site and other infrastructure

No impacts are expected to the proposed mine site infrastructure and it is extremely unlikely that the North Western Branch Railway Line and the Kamilaroi Highway will be affected by horizontal or vertical movements due to mine subsidence (DGS 2015).

Measurable subsidence and horizontal displacement as a result of mining is unlikely to occur, however environmental or 'confirmation' monitoring points are recommended. These will be established at several accessible points adjacent to the western side of the railway line easement for before and after LW 101-106 monitoring of vertical and horizontal displacements (DGS 2015).

6 Rehabilitation Actions

6.1 Managing remnant vegetation and habitat on site

The management of remnant bushland during the life of the mine will protect flora and fauna habitat from the impact of grazing, damage from machinery, weed invasion and feral pests. This will protect remnant vegetation, threatened flora habitat, including Coolabah Bertya (*Bertya opponens*) and Spiny Pepper-cress (*Lepidium aschersonii*) and habitat on site particularly for threatened fauna populations, including:

- Pale-headed Snake *(Hoplocephalus bitorquatus)*
- Glossy-black Cockatoo *(Calyptorhynchus lathami)*
- Turquoise Parrot *(Neophema pulchella)*
- Superb Parrot *(Polytelis swainsonii)*
- Speckled Warbler *(Pyrrholaemus sagittata)*
- Grey-crowned Babbler *(Pomatostomus temporalis temporalis)*
- Diamond Firetail *(Stagonopleura guttata)*
- Eastern Pygmy Possum *(Cercartetus nanus)*
- Koala *(Phascolarctos cinereus)*
- Delicate Mouse (*Pseudomys delicatulus*)
- Black-striped Wallaby *(Macropus dorsalis)*
- Eastern Long-eared Bat (*Nyctophilus bifax*)
- Little Pied Bat *(Chalinolobus picatus)*
- Yellow-bellied Sheath-tail Bat *(Saccolaimus flaviventris).*

During the establishment of drilling and borehole construction associated with the pre- and goaf gas drainage within Domain 6, locations should be determined in such a way as to minimise the amount of disturbance to remnant vegetation, threatened flora habitat and threatened fauna habitat wherever practically possible.

In addition to this, the long-term objective is to return the land to the agricultural land class or remnant vegetation type that existed prior to mining activities being undertaken. Domains 2, 3, 4, 7 and 8 will be rehabilitated to Class III lands. Disturbance of remnant vegetation along Kurrajong Creek Tributary 1 should be avoided and fencing may be used to avoid disturbance.

Disturbance works associated with drilling and borehole construction within Domain 6 are to be undertaken within their defined impact area and clearly marked to avoid any unnecessary impact on adjacent remnant vegetation. Once these gas drainage requirements are completed, each site will no longer be needed and therefore can be rehabilitated such that the final landform and final land use be

that of the surrounding land within each management area (i.e. remnant vegetation management area should be rehabilitated to the associated vegetation communities).

As a requirement of PA 08_0144, an offset strategy has been developed for Stage 1 and Stage 2 of the Narrabri Coal Mine, which incorporates the protection and management of 422 ha of onsite offsets that occur either within Domain 6 or immediately adjacent. Appropriate management of woodland areas within Domain 6 is also necessary on the basis that at the end of the mine life, an area of 1,168 ha of woodland area within Domain 6 will be added to the offset area for subsequent management for biodiversity purposes. As indicated within the Offset Strategy, the preparation of an Offset Area Management Plan will be developed to guide subsequent management of this area (ELA 2010).

There are several aspects to the management of remnant vegetation on site, including:

- Fencing to exclude stock, public access and machinery
- Control of noxious and environmental weeds
- Control of feral pests.

6.1.1 Fencing

Fencing will be used to exclude stock grazing and machinery to manage remnant vegetation and habitat on site. Fencing will be required along the northern boundary between Domains 5 and 6 to protect the remnant vegetation along Kurrajong Creek and within the remnant vegetation and riparian management areas not being impacted by infrastructure associated with the underground longwall panels within Domain 6.

In accordance with the archaeological assessment and management plan (Australian Archaeological Survey Consultants Pty Ltd 2009; NCOPL 2007b), all Aboriginal archaeological sites will be fenced to prevent surface disturbance of these sites. These sites are located in Domains 5 and 6 (Australian Archaeological Consultants Pty Ltd 2009).

The fencing around Kurrajong Creek and other remnant vegetation within Domain 6 will be of sufficient standard to exclude all mining machinery. This will involve fencing the northern boundary between Domain 5 and 6, adjacent to the remnant vegetation along Kurrajong Creek, and within remnant vegetation and riparian management areas not being impacted by infrastructure associated with the underground longwall panels within Domain 6. Entry to the fenced areas will not be permitted and approval to enter this area will be required from the Environmental Manager.

<u>Short-Term</u>

The northern boundary between Domain 5 and 6 will be fenced to prevent disturbance to native vegetation and Aboriginal archaeological sites along Kurrajong Creek. Within Domain 6, all woodland vegetation should be fenced to provide a separation from existing grazing areas to prevent disturbance to native vegetation and potential stock grazing.

<u>Long-Term</u>

Prior to mine closure, all property boundaries owned by the NCOPL will be fenced with adequate stock proof fencing so the property can be used for agricultural purposes. All woodland vegetation should

be fenced to provide a separation from existing grazing areas to prevent disturbance to native vegetation and potential stock grazing.

6.1.2 Weed control

Weeds are a threat to areas of remnant vegetation and habitat on site. The control of noxious and environmental weeds will be required not only in areas of remnant vegetation in the Pit Top Area and Underground Longwall Area, but across the entire area of operations as illustrated in Figure 2 of Section 4. This is discussed further in Section 6.5.1.

6.1.3 Feral pests

The control of feral pests is important to the management of remnant vegetation. Feral Pigs and Hares have been observed in Domain 6 (along Kurrajong Creek) and will affect the regeneration of native vegetation and habitat along Kurrajong Creek. Similarly Feral Dogs, Cats and Red Foxes also threaten fauna habitat on site. The control of feral pests will be required and is discussed in Section 6.5.2.

6.2 Minimising impacts on fauna

In order to protect fauna on the site, Narrabri Mine will both protect trees and habitat and conduct revegetation using native species.

6.2.1 Habitat protection

The clearance of individual trees in the Pit Top Area under Stage 1 of the Narrabri Coal Mine has been minimal. The clearance of trees within Domain 6 under Stage 2 is being undertaken in association with the installation of infrastructure and establishment of drilling and borehole construction associated with the pre- and goaf gas drainage. Vegetation clearing works are being undertaken in line with the Statement of Commitments for Site Operations and Management for Stage 2 (DoP 2010). These commitments include:

- Undertaking pre-clearing surveys by a qualified ecologist to identify if any threatened species, populations or communities or their habitat is present
- Assessing whether aquatic or fish habitat is present within the drainage features to be traversed by the access road and/or power line corridors
- Determining appropriate paths for access tracks and other disturbance with the aim of least impact on environmental values where practically possible
- Relocating or reorientating proposed disturbance if threatened species, populations or communities or their habitat is identified. If the relocation or re-orientation of the area to be disturbed is not practicable (for reasons of mine / operational safety), a qualified ecologist will relocate any fauna species residing within the area to be cleared;
- Retaining all substantial habitat trees, wherever possible
- Undertake tree felling, where practicable, outside fauna breeding seasons
- Undertake any tree-felling in accordance with a Tree Felling Protocol. The Tree Felling Protocol will be developed by a qualified ecologist and will include, but not necessarily be limited to a description of:

- the best time of the year for felling
- pre-felling mapping of habitat trees
- inspections of trees on the day of felling
- procedures for the safe removal of fauna species
- a relocation/release protocol
- a protocol for the assessment and salvaging of tree hollows (R.W. Corkery & Co. 2009).

During clearing activities for drilling and gas drainage sites of Domain 6, trees upon felling are to be broken into small sections and positioned adjacent to the disturbed areas for future use in the rehabilitation of the disturbed areas for fauna habitat.

Clearing activities across the remainder of the ML should incorporate the dispersal and spread of cleared native vegetation around the disturbed areas to provide fauna habitat, increase seed bank and to provide a mulch material for nutrient cycling and water retention.

Hollow-bearing trees removed during authorized clearing works should be relocated in appropriate areas (i.e. rehabilitation areas or areas outside the current operations) where practicable for potential fauna habitat.

Any clearing of native vegetation will require approval from the Environmental Officer under the pre-clearance permit arrangements.

The protection of habitat by these means will minimise the impacts on fauna and ensure the protection of habitat for threatened species that have been recorded in the area, as listed above in Section 6.1.

6.2.2 Revegetation

The revegetation of the site will occur for landscaping purposes and rehabilitation of drilling and borehole construction associated with the pre- and goaf gas drainage and associated infrastructure within Domain 6. This will primarily be confined to the planting of overstorey species. In the long-term this will provide fauna habitat. This is discussed further in Section 6.3.

6.3 Minimising visual impacts

Minimising visual impacts through rehabilitation will be progressive for disturbed areas during the mining operations. This progressive rehabilitation will comprise landform creation and stabilisation, spreading of soils and revegetation.

Minimising visual impacts of the Pit Top Area and Underground Longwall Area will be undertaken through landscape plantings and revegetation activities to reduce the visual impact of mining activities as described in the Stage 2 MOP (Section 4.5). Landscaping and revegetation activities has several benefits for the mine's operations and rehabilitation. The benefits include:

- Improvements to the mine's amenity for mine workers, local residents and the public
- The threat of soil erosion will be reduced

- Fauna habitat is created, particularly for birds and bats
- Stock shelter is created (beyond the life of the mine).

To minimise visual impacts of the mine and enhance landscaping, actions outside of the areas of disturbance will include:

- Top soil will be retained to prevent soil erosion and sediment fencing will be installed where required
- Top soil will be sown with a pasture seed mix to stabilise the soil
- All paddock trees and native vegetation along creek lines will be retained where possible
- Internal planting (south of the access road) will be undertaken to improve site amenity.

6.3.1 Internal landscaping

Internal landscaping will consist of sowing pasture grasses and planting clumps of trees throughout the Pit Top Area and Underground Longwall Area that are not involved in the mine's production in the short-term or are subject to progressive rehabilitation during the life of mine. In the long-term, areas involved in the mines operation will be sown with pasture grasses and revegetated with clumps of trees and shrubs (Figure 7).

Short-term

Within Domain 5 and Domain 6, areas not used for mine infrastructure (south of the rail loop and other mine infrastructure), drill sites and redundant gas drainage infrastructure and areas affected by subsidence within the agricultural management area of Domain 6 will be sown with a pasture seed mix relevant to the season of planting, with a typical fertiliser application rate (Table 6). Following this, the areas will be planted with clumps of trees which are to consist of trees species in Table 7.

Table 6: Pasture species to be sown to stabilise top soil

Summer			Winter		
Pasture Species	**Rate (kg/ha)**	**Fertiliser**	**Pasture Species**	**Rate (kg/ha)**	**Fertiliser**
Grasses					
Bombasti Panic	1 – 2	Di-ammonium Phosphate (DAP) 250kg/ha	Phalaris (Sirolan or Holdfast)	1 – 2	Di-ammonium Phosphate (DAP) 250kg/ha
Green Panic*[2]	2 – 4		Wallaby Grass		
Legumes*[1]					
Subterranean Clover	4 – 5		Subterranean Clover	4 – 5	
			Barrel (Sephi) Medic	2 – 4	
			Snail (Sava) Medic*[2]	3 – 5	
			Woolly Pod Vetch	4 – 6	
			Serradella (Elagara)	1 – 2	
			Lucerne	0.5	

*[1] Inoculated with appropriate rhizobia;

*[2] Specific soil conservation application;

Table adapted from R.W. Corkery & Co. Pty Ltd (2007) and NCOPL 2011

Table 7: Species to be used for mine site landscaping

Species Name	Common Name
Acacia pendula	Myall
Brachychiton populneus	Kurrajong
Callitris glaucophylla	White Cypress Pine
Casuarina cristata	Belah
Eucalyptus albens	White Box
Eucalyptus microcarpa	Grey Box
Eucalyptus populnea	Poplar Box

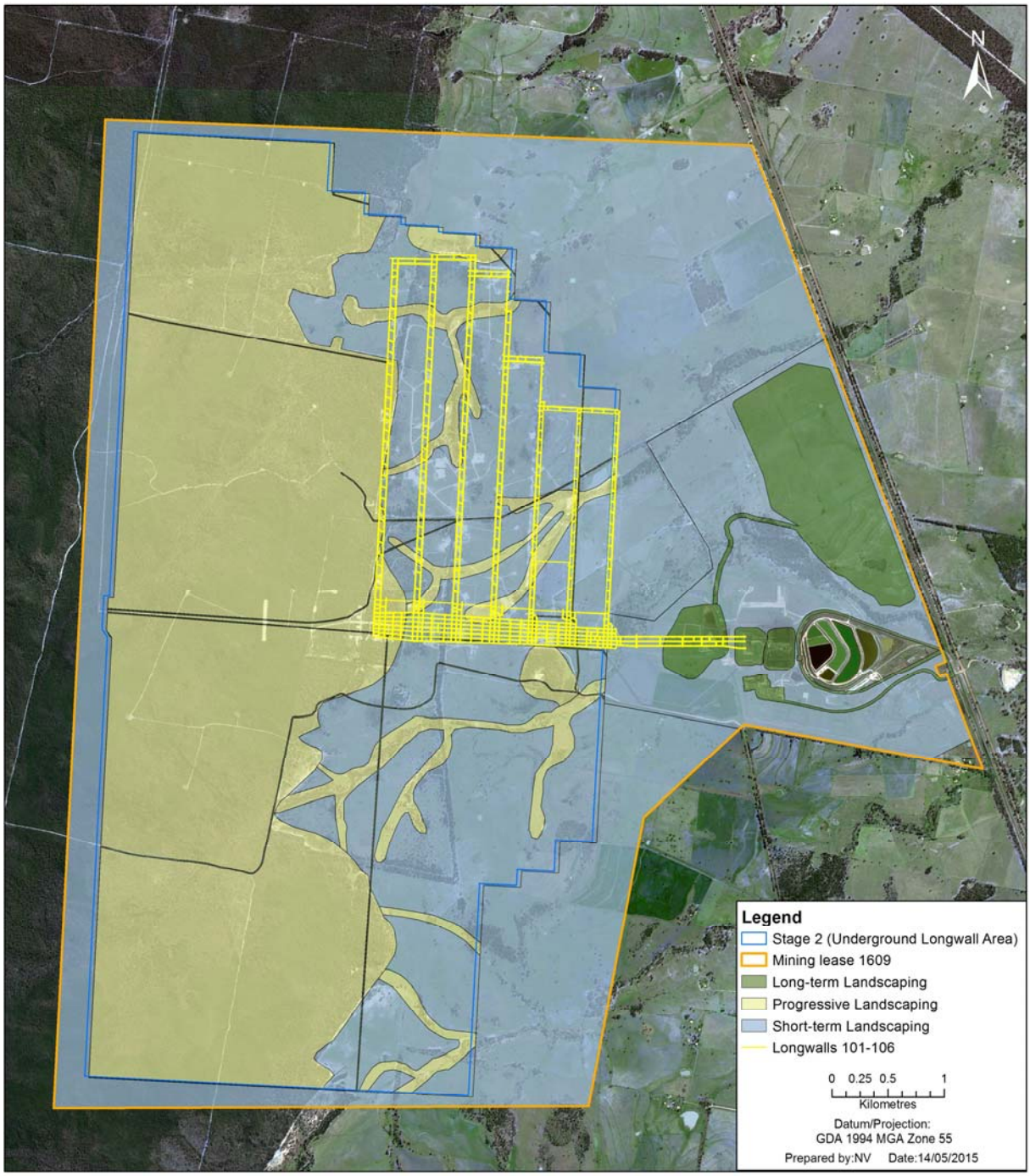


Figure 7: Proposed short and long-term landscaping

Long-term

The area to be landscaped in the long-term is largely conceptual at this stage and a description of the proposed landscaping activities is below and illustrated in Figure 7.

Following mine closure, surface infrastructure including Domain 3 (the Box Cut), Domain 2 (the ROM Coal Stockpile Area), Domain 4 (Evaporation Storage Ponds), Domain 7 (Brine Storage Dams) and Domain 8 (Rejects Emplacement Area) will be landscaped and sub-soil and top soil will be spread. Prior to sub-soil and top-soil spread upon Domain 4 and Domain 7, accumulated salt will need to be removed as outlined within the MCP (Section 5.1.5).

The surface infrastructure area will be contoured to slopes between 1 – 4% or equivalent to the pre-mining topography (R. W. Corkery & Co Pty Ltd 2009 and NCOPL 2011). These areas will then be stabilised by sowing a pasture seed mix relevant to the season of planting, with a typical fertiliser application rate (Table 6) (R. W. Corkery & Co Pty Ltd 2009 and NCOPL 2011).

Following the establishment of these pasture species, the areas will be planted with clumps of trees which consist of tree species in Table 7.

These plantings will form 400 m^2 (20 x 20 m) clumps with trees planted at a density of one plant per 2 m^2. All plants will be planted as tube stock. The use of tree guards will be determined at the time of planting depending upon the predicted level of grazing and or weather conditions.

Drainage control structures within the ML, such as diversion banks upstream and downstream catch banks will be pushed over and profiled to natural surface level. The profiled surface will then be ripped or lightly scarified, covered with available sub-soil and top soil and then stabilised by sowing a pasture seed mix relevant to the season of planting, with a typical fertiliser application rate (Table 6) (NCOPL 2011).

Other cleared areas within the ML will be ripped and scarified with the remaining sub-soil and top soil and broken vegetation which has been stockpiled and spread over the area. The proposed final land use will determine whether pasture or native tree and shrub species will be used for re-seeding.

6.3.2 Pit top area perimeter bund

Surrounding the southern and western boundaries of Domain 5, a perimeter bund has been established using spoil material from the Box Cut and covered with top soil. This bund has been largely rehabilitated with establishment of a cover crop and planted out to native vegetation. This provides the benefit of conserving the top soil in the perimeter bund, until it is used to reshape the landscape of the Pit Top Area in the long-term. It also provides a barrier for views to the facilities of the Pit Top area from Kurrajong Creek Rd and nearby properties.

Short-term

The external boundary from the base of the perimeter bund to the fenceline, has been planted with species endemic to the area as a mixture of trees and shrubs (Table 8). Additional planting will take place at a density of one plant per 5 m^2, with shrubs planted at a density of two plants per m^2.

Long-term

At the closure of the mine, in areas where the perimeter bund will be removed, the soil will be used to reshape the disturbed areas of the Pit Top Area. Any perennial vegetation that has established on the

perimeter bund will be required to be removed. All vegetation not on the perimeter bund will remain in situ.

The area where the perimeter bund was will be sown with pasture species shown in Table 6 to stabilise it and prevent soil erosion.

Table 8: Species to be used for perimeter landscaping

Species Name	Common Name
Overstorey	
Eucalyptus populnea	Poplar Box
Eucalyptus albens	White Box
Eucalyptus macrocarpa	Grey Box
Callitris glaucophylla	White Cypress Pine
Acacia pendula	Myall
Understorey	
Geijera parviflora	Wilga
Acacia decora	Western Silver Wattle
Acacia deanei	Deane's Wattle
Myoporum montanum	Western Boobialla
Senna artemisioides filifolia	Senna
Capparis mitchelli	Wild Orange
Dodonaea viscosa cuneata	Hop Bush

6.3.3 Ventilation shaft perimeter bund

The Ventilation Shaft within the infrastructure management area of Domain 6 and subsequent additional ventilation shafts will be surrounded by a perimeter bund and will be grassed (Table 6) to reduce visual contrast.

Short-term

The ventilation shaft bunds are to be constructed utilising the sub-soil and top soil removed during the construction of the ventilation shafts and are to be stabilised by sowing a pasture seed mix relevant to the season of planting, with a typical fertiliser application rate (Table 6) (NCOPL 2011).

