



(ABN 65 086 426 253)

Closure Plan Update/Annual Environmental Management Report

for the

**Canyon Coal Mine
(MLs 1464 and 1471)**

01 July 2011 – 30 June 2012

Whitehaven Coal Mining Limited
Mine Closure Progress Report
for the
Canyon Coal Mine
(MLs 1464 and 1471)

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1 INTRODUCTION

The purpose of this report is to provide an update on the progressive closure of Whitehaven's Canyon Mine (ML1464 and ML1471) for the period 1st July 2011 – 30th June 2012.

2 ACHIEVEMENTS

2.1 Outline

Since mining ceased in July 2009, progressive rehabilitation, environmental monitoring and maintenance have occurred. Since October 2009, 11,560 trees and understorey species have been planted.

Overall the site is presenting an area that blends in with the surrounding agricultural landscape. The final void area is generally a stable landscape that possesses good vegetation cover and drainage structures resulting in a secure void water body, however during the heavy rainfall in early 2012 some erosion occurred (see Section 2.4).

The site has been fenced for the exclusion of stock and public access, with the fence being of the agricultural type to enhance the blending in with the surrounding agricultural landscape. The exclusion of stock and vehicle access has assisted in the success of the site's rehabilitation. Site personnel maintain observations of site to ensure both weeds and feral animals are eradicated on an as needs basis.

The offset requirements for the Canyon site have been endorsed as being included in Whitehaven's Regional Biobank site as evidenced by a letter of approval from the Department of Planning. The Biobank site was registered with the OEH on 28th June 2012.

From a social perspective, the progress of closure at the site has satisfied the surrounding community with good feedback received at the 2009 and 2010 Community Consultative Committee (CCC) meetings. Four attempts were made to hold a CCC meeting in 2011, however the meetings were delayed because of poor weather and then ultimately cancelled due to lack of attendance. The 2012 meeting was held outside of the reporting period for this closure plan update. The attendees at this meeting again provided positive feedback in relation to the progression of rehabilitation.

The following sub-sections provide a more detailed summary of the progress within each domain (as shown in Plate 9). Table 2 at the end of this section provides an updated schedule of works, with revised timeframes, where required.

2.2 Infrastructure Areas

1(a) Site Office and Facilities and Former Orica Hardstand

The crib and office facilities were removed in August 2010 with the exception of the toilet block, which is used by the environmental team and contractors associated with closure activities. The area, including the car park, was then topsoiled and seeded. Additionally, a small waterway was constructed to slowly drain away runoff into storage dams to the east of this area. The former Orica hardstand is yet to be rehabilitated, as it currently provides a useful safe stopping area for haul trucks on the passing haul road.

1(b) Workshop, Fuel Farm and Hardstand

In mid 2010, the two 50,000L diesel storage tanks were removed from the bunded area which had a capacity of 240,000L. The bunded area, which also contained stored oils, incorporated a clay over plastic over clay liner to minimise the potential of soil contamination in the event of a spill. Pipes and lockable valves were in place to enable removal of spills and rainwater from the area.

On 18th August 2010, soil testing for hydrocarbon contamination was conducted around the old fuel storage area which comprised collecting soil samples from 8 separate pits. Soil samples were taken at the surface, 1m and 2m intervals from pits dug out by a backhoe. Four pits were located around the fuel storage area, one within the storage area and the remaining three down slope of the site to determine whether there has been any soil contamination away from the direct location. These samples were tested for total metals, recoverable metals and total petroleum hydrocarbons.

Analysis of the soil samples was conducted by ALS Laboratory Group Environmental Division in Sydney. Results of the sampling indicated that in two locations the levels of C10 – C36 Fractions of Hydrocarbons (Diesels and Lubricating Oils) exceeded the threshold concentrations for sensitive land use set in the NSW EPA Guidelines for Assessing Service Station Sites (2004). Heavy metals analysis indicated all samples were well within threshold limits.

Based on these results, the contaminated material was excavated and disposed of within a designated bunded area in September 2010 for future bioremediation. Following excavation of this material it was noted that contamination was present at greater depths than first identified. Subsequently, additional soil samples were

collected to a depth of 2.5m, along with a resample of the two locations within the pit, to ensure all contaminated material was removed. Results of these sites found that contaminated material had been removed from all but one area (2 samples within the one large pit).

Wet weather hampered the continuation of remediation of the fuel storage area. When conditions permitted, the additional contaminated soil was excavated and stored in the bunded area onsite for bioremediation. Once bioremediated, the soil was disposed of offsite as general waste.

The former workshop has been decommissioned to the basic structure, as a potential agricultural shed for future land use on the site. The hardstand and storage area has had all mining related stores removed. The wash down sump has had an oil and grease analysis completed, with results indicating all parameters within compliance levels.

For the purposes of the commitments provided in the original Closure Plan, works in this domain have been completed. However, following submission of the Closure Plan Whitehaven sought approval from Narrabri Shire Council (NSC) for construction of offices, a storage shed and hardstand areas for a centralised maintenance storage area for Whitehaven's open cut mines (Plate 1 and Plate 2). Consent was issued by NSC in mid 2011 and the final occupation certificate was issued in early 2012. The Maintenance Facility will remain for the foreseeable future and therefore may need to be excised from the Canyon ML at the time of relinquishment.



Plate 1 - Maintenance Facility Buildings



Plate 2 - Maintenance Facility Yard

1(c) Coal loading bin and ROM Pad

The removal of coal loader and associated infrastructure was completed in September 2010, with the loadout bin being commissioned at Whitehaven's Sunnyside Coal Mine. The ROM pad and ROM facilities area totalled 7.5 ha and was reshaped, stabilised with contours and waterways for drainage, top-soiled and seeded with a summer pasture mix. The waterway spills into a rehabilitated area to the south of the pad that is designed to slowly drain runoff into the final void. This area has also been top-soiled and seeded with a summer pasture mix for prevention of erosion. Further planting of native trees in clump formations was undertaken in November 2011 (Plate 3).



Plate 3 - Revegetation Near Former Coal Bin

1(d) Explosives Magazine

The explosives magazine is still currently used by blasting contractor Orica Mining Services. Whitehaven plans to leave the magazine in its current location for the foreseeable future as it provides a secure area which is isolated from the general public.

2.3 Rehabilitation Zones

2(a-f) - Pasture and Native Vegetation Zones

Infill planting of 350 trees occurred south of the ROM pad and west of the haul road (zone 2(f)) in October 2009.

A total of 5,660 tubestock was planted over January and February 2010 in the designated native vegetation rehabilitation zones 2(b), (d), (e) and (f). The tubestock consisted of a diverse range of shrub and tree species native to the area. Whitehaven made particular effort to ensure a significant mix of overstorey and understorey species were planted. This will ensure that the native vegetation zones regenerate in a way that enhances the original landscape by providing improved biodiversity.

A planting campaign of 3,800 tubestock, which incorporated a mix of tree and understorey species were planted over June 2010 using a contracted tree planting machine. 2,000 tubestock were sourced from those left over from the January/February 2010 campaign and the remaining 1,800 were supplied by the contractor. The area targeted was native vegetation zone 2(f) within the south-east corner of the site.

Further infill planting of 1,000 understorey species was undertaken in September 2010 in Zones 2(b) and 2(d). Areas targeted within the zones were those on the mid-plateau section of rehabilitation which is a native vegetation zone consisting of trees planted around five years ago. The infill planting will ensure the introduction of a shrubby understorey such as Hop Bush and Golden Wattle, and hence will further improve the ecological merit of the area. Preparation for the planting involved adding fresh rip lines between existing vegetation and undertaking grass/weed control with a pre-spray of glyphosate, two weeks prior to planting.

Further infill planting of 320 understorey tubestock occurred in June 2011 on the western area of the rehabilitation.

Plate 4 to Plate 7 show the progress of rehabilitation across the native vegetation rehabilitation zones while Table 1 provides a summary of the number and type of species planted during the period July 2009 to November 2011.



Plate 4 - Established Revegetation on Western Slope (2c)



Plate 5 - Trees on Western Slope (2c)



Plate 6 - Revegetation on Eastern Slope near Plateau (2b/2d)



Plate 7 - Infill Understorey Plantings on Plateau (2b)

Table 1 – Rehabilitation Species List

Date	Species	Common Name	Approx. Quantity
20 Oct 2009	<i>Eucalyptus albens</i>	White Box	75
	<i>Eucalyptus melliodora</i>	Yellow Box	75
	<i>Eucalyptus crebra</i>	Narrow-leaf Ironbark	100
	<i>Eucalyptus populnea</i>	Bimble Box	100
14 Jan 2010	<i>Acacia deanei</i>	Deans Wattle	200
	<i>Acacia decorai</i>	Western Golden Wattle	200
	<i>Acacia oswaldii</i>	Umbrella Wattle	120
	<i>Acacia salicina</i>	Cooba	160
	<i>Alectryon oleifolium</i>	Bullock Bush	30
	<i>Allocasaurina leuhmanii</i>	Bull Oak	160
	<i>Atalya hemoglauca</i>	White Wood	240
	<i>Brachychiton populneus</i>	Kurrajong	360
	<i>Callitris glaucophylla</i>	White Cypress	120
	<i>Casuarina cristate</i>	Belah	40
	<i>Dodonea heteromorpha</i>	Hop Bush	200
	<i>Dodonea viscosaa</i>	Sticky Hop Bush	800
	<i>Hovea lanceolata</i>	Lance-leaf Hovea	80
	<i>Notolea microcarpa</i>	Native Olive	40
	<i>Parsonsia eucalyptaphylla</i>	Gargaloo	80
	<i>Pittosporum angustifolium</i>	Budda Bush	800
	<i>Senna articimoides</i>	Silver Cassia	80
	<i>Eremophila debile</i>	Winter Apple	20
	<i>Eucalyptus clauroclada</i>	Baradine Red Gum	320
	<i>Eucalyptus melanophloia</i>	Silver Leaf Ironbark	280
	<i>Eucalyptus albens</i>	White Box	200
<i>Eucalyptus melliodora</i>	Yellow Box	240	
<i>Eucalyptus crebra</i>	Narrow-leaf Ironbark	280	
<i>Eucalyptus populnea</i>	Bimble Box	240	
<i>Eucalyptus pilliganensis</i>	Pilliga Box	600	
25 Feb 2010	<i>Atalya hemoglauca</i>	White Wood	120
	<i>Eucalyptus populnea</i>	Bimble Box	100
	<i>Dodonea heteromorpha</i>	Hop Bush	80
	<i>Dodonea viscosaa</i>	Sticky Hop Bush	80
	<i>Pittosporum angustifolium</i>	Budda Bush	320
	<i>Eucalyptus albens</i>	White Box	60
	<i>Eucalyptus clauroclada</i>	Baradine Red Gum	80
	<i>Eucalyptus crebra</i>	Narrow-leaf Ironbark	200
	<i>Eucalyptus melliodora</i>	Yellow Box	40
	<i>Eucalyptus pilliganensis</i>	Pilliga Box	160
	<i>Callitris glaucophylla</i>	White Cypress	30
	<i>Casuarina cristate</i>	Belah	80
	<i>Davisea genistifolia</i>	Broom Bitter Pea	400
<i>Indigofera australis</i>	Native Indigo	20	
25 June 2010 (includes 2000 mixed species from Jan/Feb list)	<i>Dodonea viscosaa</i>	Sticky Hop Bush	300
	<i>Pittosporum angustifolium</i>	Budda Bush	300
	<i>Eucalyptus melliodora</i>	Yellow Box	350
	<i>Eucalyptus crebra</i>	Narrow-leaf Ironbark	200
	<i>Eucalyptus albens</i>	White Box	350
	<i>Eucalyptus populneus</i>	Bimble Box	150
	<i>Brachychiton populneus</i>	Kurrajong	150
28 Sept 2010	<i>Dodonea viscosaa</i>	Sticky Hop Bush	300
	<i>Pittosporum angustifolium</i>	Budda Bush	150
	<i>Acacia deanei</i>	Deans Wattle	200
	<i>Acacia decorai</i>	Western Golden Wattle	150
	<i>Dodonea heteromorpha</i>	Hop Bush	200
28-29 June 2011	<i>Senna coronilloides</i>		40
	<i>Pittosporum angustifolium</i>	Budda Bush	40