Following the establishment of these pasture species, the areas will be planted with clumps of trees which consist of tree species in Table 7. The bund itself will comprise understorey plantings with the area immediately outside the bund to be planted to over-story species.

Long-term

At the closure of the mine, the ventilation shaft bunds will be removed following removal of the fan and shaft, and capping and sealing of the shaft structure. The soil will be used to reshape the disturbed areas of the ventilation shafts. Any perennial vegetation that has established on the ventilation shaft bunds will be required to be removed. The reshaped land will be revegetated to conform with that of the surrounding land within each management area (i.e. remnant vegetation management area should be rehabilitated to the associated vegetation communities). Each site will be rehabilitated with canopy, shrub and grass species endemic to the vegetation communities (Table 8) or agricultural land consistent with the pre-mining agricultural land class.

6.3.4 Drilling and gas drainage sites

Drilling and gas drainage activities will be temporary in nature within Domain 6 and once these gas drainage requirements are completed, each site can be rehabilitated such that the final landform and final land use is consistent with the surrounding land within each management area (ie remnant vegetation management area should be rehabilitated to the associated vegetation communities).

These sites will be rehabilitated progressively during the life of the mine and initially will involve the decommissioning and removal of infrastructure, including gas drainage vacuum pump and generators. Boreholes will then be backfilled and capped, following the EDG01 guideline "*Borehole Sealing Requirements of Land: Coal Exploration".*

Sites located within the agricultural management area of Domain 6 will be rehabilitated to the appropriate agricultural land class, sown with a pasture seed mix relevant to the season of planting, with a typical fertiliser application rate (Table 6).

The sites located within the riparian and remnant vegetation management areas of Domain 6 will be rehabilitated using endemic species to the corresponding vegetation communities that exist immediately adjacent to each site (Figure 8). Each site will be rehabilitated with canopy, mid-storey, shrub, and groundcover species endemic to the vegetation communities (Table 9).

The rehabilitation of canopy, mid-storey, shrub and groundcover species should reflect densities that occurred pre-disturbance. At a minimum, rehabilitation of canopy species should reflect the number of trees identified for clearance during pre-clearing survey or as a minimum count per m^2 as follows:

- Canopy – 1 canopy planting per 10 m2
- Mid-storey - 1 mid-storey planting per 5 m2
- Shrub - 1 shrub planting per 1 m2
- Groundcover - 4 groundcover plantings per 1 m2

6.3.5 Access tracks

Access tracks located throughout the ML and specifically within the infrastructure management area of Domain 6 will be progressively closed and rehabilitated. Tracks will be ripped and previously removed top soil (in accordance with Section 6.4) and vegetation will be pushed over the ripped surface. Natural revegetation will be allowed to take place, however if this is not successful within 3 months during peak growing periods (spring and summer) and 6 months during slower growing periods

(autumn and winter) of ripping, the site will be seeded, utilising species endemic to adjacent remnant vegetation or agricultural land class (Table 9).

Table 9: Species to be used for Domain 6 drill and redundant gas drainage remnant vegetation and riparian management areas

Vegetation Community	Dominant Canopy Species	Dominant Mid-storey Species	Dominant Shrub Species	Dominant Groundcover Species
Brown Bloodwood/Piliga Box Woodland	*Corymbia trachyphloia*	*Callitris glaucophylla*	*Calytrix tetragona*	*Pomax umbellata*
	Eucalyptus pilligaensis	*Acacia homalophylla*	*Phebalium squamulosum*	*Eragrostis brownii*
	Eucalyptus fibrosa	*Acacia harpophylla*	*Acacia burrowii*	*Dianella revoluta*
			Persoonia sericea	*Microlaena stipoides*
			Allocasuarina diminuta	*Goodenia hederacea*
Callitris Forest	*Callitris glaucophylla*			*Eragrostis cilianensis*
				Goodenia rotundifolia
				Aristida benthamii
				Austrostipa aristiglumis
				Cleistochloa rigida
Inland Grey Box Woodland	*Eucalyptus microcarpa*	*Geijera parviflora*	*Geijera parviflora*	*Aristida benthamii*
	Eucalyptus populnea	*Callitris glaucophylla*	*Maytenus cunninghamii*	*Solanum ferocissimum*
	Eucalyptus blakelyi	*Casuarina cristata*	*Acacia homalophylla*	*Austrostipa ramosissima*
		Capparis mitchellii		*Austrostipa verticillata*
				Chrysocephalum apiculatum
Riparian Forest	*Casuarina cunninghamiana*	*Eremophila mitchellii*	*Geijera parviflora*	*Aristida benthamii*
	Casuarina cristata	*Myoporum montanum*	*Acacia penninervis*	*Austrostipa aristiglumis*
	Eucalyptus populnea		*Notelaea microcarpa*	*Austrostipa ramosissima*
	Eucalyptus microcarpa			*Bothriochloa decipiens*
				Cyperus gracilis

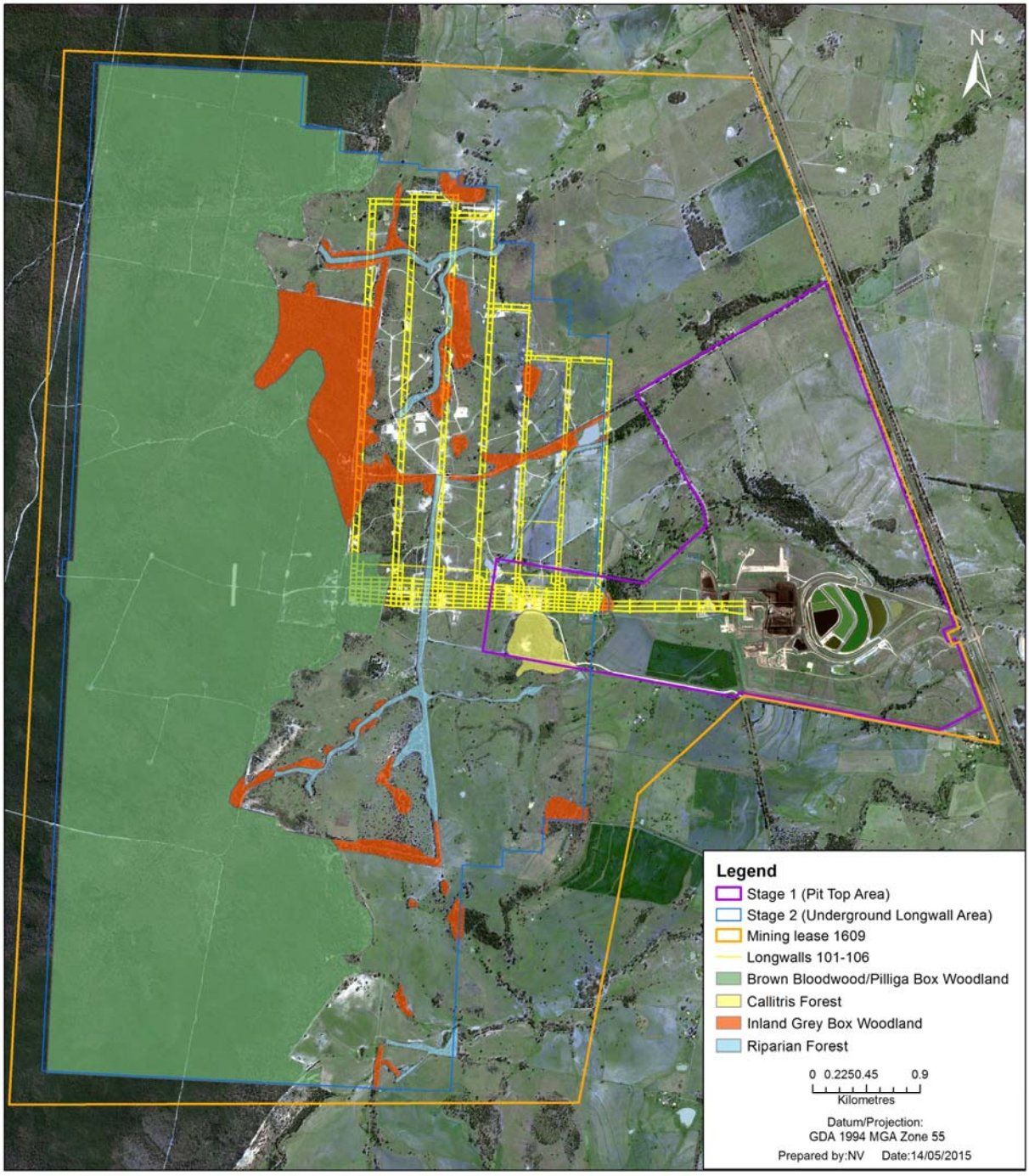


Figure 8: Vegetation communities within Domain 6

6.4 Conserving and reusing top-soil and sub-soil

6.4.1 Top-soil conservation

The soil properties and conservation measures of the Pit Top Area and Underground Longwall Area have been described by Cunningham (2007 and 2009). This information has been used to identify the short-term and long-term conservation measures of top-soil and sub-soil in the Stage 2 MOP (NCOPL 2011). The storage of top-soil and sub-soil is described below.

Soil stripping associated with the construction of infrastructure for the Narrabri Coal Mine drill sites, ventilation shaft areas and access roads will be undertaken at no deeper than the depths identified by Cunningham (2009) using mainly scrapers or a bulldozer and either a front-end loader or backhoe to place the soil in stockpiles.

Top-soils and sub-soils will be stockpiled separately to enable easy recognition and retrieval once rehabilitation is underway. The following stockpile management measures will be adhered to for the life of the mine:

- All soils within the areas to be disturbed would be stockpiled in wind rows immediately adjacent to the area of disturbance
- Top-soil stockpiles are to be created no higher than 2 m and with slopes no greater than 1:2 (V:H) to minimise soil erosion
- Sub-soil stockpiles are to be created no higher than 3 m with slopes no greater than 1:2 (V:H) to minimise soil erosion
- Sedimentation controls including catchment banks, silt-stop fencing or straw bales will be placed immediately down slope of any soil stockpiles and will be maintained until such time as a stable vegetation cover over the stockpile is achieved
- Soil stockpiles will be left with a roughened surface and those stockpiles to be retained for more than three months that do not have a naturally established vegetation cover will be seeded with a selection of pasture species including fast growing, non-persistent cover species like Triticale, Ryecorn or Millet and perennial species such as Phalaris, Cocksfoot, Perennial Rye and Sub Clover
- In the event that unacceptable weed generation is observed on soil stockpile areas, a weed control program will be implemented
- Following stockpile construction, the operation of machinery on the top-soil and sub-soil stockpiles will be avoided in order to prevent compaction and maintain soil aggregation.

During soil stripping activities, in the event of discovery of a potential Aboriginal site or artifact, the measures outlined within Section 3.3 of the Aboriginal Cultural Heritage Management Plan (ACHMP) will require implementation.

In the event that an identified site cannot be avoided during soil stripping activities, a site salvage procedure should be implemented as outlined within Section 3.5 of the ACHMP.

6.4.2 Top-soil replacement

Top-soil will be reused by replacing it back in the appropriate areas and order. For example, SMU 1 soils (soils from the Floodplain of Kurrajong Creek) will be placed back in the area where they came from (the floodplain of Kurrajong Creek). This will apply to all areas where top-soils and sub-soils will be replaced. Following this the top-soil will be ripped along the contour to prevent soil erosion and finally sown with pasture species described in Section 6.3.

When the top-soil is replaced it will be replaced such that it resembles the surrounding landscape. This will be in accordance with Conceptual Final Rehabilitation for Lease Relinquishment (Plan 6) of the MOP (Appendix A). Before the top-soil is spread, the ground will be scarified along the contour to a depth of 50-100 mm to break up any hard setting surfaces and to provide a good bond between the re-spread material and sub-soil. The top-soil will be spread to a minimum depth of 150 mm. The re-spread top-soil will be ripped to a depth of 300 mm along the contour with rip lines being a maximum of 1 m apart.

Drilling and gas drainage sites will be rehabilitated progressively during the life of the mine and initially will involve the decommissioning and removal of infrastructure, including gas drainage vacuum pump and generators. Boreholes will then be backfilled and capped, following the EDG01 guideline "*Borehole Sealing Requirements of Land: Coal Exploration".*

6.5 Controlling weeds, feral pests and access

The control of weeds, feral pests and site access is discussed separately below.

6.5.1 Weed control

The ecological assessment undertaken by Ecotone Ecological Consultants (2007) for Stage 1 and Ecotone Ecological Consultants (2009) for Stage 2 and site visits for the development of the RMP for Stage 1 and Stage 2 has identified 93 species of introduced flora on the mine site (Appendix B). Of these weeds, nine species are declared noxious weeds under the NSW *Noxious Weeds Act 1993* in the Narrabri Shire Council (NSC) (Table 10), of which the majority are Category 4 noxious weeds, with one Category 5 noxious weed. The location of these noxious weed species observed within the ML is illustrated within Figure 9.

Table 10: Declared noxious weeds recorded on the mine

Common Name	Species Name	Domain	Noxious Weed Category
Mother of Millions	*Bryophyllum delagoense*	6	4
Spiny Burrgrass	*Cenchrus longispinus*	5 & 6	4
Innocent Burrgrass	*Cenchrus incertus*	Uncertain*	4
African Boxthorn	*Lycium ferocissimum*	5 & 6	4
Prickly Pear	*Opuntia stricta* var. *stricta*	6	4
Galvanised Burr	*Sclerolaena birchii*	5	4
Noogoora Burr	*Xanthium occidentale*	5 & 6	4
Bathurst Burr	*Xanthium spinosum*	3 & 6	4

* Not classed as noxious at time of EA and so location uncertain.

Several other significant introduced flora species were observed, these being significant environmental and/or agricultural weeds (Table 11).

These species are strongly recommended for control as they will reduce the agricultural productivity of the land in the long-term once the mine is closed, they are declared noxious weeds in the adjacent council areas, they are significant environmental weeds or they can significantly increase fuel loads and bush fire threat to the mine.

Table 11: Other introduced flora that require control

Common Name	Scientific Name	Domain	Threat
Coolatai Grass	*Hyparrhenia hirta*	5	Fire, Environmental & Agricultural
Skeleton Weed	*Chondrilla juncea*	3	Agricultural
Mintweed	*Salvia reflexa*	5	Agricultural
Patterson's Curse	*Echium plantagineum*	5	Agricultural & Environmental
Cathead	*Tribulus terrestris*	5	Agricultural

The location of some of these noxious weeds and other environmental weeds is shown in Figure 9.

The control of noxious and environmental weeds will assist with the protection and management of remnant vegetation and habitat and minimise the impacts on fauna on the mine site.

The development of a detailed weed management plan is recommended and will benefit the control of noxious and environmental weeds found across the Pit Top Area and Underground Longwall Area.

Short-Term

The growth and spread of all noxious weeds will be controlled in accordance with the Noxious Weeds Act across the Pit Top Area and Longwall Area. All noxious weeds 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 except Galvanised Burr (*Sclerolaena birchii*). These plans are included in Appendix C.

Coolatai Grass will be controlled by the techniques described by the former I&I NSW (Appendix D). Other agricultural and environmental weeds will be controlled by techniques described by the local Authority.

Noxious weed management within the ML has been ongoing to date, and various methods for controlling Prickly Pear and Mother-of-Millions have been successful. These methods include:

- **Prickly Pear** - being managed using cochineal insects. This method should continue, targeting new stands when identified by transferring the insects from existing stands
- **Mother-of-Millions** - spraying mother-of-millions as soon as they are identified has proven the best control method and this method should continue as new stands are identified

Long-Term

At the time of mine closure, any noxious weed species present in the Pit Top Area and Underground Longwall Area will continue to be subject to a noxious weed management plan to be prepared by NSC.

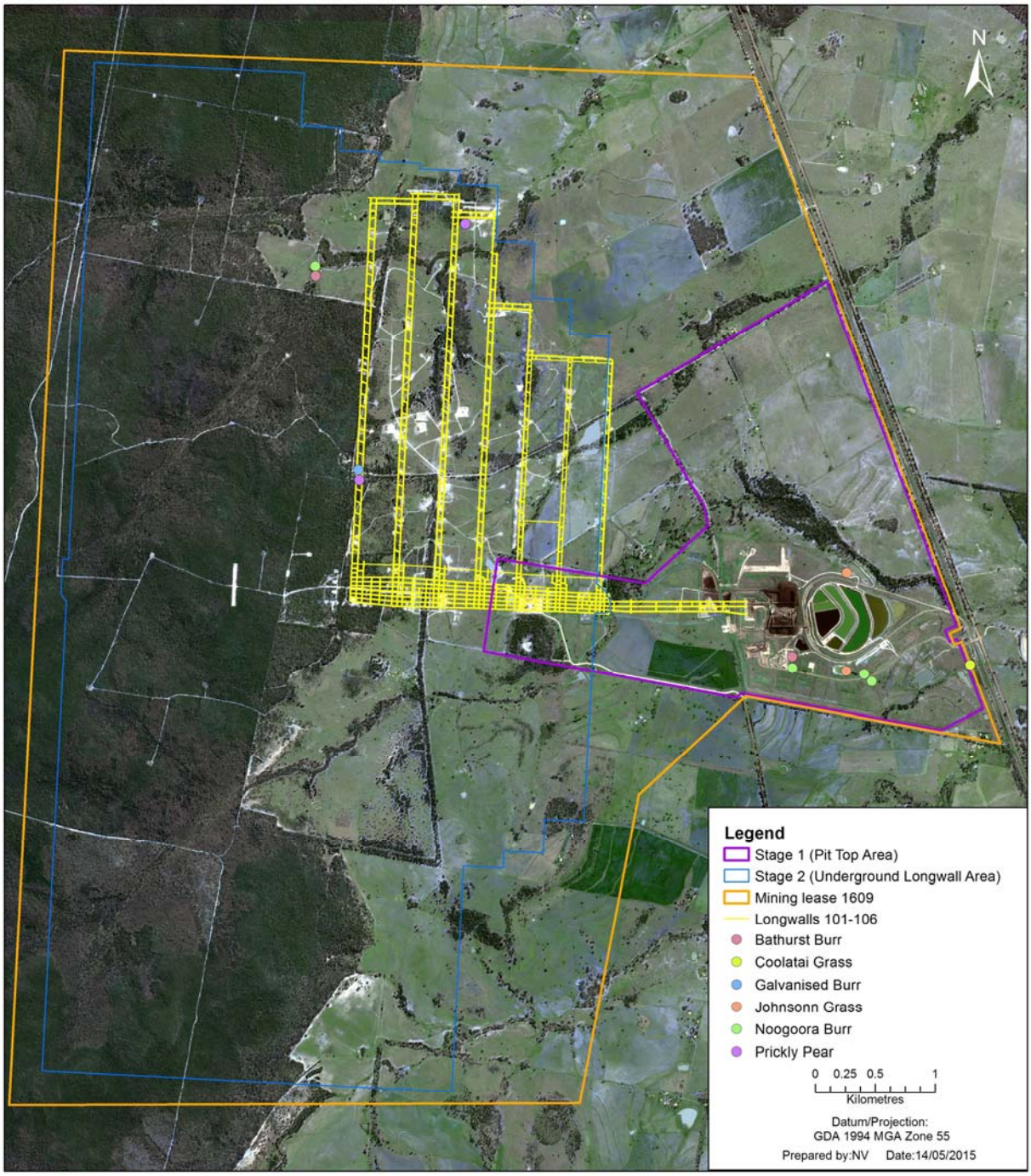


Figure 9: Location of noxious and environmental noxious weeds observed on the mine site

6.5.2 Feral pests

The aim of feral animal control is to minimise the effect that introduced vertebrate pests may have on grazing production, wildlife populations and soil stability. Fauna surveys during the environmental assessments for the project recorded eight introduced species of fauna across the mine. Three species, the Wild Dog (*Canis familiaris*), Rabbit (*Oryctolagus cuniculus*) and Pig (*Sus scrofa*), are declared pests under the NSW *Rural Lands Protection Act 1998* (RLP Act). One species, the Red Fox (*Vulpes vulpes*) is considered a nuisance species in NSW under the RLP Act and three other significant pest species, the Feral Cat (*Felis catus*), Brown Hare (*Lepus capensis*) and Starling (*Sturnus vulgaris*) were also recorded. The remaining introduced animals, Cattle (*Bos taurus*) and Sheep (*Ovis aries*), are domestic stock and these animals will be prevented from grazing in the Pit Top Area but may graze areas within the Longwall Areas that have been designated as agricultural grazing land.