Date	Species	Common Name	Approx. Quantity
Western rehabilitation (near fire break)	<i>Acacia hakeoides</i>		40
	<i>Dodonaea viscosa</i>	Sticky Hop Bush	80
	<i>Acacia decora</i>	Western Golden Wattle	40
	<i>Acacia salicina</i>		40
	<i>Senna artemisioides</i>	Punty Bush	40
10 Nov 2011 Old coal loader and opposite weighbridge	<i>Brachychiton populneum</i>	Kurrajong	40
	<i>Callitris glaucophylla</i>	White Cypress Pine	20
	<i>Capparis mitchelli</i>	Wild Orange	10
		Acacia	40
	<i>Eucalyptus albens</i>	White Box	20
	<i>Eucalyptus populneas</i>	Bimble Box/Poplar Box	20
	<i>Eucalyptus crebra</i>	Silver Narrow-leaved Ironbark	40
16 Nov 2011 Old coal loader and opposite weighbridge	<i>Eucalyptus melanophloia</i>	Silver Leaf Ironbark	30
	<i>Eucalyptus crebra</i>	Narrow-leaf Ironbark	20
	<i>Eucalyptus populneas</i>	Bimble Box/Poplar Box	20
	<i>Eucalyptus albens</i>	White Box	30
	<i>Acacia deanei</i>	Deans Wattle	20
	<i>Acacia viscosa</i>		20
	<i>Brachychiton populneum</i>	Kurrajong	80
	<i>Callitris glaucophylla</i>	White Cypress Pine	20
	Total	11,560	

2.4 Final Void

3 - Void

Although a summer cover crop consisting of predominately Japanese Millet was present in the void area, the intensity of rainfall events over late December 2009 and early January 2010 (a total of 184.6mm fell from the 22/12/09 – 3/1/10) resulted in numerous instances of gully erosion through contour banks and dam walls within the void. The major areas affected included the southern side of the void with three small instances of gully erosion through contours, and one small instance on the northern side of the void. A large channel was also eroded through the dam wall which was acting as a water velocity control structure in the lower void. These areas were further affected by 180.8 mm of rainfall over the following months of February and March 2010, creating major damage to the first void dam to the east with a large channel cut through the dam wall. In total an area of around 0.5ha was affected by erosion in the void.

Remediation work began in May 2010 with dozer contractors patching the problematic areas and reseeding with a winter cover crop consisting of predominately Rye Corn to further stabilise the soil. Major work occurred on the dam entering the void (to the east) with the wall filled and enlarged to incorporate a new rock lined spillway turfed with kikuyu grass. This work has prevented further instances of channelling through the dam wall and slowed water entering the void from the east, therefore reducing the chances of gully erosion through the lower water structures to the west. Works on the southern side of the void were also undertaken and included shaping and seeding of steeper slopes that were previously left due to access issues.

Earthen mounds were installed in June 2010 within the void to provide an alternative to rip-lines and were anticipated to be incorporated into future tree planting campaigns. Mounds also provide further stability within the void slope acting as smaller intermediate contours between larger contours, catching water runoff and therefore providing moisture to developing tubestock.

The approximate 35.9 ha of the void was re-seeded in September 2010 with a summer pasture mix to provide further stability on void slopes. The seed mix consisted of 250kg of Japanese Millet, 50kg Bambatsi Panic, 50kg Purple Pigeon Grass and 50kg Premier Digit Grass, which equates to approximately 11kg/ha of pasture. The new crop was required to replace the annual winter species crop and was particularly important in the prevention of erosion of slopes during summer storms.

As discussed previously, heavy rains in early 2012 resulted in new erosion on the southern face of the void. The area was remediated in late 2012 by Wards Earthmoving (Plate 8). Whilst works like this will occur as required, at this stage progression to final rehabilitation of the void have been delayed due to the pending Vickery Coal Project which will ultimately result in the Canyon void being backfilled with waste rock from the Vickery Project.



Plate 8 - Repair Works to Void, 2012

2.5 Enrichment Planting Zones

4(a-c) Enrichment Zones

Enrichment planting in zones 4a and 4c has not occurred. These zones formed part of the biodiversity offset for Canyon however, as discussed in Section 2.1 the Canyon's offset requirements have been included in Whitehaven's Regional Biobank Area. As a result, enrichment planting in these zones will not be undertaken.

Enrichment planting in zone 4b will also not be undertaken pending approval of the Vickery Coal Project as the Vickery waste emplacement will cover this area.

2.6 Emplacement Areas

(5a-b) – Emplacement Areas 1 and 2

Both reject emplacement 1 (north) and 2 (south) areas have been filled, reshaped, top-soiled and seeded with summer pasture mix during September 2010. Planting of native trees was undertaken in November 2011.



Plate 9 – Closure Domain Areas

Table 2 - Update of Completed Works

DOMAIN	ACTIVITY	COMPLETION DATE
1(a) Infrastructure Area: Site Office and Facilities Crib Room First Aid Room Car Park Area Former Orica Hardstand	Removal of relocatable offices, piers and associated infrastructure	Completed
	Ripping of hardstand areas, removal of concrete pathway, sowing of cover crop	Completed (except former Orica hardstand which will remain for the foreseeable future)
1(b) Infrastructure Area: Workshop Fuel Farm Storage/Hardstand Area	Dismantling of Workshop and removal off site.	Completed (main shed retained)
	Break up and removal of concrete off site	Completed
	Removal of wash down facilities (Truck tray and oil separating tank)	Completed
	Removal of all stored items from hardstand area	Completed
	Removal of fuel tanks, pumps and associated infrastructure from fuel farm	Completed
	Soil sampling at depth ranges at workshop area, fuel farm and downslope of fuel farm, and at washdown bay.	Completed
	Soil remediation or removal if required	Completed
	Ripping of hardstand areas, replacement of topsoil, placement of drainage structures and sowing of cover crop	Completed. Part of this area has remained for the Maintenance Facility.
1(c) Infrastructure Area: Coal Loading Bin ROM Pad Coal Loading facilities and road access area	Dismantling of Coal Bin and loader and transfer off site.	Completed
	Relocation of structures associated with coal loader	Completed
	Removal of all coal stockpiles at the ROM Pad	Completed
	Deep ripping of ROM Coal Pad and road access area	Completed
	Replacement of topsoil, placement of drainage structures	Completed
	Sowing of cover crop	Completed
	Planting to native vegetation	Commenced Nov 2011 – Completion for end 2013.
1(d) Infrastructure Area Explosives Magazine	Dismantling and removal of magazine	To remain at this stage.
	Deep ripping and replacement of topsoil	To remain at this stage.
	Sowing to cover crop	To remain at this stage.
2(a) Pasture Zone 1	Reshaping, replacement of subsoil and topsoil, drainage structure establishment	Completed
	Establishment of cover crop	Completed
	Establishment of monitoring plot	Completed
	Planting of clumps of native vegetation	End 2013

DOMAIN	ACTIVITY	COMPLETION DATE
2(b) Pasture Zone 2	Deep Ripping of compaction zones (ie access roads, truck park area)	Completed
	Replacement of topsoil, placement of drainage structures	Completed
	Sowing to cover crop	Completed
2(c) Native Vegetation Zone 1	Reshaping, replacement of subsoil and topsoil, drainage structure establishment	Completed
	Establishment of cover crop	Completed
	Establishment of monitoring plot	Completed
	Establishment of riplines	Completed
	Planting to native vegetation	Completed
	Infill planting with understorey species	Completed
2(d) Native Vegetation Zone 2	Reshaping, replacement of subsoil and topsoil, drainage structure establishment	Completed
	Establishment of cover crop	Completed
	Establishment of monitoring plot	Completed
	Establishment of riplines	Completed
	Planting to native vegetation	Completed
	Infill planting with understorey species	Completed
2(e) Native Vegetation Zone 3	Reshaping, replacement of subsoil and topsoil, drainage structure establishment	Completed
	Establishment of cover crop	Completed
	Planting to native vegetation	Completed
2(f) Native Vegetation Zone 4	Cessation of active mining	Completed
	Reshaping, replacement of subsoil and topsoil, drainage structure establishment	Completed
	Establishment of cover crop	Completed
	Planting to native vegetation	Completed
3 Final Void	Final Shaping at depth of approximately 25 metres	Completed
	Final batter grades achieved in accordance with MOP	Completed
	Subsoil and topsoil replaced	Completed
	Drainage structures installed	Completed
	Banks of void sown to cover crop	Completed
	Banks of void planted out to native vegetation	Not to be completed, pending Vickery Project approval.
4(a) Enrichment Planting Zone 1	Establishment of rip lines through existing native pasture	Replaced by Biobank site (see section 2.5)
	Planting to native vegetation	Replaced by Biobank site (see section 2.5)

DOMAIN	ACTIVITY	COMPLETION DATE
4(b) Enrichment Planting Zone 2	Planting to concentrated clump of native vegetation within existing rehabilitation area	Not to be completed pending Vickery approval.
4(c) Enrichment Planting Zone 3	Establishment of riplines through existing native pasture	Replaced by Biobank site (see section 2.5)
	Planting to native vegetation	Replaced by Biobank site (see section 2.5)
5(a) Emplacement Area 1	Reject emplacement area filled	Completed
	Reject emplacement covered with a minimum of 3 metres of inert overburden material	Completed
	Replacement of subsoil and topsoil	Completed
	Drainage structures in place	Completed
	Cover crop established	Completed
5(b) Emplacement Area 2	Reject emplacement area filled	Completed
	Reject emplacement covered with a minimum of 3 metres of inert overburden material	Completed
	Replacement of subsoil and topsoil	Completed
	Drainage structures in place	Completed
	Cover crop established	Completed
	Rip lines established	End 2013
	Planting to native vegetation	End 2013

3 ENVIRONMENT AND COMMUNITY

Monitoring of environmental parameters continues to be carried out on site during the closure process. These include air quality, wet weather discharge, void water, groundwater and flora and fauna monitoring.

In January 2012, in recognition of the site being in closure the Environment Protection Authority removed all monitoring locations from the Environment Protection Licence, with the exception of wet weather discharge points. Criteria for noise are still included and DA 8-1-2005 MOD 2 still includes monitoring requirements for dust, noise, blasting and water. All monitoring has continued to date with the exception of noise and blasting, given production at the site ceased in mid 2009. Despite ongoing monitoring and application of consent criteria, it would be difficult to attribute any exceedances to the site given there is no production and the site is well rehabilitated.

3.1 Air Quality

Air quality is monitored monthly, with the intention of staged removal of monitoring points on relinquishment of area. Results are shown in Figure 1.