The recommended control techniques for Wild Dogs and feral pigs include the use of poison meat baits with 1080 (sodium mono-fluroacetate), trapping and shooting. Poison meat baits will be laid around the boundary of the Pit Top Area and Longwall Area as and when required in consultation with the Livestock Health and Pest Authority (LHPA).

The recommended control techniques for Rabbits include baiting rabbits with 1080 (sodium mono-fluroacetate) and pindone poisoned carrots, biological controls such as myxomatosis and Rabbit Haemorrhagic Disease (RHD) and ripping of rabbit warrens.

The requirement for pest control will be assessed on whether there is a legal responsibility for NCOPL to undertake pest control and the significance of the threat (where NCOPL does not have a legal responsibility) to the management of the Pit Top Area and Longwall Area, areas of remnant vegetation and wildlife.

NCOPL have a legal responsibility to control Wild Dogs, Rabbits and Feral Pigs on the property and nuisance species will not be targeted for control unless they are causing problems on site. However, the Red Fox is susceptible to 1080 poison meat baits and baiting for Wild Dogs and Feral Pigs will also control the Red Fox.

Species such as the Brown Hare, Feral Cat and Common Starling will only be controlled if they are affecting the management of the Pit Top Area and Longwall Area, areas of remnant vegetation or wildlife.

All feral animal control techniques will be consistent with procedures recommended by the local LLS office and will have due regard to the welfare of the animals being controlled. If control is required, all available control methods will be investigated with the most effective and appropriate technique utilised. It must be noted that an integrated approach to feral animal control is often more effective and will involve several different control techniques to control feral animal populations effectively.

Short-Term

All feral animals declared as pests under the RLP Act, found on the Pit Top Area and Longwall Area will be controlled using techniques recommended by the local LLS. Nuisance species will be controlled if they are affecting the management of the Pit Top Area and Longwall Area using techniques recommended by the local LLS.

Long-Term

The short-term control of declared pests and nuisance pests will continue for the life of the mine as these pests are likely to continue to be present across the mine site in the long-term.

6.5.3 Access

Access to the Pit Top Area and Longwall Area will only be allowed for authorised personnel and machinery. Actions to be undertaken to prevent un-authorised access to the mine, will include:

- Signage at the entry of the mine site access road (intersection with the Kamilaroi Highway) indicating that authorised personnel only are permitted on site
- Signage on all boundary fencing indicating that the site is an active mine and indicating that unauthorised access is not permitted
- All visitors and contractors are required to sign in when arriving on site
- Utilisation of a system of inductions for all staff
- No machinery is permitted along Kurrajong Creek and remnant vegetation areas (Domain 6) without approval from the Environmental Officer
- All visitors and personnel not inducted will be required to be accompanied by an inducted person at all times.

These actions will be maintained for the life of the mine.

6.6 Bushfire management strategy

The bushfire management strategy for the mine is to identify all hazards and risks associated with bushfires for all properties owned by NCOPL. These objectives include:

- monitoring and maintaining areas where bushfire hazards are identified
- contain all outbreaks of fire related to the mine
- protect surrounding properties from fire damage originating from the NCOPL owned land.

The General Manager will have overall responsibility for the mining operation, including the responsibility for compliance in regards to bushfire management. The General Manager will ensure that all safeguards and controls are in place for the prevention of bushfires and that the desired environmental outcomes are achieved. It is recommended that a Bushfire Management Plan (BMP) be prepared for the mine operations, given the extent of native vegetation within and adjacent to the ML.

Potential cause of bushfire

The following are recognised as potential causes of bushfire across the mine:

- Fires on plant and equipment and/or occurring as a consequence of maintenance activities of plant or equipment
- Spontaneous combustion from stockpiled coal

- Inappropriate staff behaviour i.e. smoking on site (which is in breach of site rules) and/or undertaking activities without adequate controls
- Unrelated mining incidents e.g. lightning strike and ember attack
- Fire from adjacent land holdings.

Controls

NCOPL understands the need to follow adequate bushfire control measures to minimise potential bushfire hazards of the mine. These control measures are discussed below.

Mobile equipment

All earth moving machinery operating on the mine will be required to be:

- In good working order with efficient exhaust systems and spark arrestors. Regular inspections of these vehicles will be carried out as required by Clause 45 of the Coal Mine Health and Safety Regulation 2006
- All earth moving machinery and mobile equipment will be fitted with two appropriately sized and approved fire extinguishers (80 BE rated fire extinguishers) for the control of flammable liquid and electrical fires
- Where deemed required by risk assessment heavy machinery may be fitted with independent fire suppression systems.

Cutting and welding operations

Cutting and welding operations have the ability to start fires from sparks or hot materials. Where practical all cutting and welding activities will be confined to the main workshop area. If welding or cutting of materials is required outside of the main workshop area, the following safeguards will be employed:

- An area with a 10 m radius will be cleared of all flammable material, including oils, greases and fuels
- Fire extinguishers of an 80 BE rating will be positioned within 10 m of the work area
- A fire tender or water cart with fire suppression capacity will be put on stand-by during the welding or cutting operations.

Fixed plant and buildings

All fixed plant and buildings will be required to meet the BCA (Building Code of Australia) and comply with Australian Standard AS2419 and related Australian fire system standards. Where necessary, critical electrical control equipment will be protected by an automatic detection gas deluge systems.

Fuel and oil management

Fuel and oil storage is a potential source of fire and these areas will be managed by:

- All fuel and oil storage areas will be located and constructed in accordance with the requirements of the NSW OHS Amendment (Dangerous Goods) Act 2003

- Fuel and oil storages will be required to be signposted as to the contents of the materials and will be fitted with two 80 BE rated fire extinguishers
- All fuel tanks will be fully self-bunded to ensure that if leakage or rupture occurs, no fuel can escape from bunded areas
- Each bunded area will have the capacity for a minimum of 110% of the largest tank
- Drainage from the workshop, workshop apron and wash down areas will be directed to an oil separator and containment system for subsequent pumping and disposal
- A foam generator and an adequate supply of high expansion foam will be available on-site for combating oil-based fires

Smoking on-site

Smoking is a potential source of ignition. To minimise this risk, the mine is a non-smoking site and there are no designated smoking areas.

Spontaneous combustion

To reduce the potential for spontaneous combustion of coal stockpiles:

- Coal will be routinely turned over in the ROM and product coal stock pile areas to minimise stockpile storage time
- Longer term stockpiles will be shaped with a battered face created in the direction of the prevailing winds
- The stockpile area will be compacted by the use of mobile equipment
- Regular visual inspections for evidence of combustion (visual and smell) will be undertaken.

To reduce the potential for spontaneous combustion of the underground longwall panels and associated gas drainage systems, the following has been advised within the Environmental Assessment (R.W. Corkery & Co. 2009):

- The mine design should employ a low resistance ventilation system achieved through a seven heading mains trunk and two heading gate roads
- Small diameter ventilation shafts to be installed at the rear of every third gate road panel for ventilation of the gate road in bye of the active longwall face thus negating the need for a bleed system skirting the perimeter of the goaf
- Pre- and post- (goaf) gas drainage systems are to be implemented for gas management purposes thereby minimising ventilation pressures that would result if the ventilation system only were used to maintain gas concentration to acceptable levels
- Planned installation of high standard ventilation control devices
- Installation, operation and maintenance of a dual ventilation monitoring system (telemetric and tube bundle)
- On-site gas chromatograph

- On-site inertisation capability:
    - Pipework and valves fitted to all goaf seals to allow the injection of inert gas
    - Potential utilisation of in-seam drainage ranges
    - Access to Thomlinson Boiler and PSA Nitrogen gas generators, if required
- Implementation of Ventilation and Monitoring Arrangements and the related spontaneous combustion procedures and action response plans
- Implementation of a Gas Drainage and Outburst Management Plan which would
    - Define acceptable negative pressures at the collars of in-seam boreholes
    - Establish methods of intersecting and management of in-seam boreholes (R.W. Corkery & Co. 2009).

Emergency vehicle access

In order to control any fires that may occur on the mine:

- Access for emergency vehicles will be required and maintained around all mining related activities
- Clear access for emergency vehicles will be required around buildings associated with the mine
- Access gates to Domain 6, will be required for emergency vehicles to gain access in the event of a bushfire that may occur in this area.

Remnant vegetation

In Domain 6 where remnant vegetation can be found, the following protocol will be followed:

- Fuel loads will be monitored at 6 monthly intervals, with an inspection prior to the beginning of each bushfire season
- Access for emergency vehicles through gates to this area for fire fighting purposes will be required
- A graded fire break will be maintained along the boundary of Domain 5 to a minimum width of 6 m
- If fuel levels are identified as unacceptable, a fuel reduction burn may be implemented through consultation with the local Rural Fire Service (RFS) and NSC.

Stock grazing

NCOPL own fourteen properties (Table 3) surrounding the mine. The outside of the Pit Top Area, within the Domain 6 agricultural management area will require grazing at sustainable stocking rates to reduce pasture fuel loads and the fire risk from entering and leaving these NCOPL properties. This grazing regime will be maintained for the long-term and will be influenced by seasonal variation.

The Pit Top Area and active Longwall mining Areas (Remnant Vegetation, Riparian and Infrastructure Management Areas) will not be grazed as this will interfere with mining activities. Pasture areas in the Pit Top Area and Underground Longwall Area may require to be slashed to reduce pasture growth during summer months.

Fire fighting equipment

The following requirements will be followed for fire fighting purposes on the mine:

- A provision of fire equipment will be kept on-site in accordance with the operations emergency management plan
- All fire extinguishers will comply with AS/NZS 1841.1:2007
- All fire fighting equipment will be kept in operational condition and be inspected on a monthly basis
- A surface water truck equipped with water cannon will be maintained on site to provide an immediate response to a bushfire.

The minimum fire fighting equipment requirements at Narrabri Mine are defined in the Fire Fighting Equipment Standard which make provision for:

- 30 m x 60 mm fire hoses
- 30 m x 35 mm fire hoses to allow two hoses with two nozzles to be used simultaneously
- Breaching piece with manually operated cut-off valves
- Branch pipes and nozzles with 12 mm diameter outlets and suitable spanners
- Diffusers
- 80 BE fire extinguishers
- Approved foam making compound
- Approved foam making branch applicator
- 60 mm to 35 mm hose adaptor.

Water supply

Water for fire fighting purposes will be sourced from various water storages within the landholdings held by NCOPL.

Fire breaks

Suitable fire breaks will be established and maintained around the perimeter of the mining lease or associated landholdings and any flammable materials storage areas. These fire breaks will be:

- A minimum of 6 m wide
- Clear earth breaks free of flammable material
- Maintained at 6 monthly intervals and prior to the fire season.

Staff training

Training associated with fire control will include:

- All mine personnel, visitors and sub-contractors will be advised of the emergency escape protocol and safety points in the case of an emergency.

External assistance

In the event that a fire cannot be controlled by mine fire fighting teams, threatens surrounding private or public property, the emergency procedures identified in the NCOPL Fire and Emergency System will be followed. This will include the evacuation of all staff from the property and notification of external emergency services.

Reporting

The mine will liaise with the local RFS located in Narrabri and report on bushfire management measures, as required.

Bushfire management actions will be discussed in the AEMR.

6.7 Aboriginal cultural heritage

Archaeological Surveys and Reports Pty Ltd (AS&R) conducted an Aboriginal Heritage Assessment in 2009 for Stage 2. The assessment involved researching the existing archaeological records, consultation with the local Aboriginal community and a field survey of areas which are likely to be disturbed as a result of mining or mining related activities. The areas included in the field survey were the areas above longwall panels 1 to 26 (hereafter referred to as Domain 6), the Brine Storage Area (hereafter referred to as Domain 7) which is located in the Pit Top Area and the route of the proposed water pipeline between the Mine Site and the Namoi River (R.W. Corkery & Co. 2009). A detailed field survey was conducted over LW101-107, and a reconnaissance survey conducted over LW108-126. As a consequence, prior to disturbance above LW108-126, a more detailed field survey will be undertaken with an appropriately qualified archaeologist and the Aboriginal stakeholder groups.

6.7.1 Domain 6

A total of 112 Aboriginal Cultural Heritage sites were identified in Domain 6, with the exception of one site, all are located within 50 m of creek or drainage lines. There are 46 known Aboriginal Archaeological Sites above LW 101-106. The Project Approval conditions require sites of 'high' archaeological significance to be protected from mine subsidence related impact, Sites of 'high' archaeological significance include:

- Five scattered artefact sites above LW104
- Two grinding groove sites which comprises grooves in separate sandstone floaters above LW102 and LW105
- An open camp site is located to the south and outside of the extraction limits for LW105
- Two scarred trees above LW101 and 106 (DGS 2015)

The artefact sites were assessed for their significance by AS&R (2009) and of the 112 sites recorded above Domain 6, ninety-eight were deemed to be of low scientific significance due to the low densities of artefacts identified and being located in a disturbed context. The sites which are of high scientific

significance contain over 100 artefacts, with the potential of there being more than 500 artefacts. These high-density sites may provide information on knapping strategies, material choices and tool types. The site which has been identified as a fireplace is also significant in terms of it being able to provide information as to the period of Aboriginal occupation by way of radio-carbon dating charcoal or ash remains.

The sites which are determined to be of environmental significance will be protected from inadvertent or accidental damage by vehicular traffic by the erection of fencing, para-webbing or similar with 'Environmental Protection Zone' signage. Fencing would be removed upon completion of activities in the area so that cattle could resume grazing in the area which would provide a means of weed control and grass-fire hazard reduction. Where practicable the proponent has committed to avoiding the remaining aboriginal sites by modifying the location or alignment of surface disturbing activities and access roads. A majority of the sites will be avoided as a result of their locations being unsuitable for drilling purposes (R.W. Corkery & Co. 2009).

The Aboriginal sites over the remainder of the mining area will be subject to more detailed field surveys, targeting more specific areas. The field survey and development of specific management measures would be undertaken in accordance with the updated Aboriginal Cultural Heritage Management Plan (ACHMP) for the mine site. This approach to managing Aboriginal sites is appropriate as during the time in which longwall mining commences and disturbance over longwall 8 and beyond occurs, it is likely that sites which are currently not visible will become so and sites which are exposed will no longer be identifiable.

It has been acknowledged by the proponent that on some occasions the location of disturbance associated with ventilation and gas drainage is unable to be relocated without compromising a safe underground environment. A list of these sites is contained within the Narrabri Coal Mine Stage 2 Longwall Project Environmental Assessment. In the instance that any of these sites are unable to be avoided the artefacts would be salvaged and removed to a secure place which has been agreed upon by the registered Aboriginal stakeholders. Prior to salvage operations the Narrabri Local Aboriginal Land Council and Gomeroi Narrabri People would be consulted. Subject to agreement with the local Aboriginal stakeholders, salvage would be undertaken in accordance with the ACHMP as follows:

- Artefacts would be salvaged by an archaeologist who would be accompanied by Sites Officers from Narrabri LALC and Gomeroi Narrabri People
- The archaeologist would tag the artefacts and undertake a full analysis of the material in order to provide an appropriately detailed salvage report
- The salvaged artefacts would be returned to the authorised Aboriginal organisation within 21 days of salvage
- An Aboriginal organisation, agreed upon by Narrabri LALC and Gomeroi Narrabri People will become custodians of the artefacts
- A report would be produced by the archaeologist which would provide full descriptions of the salvaged material and an interpretation of the archaeological record within the Salvage area
- Copies of the reports would be given to Narrabri LALC, Gomeroi Narrabri People, OEH and the proponent

- Updated Site Recording Forms would be lodged to OEH by the archaeologist for those sites which have been salvaged so that the AHIMS Site Register can be updated
- The proponent has committed to provide an interim storage facility should an appropriate long term storage facility or 'keeping place' be unavailable at the time of salvage. This interim storage facility will be decided upon following consultation with the local Aboriginal stakeholders and OEH (R.W. Corkery & Co. 2009).

A requirement of the Aboriginal Cultural Heritage Management Plan is that Kurrajong Creek is fenced and protected to prevent disturbance from mining activities in this area. Access to this area requires permission from the Environmental Manager. The rehabilitation works that require access to Kurrajong Creek include weed control works and the establishment of fire breaks.

The weed control works will result in minimal soil disturbance. These works will not disturb the Aboriginal Cultural Heritage sites in Domain 6. Similarly, the fire break to be established in this area is to be a slashed fire break and this work will not disturb the soil and the Aboriginal Cultural Heritage sites in Domain 6. The Aboriginal Cultural Heritage site in Pine Creek will not be disturbed by mining activities.

There is no conflict between rehabilitation works for the mine and Aboriginal Cultural Heritage for Domain 6.

If future works require major soil disturbance works, in the vicinity of Aboriginal Cultural Heritage sites, the actions outlined in the Aboriginal Cultural Heritage Management Plan will be followed.

6.7.2 Domain 5

A total of nine artefact sites were identified in this domain, three of which contained isolated artefacts, two contained 2 artefacts, two contained 3 artefacts and two contained 5 artefacts (R.W. Corkery & Co 2009).

None of the sites identified within this domain have been determined to be of scientific significance by AS&R (2009) (R.W. Corkery & Co. 2009)

If future works require major soil disturbance works, in the vicinity of the site, the actions outlined in the Aboriginal Cultural Heritage Management Plan will be followed.

6.7.3 Proposed water pipeline

There were no sites identified during the survey of the proposed Water Pipeline Route (R,W, Corkery & Co.2009) .

6.7.4 Protecting aboriginal cultural heritage sites

Aboriginal Cultural Heritage Sites are required to be marked where disturbance is predicted to occur in order to avoid inadvertent damage to the heritage sites.

Temporary identification of these sites will be required if future works require major soil disturbance, in the vicinity of Aboriginal Cultural Heritage sites. If this occurs the actions outlined in the Aboriginal Cultural Heritage Management Plan will be followed.

If new Aboriginal Cultural heritage sites are discovered, the process identified in **Section 3.4** of the Aboriginal Cultural heritage Management Plan will be followed.

6.7.5 Aboriginal cultural heritage education

To protect these Aboriginal Heritage sites from rehabilitation works, all staff working in these areas will have undertaken Cultural Awareness training as included as part of the general mine site induction

6.7.6 Monitoring and reporting

All monitoring undertaken by the Narrabri Local Aboriginal Land Council and the Gomeroi Narrabri People will be documented and included in the AEMR on the measures that have been implemented to preserve and protect the Aboriginal Cultural Heritage sites on the mine.

The results of the monitoring undertaken will be provided to the local Aboriginal community as part of the ongoing consultation between the Narrabri Local Aboriginal Land Council and the Gomeroi Narrabri People and NCOPL.

6.7.7 Discovery of potential aboriginal sites or artefacts

The ACHMP has outlined a procedure which will be followed in the event that potential sites or artefacts are subsequently discovered:

1. Work will cease in the area of discovery
2. If the area of discovery is in deposited material, then work will also cease in the area that the material has come from
3. The person discovering the artefact will notify their superior who will then ensure that work has ceased and the area(s) is(are) cordoned off with tape
4. The supervisor will notify the General Manager or senior NCOPL person on site
5. The General Manager will:
    a. Request a qualified archaeologist to attend to the site and advise on its archaeological significance
    b. Request the site monitor for Gomeroi Narrabri People and the Narrabri LALC, if not already present to attend and advise on its cultural significance in consultation with the qualified archaeologist
    c. If the find is determined to be a site, notify the OEH with the advice from the archaeologist and the Gomeroi Narrabri People and Narrabri LALC for determination of further procedures
6. If the find is confirmed as site, the archaeologist will complete a Sites Register Card and forward to the OEH for inclusion on the Aboriginal Heritage Information Management System (AHIMS) database
7. Subject to the determinations by the archaeologist and the Gomeroi Narrabri People and Narrabri LALC, the appropriate permit to disturb (under Section 90 of the *National Parks and Wildlife Act 1974* (NPW Act)) or transfer (under Section 85A of the NPW Act) will be applied

prior to further work being undertaken in the vicinity of the site. Any such action to disturb or transfer Aboriginal items will also require the development of excavation or salvage plans in consultation with OEH

8. The General Manager will implement any other procedures or recommendations issued by the OEH (Narrabri Coal P/L 2007).

6.7.8 Contingency plan

Should damage inadvertently occur to any Aboriginal Site or place within the mine site, the activities causing the damage will cease immediately and procedures identified in section 3.4 of the ACHMP (outlined in Section 6.7.7 of this report) will be followed.

7 Completion Criteria

Completion criteria for the long-term rehabilitation of the mine are largely conceptual as the life of the mine will exceed 25 years. Long-term completion criteria have been outlined in the Stage 2 MOP (NCOPL 2011) and relate closely to the rehabilitation actions in Section 5 of this RMP. Rehabilitation actions and associated completion criteria are listed in Table 12. Completion criteria include:

- Decommissioning and removal of all project related infrastructure not required for the future use of the site
- The creation of a low maintenance, geo-technically stable, safe and well vegetated landform which blends with the surrounding natural landscape
- The cut and fill disturbance within the ROM Coal Pad, Product Coal Stockpile Area and longwall unit assembly area would be profiled to ensure it has safe and stable slopes on construction. These slopes would be shaped to create a more undulating landform consistent with the surrounds
- Backfilling of the box cut and blending of the final landform with the surrounding topography such that the visual impact of the post-mining landform is minimised
- The perimeter amenity bund within the Pit Top Area will be removed (with the exception of the area adjacent to or near Kurrajong Creek) with the material used to backfill the box out. The retained section of bund would be well vegetated and would act as a wind break for future agricultural activities and fauna habitats
- Progressive rehabilitation of drilling and gas drainage sites to undertaken, including capping and revegetation
- Remediating any land contaminated by accumulated salts or hydrocarbon spills / leaks
- Re-establishment of agricultural land of comparable land capability to that of the pre-disturbance environment i.e. Class III.

7.1 Landform stability

Rehabilitation activities identified in the Stage 1 MOP (R.W. Corkery & Co. Pty Ltd 2007) and Stage 2 MOP (NCOPL 2011) that relate to landform stability include the:

- Creation of a low maintenance, geo-technically stable, safe and well vegetated landform which blends with the surrounding natural landscape
- Backfilling of the box cut and blending of the final landform with the surrounding topography such that the visual impact of the post-mining landform is minimised.

Table 12: Completion criteria for a stable landform

Rehabilitation Action	Completion Criteria	Rehabilitation Criteria Addressed	Corrective Action
Landscaping	• Geotechnically stable, and safe landform • Blends with surrounding landscape	Section 6.3	Develop and agree on new objectives with DRE and DP&E
Weed Management	• Weed management procedures have been implemented to control noxious weeds • Target weed species are reduced from initial levels • Appropriate steps have been taken to minimise the introduction of new weeds from machinery, top soil and seed mix • The site is of comparable land capability to that of pre-disturbance environment	Section 6.5.1	Liaise with local pest authority to discuss alternative/new weed control actions
Contouring	• Slopes have been contoured to pre-determined or equivalent to pre-mining topography • Top soil has been replaced over areas of disturbance in the appropriate order i.e. 15 cm for top-soil and 25 cm for sub-soil • Top-soil has been ripped to a depth of 300 mm at 1 m spacing's	Section 6.4	Operations will be undertaken a second time if required
Landform Stability	• Minimal evidence of rilling >5 mm deep and >5 mm wide	Section 6.4	Reform landscapes if significant rilling occurs
Soil Suitability	• EC values are sufficiently low to allow survival and growth of preferred plant species	Section 6.4	Determine the cause of any problems identified and identify what corrective actions can be implemented

Rehabilitation Action	Completion Criteria	Rehabilitation Criteria Addressed	Corrective Action
	• Visual inspections show that no crusting of soil or excessive compaction exists		Implement corrective actions
Land Capability	• Area of land re-habilitated to Class III with Class VII lands confined to Kurrajong Creek	Section 6.3	
Monitoring and Maintenance	• A monitoring programme has been implemented that addresses completion criteria and influences site management	Section 8	

7.2 Removal of infrastructure

At the cessation of mining activities, much of the infrastructure will be decommissioned (R.W. Corkery & Co. Pty Ltd 2007 and NCOPL 2011), including:

- The Coal Handling and Preparation Plant (CHPP) and associated infrastructure
- ROM and product coal stockpile hardstand areas
- Various fuel storages, workshops and offices
- Infrastructure related to the transport, conveyor and ventilation drifts
- Ventilation shafts and associated infrastructure
- Drilling and gas drainage associated infrastructure
- All structural foundations to ground level
- Roads not to be maintained in the final landform.

However, the future landowner may wish to retain some items of surface infrastructure and this will be negotiated at the time with the future landowner. The rehabilitation criterion for the removal of infrastructure has been addressed in the MCP.

7.3 Rehabilitation assessment sign-off

Once the rehabilitation monitoring indicates that the completion criteria have been achieved, the NCOPL Environment Manager will undertake the following steps:

- Engage suitably qualified and experienced consultants to complete a final rehabilitation assessment and record findings to ensure all objectives have been met

- Collate all AEMR for reporting to the DPI – Minerals as part of the Lease Relinquishment Report (LRR), which will be prepared by the NCOPL Environment Manager
- The NCOPL Environment Manager is to arrange for a meeting with NSW Trade and Investment to discuss the outcomes of the LRR and address any outstanding issues that may potentially exist
- Arrange for a meeting with relevant Government agencies to obtain consensus that the necessary requirements have been fulfilled and that no further work is required.

8 Rehabilitation Monitoring

Rehabilitation actions will be monitored regularly as part of this RMP. The objectives to be monitored for include:

a) Longwall subsidence (Section 5)

b) Managing remnant vegetation, habitat and minimising impacts on fauna on site (Sections 6.1 and 6.2)

c) Minimising visual impact (Section 6.3)

d) Top-soil conservation measures (Section 6.4)

e) The control of weeds (Section 6.5.1)

f) The control of feral animals (Section 6.5.2)

g) The control of access to the mine site (Section 6.5.3)

h) Bushfire management (Section 6.6).

Further details of the monitoring methodologies are described below. These results will be:

- Compared against rehabilitation objectives and targets
- Identify possible trends
- Options to improve rehabilitation.

All monitoring will be reported in the AEMR for the mine.

8.1 Rehabilitation monitoring methods

The following methods are proposed to monitor the objectives above.

8.1.1 Remnant Vegetation and Fauna Habitat

The effective management of habitat and minimisation of impacts on fauna will be monitored by the production of vegetation maps and photo monitoring points.

The vegetation maps will document the extent of remnant vegetation across the Pit Top Area and Underground Longwall Area through time to illustrate that no vegetation has been cleared outside of the development footprint on a yearly basis. At the closure of the mine, the extent of remnant vegetation along the Kurrajong Creek will be at least the same as the pre mining landscape or in improved condition.

Associated with this will be the establishment and subsequent monitoring of photo monitoring points. Appropriate numbers of photo monitoring points will be established across the areas of remnant vegetation (Kurrajong Creek and Domain 6) to demonstrate that the remnant vegetation and habitat is being managed and that impacts to fauna are being minimised. At the closure of the mine, the condition of the remnant vegetation along Kurrajong Creek and the Domain 6 is to be similar to the pre-mining landscape.

A standard photo monitoring point will include:

- Two six foot star droppers 10 m apart, the second star picket will be in a south east direction from the first star picket
- Tag the star droppers with flagging tape and replace flagging tape on an annual basis
- The location of the first star picket will be recorded with a GPS
- Use a range pole as a reference point against the second star dropper, with details of the photo monitoring point marked
- Take a digital photo of each photo monitoring point from the first star picket in a south east direction to the second star dropper, with the whole length of the range pole in view
- Organise the digital photos logically with each image labelled with a unique reference number indicating the location of the photo monitoring point and the date the photo is taken (i.e. "01_2009_09_08" for photo point 1 taken on the 8 September 2009).

Both the vegetation maps and photo monitoring points will be monitored on an annual basis when the mine begins operations, until mine closure is complete.

8.1.2 Top-soil conservation measures

Top-soil stockpiles will be monitored using photo monitoring points as described above in Section 8.1.2. Ten photo monitoring points will be established to monitor top-soil stockpiles across the Pit Top Area. At each top-soil stockpile associated with the longwall mine ventilation shafts and gas drainage sites, monitoring will be undertaken utilising the same method mentioned above, until the stockpile is used to cap and backfill. The top-soil will be considered stable after five consecutive years showing the growth of pasture grass. This information will be reported in the AEMR.

8.1.3 Weed control

All areas where weed control is undertaken will be recorded using a GPS and details will be recorded on field data sheets identifying the species being controlled, the method of control, numbers of plants controlled and growth stage of the plant. This will provide a record of actions undertaken on a yearly basis which will assist in verifying the effectiveness of control treatments.

Bi-annual surveys will be undertaken across the Pit Top Area and Longwall Area to survey for new infestations of weeds. Any new infestations will be subject to an appropriate weed control programme.

Completion criteria for weed control will involve the demonstration that all reasonable steps have been undertaken to control known infestations of target weed species across the Pit Top Area and Longwall Area.

8.1.4 Feral animal control

The Wild Dog is the only feral animal species that requires control across the site. The number of baits placed, the number of baits taken and any dead animals observed will be recorded. This will be undertaken for each baiting period as recommended by the local LLS officer. This will be undertaken for the duration of the mining lease.

8.1.5 Access

Access will be monitored by recording the number of incidences of non-compliance with the strategies outlined in this RMP. If NCOPL deem the number of incidences as unacceptable, these strategies will be revised. The number of non-compliance incidences will be reported annually.

8.1.6 Bushfire

Bushfire monitoring strategies will require monitoring. The monitoring requirements have been discussed below in Table 13.

Table 13: Bushfire strategy monitoring requirements

Bushfire Strategy	Monitoring Action	Monitoring Regularity
Mobile Equipment	• Exhaust systems and spark arrestors functioning adequately • All vehicles fitted with appropriate fire extinguishers	• Monthly • Monthly
Fixed Plant and Buildings	• All plant and buildings fitted with appropriate fire extinguishers	• Monthly
Fuel and Oil Management	• Contents of fuel and oil storage identified • Appropriate fire extinguishers fitted • Foam generator in working order • Adequate supply of high expansion foam available	• Monthly • Monthly • Monthly • Monthly
Spontaneous Combustion	• Ensure regular turn-over of coal stocks • Long-term stockpiles battered • Stockpile area compacted by mobile equipment • Visual inspections for combustion	• Weekly • Monthly • Monthly • Weekly
Emergency Vehicle Access	• Access for emergency vehicles maintained	• 6 monthly
Remnant Vegetation	• Visual assessment of fuel loads	• 6 monthly
Fire Fighting Equipment	• Fire fighting equipment available meets requirements of *Coal Mine Health and Safety Regulation 2006.* Fire fighting equipment in operational condition	• Yearly • Monthly
Water Supply	• Water supplies available	• Monthly
Fire Breaks	• Fire breaks established and maintained to standards	• 6 monthly
Staff Training	• Fire training requirements implemented • Fire teams formed and operational	• As required • 6 monthly

8.1.7 Landform stability

Point intercept transects will be established to monitor landform stability. The numbers of transects established for monitoring purposes for each domain are shown in Table 14 and each transect will be a minimum of 50 m apart. Each transect will be 100 m in length and will run in an east-west direction,

roughly perpendicular to the contour. The beginning and end of each transect will be permanently marked with a star dropper. Along each transect at every 1 m interval the following information will be recorded:

- Pasture species touching the point
- The presence/absence of bare ground
- Erosion occurring at the point.

While implementing the monitoring programme, if the key monitoring objectives (i.e. soil erosion, new weed species) are observed adjacent to the transect (i.e. not directly on the transect), the location will be recorded and included in the report as occurring outside of the monitoring transects.

These monitoring transects will be established within Domain 5 upon approval of the RMP. These transects will not be established in Domains 2, 3, 4, 6, 7 and 8 until mine closure is initiated.

The final landform will be considered stable when for five consecutive years >85% of pasture grasses are established, there is <15% bare ground and there are no visible signs of erosion for each domain.

Table 14: Number of monitoring transects required in each domain

Domain	Number of Transects	Comments
1	0	Infrastructure is to remain, no monitoring required
2	3	Transects to be 50 m apart
3	3	Transects to be 50 m apart
4	6	Transects to be 50 m apart
5	10	Transects to be 50 m apart
6	1 or more (depending on ventilation shafts)	Transects to be 50 m apart around ventilation shaft areas
7	3	Transects to be 50 m apart
8	6	Transects to be 50 m apart

8.1.8 Revegetation

Areas where revegetation has occurred will be monitored by counting the survival rate of trees that have been planted from 50% of areas planted. The number of trees planted in each area will be recorded when they are planted and the survival rate will be monitored on a 6-monthly basis for the first two years and a yearly basis after that. If the survival rate of trees falls below 50% additional plantings will be undertaken to reflect a minimum of 80% of the initial plantings of each area.

Table 15: Summary of monitoring actions and associated completion criteria

Objective	Action	Timing	Completion Criteria
Remnant Vegetation and Habitat Monitoring	• Photo Monitoring points • Vegetation Mapping	• Yearly	• Vegetation is in similar condition to pre-mining condition • Remnant vegetation extent along Kurrajong Creek is the same as

Objective	Action	Timing	Completion Criteria
			the pre-mining extent
Top Soil Conservation	• Photo Monitoring points	• Yearly	• Five consecutive years of photos showing pasture growth on top soil
Weed Control	• Weed distribution maps • New outbreaks	• Yearly • Bi-annually	• Targeted weed control has been undertaken throughout the mines operation
Feral Animal Control	• Wild Dog control is undertaken	• Twice Yearly	• Feral animal control undertaken throughout the mines operation
Access	• All identified steps to restrict access are followed	• Yearly	• Access is maintained and monitored throughout the life of the mine
Landform Stability	• Transects monitored as required	• Yearly	• Five consecutive years of landform stability
Revegetation	• 50% of revegetation plots monitored	• Yearly	• >50% survival rate for all revegetation

8.2 Longwall subsidence area monitoring

The aim of the monitoring over the longwall impact areas is to enable NCOPL to demonstrate progression towards the management objectives outlined within the EP. The key relevant management objectives are:

- To maintain and/or restore biodiversity and ecological integrity of areas affected by mining or agriculture within the mining lease
- To maintain and/or re-establish agricultural land of comparable land capability to that of the pre-disturbance environment
- Creation of stable post-disturbance landform
- To monitor rehabilitation success in terms of physical and biological parameters.

8.2.1 Impact zones

Both modelled and empirical studies indicate that LWMS at the site will create a series of surface troughs on the landscape (Figure 10) (MSEC 2007, DGS 2015). For impact monitoring we have considered that the surface zones can be classified as: the zone of maximum subsidence (longwall); the zone of maximum stress and tilt (transition) and the zone above the pillar with minimal subsidence (pillar). Control zones (no impact) will be selected from sites located outside of any predicted subsidence zone.

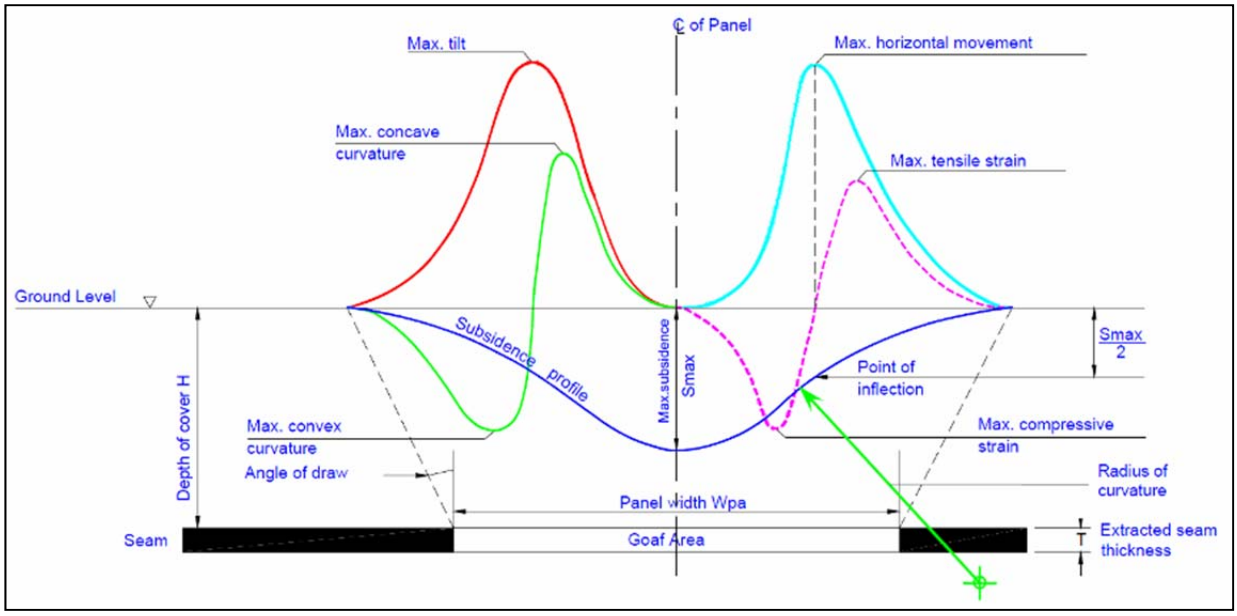


Figure 10: Longwall profile including subsidence and stress zones (MSEC 2007)

8.2.2 Summary of impacts and environmental consequences

Considering the landscapes and land uses in the mining area and the planned extraction methods, surface impacts range from slight to potentially significant. Table 16 provides a summary of the potential surface consequences of longwall mine subsidence in the area.

An assessment of the predicted impacts and potential consequences on agricultural, native woodland and channel areas includes:

- Agricultural consequences: soil erosion and deposition; altered soil moisture and nutrient distribution; reduced pasture productivity
- Woodland consequences: tree and shrub loss; reduced canopy condition; altered vegetation structure; soil erosion and deposition; altered soil moisture and nutrient distribution
- Creek line consequences: ponding; increased erosion; riparian vegetation degradation.

In addition to these consequences there is potential to increase weed species numbers and cover through changes to site management and water movement.

Table 16: Consequences associated with longwall mine subsidence

Subsidence consequence	Potential environmental consequence		Potential ecological/agricultural response
Surface Subsidence Trough	Tilted ground surface	Tilted of trees and shrubs	Tree and shrub loss through tree fall
	Altered surface and subsurface flow	Redirection of soil moisture and material/chemicals transported by flow	Altered soil moisture or nutrient distribution patterns
Surface Cracking	Cracking in the soil	Increased surface drainage	Altered vegetation and habitat, decreased or increased productivity
		Root shear	Potential tree/shrub death
		Large cracks in soil surface	Increased risk of erosion
			Fauna may fall into cracks which could cause injury or death
Subsurface Cracking	Altered surface and subsurface flow	Changes to both surface and groundwater availability	Alteration of vegetation structure and diversity, alteration of habitat
			Changes to floristics and/or structure of Groundwater dependant ecosystems occur near the site
	Cracking in the subsurface of the soil	Root shear	Potential tree/shrub death
Slope Instability	Landslip of surface terrain	Increased erosion and sedimentation of drainage lines	Soil loss and exposure of sub-soil
	Headcuts above chain pillars		Loss of vegetation
Valley Uplift	Tilted ground surface	Re-routed surface flows which resurface downstream of damaged areas	Altered vegetation structure and diversity, altered habitat
		Sequence of troughs and ridges akin to chain-of-ponds	
Ponding	Drainage channel re-alignment		Degradation of riparian vegetation
	Increased local erosion, localised changes in water availability		Increased erosion
Altered channel	In-stream and over bank ponding		Degradation of riparian vegetation

Subsidence consequence	Potential environmental consequence	Potential ecological/agricultural response
gradient	Increased salinity downstream as a result of ponding over saline soils	Decreased productivity on agricultural lands
	Increased erosion of creek banks	Altered vegetation and habitat

8.2.3 Longwall Mine area monitoring procedures

Given the size of the target area and the multiple land uses and key environments a multi-scale, multi-data source monitoring approach has been developed (Table 17). It is proposed to use remote sensing data (LiDAR, multi-spectral imaging) to monitor across the entire target area including control areas and EM38 to survey the soil in the agricultural areas. The remotely sensed data will provide for quantitative comparison of key land surface condition parameters in agricultural, woodland 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.