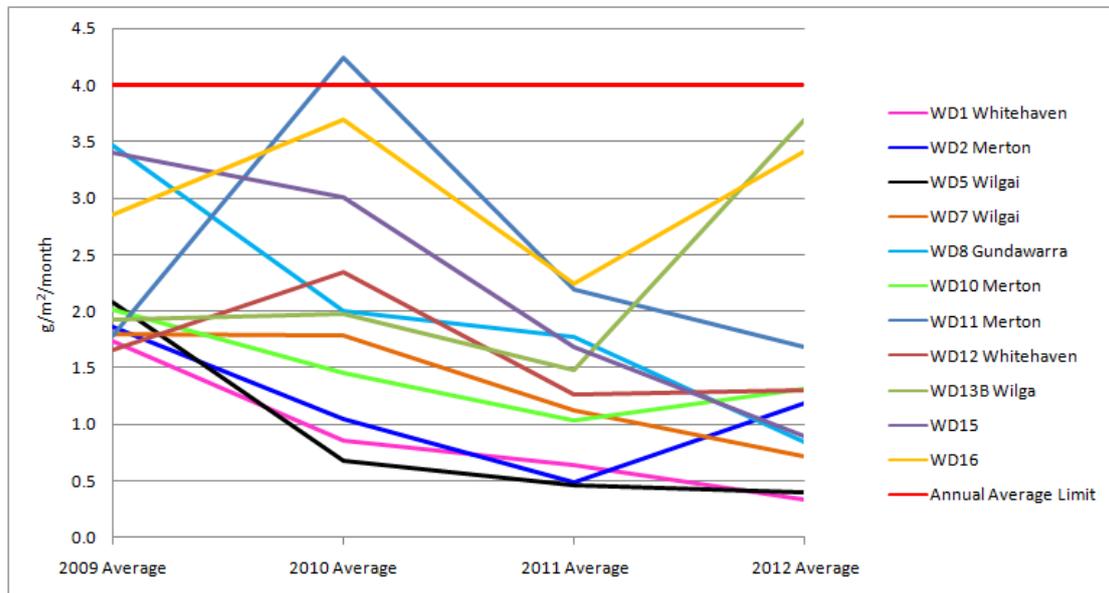


Figure 1 - Annual Average Deposited Dust Results

Figure 1 shows the annual average for each monitoring point since July 2009, compared with the consent limit of $4\text{g}/\text{m}^2/\text{month}$. It should be noted that September 2009 results have been excluded from the graphed data for all monitoring locations as these results were skewed by regional bushfires. December 2010 and January 2011 deposited dust results have also been excluded from WD-13B Womboola as they were highly anomalous with results from that monitoring location during other months as well as results from other monitoring locations during December and January.

The graph shows that all monitoring locations have remained below the annual average criteria of $4\text{g}/\text{m}^2/\text{month}$ since mining ceased in mid 2009, with the exception of WD11 Merton in 2010. WD11 is located on a privately-owned property which is subject to agricultural activities.

The overall trend of the data shows that deposited dust levels are generally remaining at low levels around the Canyon site and are continuing to fall as a consequence of established groundcover across all rehabilitated areas.

3.2 Wet Weather discharge – Surface Water

Wet weather surface water quality is monitored on the basis of wet weather discharge events, with the intention of staged removal of the relevant monitoring points on relinquishment of the area. WW8 and WW9 are the licenced discharge points whilst WW11 and WW12 provide upstream and downstream water quality comparisons. During the period July 2011 – June 2012, two discharges have occurred at Canyon. Results of pH, Total Suspended Solids (TSS) and Oil and Grease are presented below.

Figure 2 shows that the discharges from WW9 on the 14th and 24th November 2011, as well as ambient flows upstream and downstream of Canyon during this reporting period, remained within the pH thresholds of 6.5 – 8.

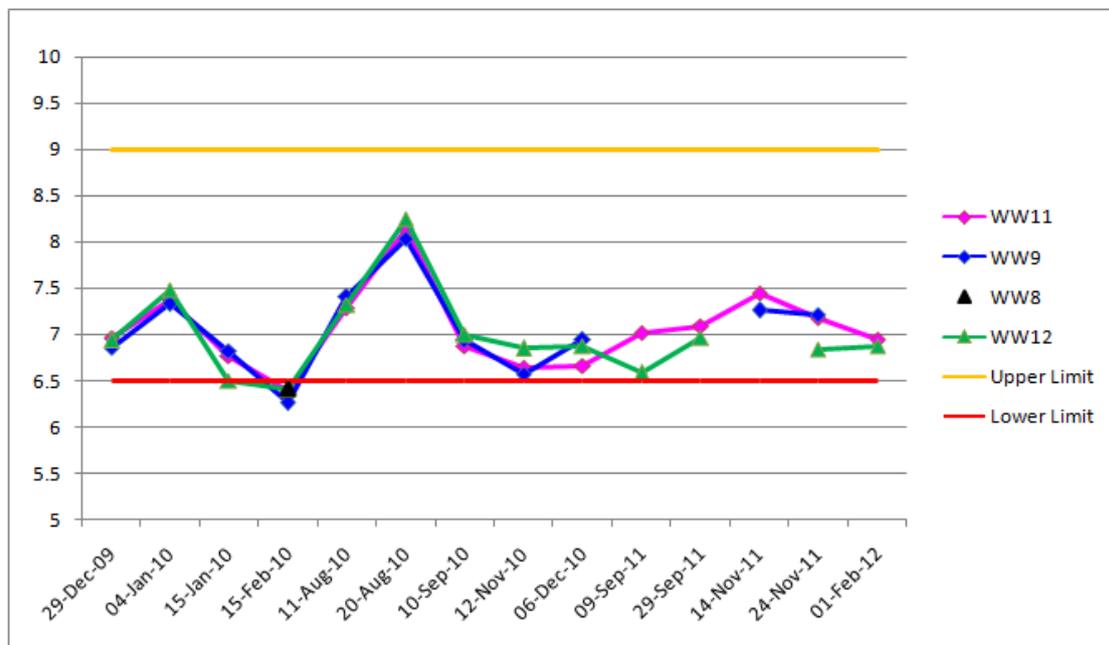


Figure 2 - Wet Weather Discharge pH (2009 - 2012)

Figure 3 shows that water quality from WW9 during the 14th and 24th November 2011 discharges remained at or below the TSS criterion of 50mg/L. TSS levels were much higher at upstream and downstream locations, indicating influence from other non-mining related sources.