At the local scale a program of field survey based on a stratified random and targeted design will be implemented for agricultural, woodland and creek line areas. Surveys will be directed into control areas and at each of the 3 impact areas (longwall, transition, pillar) and will allow direct comparison between these areas through time and space. This field survey program will be defined further within each individual EP.

Quantitative methods will include statistical techniques that permit comparisons between treatment zones and through time. At this stage ANOVA (Analysis of Variance) and time series analysis are considered sufficient for these comparisons.

8.2.4 Reporting and review

Reporting of all survey 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 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 a stakeholder workshop with key government staff to ensure continued acceptance of the methodology and results.

Table 17: Multi-scale longwall mine area monitoring program

Data source	Type	Scale	Purpose
Remote sensing	Lidar	Entire site	Topographic form Woodland parameters Creek profile and dimensions
	Multi-spectral imaging	Entire site	Agricultural pasture cover/biomass Woodland cover/biomass Erosion monitoring Direct field survey
	EM38	Agricultural areas	Soil moisture and nutrient zones
Agricultural survey	Pasture survey	Within agricultural zones (soil type, paddock)	Pasture biomass and composition
	Soil Survey	Within agricultural zones (soil type, paddock)	Soil nutrient status
Woodland survey	Vegetation survey	Within remnant and riparian patches	Woodland health and function
	Fauna survey	Within remnant and riparian patches	Woodland health and function
	Soil survey	Within remnant and riparian patches	Soil condition
Creek line survey	Geomorphic survey	Along creek lines	Creek stability and condition
	Cross-sections	Targeted pools	Bank and bed stability

9 Roles and Responsibilities

It is the responsibility of NCOPL Environmental Manager to implement, monitor and review this RMP. This will be determined by routine inspections over time and reported in the AEMR. The AEMR will identify:

- what actions have been undertaken
- who undertook the work i.e. NCOPL or a sub-contractor
- what actions have not been undertaken and why not
- outcomes of management actions and monitoring
- problems associated with management actions
- proposed changes to management actions to improve outcomes.

References

Australian Archaeological Survey Consultants Pty Ltd (2007) *Aboriginal Heritage Assessment. Prepared for Narrabri Coal Pty Ltd*. Prepared by Australian Archaeological Survey Consultants Pty Ltd

Cunningham, G. (2007) *Narrabri Coal Project, Soil Survey and Land Survey Capability Study.* Prepared for Narrabri Coal Pty Ltd. Prepared by Geoff Cunningham Natural Resource Consultants, Pty Ltd

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.

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.

Eco Logical Australia (2010) *Narrabri Coal Mine Stage 1 and 2 Biodiversity Offset Strategy.* Prepared for Narrabri Coal Operations Pty Ltd

Eco Logical Australia (2009) *Narrabri Coal Mine Stage 1 Landscape Management Plan*. Prepared for Narrabri Coal Operations Pty Ltd

Ecotone Ecological Consultants Pty Ltd (2007) *Narrabri Coal Project Ecological Assessment*. Prepared for R. W. Corkery and Co. Pty Ltd

MSEC 2007, *Introduction to longwall mining and subsidence*, Revision A, August 2007, Mine Subsidence Engineering Consultants, Sydney, www.minesubsidence.com/index_files/page0004.htm

Narrabri Coal Operations Pty Ltd (2014) *Annual Environmental Management Report (ML1609) and Annual Review (PA 08_0144 MOD 2) for the Narrabri Mine*. Narrabri Coal Pty Ltd Gunnedah

Narrabri Coal Operations Pty Ltd (2011) *Mining Operations Plan for the Stage 2 Longwall Project of the Narrabri Coal Mine.* Narrabri Coal Pty Ltd Gunnedah

Narrabri Coal Operations Pty Ltd (2007a) *Narrabri Coal Pty Ltd Environmental Management Strategy for the Narrabri Coal Mine*. Narrabri Coal Pty Ltd Gunnedah

Narrabri Coal Operations Pty Ltd (2007b) *Narrabri Coal Pty Ltd Aboriginal Cultural Heritage Management Plan for the Narrabri Coal Mine.* Narrabri Coal Pty Ltd Gunnedah

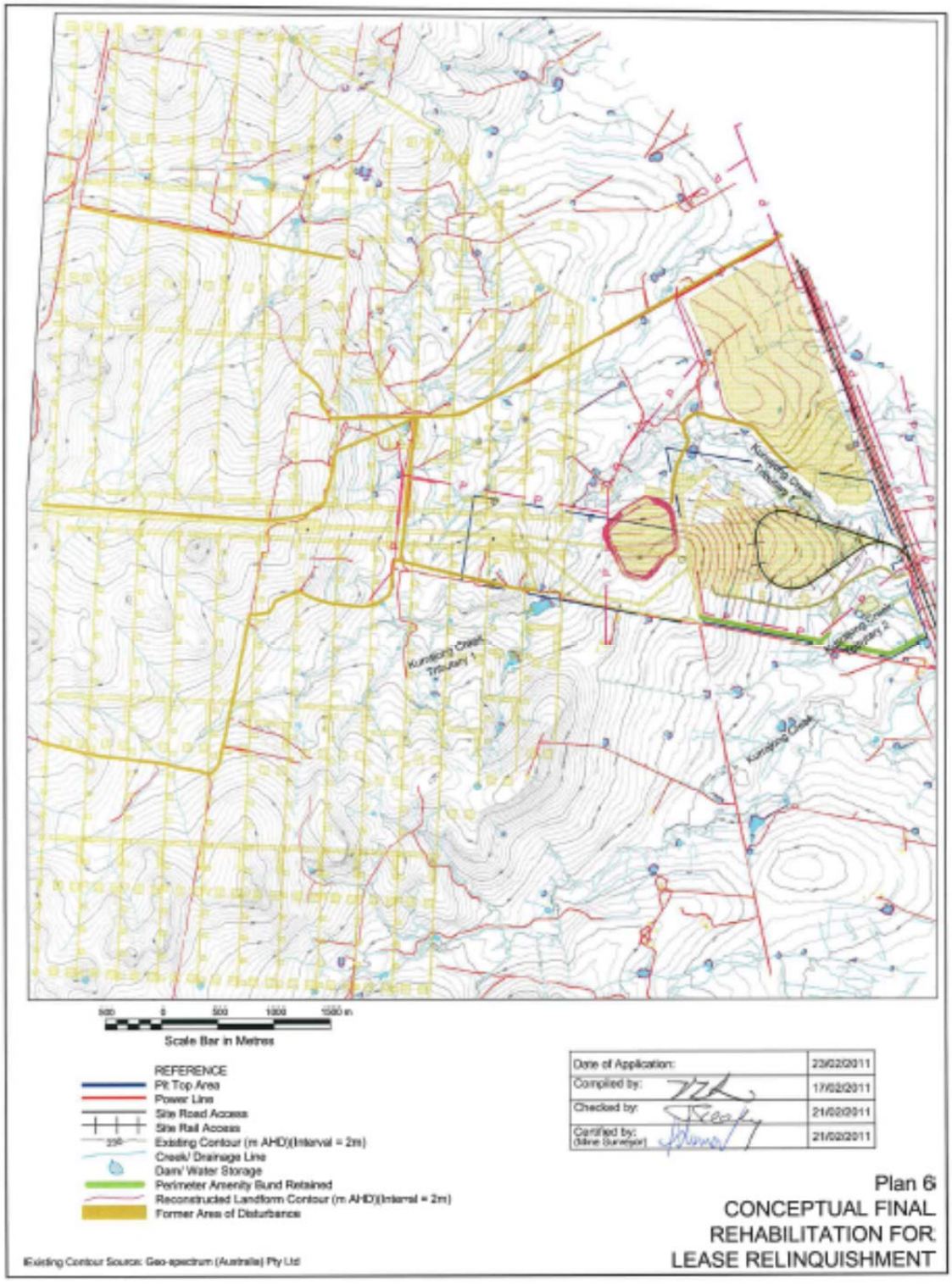
NSW Department of Planning (DoP) (2010) *Project Approval – Section 75J of the Environmental Planning and Assessment Act 1979.*

NSW Minerals Council Ltd (2007) *NSW Minerals Council Rehabilitation by Design, Practice Notes*. NSW Minerals Council Ltd Miningenuity, Sydney Australia.

R. W. Corkery & Co Pty Ltd (2007*) Narrabri Coal Pty Ltd Mining Operations Plan for the Construction and Continuous Miner Development of Stage 1 of the Narrabri Coal Mine for the Period Ending 31 December 2011*. R. W. Corkery and Co Pty Ltd

R. W. Corkery & Co Pty Ltd (2009) *Environmental Assessment for the Narrabri Coal Mine Stage 2 Longwall Project.* R. W. Corkery and Co Pty Ltd

Appendix A Conceptual Final Rehabilitation for Lease Relinquishment



Appendix B Weed Species Recorded

Scientific Species	Common Name	Noxious Weed Category
Alternanthera pungens	Khaki Weed	
Amaranthus retroflexus	Red-root Amaranthus	
Arctotheca calendula	Capeweed	
Argemone ochroleuca	Mexican poppy	
Aster subulatus	Wild aster	
Bidens subalternans	Greater beggar's ticks	
Cenchrus incertus	Spiny-burr Grass	4
Cenchrus longispinus	Innocent weed / spiny burrgrass	4
Chenopodium pumilo	Fishweed	
Chloris gayana	Rhodes grass	
Chloris virgatus	Feathertop Rhodes Grass	
Chondrilla juncea	Skeleton Weed	
Cichorium intybus	Chicory	
Cirsium vulgare	Spear Thistle	
Citrullus lanatus	Camel Melon	
Convolvulus remotus	Field Bindweed	
Conyza bonariensis	Flaxleaf Fleabane	
Cucumis myriocarpus	Paddy Melon	
Cynodon dactylon	Couch	
Dittrichia graveolens	Stinkweed	
Eragrostis cilianensis	Stinkgrass	
Eragrostis curvula	African Lovegrass	
Fumaria sp.	Fumitory	
Glandularia aristigera	Moss verbena / Mayne's pest	
Gomphocarpus fruiticosus	Swan Plant	
Gomphrena celosioides	Gomphrena Weed	
Hibiscus trionum	Bladder Ketmia	
Hyparrhenia hirta	Coolatai Grass	
Hypochaeris radicata	Flatweed/catsear	

Scientific Species	Common Name	Noxious Weed Category
Lepidium africanum	Peppercress	
Lepidium sp.	Peppercress	
Malva parviflora	Mallow Weed	
Malvastrum americanum	Spiked Malvastrum	
Marrubium vulgare	White horehound	
Medicago polymorpha	Burr medic	
Medicago sativa	Lucerne	
Melinis repens	Red Natal Grass	
Oxalis perennans	A wood sorrell	
Pavonia hastata	Pink pavonia	
Petrorhagia nanteuilii		
Rapistrum rugosum	Turnip Weed	
Rumex crispus	Curly dock	
Salvia reflex	Mintweed	
Schinus areira	Pepper tree	
Schkuhria pinnata	Dwarf Marigold	
Setaria sp.	Pigeon grass	
Sida rhombifolia	Paddy's lucerne	
Sonchus asper	Prickly-sow Thistle	
Sonchus oleraceus	Common Sow Thistle	
Sorghum halepense	Johnson Grass	
Tribulus terrestris	Cathead	
Urochloa panicoides	Liverseed Grass	
Verbena bonariensis	Purple top	
Vicia sativa subsp. nigra	Narrow-leaved vetch	
Xanthium occidentale	Noogoora Burr	4
Xanthium spinosum	Bathurst Burr	4
Anagallis arvensis	Scarlet Pimpernel	
Arctotheca calendula	Capeweed	
Avena fatua	Wild Oats	
Bidens pilosa	Cobblers Peg	

Scientific Species	Common Name	Noxious Weed Category
Bryophyllum delagoense	Mother of Millions	4
Carthamus lanatus	Saffron Thistle	
Chloris truncata	Windmill Grass	
Chloris ventricosa	Plum Windmill Grass	
Conyza sp.	Fleabane	
Cyclospermum leptophyllum	Slender Celery	
Echium plantagineum	Salvation Jane	
Emex australis	Three-cornered jack	
Hedypnois rhagadioloides ssp. cretica	Cretan Weed	
Lamium amplexicaule		
Lolium perenne	Rye Grass	
Lycium ferocissimum	African Boxthorn	4
Medicago minima	Wooly Burr Medic	
Medicago praecox	Small Leaf Burr Medic	
Medicago truncatula	Barrel Medic	
Opuntia stricta var. stricta	Prickly Pear	4
Oxalis corniculata	Creeping oxalis	
Paspalum dilatatum	Paspalum	
Paspalum distichum	Water Couch	
Pennisetum villosum	Feathertop	
Phalaris paradoxa	Paradoxa Grass	
Polygonum aviculare	Wire Weed	
Rumex brownii	Swamp Dock	
Sclerolaena birchii	Galvanized Burr	
Silybum marianum	Variegated Thistle	
Soliva sessilis	Bindi	
Trifolium arvense	Haresfoot Clover	
Trifolium campestre	Hop Clover	
Trifolium tomentosum	Wooly Clover	
Triticum aestivum	Wheat	
Verbena aristigera	Moss Verbena	

Scientific Species	Common Name	Noxious Weed Category
Verbena officinalis	Common Verbena	
Verbena rigida	Veined Verbena	

Appendix C Noxious Weed Management Plans for NSC

Available at:

http://www.narrabri.nsw.gov.au/weeds-management-plans-1115.html

African Boxthorn
Class 4
Weed Control
Management Plan

Family Name: *Solanaceae*

Scientific Name: *Lycium ferocissimum*

Common Names: African Boxthorn, Boxthorn

Weed status: *The abovementioned weed is a Class 4 noxious weed declared under section Control Order 28 of the Noxious Weeds Act 1993.*

Plan Period
Starting Date: 01 Sept 2011 **Review Date:** 30 June 2016 (Unless otherwise revoked)

Control Requirements:
Under Control Order 28, Noxious Weeds Act 1993 it is required that:

"The growth of the plant must be managed in a manner that reduces its numbers, spread and incidence and continually inhibits its reproduction and the plant must not be sold, propagated or knowingly distributed".

Control Methods/Techniques: (Any combination of the following methods is suitable)

Manual/Mechanical: Manual removal (hand pulling) and burning is the most effective method for small infestations, remove bushes in winter when ground is wet making sure to remove as suckering can occur.

Chemical: There are a number of herbicides registered for use on African Boxthorn. Spot spray, cut stump and basal bark methods.

Cultural/Biological: There are no successful biological control agents for use on African Boxthorn.

Revegetation: Plant prickly native bushes such as Rosemary's Grevillia *(Grevillia rosmariifoli),* prickly paperbark *(Melaleuca styphelioides)* or any flowering shrubs eg bottle brush *(Callistemon sp.)* This provides habitat and groundcover as Boxthorns gradually die off.

Area of Operation:

Narrabri Shire Council (NSC) is in the heart of the Namoi Valley with an area of 13,030km² and population of 13,507. NSC includes the towns of Baan Baa, Bellata, Boggabri, Edgeroi, Gwabegar, Narrabri, Pilliga and Wee Waa. The shire's largest town of Narrabri is positioned on the crossroads of the Newell and Kamilaroi highways.

References:
DPI Primefacts, Noxious and Environment Weed Control Handbook 5th edition, 2011 NSW DPI.

Registered Herbicide Application Rates:
Access® 1L per 60L Diesel (cut stump & Basal
Glyphosate 360g/L (various trade names) at 700ml/100L water. (spot spraying)
Triclopyr 300g/L + Picloram 100g/L + Aminipyralid 8g/L (Grazon ®Extra) at 500ml/100L water. (spot spraying) Only apply to plants less than 2m tall.
Triclopyr 300g/L + Picloram 100g/L (various trade names) at 500ml/100L water. (spot spraying) Only apply to plants less than 2m tall.

Optimum months for control:

J	F	M	A	M	J	J	A	S	O	N	D
☐	☐	☐	☑	☑	☑	☑	☑	☑	☑	☐	☐

Critical Comments:
- Apply when bushes have good leaf cover, growth and no leaf fall.
- Consult your weeds officer for application tips.
- Read MSDS and Label of respective herbicides

Linkages to other Plans / Strategies
National Weed Strategy and control plans, NSW Weed Strategy and control plans. NIWAC Regional Weed Strategy and control plans. However, in some instances it is also important for a land manager to consider other strategies.

For further information contact:
Narrabri Shire Council
Phone: (02) 6799 6702 Fax: (02) 6799 6888
Email: council@narrabri.nsw.gov.au
Website: www.narrabri.nsw.gov.au

Northern Inland Weeds Advisory Committee:
Website: www.niwac.org

African Boxthorn Weed Profile Sheet

Family Name: Solanaceae

Scientific Name: *Lycium ferocissimum*

Common Names: African Boxthorn, Boxthorn

Country of Origin: Africa (Southern Coast). Imported in the mid 1800's and commonly used as a hedge plant.

Habit

Life Span: Perennial

Life Form: Erect shrub to 5m tall and 3m wide.

Habitat Sub humid and semi arid subtropical regions, occurring in drier soils. It grows well in all soil types, but prefers lighter soils particularly along dry creek beds.

Environmental Impact:

Existing: An escaped garden hedge plant in Australia where it has spread into pastures, natural bush-land neglected areas, roadsides and waterways.
Plants compete against local native plants for light, water, nutrients and space.

Potential: Due to the impenetrable barrier the plant creates it forms dense stands restricting access by native fauna and humans. Can impact heavily on both agriculture and the environment through reduced carrying capacity and the plant's sharp thorns have been known to damage the eyes of grazing animals.

African boxthorn is an aggressive invader of pastures, roadsides, reserves, remnant bushland and waterways. It forms an impenetrable, spiny thicket that inhibits the movement of stock and provides a haven for feral animals.

Many insects, including fruit fly, the common house fly and the tomato fly, breed in the fruit of this weed.

Reproduction

Flower: Fragrant, 5 petals, white with purple or lilac marks in the throat, about 1cm in diameter, formed singly or in pairs on short stalks in the leaf axils.

Fruit: Green ripening to orange/red, shiny, globular or ovoid berry about 1cm in diameter borne on short stalks, drooping from leaf axils with prominent Calyx.

Seed: Light brown or yellow, numerous, ovoid or irregularly flattened, 2.5mm long by 1.5mm wide, smooth, dull with small raised dots on the surface.

Characteristics

Leaves: Glabrous, fleshy 3.5cm long, 2cm wide, ovate to elliptical formed on short stalks in clusters at the numerous nodes.

Stem/Branches: Light brown when young, grey or brown when mature, erect and much branched. Spines to 15cm long are borne on the main stems, smaller spines on the numerous branchlets

Underground Structures: Extensive deep branched taproot producing new growth when damaged. (suckering)

Dispersal: By seed, fruit commonly eaten by birds and foxes and later void in faeces. (Bird lollies)

Confusing Species

Cockspur, Bursaria (Black thorn), Pyracantha

Bathurst burr
Class 4
Weed Control
Management Plan

Family Name: *Asteraceae (daisy family)*

Scientific Name: *Xanthium spinosum*

Common Names: Bathurst Burr

Weed status: *The abovementioned weed is a Class 4 noxious weed declared under section Control Order 28 of the Noxious Weeds Act 1993.*

Plan Period
Starting Date: 01 Sept 2011 **Review Date:** 30 June 2016 (Unless otherwise revoked)

Control Requirements:
Under Control Order 28, Noxious Weeds Act 1993 it is required that:

"The growth of the plant must be managed in manner that reduces its numbers, spread and incidence and continuously inhibits its reproduction."

Control Methods/Techniques: Individual plants and small infestations must be totally controlled.

Manual/Mechanical: Hand removal of young plants, hoeing, chipping or slashing of older plants before seeding commences. Cultivation should be repeated after each germination. If after seeding plants should be carefully removed and burnt to prevent spread of seed. Maintain competitive pastures.

Chemical: Spot spraying with hand gun or knapsack—thoroughly wetting leaves of actively growing plants before seed set. Many chemicals are registered for use on Bathurst Burr depending on growth stage and/or situation.

Biological: There are several biological agents established but all are only minimally effective. A blight fungus *colletotrichum orbiculare,* rust fungus *Puccinia xanthii*, the Bathurst Burr seed fly *Euaresta bullans* and several native insects.

Area of Operation:
Narrabri Shire Council (NSC) is in the heart of the Namoi Valley with an area of 13,030km² and population of 13,507. NSC includes the towns of Baan Baa, Bellata, Boggabri, Edgeroi, Gwabegar, Narrabri, Pilliga and Wee Waa. The shire's largest town of Narrabri is positioned on the crossroads of the Newell and Kamilaroi highways.

References:
DPI Primefacts, Noxious and Environmental Weed Control Handbook 5th edition, 2011 NSW DPI.

Registered Herbicide Application Rates:

2,4 D amine 625g/L (various trade names) at 80-110ml per 150L of water (spot spray seedlings only)
MCPA 500g/L (various trade names) 2L/ha (apply at seedling stage)
Metsulfuron methyl (Brushkiller 600®) at 5-7.5g per 100L of water
Fluoxypyr 200g/L (various trade names) at 75ml per 100L of water
Fluoxypyr 333g/L (Starane® Advanced) at 45ml per 100L of water

(Note: Not all herbicides registered for these purposes may be listed. Consult Weed Officers for more options).

Optimum months for control:

J	F	M	A	M	J	J	A	S	O	N	D
✓	✓	✓	☐	☐	☐	☐	☐	☐	☐	☐	☐

Critical Comments:

- Spray or remove plants while actively growing before flowering and preferably before seed set. Mature fruits are very easily spread causing long term land contamination.
- Because Bathurst Burr is an annual weed an infestation can eventually be

Linkages to other Plans / Strategies
National Weed Strategy and control plans, NSW Weed Strategy and control plans.
NIWAC Regional Weed Strategy and control plans.

For further information contact:
Narrabri Shire Council
Phone: (02) 6799 6702 Fax: (02) 6799 6888
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Website: www.narrabri.nsw.gov.au

Northern Inland Weeds Advisory Committee:
Website: www.niwac.org

Bathurst Burr Weed Profile Sheet

Family Name: *Asteraceae (*daisy family)

Scientific Name: *Xanthium spinosum*

Common Names: Bathurst Burr

Country of Origin: South America (probably Chile)

Habit

Life Span: Summer growing annual plants.

Life Form: Multi stemmed, much branched, erect, annual herb usually to 1m but usually 30-60cm tall.

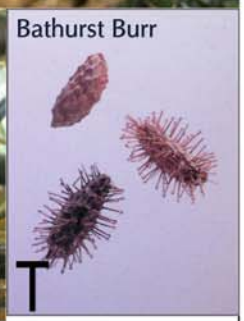
Habitat

Prefers exposed warm situations on high fertility, disturbed soils. Common in sheep and cattle camps, watercourses, dam banks and floodplains.

Environmental Impact:

Existing: Seedlings are poisonous to cattle, goats, poultry, sheep and in particular horses and pigs. Burrs contaminate wool adding to the cost of final products. Bathurst Burr is one of the worst cases of vegetable fault in wool.

Potential: Plants can compete strongly with summer pasture production for space and nutrients and reduces pasture grazing. Plants also enter natural systems competing against endemic native species.



Reproduction

Flowers: Creamy green, small and inconspicuous. Both male and female flowers are borne on the same plant. Male flowers formed in clusters at the ends of branches.

Fruit: Oval or egg shaped 10-15mm long, 4-5mm wide with many yellow hooked spines and occasionally 1 or 2 straight terminal spines. These burrs are the smallest of all Xanthium spp. Immature fruits are green and fleshy, mature fruits are straw coloured and somewhat woody. Burrs occur February to April.

Seeds: Brown or black , there are two seeds to each burr, flattened, one slightly larger than the other. One will germinate the first season, the other may lay dormant for many years.

Characteristics

Leaves: Upper surface usually dark green, shiny and with short appressed hairs denser on the veins, pale green and downy on the under surface. Alternate to 7cm long, mostly 3 lobed (some more) with the middle lobe to 4cm long and much longer than the others, with prominent mid veins.

Stem/Bark: Greenish yellow, finely hairy, main stem to 1.5m long, generally curved, much branched, faintly striated, armed at the base of each leaf stalk and stem node with one or two 3 pronged yellow spines, each 1.5-2.5cm long.

Underground Structures: Branched taproot and lateral feeder roots.

Dispersal: The hooked spines of the burr attach themselves to the wool and fur of animals. Also easily distributed by flood waters.

Confusing Species:
Other Xanthium (burr) spp (but leaves of Bathurst Burr are very different), some thistle spp (before seeding occurs). Datura spp.

Mother of Millions
Class 4
Weed Control
Management Plan

Family Name: Crassulaceae

Scientific Name: *Brophyllum delagoense*

Common Names: Mother of Millions,

Weed status: *The abovementioned weed is a Class 4 noxious weed declared under section Control Order 28 of the Noxious Weeds Act 1993.*

Plan Period
Starting Date: 01 Sept 2011 **Review Date:** 30 June 2016 (Unless otherwise revoked)

Control Requirements:
Under Control Order 28, Noxious Weeds Act 1993 it is required that:

"The growth of the plant must be managed in manner that reduces its numbers, spread and incidence and continuously inhibits its reproduction and the plant must not be sold, propagated or knowingly distributed.

Control Methods/Techniques: Individual plants and small infestations must be totally controlled.

Manual/Mechanical: Preventing the spread is the best control measure. If found remove immediately using a combination of control methods including hand removal, fire, herbicide application and rehabilitation. For small infestations Mother of Millions can be removed by hand and burnt/ disposed of in plastic bags.

Chemical: Thorough spraying of Mother of Millions with herbicide is effective if sufficient wetting agent is used to penetrate the waxy outer covering of the plant any time of the year.
Spraying may not be 100% successful so the site should be monitored.

Biological: The South African citrus thrip is present in Southern Queensland & Northern NSW. This thrip damages the outer tissue of the mother-of-millions plant and also lays its eggs under the outer tissue. Where high populations of thrips exist, the number of viable plantlets and flowers forming on mother-of-millions is reduced.

Area of Operation:
Narrabri Shire Council (NSC) is in the heart of the Namoi Valley with an area of 13,030km² and population of 13,507. NSC includes the towns of Baan Baa, Bellata, Boggabri, Edgeroi, Gwabegar, Narrabri, Pilliga and Wee Waa. The shire's largest town of Narrabri is positioned on the crossroads of the Newell and Kamilaroi highways.

References:
DPI Primefacts, Noxious and Environmental Weed Control Handbook 5th edition, 2011 NSW DPI.

Registered Herbicide Application Rates:

Triclopyr 300g/L + Picloram 100g/L + Aminopyralid 8g/L (eg Grazon Extra®)
500ml per 100L of water (spot/boom) - apply at flowering, add a surfactant.
Triclopyr 300g/L + Picloram 100g/L (eg Grazon DS®)
500ml per 100L of water (spot/boom) - apply at flowering, add a surfactant.
2,4-D 300g/L (eg Affray®) 70ml in 10L - thorough even coverage of leaves.

(Note: Not all herbicides registered for these purposes may be listed. Consult Weed Officers for more options).

Optimum months for control:

J	F	M	A	M	J	J	A	S	O	N	D
☐	☐	☐	☐	✓	✓	✓	✓	☐	☐	☐	☐

Critical Comments:
- Winter is the best time to treat MOM.
- Read MSDS and label of respective herbicides.

Linkages to other Plans / Strategies
National Weed Strategy and control plans, NSW Weed Strategy and control plans.
NIWAC Regional Weed Strategy and control plans.

For further information contact:
Narrabri Shire Council
Phone: (02) 6799 6702 Fax: (02) 6799 6888
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Website: www.narrabri.nsw.gov.au

Northern Inland Weeds Advisory Committee:
Website: www.niwac.org

Mother of Millions Weed Profile Sheet

Family Name: Crassulaceae

Scientific Name: *Bryophyllum delagoense*

Common Names: Mother of Millions (MOM)

Narrabri SHIRE
Heart of the North West

Country of Origin: Africa and Madagascar

Habit

Life Span: Succulent perennial plan

Life Form: The common name "Mother of Millions" is based on the plant's ability to reproduce vegetatively in large numbers.

Habitat It is adapted to dry conditions and can survive long periods of drought, growing 30cm to 1m in height.

Environmental Impact:

Existing: MOM is poisonous when ingested due mainly due to bufadienolides which cause heart failure. The toxins are present in all parts of the plant, however flowers are five times more poisonous than the leaves and stems. Eating 5kg of MOM would kill an adult cow.

Potential:

Confusing Species: In NSW there are two less common Bryophyllum Species. These are hybrid mother of millions (*Bryophyllum daigremontianum x Bryophyllum delagoense*) and resurrection plant (*Bryophyllum pinnatum*)

Reproduction

Flowers: Orange-red in colour and occur in a cluster at the top of a single stem. Flowering can occur from May to October.

Fruit:

Seeds: MOM also produces numerous seeds which can survive in the soil for a number of years before germinating.

Characteristics

Leaves: Pencil shaped, pale green to pale brown in colour with dark green patches and a shallow groove on the upper surface. There are up to 7 projections at the tip of each leaf which when broken off can develop into new plants.

Stem: Pinkish-brown or grey in colour.

Underground Structures:

Noogoora Burr
Class 4
Weed Control
Management Plan

Family Name: *Asteraceae (daisy family)*

Scientific Name: *Xanthium strumarium* *(collective name for similar species)*

Common Names: Noogoora Burr, Cockle Burr, California Burr

Weed status: *The abovementioned weed is a Class 4 noxious weed declared under section Control Order 28 of the Noxious Weeds Act 1993.*

Plan Period
Starting Date: 01 Sept 2011 **Review Date:** 30 June 2016 (Unless otherwise revoked)

Control Requirements:
Under Control Order 28, Noxious Weeds Act 1993 it is required that:

"The growth of the plant must be managed in manner that reduces its numbers, spread and incidence and continuously inhibits its reproduction."

Control Methods/Techniques: Individual plants and small infestations must be totally controlled.

Manual/Mechanical: Hand removal of young plants, hoeing, chipping or slashing of older plants before seeding commences. If after seeding plants should be carefully removed and burnt to prevent spread of seed.

Chemical: Spot spraying with hand gun or knapsack—thoroughly wetting leaves of actively growing plants before seed set. Many chemicals are registered for use on Noogoora Burr depending on growth stage and/or situation.

Biological: There are no successful biological control agents, although a rust fungis *Puccinia xanthii* has a limited effect.

Area of Operation:
Narrabri Shire Council (NSC) is in the heart of the Namoi Valley with an area of 13,030km² and population of 13,507. NSC includes the towns of Baan Baa, Bellata, Boggabri, Edgeroi, Gwabegar, Narrabri, Pilliga and Wee Waa. The shire's largest town of Narrabri is positioned on the crossroads of the Newell and Kamilaroi highways.

References:
DPI Primefacts, Noxious and Environmental Weed Control Handbook 5th edition, 2011 NSW DPI.

Registered Herbicide Application Rates:

2,4 D amine 625g/L (various trade names) at 800ml—1.1L /ha (seedlings only)
Metsulfuron methyl 600g/Kg (various trade names) at 7.5g per 100L of water
MCPA amine 500g/L (various trade names) at 1 –2 L /ha (spray young seedlings only)
Fluroxypyr 33g/l (Starane Advanced®) 45ml in 100L water (apply to actively growing plants, seedlings and young plants to 40cm high)

(Note: Not all herbicides registered for these purposes may be listed. Consult Weed Officers for more options).

Optimum months for control:

J	F	M	A	M	J	J	A	S	O	N	D
✓	✓	✓									

Critical Comments:

- Spray or remove plants while actively growing before flowering and preferably before seed set. Mature fruits are very easily spread causing long term land contamination.
- Because these burrs are annual weeds an infestation can eventually be eradicated if seeding/fruiting is prevented.
- Read MSDS and label of respective herbicides.

Linkages to other Plans / Strategies
National Weed Strategy and control plans, NSW Weed Strategy and control plans.
NIWAC Regional Weed Strategy and control plans.

For further information contact:
Narrabri Shire Council
Phone: (02) 6799 6702 Fax: (02) 6799 6888
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Website: www.narrabri.nsw.gov.au

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Website: www.niwac.org

Noogoora Burr Weed Profile Sheet

Family Name: *Asteraceae (*daisy family)

Scientific Name: *Xanthium strumarium* (collective name for similar species)

Common Names: Noogoora Burr, Cockle Burr, California Burr

Country of Origin: North and South America

Habit

Life Span: Summer growing annual plants.

Life Form: Single stemmed or multi branched, erect, annual herb usually to 1.5m but can reach 2.5m tall.

Habitat

Prefers riparian areas and fertile soils. Tolerates flooding at all growth stages.

Environmental Impact:

Existing: Seedlings are poisonous to domestic stock. Burrs contaminate wool.

Potential: Plants compete with pasture production for space and nutrients. Plants also enter natural systems competing against endemic native species.

Reproduction

Flowers: Inconspicuous flowers formed in clusters at the ends of branches. Flowering occurs from late February to April. Both male and female flowers are bourne on the same plant.

Fruit: Oval or egg shaped 12-20mm long with many hooked spines. Immature fruits are green and fleshy, mature fruits are brown and woody.

Seeds: There are two seeds to each burr, one slightly larger than the other, flattened on one side. One will germinate the first season, the other may lay dormant for many years.

Characteristics

Leaves: Large, grape or maple leaf shaped. Dark green above, paler beneath, distinguished by prominent purple veins and stems.

Stem/Bark: Green zig-zagged stems are mottled with purple blotches.

Underground Structures: Stout taproot and extensive lateral roots.

Dispersal: The hooked spines of the burr attach themselves to the fur of animals. Also easily distributed by flood water.

Confusing Species: Californian and Cockle Burr are very similar but flower at different times. They have no purple colouring and have different shapes and sizes of burrs.
Actual scientific names—Noogoora Burr *X. occidentale,*
Cockle Burr *X. italicum*, California Burr *X. orientale*

Prickly Pears
Class 4
Weed Control
Management Plan

Family Name: *Cactaceae*

Scientific Name: *Opunta stricta*

Common Names: Prickly Pears, Common Pest Pear

Weed status: *The abovementioned weed is a Class 4 noxious weed declared under section Control Order 28 of the Noxious Weeds Act 1993.*

Plan Period
Starting Date: 01 Sept 2011 **Review Date:** 30 June 2016 (Unless otherwise revoked)

Control Requirements:
Under Control Order 28, Noxious Weeds Act 1993 it is required that:

"The growth of the plant must be managed in a manner that reduces its numbers, spread and incidence and continuously inhibits its reproduction and the plant must not be sold, propagated or knowingly distributed.

Control Methods/Techniques: Individual plants and small infestations must be totally controlled.

Manual/Mechanical: Manual/mechanical removal and burning of plants is the most effective method of control, taking care to remove all plant segments and fruit. As much of the root system as possible should be removed to prevent suckering.

Chemical: There are a number of herbicides registered for use on these Cactus species.

Biological: There are a number of biological agents available for use on these cacti. They are all generally species specific. The most well known are Cactoblastis moth, and Cochineal insects. (consult your Weeds Officer for more details).

Area of Operation:
Narrabri Shire Council (NSC) is in the heart of the Namoi Valley with an area of 13,030km² and population of 13,507. NSC includes the towns of Baan Baa, Bellata, Boggabri, Edgeroi, Gwabegar, Narrabri, Pilliga and Wee Waa. The shire's largest town of Narrabri is positioned on the crossroads of the Newell and Kamilaroi highways.

References:
DPI Primefacts, Noxious and Environmental Weed Control Handbook 5th edition, 2011 NSW DPI.

Registered Herbicide Application Rates:

Triclopyr 300g/L & Picloram 100g/L (various trade names) at 500ml per 100ml water
Triclopyr 600g/L (Various trade names) 1L in 75L distillate or 3L in 100L water (foliar spray)
Triclopyr 240g/L + Picloram 120g/L (Access®) 1 L in 60L of distillate (foliar application)
(Thoroughly wet plants)

(Note: Not all herbicides registered for these purposes may be listed. Consult Weed Officers for more options).

Optimum months for control:
Common pears can be treated anytime during the year, although best time is when plants are actively growing.

J	F	M	A	M	J	J	A	S	O	N	D
✓	✓							✓	✓	✓	✓

Critical Comments:
- Specific herbicide registrations apply for different species.
- Apply as a thorough foliar spray, being careful under desirable species
- Consult your weeds officer for application tips
- Read MSDS and label of respective herbicides.

Linkages to other Plans / Strategies
National Weed Strategy and control plans, NSW Weed Strategy and control plans.
NIWAC Regional Weed Strategy and control plans.

For further information contact:
Narrabri Shire Council
Phone: (02) 6799 6702 Fax: (02) 6799 6888
Email: council@narrabri.nsw.gov.au
Website: www.narrabri.nsw.gov.au

Northern Inland Weeds Advisory Committee:
Website: www.niwac.org

Prickly Pear Weed Profile Sheet

Family Name: *Cactaceae*

Scientific Name: *Opuntia stricta*

Common Names: Prickly Pears, Common Pest Pear

Country of Origin: North, Central and Tropical America (this sheet is for Prickly Pear, but all other cacti spp are very similar and their particular control requirements are the same).

Habit

Life Span: Perennial succulent shrubs.

Life Form: Erect succulent shrubs, growing from 0.5m to 5m tall varying by species. All species reproduce by seed and branch segments.

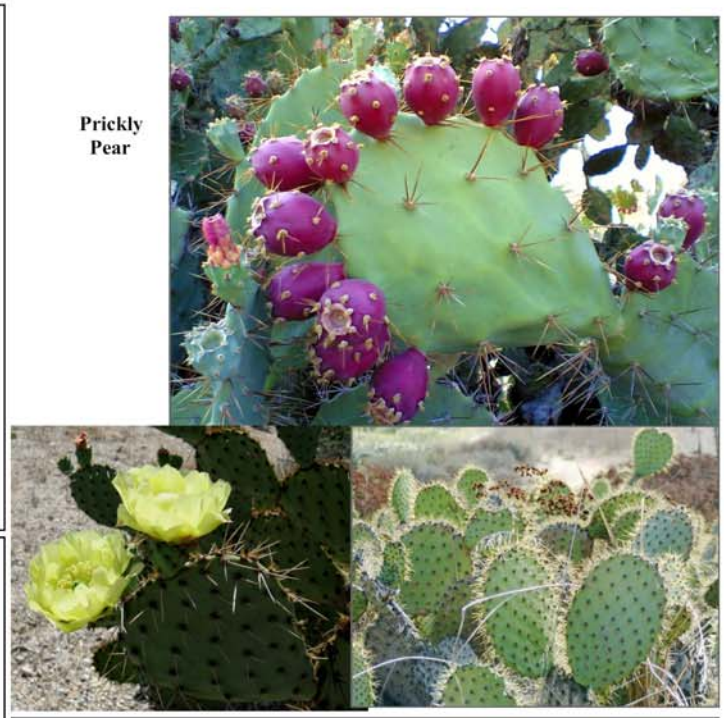
Habitat Semi arid savannas in warm temperate, subtropical and tropical regions, growing well in both exposed and semi arid shade situations. Before the introduction of biological control agents it was the most serious weed in Australia and capable of growing in most parts of the continent.