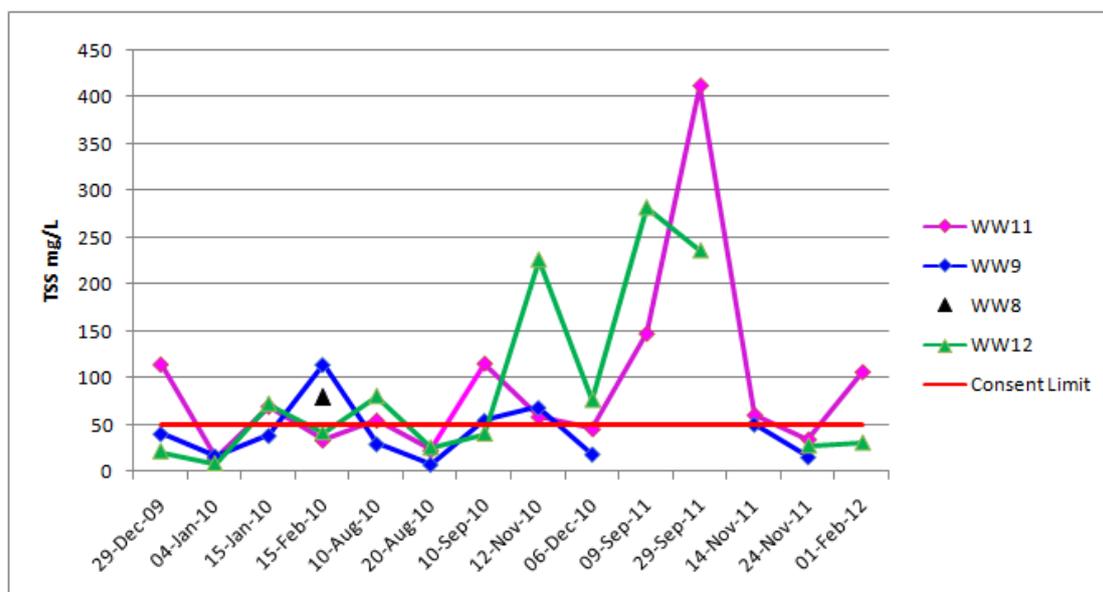


Figure 3 - Wet Weather Discharge TSS (2009 - 2012)

The oil and grease level during both discharges in November 2011 from WW9 were compliant at <5mg/L. All upstream and downstream samples during the reporting period were also <5mg/L.

3.3 Void – Surface Water

During final shaping of the void, care was taken to ensure the RL of the void floor was higher than the RL of the extracted coal seam in order to avoid groundwater seepage into the void. Initial water quality testing since completion of the final void is indicative of EC levels expected in surrounding surface water storages, with no indication of groundwater infiltration. The EC remained stable between July 2011 and June 2012, ranging from 358mg/L to 451mg/L in the lower void. This is consistent with results since mine closure. During mining operations, pit water was generally in the range of 3000-4000 μ s/cm. pH levels remained between 7.65 and 8.52 from July 2011 to June 2012. The water will continue to be monitored over time to determine any change in void water quality.

3.4 Groundwater

Quarterly groundwater monitoring incorporates Standing Water Level (SWL), field Electrical Conductivity (EC) and field pH. Six monthly monitoring includes SWL, field pH and EC as well as laboratory analysis of EC, pH, metals and trace elements. Groundwater monitoring will be ceased through staged removal of relevant monitoring points on relinquishment of the area.

Figure 4 shows the SWL at all monitoring locations has generally remained consistent between 2009 and mid 2012. Any variations in SWL at this stage are considered to be influenced by non-mining activities or seasonal variation.

Figure 5 shows a significant drop in EC levels since mine closure at some monitoring locations, particularly GW-7, GW-8 and GW-9. Ongoing EC trends will be closely monitored over the next 12 months to verify if EC levels remain consistent at these locations.

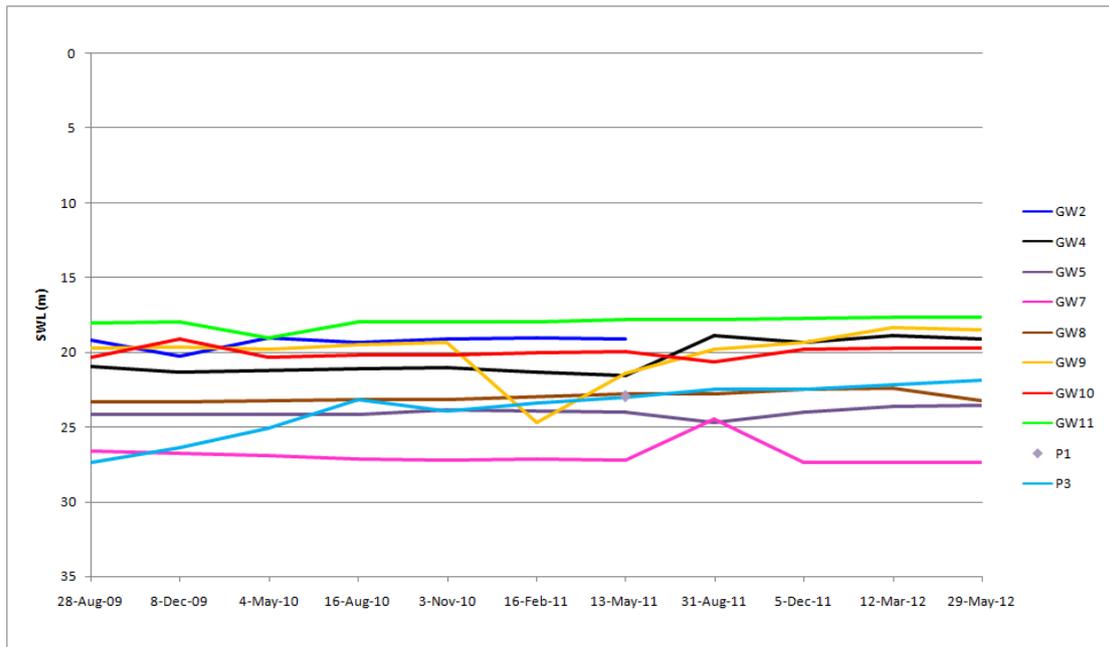


Figure 4 - Standing Water Level (2009 - 2012)

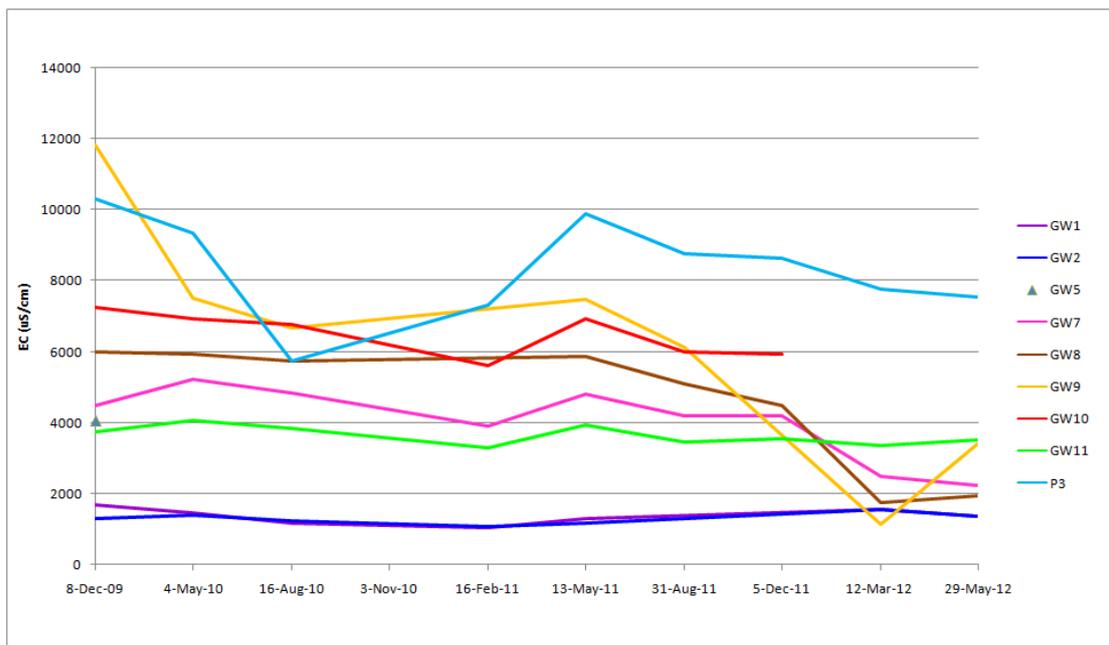


Figure 5 - Groundwater Electrical Conductivity (2009 - 2012)

3.5 Flora and Fauna

Flora and fauna has traditionally been monitored annually by Countrywide Ecological Services and Geoff Cunningham Natural Resource Consultants. Eco Logical Australia Pty Ltd (Eco Logical) was engaged in 2011 to develop a more detailed rehabilitation monitoring program which assesses landscape functionality (rather than flora and fauna in isolation) to enable demonstration of progression towards rehabilitation goals and relinquishment. The first monitoring event was undertaken by Eco Logical in Spring 2011. The report (Appendix 1) indicated that rehabilitation of the Canyon site has been successful to date and that landscape functionality is continuing to trend towards that found in nearby control plots. A number of key ongoing monitoring recommendations were provided. These recommendations have been reviewed and implemented, where practicable, in the Spring 2012 monitoring event.

3.6 Complaints

No complaints were received in the period July 2011 to June 2012. This is not unexpected given the site is in closure. The last complaint was recorded in 2007 when the site was in operation.

Appendix 1 – Rehabilitation Monitoring Report, Spring 2011



Canyon Coal Mine - Rehabilitation Monitoring Report

Spring 2011

Prepared for
Whitehaven Coal Mining Limited

29 August 2012



DOCUMENT TRACKING

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Abbreviations

ABBREVIATION	DESCRIPTION
CHM	Canopy Height Model
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i> (Commonwealth)
NDVI	Normalised Difference Vegetation Index
PCC	Projected Canopy Cover
PFC	Projected Foliar Cover
RMP	Rehabilitation Monitoring Program
TPFC	True Projected Foliage Cover
TSC Act	<i>Threatened Species Conservation Act 1995</i> (NSW)
WCM	Whitehaven Coal Mining Limited

1 Introduction

Canyon Open Cut Coal Mine (Canyon), owned by Whitehaven Coal Mining Pty Ltd (WCM), was established in 2000 as a trial coal mining operation and progressed to long-term operations later that same year. Further expansion towards the south was approved in 2005 to incorporate additional coal reserves. The mine is located within the Narrabri Shire, approximately 30 km north-west of Gunnedah and 16 km south-east of Boggabri in the Gunnedah coalfields of NSW (**Figure 1-1**). The mine lies within the mining leases (MLs) 1464 and 1471. The mine exists on the former “Whitehaven” and “Womboola” properties as well as a small section of the “Merton” property. Prior to mining activities these properties were used for agricultural cultivation and grazing.