Environmental Impact:

Existing: Escaped ornamental shrubs, food or fodder plants. Although slow growing these Cactus spp can form large impenetrable hedges and have the capacity to cover hundreds of hectares if left unchecked competing for light, water, nutrients and space.

Potential: Due to the impenetrable barrier the plant creates it forms dense stands restricting access by animals and humans. Can impact heavily on both agriculture and the environment.

Prickly Pear



Reproduction

Flower: Lemon yellow with greenish or pinkish markings on the back, 6-8cm in diameter, sessile, each with a fleshy base which becomes the fruit, borne mostly on the margins of the segments.

Fruit: Skin reddish purple, flesh reddish, somewhat pear shaped, 4-6cm long, bearing tufts of fine barbed bristles in areoles.

Seed: Yellow or pale brown, rounded, 5mm in diameter, numerous embedded at the centre of the fruit.

Characteristics

Leaves: Small scale like, produced beneath the areoles, on young segments only and are shed as segments mature.

Stem/Branches: Often dull or bluish green, glabrous, consisting of a series of fleshy segments each to 30cm long, 15cm wide and 1-2cm thick, each areole contains tufts of short, very finely barbed bristles, and occasionally 1 or 2 stout yellow spines about 2-4cm long.

Underground Structures: Fibrous shallow roots.

Dispersal: Initially distributed because of its use as an ornamental or edible spp, but also through careless dumping of plants and dispersal of seeds in faeces when fruit is eaten by birds, pigs and cattle. New plants from when plants segments of fruiting bodies touch the ground. Seeds can germinate at any time.

Confusing Species:

Other cactuses, Opuntia and Harrisia spp.

Spiny Burr Grass
Class 4
Weed Control
Management Plan

Family Name: *Poaceae*

Scientific Name: *Cenchrus incertus & Centrus longispinus*

Common Names: Spiny burr grass, Innocent Weed

Weed status: *The abovementioned weed is a Class 4 noxious weed declared under section Control Order 28 of the Noxious Weeds Act 1993.*

Plan Period

Starting Date: 01 Sept 2011 **Review Date:** 30 June 2016 (Unless otherwise revoked)

Control Requirements:

Under Control Order 28, Noxious Weeds Act 1993 it is required that:

"The growth of the plant must be managed in a manner that reduces its numbers, spread and incidence and continually inhibits its reproduction and the plant must not be sold, propagated or knowingly distributed."

Control Methods/Techniques: Individual plants and small infestations must be totally controlled.

Manual/Mechanical: Hand removal of plants, hoeing, chipping or mechanical cultivation before seeds develop. If the plants contain developed burrs, they should be collected and bagged for suitable disposal by either burning or deep burial. Maintain a competitive pasture.
A strong competitive pasture will assist with effective control. Ensure equipment hygiene is used to prevent seed dispersal and also quarantine the infestation.

Chemical: Small infestations can be spot sprayed with a knapsack or hand gun, larger infestations can be treated by boom spray. Apply chemicals before the seed forms.

Biological: There are no biological controls available.

Area of Operation:

Narrabri Shire Council (NSC) is in the heart of the Namoi Valley with an area of 13,030km² and population of 13,507. NSC includes the towns of Baan Baa, Bellata, Boggabri, Edgeroi, Gwabegar, Narrabri, Pilliga and Wee Waa. The shire's largest town of Narrabri is positioned on the crossroads of the Newell and Kamilaroi highways.

References:

DPI Primefacts, Noxious and Environmental Weed Control Handbook 5th edition, 2011 NSW DPI.

Registered Herbicide Application Rates:

Glyphosate 360g/L (various trade names) at 2-3L per hectare (boom spray).
500-700ml per 100L of water (high volume spot spray)
MSMA 800g/L (various trade names) 1L in 100L water (spot spray application)
Do not cut or graze affected area for 5 weeks.

(Note: Not all herbicides registered for these purposes may be listed. Consult Weed Officers for more options).

Optimum months for control:

J	F	M	A	M	J	J	A	S	O	N	D
✓	✓	✓					✓	✓	✓	✓	✓

Critical Comments:

- Treat actively growing plants before seeding.
- Do not cut or graze affected areas for 5 weeks after using MSMA
- Read MSDS and label of respective herbicides.

Linkages to other Plans / Strategies

National Weed Strategy and control plans, NSW Weed Strategy and control plans.
NIWAC Regional Weed Strategy and control plans.

For further information contact:

Narrabri Shire Council
Phone: (02) 6799 6702 Fax: (02) 6799 6888
Email: council@narrabri.nsw.gov.au
Website: www.narrabri.nsw.gov.au

Northern Inland Weeds Advisory Committee:
Website: www.niwac.org

Spiny Burr Grass Weed Profile Sheet

Family Name: *Poaceae*

Scientific Name: *Cenchrus incertus & Cenchrus longispinus*

Common Names: Spiny Burr Grass, Innocent Weed

Country of Origin: North and Central America

Habit

Life Span: Annual grass, *C. incertus* is occasionally perennial in some environments.

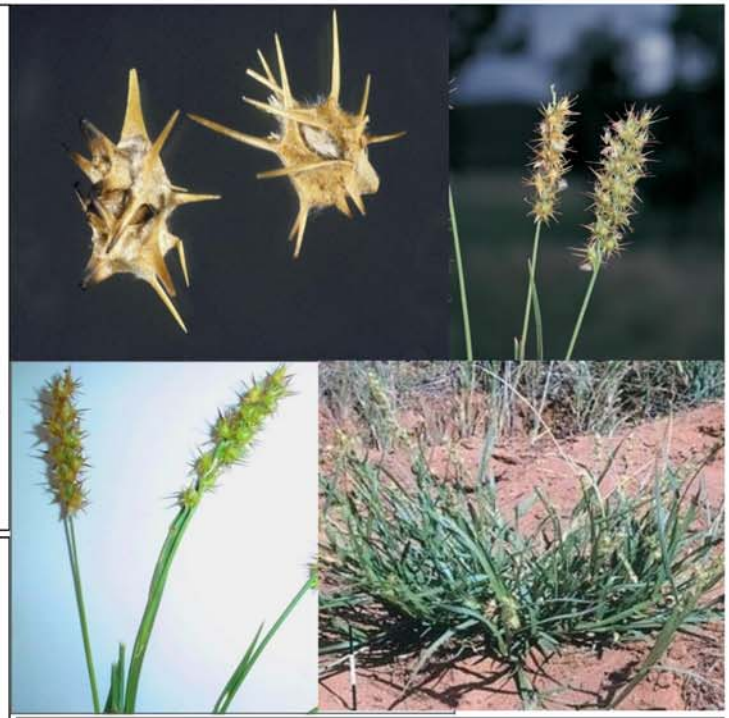
Life Form: Erect or spreading grass to 60cm tall, reproducing by seed.

Habitat Spiny burr grass is common on most light soil areas of the central, northern and western parts of NSW, and scattered parts of the southern NSW. Also found in coastal areas on sandy soils.

Environmental Impact:

Existing: Displaces desirable vegetation by competing for light, water, nutrients and space. The burrs become entangled in wool, causing downgrading of wool quality, injury and discomfort to shearers. The burrs also cause ulcers in the mouths of grazing animals, and can contaminate lucerne hay. Hard to recognise until the burrs mature, so control is difficult before seed set.

Potential: Spiny burr grass is capable of growing in light sandy soils under arid conditions, particularly in areas which have been disturbed. It is capable of infesting large areas of the coast, in particular the native grasslands in dunal and headland situations and grassed reserves.



Reproduction

Inflorescence: A spike like panicle 3-8cm long consisting of up to 40 burrs but commonly many less, partially enclosed in a leaf sheath.
The burr is straw coloured 3-7mm in diameter (excluding pines) comprising 1-4 florets, spines spreading or reflexed, slender but broadened at the base. Sharply pointed, rigid and finely barbed.
(*C. longispinus* spines usually more than 40, 7mm long and purple tinged.)
(*C. incertus* 11-43 spines, 2-5mm long).
Seed: Smooth, ovoid but flattened on one side, 2 to4mm long, 2-3mm wide, 1-3 per burr. The first seed formed is the largest and is capable of germination within a few months of formation, while most remain dormant for up to 3 years.

Characteristics

Leaves: Up to 20cm long, 5-8mm wide, smooth but sometimes twisted and wrinked, finely serrated, with flattened sheaths. The ligule is a narrow membrane fringed with hairs, 1-1.5mm long.
Stems/Branches: Several produced from the base, branched, glabrous. Somewhat flattened particularly at the base, either erect or spreading and ascending, roots forming at the basal nodes if in contact with the soil.
Underground Structures: Roots are fibrous and shallow but can be over 30cm deep in some soils.

Dispersal: Up to 1000 seeds are produced per plant, and dispersal is only by seed. The burrs when mature detach readily from the plant, attach via their barbed spines and are carried considerable distances on machinery, clothing or wool.
The plants grow well on the sides of roads and easily attach to car tyres. Burrs are also moved by water in irrigation areas and have been found as a contaminant in hay.

Appendix D Management recommendations for the control of Coolatai Grass

Available at:

http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/347155/awmg_coolatai.pdf

Coolatai grass *(Hyparrhenia hirta)*

The problem

Coolatai grass is a tall, bulky, introduced grass invading grassy woodlands and grasslands that represent some of southern Australia's rarest native plant communities, including the white box—yellow box—Blakely's red gum grassy woodlands and derived native grasslands. This community is listed nationally as a Critically Endangered Ecological Community under the *Environment Protection and Biodiversity Conservation Act 1999*. Coolatai grass forms densely tufted tussocks that can become the dominant ground cover, reducing native plant diversity and affecting native fauna populations. It also dominates extensive areas of pasture. It is becoming conspicuous along roadsides in agricultural regions and is of concern to fire authorities due to the abundance and flammability of its dry leaves and stalks.

Coolatai grass was introduced for pasture and is very persistent under grazing, but not generally preferred as feed for livestock. Once established, it is very difficult to control and requires a sustained control program, integrating various methods. It is rapidly becoming more widespread.

Coolatai grass is just one of many perennial grass weeds invading Australia's native vegetation, particularly grassy plant communities, rangelands and coastal areas. Invasive grasses displace native plants and can also contribute to changed fire regimes that affect native vegetation structure and biodiversity. They include needle-grasses (*Nassella* spp.), feather-grasses (*Pennisetum* spp.), veldt grasses (*Ehrharta* spp.), buffel grass (*Cenchrus ciliaris*), wheat-grasses (*Thinopyrum* spp.), Rhodes grass (*Chloris gayana*) and African lovegrass (*Eragrostis curvula*). Several of these are also sown as pastures. Non-native grass weeds, such as gamba grass (*Andropogon gayanus*), are a particular threat to tropical savannas in northern Australia.

Coolatai grass can replace diverse native understorey in grassy box woodlands: Travelling Stock Reserve, Manilla, NSW.
Photo: V. Chejara

Key points

- Remnant grassy box woodlands in southern Australia are threatened by Coolatai grass.
- Coolatai grass spreads by seed and is commonly dispersed by mowing and water movement.
- It rapidly regrows after it is burnt, grazed or slashed, with maximum growth rates in warm to hot conditions.
- Stock will graze fresh leaf growth but avoid older growth, assisting Coolatai grass to become dominant in pastures.
- Accurate identification of grasses is essential before control.
- Small infestations can be grubbed.
- A single dose of herbicide may not kill mature Coolatai grass tussocks, but combining physical and chemical treatment can be effective. Correct timing is essential.
- Coolatai grass could become established in new regions unless preventive measures are applied.
- In regions where Coolatai grass is widespread, sites of high biodiversity value should be a priority for control measures.

The weed

Grasses in the genus *Hyparrhenia* are often known as thatching grass because in Africa the tough dry stalks are commonly used for roof thatch. In Australia, *H. hirta* is generally known as Coolatai grass, after a property in northern NSW where it was introduced in the 1890s. Sometimes (especially in WA) it is known as Tambookie grass, but this is the name of the related grass *H. filipendula*, native to coastal Queensland and NSW.

Coolatai grass is a perennial tussock grass, up to 1.5 m tall, that spreads by seed. Its main growth period is in late spring to summer, but where winters are not severe it can remain green all year. It is deep-rooted (up to 3 m) and drought-resistant. It readily resprouts from its tough basal crown after defoliation or seasonal dormancy and can respond rapidly to summer rainfall.

Leaves are pale greyish-green, hairless or nearly so; older leaves are rough to the touch. The leaf blade is flat, 1–5 mm wide, with a prominent mid-vein and a long membranous ligule at its base where it adjoins the sheath. The inflorescence is long and much branched: each branch ends in a pair of racemes made up of grey-white, hairy flowers along a stalk. At the base of each branch is a floral leaf that may turn reddish in colour. Five to eight pairs of spikelets are closely packed along each raceme; one in each pair has an awn. The tiny (approximately 2 mm long) grain is dispersed inside an awned, hairy husk.

Weed identification and similar species

Related species

In addition to Coolatai grass, one native and one introduced species of *Hyparrhenia* occur in the wild in Australia. Tambookie grass *(H. filipendula)* is the native species. Jaragua grass *(H. rufa)* is a tropical pasture species introduced from Africa. Coolatai grass is the only one that currently occurs in southern Australia.

How to identify *Hyparrhenia* species in Australia

	Tambookie grass *(H. filipendula)*	Coolatai grass *(H. hirta)*	Jaragua grass *(H. rufa)* (2 subspecies)
STATUS	NATIVE	WEED	WEED (tropical)
Plant habit	Tufted grass to 1.5 m tall	Dense tussocks to 1.5 m tall	Tussocks to 2 m tall; annual or perennial
Flower racemes	In pairs, 15–25 mm long, upper raceme on a thin stalk, 7–8 mm long	In pairs, 15–50 mm long	In pairs, 20–50 mm long
Spikelets / racemes	Smooth or hairy	White hairs	Rust-coloured hairs
No. of awns per raceme	1–3	5–7, rarely 8	9 or 10
Awn	40–50 mm long	15–25 mm long	16–22 mm long
Current distribution in Australia	NSW, Qld	ACT, NSW, Qld, SA, Vic., WA	NT, NSW, Qld

Note: illustrations on page 3

Coolatai grass *(Hyparrhenia hirta)*: NSW.
Photo: V. Chejara

Jaragua grass (*Hyparrhenia rufa*): Hawaii.
Photo: Forest and Kim Starr

Distinguishing between native and Coolatai grasses

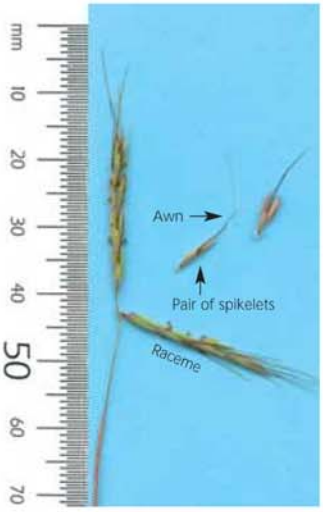
A range of tall, native perennial grasses occur in habitats invaded by Coolatai grass.

A combination of key features distinguish the weed from these species:

- it has **floral leaves** at branching points of flowering stems
- the paired, grey—white, hairy flower racemes form a 'V' at the end of the branches, each raceme has **5–7 brown awns**
- leaves are flat or folded with a prominent midrib, **not aromatic**
- the ligule at the leaf—stem junction is a **membrane, 2–4 mm long**.

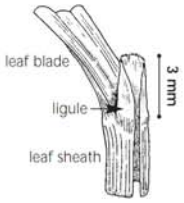
It is often difficult to distinguish different species of grasses when not in flower, especially as seedlings and it is useful to preserve an identified, dried specimen of the weed grass, which can serve as a reference for comparison with local native grass species in the field. As well as the fertile parts, include young and mature leaves, showing the leaf sheath, leaf blade and the ligule where they join, the base of stems and stem nodes. Mount the sample on card with a plastic protective covering.

Coolatai grass flower racemes form a 'V' at the ends of the branches.
Photo: S. Warner



Racemes are approximately 1.5–5 cm long with 5–7 awned spikelets.
Photo: Andrew Storrie

The ligule is at the base of the leaf blade.
Photo: Jackie Miles and Max Campbell



Coolatai grass leaves have a membranous ligule, 2–4 mm long.
Drawing: Andrew Craigie

Summer-active native grasses that may be confused with Coolatai grass

Barbed wire grass (*Cymbopogon refractus*) and other lemon-scented grasses (*Cymbopogon* spp.) have linear, paired (or sometimes three) racemes and floral leaves, but the leaves smell like lemon when crushed.
Photo: Jackie Miles and Max Campbell

Kangaroo grass (*Themeda triandra*) seedlings may look similar to Coolatai grass. Ligule is a membrane, up to 1 mm long. Inflorescence has floral leaves but is otherwise distinctive—flower heads are triangular in shape, rust-coloured when mature and not hairy.
Photo: Jackie Miles and Max Campbell

Red-leg grass (*Bothriochloa macra*) is widespread in eastern Australia. It may look similar to Coolatai grass when young. Stems are reddish and flower heads have more than two racemes.
Photo: Jackie Miles and Max Campbell

Other native grasses with finger-like racemes (generally more than 2) occur in the genera *Eulalia*, *Dichanthium* and *Chloris*. Note: *Chloris* also includes some introduced species.

Coolatai grass often spreads along roadsides: Bingara to Narrabri Rd, NSW.
Photo: Les Tanner

How it spreads

Coolatai grass spreads by means of tiny seeds with hairy, awned husks that adhere to clothing, animals, vehicles and tools, especially when wet. Human activities such as slashing or traffic assist in spreading the weed, especially along roadsides. It spreads along drainage lines, indicating that water can also transport the seeds. In pastures and stock routes livestock can spread seeds.

Coolatai grass is self-fertile, enabling new populations to arise from a single plant. Large populations can produce sufficient seed to spread rapidly, in spite of the apparently low proportion of florets that set viable seed. Seed can germinate readily in different light regimes, over a wide range of temperatures, pH levels and under marginal water stress. Seedlings can emerge from a depth of up to 9 cm. Seedling recruitment can occur within established stands and in soil with a plant litter layer.

Where it grows

The original range of Coolatai grass is extensive, including Mediterranean Europe, southern and northern Africa and into west Asia. It includes areas receiving low to relatively high rainfall, with maxima in summer or winter. In southern Africa, Coolatai grass occurs in undisturbed ecosystems and is widespread in native pastures, but also colonises degraded grasslands. It is naturalised in America but is not currently reported as a significant weed there.

Coolatai grass was introduced into Australia as a potential pasture plant. Before its negative aspects had become apparent it had escaped cultivation and become naturalised, firstly in Qld or northern NSW. It now also grows wild in a range of climatic conditions in WA, SA, Vic. and the ACT. Introduced for light soils, it has been recorded on a wide range of soil types including hard rocky soils and deep sands.

Potential distribution

Coolatai grass is spreading in the agricultural and near-urban regions of WA and SA, near the Murray River in Vic., and in NSW and Qld. Without effective detection, prevention and containment programs, it has the potential to become more abundant within its current range and to spread into new areas. Like most other grass weeds, it tends to become dominant in open habitats such as woodlands and grasslands, not in closed forests or dense shrub understorey.

In Australia, most large populations currently occur in areas with annual average rainfall of 400–800 mm, but the species occurs in arid regions elsewhere. *H. hirta* forms adapted to low rainfall may already be present in Australia as 'sleeper populations', be stored in Australia's germplasm collections (in SA and Qld) or be introduced in the future.

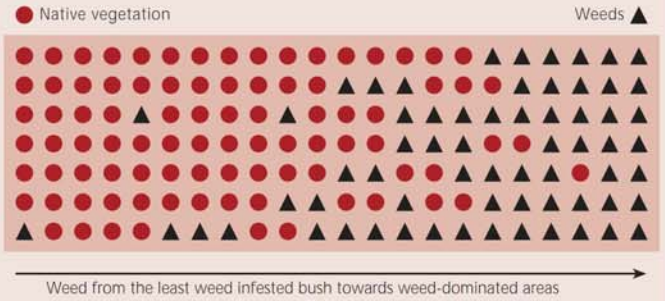
Growth cycle

Coolatai grass mainly grows and flowers during late spring to autumn, depending on adequate moisture being available. It grows rapidly after summer rains and if the winter is relatively mild the plant may be green all year. With low temperatures the leaves may dry off, but generally the plant survives and will regrow from the base. Plants may produce seed in their first growth season. Seed is produced over an extended period and shed as it matures. The fast germinating character of Coolatai grass in relatively warm conditions provides a competitive advantage in rapidly capturing soil moisture from summer rainfall, especially in sandy soils.

Coolatai grass may remain green and flower during mild wet winters. Flowering tussock, 0.9 m tall: Mount Lofty Ranges, SA.
Photo: S. Warner

5

Strategic weeding in native vegetation



What to do about it

There are many locations where Coolatai grass has not yet become established although conditions may be suitable. Through coordinated and consistent action, its spread can be prevented. In those regions where the weed is already widespread, total eradication is not a realistic goal. However, at the local scale a long-term management program can help to contain it, reduce its harmful effects and encourage native vegetation to recover. In parts of NSW and Qld, pastures require intensive management to graze young Coolatai grass leaf growth and minimise the accumulation of unpalatable mature growth including seed heads.

Prevent Coolatai grass spreading

- Learn to recognise Coolatai grass and report new populations to your local council or natural resource management authority if you find it. Accurate weed identification is essential—in some cases, the grass was initially thought to be native when first detected.
- Ensure that Coolatai grass is not planted. More suitable, non-weedy species are available for pasture, landscaping and soil stabilisation.
- Remove small, isolated infestations before they seed.
- Contain existing infestations—monitor areas to which the weed may spread. Particular vigilance is needed along dispersal routes such as roadsides and drainage lines.
- Practise weed hygiene in areas that need to be slashed such as roadsides:
  - where possible, slash before seeds develop
  - slash into rather than away from patches of Coolatai grass
  - always clean vehicles and clothing before moving to uninfested areas.

Reduce established infestations

Where large infestations of Coolatai grass occur in native vegetation a planned, strategic approach is essential to ensure that after treatment, it is replaced by plant cover other than new Coolatai grass seedlings, regrowth or other weeds. Sites of high biodiversity value should be identified and targeted first. As well as the information presented in this guide on Coolatai grass biology and control methods, a plan needs to be based on specific knowledge about the site—including the distribution of other major weeds.

Develop and implement a **long-term** weed management plan.

1. Investigate the site

- **Identify all plant species:** weeds and native plants, including grasses.
- **Map Coolatai grass infestations:** indicate weed density throughout the site, identify sections where the weed is just beginning to invade, the main dispersal agents and pathways.
- **Map native vegetation condition:** assess its capacity for recovery after Coolatai grass is removed.
- **Identify sites of high biodiversity value:** such as rare flora or fauna habitat or threatened plant communities.
- **Define buffer zones around waterways.**

2. Develop the site action plan

- Identify goals and priorities based on the site information.
- Define priority areas for control, by overlaying maps of Coolatai grass density, native vegetation, site values and risks.
- Plan to weed strategically:
  - work from isolated Coolatai grass plants towards core infestations
  - protect the healthier native vegetation and habitats of rare fauna and flora first
  - work down the slope so that seeds are not being washed down into previously weeded areas.
- Work in stages. The size of the area targeted at each stage should be manageable enough to follow up thoroughly.
- Include control of other weeds so that they do not establish where Coolatai grass has been removed. Plan your monitoring and restoration before you begin to weed.
- Select the most suitable control method in each area, to avoid damage to native vegetation and waterways. Plan appropriate disposal of weed material.
- Prepare a weed management calendar to maximise the effectiveness of control activities and protect native species.

3. Implement the action plan

- Remove Coolatai grass from the least infested and high biodiversity value areas first. Ensure that activities do not spread weed seeds or disturb ground cover. Adapt to local seasonal conditions so that herbicide is applied when Coolatai grass is actively growing.
- Each year, follow-up weed regrowth in areas previously treated before moving to new areas of infestation.
- Coordinate control programs with neighbouring landholders to maximise effectiveness and reduce ongoing spread.

4. Monitor and evaluate outcomes and adapt the plan accordingly

Include monitoring of native plant regeneration. In weed management programs there is often a tendency to focus on the removal of weeds as a goal, but at the site level the ultimate goal is restoration of native vegetation. Recovery of local native grasses and other species may require active restoration following removal of Coolatai grass. The rate of recovery sets the pace of weeding.

Manage pastures containing Coolatai grass

For further detail, refer to the guideline on *Management for Coolatai grass on the North West Slopes of NSW* (McCormick et al 2002).

The grazing value of pastures dominated by Coolatai grass is maximised if plants are kept in the vegetative, actively growing phase as long as possible, through intensive grazing in early summer. In some situations, fertiliser and legumes have been added to maintain productivity. It is important to ensure that more palatable pasture species are not disadvantaged and to avoid extensive areas of bare soil that would favour Coolatai grass and other weeds. This is more practical if paddocks are small and stock can be removed when they have consumed the green feed. The use of supplements also allows continued grazing to reduce the bulk of low quality material. Burning of pastures before the growing season may remove dry matter and temporarily encourage fresh Coolatai grass leaf growth, but such management will not reduce its dominance without other control measures. Herbicide treatment of small patchy infestations in pastures may assist in reducing their rate of spread.

Control methods

Mature Coolatai grass tussocks are difficult to destroy because old, dry growth can shield growing leaves from contact with herbicide and a single application may not be sufficient to kill the plant. Small infestations can be removed manually, while a combination of physical and chemical treatment can be successful for extensive infestations. Spot spraying or grubbing enables tussocks to be treated individually, minimising risk of damage to other species. No biological control methods are available for Coolatai grass.

Old, dry stalks and leaves of Coolatai grass are persistent and prevent efficient herbicide application to actively growing leaves: Mount Lofty Ranges, SA.
Photo: S. Warner

Physical removal of small or sparse infestations

While it is labour intensive, physical removal has the advantage that each plant can be grubbed in one visit. Remove the weeds before seeding if possible. Bag flower heads and then grub all individual plants with a mattock, removing the base of the tussock with minimal disturbance to soil and native plants. Contain whole plants in bags and dispose of them safely. Follow up to check for regrowth and for seedlings.

Combined treatment of extensive infestations

Herbicide treatment is only effective if applied when the weed is actively growing. Efficient application of herbicide to mature Coolatai grass is difficult unless accumulated dry leaf material is removed first (by slashing or burning). In some situations, where permitted, it may be practical to burn rather than slash old growth prior to herbicide treatment. Deciding if and when to burn requires careful consideration of a range of issues and consultation with fire authorities. Stands of Coolatai grass should only be burnt as a component of a comprehensive vegetation management plan. Burning may stimulate germination of native or weed species so these would need to be managed when targeting regrowth of Coolatai grass.

Infestations can be grubbed when they are small: Cobbler Creek Recreation Park, SA.
Photo: S. Warner

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Registered herbicides for Coolatai grass

Current herbicide label registration for Coolatai grass is limited in application to small patchy infestations in perennial pastures, only in NSW. The active constituent (flupropanate) has some residual herbicide action in the soil that would have an impact on associated vegetation and subsequent regeneration.

A 'Permit to allow minor use of an AGVET chemical product' may be issued to allow registered products to be used for a purpose or in a manner that is not included on the approved label. Permits may include use of glyphosate as a spot spray by trained community groups, landowners and conservation managers for treatment of Coolatai grass in native vegetation, perennial pastures and other non-crop situations. Refer to the Australian Pesticides and Veterinary Medicines Authority website to find the relevant permit for your state or territory and obtain advice on local conditions from the permit holder (see table below). Also consult community groups working on Coolatai grass in your region. Glyphosate is non-selective and care is needed to prevent contact with off-target species.

The following treatment has been developed for Coolatai grass:

1. Mow / slash or burn in spring at start of growing season, before flowering. Contain or destroy the slashings if they contain seeds.
2. Wait for regrowth (4–6 weeks).
3. Check for native plants in the vicinity of the tussocks and protect them from spray.
4. Spot spray glyphosate diluted in water plus surfactant*.
5. Wait for regrowth and check for native plants.
6. Repeat spot spray with glyphosate mixture.
7. Follow up after the next significant rainfall—grub survivors and seedlings, or repeat the treatment cycle when the weeds are actively growing.

When using herbicides always read the label and follow instructions carefully. At least one member of a group should have formal training in the safe storage, handling, preparation and use of the herbicide that is being used. Particular care should be taken when using herbicides near waterways because rainfall runoff can carry herbicides. Check with local authorities on the width of buffer zone required around water bodies.

*Use appropriate glyphosate formulations near waterways and follow label advice on surfactants.

Contacts

State / Territory	Department	Phone	Email	Website
ACT	Dept of Territory and Municipal Services	(02) 6207 5111 or 132281	N/A	www.tams.act.gov.au/live/environment
NSW	Dept of Primary Industries Dept of Environment and Climate Change	1800 680 244 or 131555	weeds@dpi.nsw.gov.au info@environment.nsw.gov.au	www.dpi.nsw.gov.au/weeds www.environment.nsw.gov.au/pestsweeds/aboutweeds.htm
Qld	Dept of Primary Industries and Fisheries	132523	callweb@dpi.qld.gov.au	www.dpi.qld.gov.au/
SA	Dept of Water, Land and Biodiversity Conservation	(08) 8303 9620	N/A	www.dwlbc.sa.gov.au
Vic.	Dept of Primary Industries	136186	customer.service@dpi.vic.gov.au	www.dpi.vic.gov.au
WA	Dept of Agriculture and Food	(08) 9368 3333	enquiries@agric.wa.gov.au	www.agric.wa.gov.au
Australia-wide	Australian Pesticides and Veterinary Medicines Authority (APVMA)	(02) 6210 4700	N/A	www.apvma.gov.au

Contact details for state and territory agencies with responsibility for weeds are listed above, along with the APVMA. Note: Coolatai grass is not naturalised in NT or Tas. The APVMA website hosts the PUBCRIS database which contains information on all herbicides that are registered for use on weeds in each Australian state and territory, including minor use permits. Refer to the fact sheet *Off label chemical use in Victoria* (AG1214) at www.dpi.vic.gov.au for sources of advice in that state.

Consult the natural resource management organisation for your region or local council to find local contacts on managing weeds for biodiversity, including community groups working on Coolatai grass.

Refer to the CRC for Australian Weed Management website (www.weedscrc.org.au) for weed management guides in this series, as well as guides for Weeds of National Significance and Alert List species. The Introductory Weed Management Manual (also available from this website) may assist in developing a plan tailored to your situation.

Mature Coolatai grass growth is of low palatability: paddock between Warialda and Coolatai, NSW.
Photo: Andrew Storrie

Coolatai grass on travelling stock reserve (foreground) and in paddocks (background): NSW.
Photo: V. Chejara

Legislation

Invasion of native plant communities by exotic perennial grasses has been listed as a key threatening process under the NSW *Threatened Species Conservation Act 1995*. In fact, Coolatai grass is a species of special concern. In some local government areas in NSW, Coolatai grass is declared a Class 3 weed and the plant must be fully and continuously suppressed and destroyed.

Coolatai grass is a declared Class 2 plant in SA, requiring notification and control in specified parts of the state. Trade and movement are restricted throughout the state.

The AQIS Permitted Seeds List includes species of *Hyparrhenia* including *H. hirta*. Several other species of *Hyparrhenia*, not yet in Australia are not on the permitted list.

Knowledge gaps

Coolatai grass seed was imported to Australia on a number of occasions from various parts of the world but it is not known how many (or even which) of these introductions became established. There are thought to be numerous different forms of the grass in its native range and investigation is needed into which forms are present in Australia that could become future weed problems. Research is also needed into methods for controlling Coolatai grass, for site recovery post-control and for managing pastures sustainably to utilise Coolatai grass while maintaining other valued species and soil condition in the long term.

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Case study: P. Spark.

Map: Australia's Virtual Herbarium, (*Hyparrhenia hirta*), via Royal Botanic Gardens Melbourne, Council of Heads of Australian Herbaria. www.rbg.vic.gov.au/cgi-bin/avhpublic/avh.cgi. (Outlier records of doubtful or non-current status omitted.)

Diagram of *Hyparrhenia hirta* ligule reproduced with permission from Robertson, M. (2006). *Stop Bushland Weeds*, 2nd edn. The Nature Conservation Society of SA Inc.

References

Chejara, V.K., Nadolny, C., Kristiansen, P., Whalley, R.D.B. and Sindel, B.M. (2006). Impacts of *Hyparrhenia hirta* (L.) Stapf (Coolatai grass) on native vegetation in a travelling stock route in northern New South Wales. *In:* C. Preston, J.H. Watts and N.D. Crossman (eds). *15th Australian Weeds Conference Proceedings: managing weeds in a changing climate*. Adelaide, SA, pp. 207–210.

Clayton, W.D., Harman, K.T. and Williamson, H. (2006 onwards). GrassBase—The Online World Grass Flora. www.kew.org/data/grasses-db.html [accessed 08 November 2006].

Harden, G.J. (1993). Flora of NSW. Volume 4. NSW University Press.

Hunt, S. (2006). Utilisation of pastures dominated by Coolatai grass (*Hyparrhenia hirta*) in northern NSW. *In: Proceedings of the 2006 Annual Conference of the Grassland Society of NSW*. Pp. 33–45. (Reprinted in *Stipa* newsletter number 37, December 2006). www.stipa.com.au/newsletter.htm

McCormick, L., Lodge, G. and McGufficke, R. (2002). *Management for Coolatai grass on the North West Slopes of NSW*. NSW Department of Agriculture factsheet. www.agric.nsw.gov.au/reader/weed-list/coolatai-grass.pdf.

North West Weeds website: www.northwestweeds.nsw.gov.au

Warner, S. Ecological Studies of Coolatai grass (*Hyparrhenia hirta* (L.) Stapf.): An invasive weed on the Adelaide Plains. Unpublished Honours thesis, The University of Adelaide, 2004.

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...case study

Threatened grassy box woodlands: working at the invasion front

Native grassy woodlands and grasslands were formerly widespread in Australia's agricultural regions. As these vegetation communities contained useful pasture and timber and occurred on the more fertile land, most have been cleared or greatly modified. The few high quality examples that remain are generally small or narrow and are mainly found on travelling stock reserves, roadsides, cemetery reserves and in a few paddocks that have been lightly grazed. They provide habitat for a wide range of native flora and fauna species, many of which are rare. Most occur within rural landscapes, largely surrounded by crops or improved pastures and are vulnerable to a range of threats including invasion by non-native grasses.

In native woodlands, the natural diversity of plant species and forms, including grasses, broad-leaved herbs, mosses, lichens, shrubs and trees of various sizes create complex vegetation structure (vertical layers and horizontal patchiness) and habitat for a range of native fauna. If the vegetation becomes dominated by a few non-native species, this complexity with its natural openings and patches may be lost. Such an effect is apparent in areas that have become dominated by Coolatai grass.

Coolatai grass dominates large areas of pasture, roadsides, travelling stock routes and areas of remnant vegetation on the North Western Slopes of NSW, especially in the Manilla area north of Tamworth. Members of the Manilla Landcare Group noticed that there was some high quality remnant vegetation on the travelling stock reserves near Manilla, areas that would provide important habitat for woodland birds. These reserves have a history of intermittent grazing, and in many areas the vegetation retains much of its diversity and structure. However, in past decades Coolatai grass has been rapidly invading, replacing the native understorey.

Fewer native plant species were recorded in woodland densely infested with Coolatai grass: travelling stock reserve, Manilla, NSW.
Photo: V. Chejara

The landcare group implemented a management program to maintain and improve the condition of native vegetation in travelling stock reserves near Manilla, in cooperation with the Rural Lands Protection Board and with support from the Natural Heritage Trust Their objective was to prevent small patches and isolated Coolatai grass plants from becoming thick stands, allowing native grasses and other nativ plants growing in adjoining areas of native vegetation to recolonise the treated areas. They tackled the Coolata grass at the invasion front. Tussocks were spot sprayed with glyphosate when actively growing, in accordance with the relevant permit, and repeat spraying was conducted where needed The group visited their sites up to four times per year to follow up regrowth and seedlings. One site is now being cared for by the Friends of Klori. Coolatai grass is common in pastures and on roadsides in the district and wil continue to colonise from surrounding lands. Ongoing, intensive efforts will be needed to protect and restore threatened woodland habitats.

The impact of Coolatai grass on native flora and fauna has been studied in infested and non-infested native box woodlands on the travelling stock reserves near Manilla. Recent research at these sites indicated that areas dominated by Coolatai grass had lower diversity and abundance of native flora. Monitoring of native fauna at those sites indicated that in areas dominated by Coolatai grass, the abundance of ground active invertebrates was reduced. From early results, so too were the diversity and abundance of reptiles and frogs. Expert ornithologist Stephen Debus believes that Coolatai grass invasion will also lead to further decline of the ground-feeding vulnerable woodland birds Hooded Robin, Brown Treecreeper, Turquoise Parrot, Speckled Warbler and Diamond Firetail.

Strategic management of Coolatai grass

Quick reference guide

Regional / local status of Coolatai grass	Not yet established	Small, isolated outbreaks	Widely established
Management goals	Prevent establishment	Eradicate	Contain infestations and mitigate threats
Strategies required	Practise weed hygiene Monitor, detect and identify possible new infestations	Manual or herbicide treatment with follow up Prevent re-establishment or invasion by other weeds through passive or active site restoration	**Native vegetation:** Identify high priority biodiversity assets under threat from Coolatai grass and protect them through implementing long-term site management plans **Pasture:** Manage paddock by paddock to utilise pasture, minimise spread and promote competitive, non-weed species **Roadsides:** Map infestations and practise weed hygiene to prevent spread

Coolatai grass – Hyparrhenia hirta

Vegetation management or weed control?

A weed removal program can be judged successful if the weeds are ultimately replaced by vegetation that is valued. Adopt a strategic, integrated, long-term approach to restore native vegetation that is self-sustaining and minimise reinvasion by Coolatai grass or other weeds. Natural regeneration of native plants is the best form of restoration, but in sites dominated by weeds over many years, there may be no native plants or seed remaining. In such cases, revegetation will be needed.

Natural regeneration (passive restoration)

Where sparse Coolatai grass tussocks are removed and remnant native species are present, passive restoration may be possible. To assist the process, scatter locally collected native grass hay or seed. Recruitment of native grasses may be episodic and it may take years of consistent management for native species to replace weeds.

Revegetation (active restoration)

Areas cleared of dense infestations may require active restoration of the plant community, including its original structure. For example, to restore grassy woodland an understorey dominated by native grasses may be the primary objective, but planting of local trees and shrubs at a variable, sparse to moderate density may also be needed. Consider whether the natives are summer or winter active and take into account local seasonal conditions. As with passive restoration, active restoration may take many years to achieve.

Prevent Coolatai grass re-establishment

1. Follow-up physical or chemical treatment after the next significant rainfall because some plants may have been missed and seedlings may regenerate from the seedbank.

2. Restore ground cover vegetation to areas from which Coolatai grass has been removed.

3. Avoid large-scale disturbance that would create extensive areas of bare soil, such as too-frequent fire in native vegetation or overgrazing in pasture.

4. Identify and manage major seed sources and dispersal pathways.

5. Monitor weed-free areas regularly to detect and remove young plants before they seed. Coolatai grass plants can seed in their first season of growth.

Hyparrhenia hirta may grow to more than 1.5 m tall. Dense stands create a fuel hazard and hinder restoration in a previously cultivated area: Cobbler Creek Recreation Park, SA. Photo S. Warner

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CRC Weed management

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

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

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

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

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

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

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

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

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

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

ST GEORGES BASIN
8/128 Island Point Road
St Georges Basin NSW 2540
T 02 4443 5555
F 02 4443 6655

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

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

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

1300 646 131
www.ecoaus.com.au