Progressive rehabilitation to restore landscape functionality was undertaken across the site over the life of the mine (WCM 2008, 2009). WCM require that rehabilitation be monitored in accordance with their Rehabilitation Monitoring Program (RMP) in order to demonstrate progression towards rehabilitation aims.

1.1 PROJECT SCOPE

This rehabilitation monitoring report documents the Spring 2011 survey results and subsequent data analysis.

Rehabilitation monitoring surveys were undertaken in accordance with the *Rehabilitation Monitoring Program for Canyon Coal Mine* (Eco Logical Australia 2011) and included:

- Remote-sensing based landscape assessment (multi-spectral imagery and EM38/31)
- Agricultural monitoring (using a combination of pasture and soil attributes)
- Native vegetation and fauna surveys
- Analysis of results including statistical analysis.

1.2 AIMS AND OBJECTIVES

The aim of this monitoring report is document the spring 2011 survey results and provide a quantitative assessment of rehabilitation performance against nearby unmined (i.e. control) landscapes.

Specific monitoring objectives include:

- Quantitative tracking of rehabilitation performance
- Assess key aspects of flora (upper, mid and lower strata), fauna and soil, in woodland areas
- Compare data with previous monitoring
- Evaluate monitoring results against monitoring triggers and rehabilitation objectives as outlined in the RMP (Section 4)
- Provide recommendations to assist with the improvement of rehabilitation or monitoring methods.



Figure 1-1: Location of Canyon Mine

2 Site background

For detailed site background refer to *Rehabilitation Monitoring Program for Canyon Coal Mine* (ELA 2011).

2.1 LAND TENURE AND USE

The mine is located on:

- Lot 138 DP 754926 and Lot 2 DP 1038308, Parish of Boggabri
- Lot 1 DP 1015797, Parish of Vickery.

These parcels are held in freehold title by WCM and are located within the Shire of Narrabri. Mining and associated activities has been contained within the Exploration Licence (EL 4699) and MLs 1464 and 1471.

Prior to mining activities these properties were subject to agricultural cultivation and grazing.

The Schedule of Land for the Mine also lists 750 m of Shire road or Road Reserve and around 1.15 km of Crown Road Reserve.

2.2 CLIMATE

The area is characterised by mild to hot summers and cool winters. Rainfall is summer dominant with an average of 72 rain days occurring each year producing a yearly average of 619 mm. Average evaporation exceeds rainfall in all months.

2.3 TOPOGRAPHY

The site is located in a transitory region between the Nandewar, Great Dividing and Liverpool Ranges to the north-east and south and the open plains in the west. Maximum slopes range from more than 45° (Nandewar Range) to 25° (Vickery State Forest). Slopes as small as 1° are found along the floodplains of the Namoi River. Elevation ranges from 240 m AHD to 865 m AHD.

The mine area proper lies along a former north-south trending ridgeline with natural elevations on ML 1471 ranging from 250 m to 276 m AHD. Natural slopes ranged from less than 2° to 6°.

2.4 DRAINAGE

The mining leases are located within the Liverpool Plains catchment of the Namoi River Basin, one of the main tributaries of the Barwon Darling River System. The mine site is located within the Driggle Draggles catchment, an intermittent watercourse. There were no permanent watercourses on the site. Contour banks and farm dams formed part of the site drainage on the pre-mining landform.

2.4.1 Land capability

Land capability is defined as “the ability of land to accept a type and intensity of use permanently, or for specified periods under specific management, without permanent damage”. Land capability involves the consideration of the following factors and their inter-relations:

- Land resource attributes
- Land production
- Inputs and activities to achieve production
- Risks of resultant land degradation from production activities.

Land capability classification uses biophysical attributes such as local climate, soils, geology and topography to provide an indication of the potential of land for uses such as crop production, pasture improvement and grazing.

Land capability classification in NSW ranges from Class I (i.e. greatest potential for agricultural or pastoral use) to Class VIII (i.e. land unsuitable for either activity). The original land capability classes for the majority of the site were either Class II or Class III, with a very small area of Class VI located in the east (WCM 2004, **Table 2-1**).

Table 2-1: Land capability class descriptions relevant to the Canyon site

LAND CAPABILITY CLASS	DESCRIPTION
Class II	Land capable of regular cultivation. Soil conservation practices such as strip cropping, conservation tillage and adequate crop rotations required.
Class III	Land capable of regular cultivation. Structural soil conservation works such as diversion banks, graded banks and waterways are required, together with soil conservation practices listed for Class II.
Class VI	Land not capable of being cultivated but suitable for grazing. Soil conservation practices including stock control, broadcasting of seed and fertiliser, prevention of fire and destruction of vermin. Some structural works may also be required.

Source: Cunningham *et al.* 1988

2.5 FLORA

Much of the study area and surrounds has been highly modified due to agricultural activities. Nine vegetation communities were identified within the ML prior to any mining activities (**Table 2-2**). Note that only dominant tree species are listed below; the original flora assessments are referred to for full species lists.

Table 2-2: Pre-mining vegetation communities

COMM. NO.	VEGETATION COMMUNITY	TREE COVER & SPECIES ¹
1	Level Plains Country - Treeless or with Scattered Trees – Cultivated	Trees spaced 40 to >100 m apart with some small scattered patches of trees <i>Alectryon oleifolius</i> (Rosewood) <i>Eucalyptus populnea</i> subsp. <i>bimbil</i> (Bimble Box) <i>Eucalyptus pilligaensis</i> (Pilliga Grey Box) <i>Casuarina cristata</i> (Belah)
2	Level Plains Country - Treeless or with Scattered Trees – Uncultivated	Trees are spaced from 15 to >100 m apart (where present) <i>Eucalyptus populnea</i> subsp. <i>bimbil</i> (Bimble Box) <i>Alectryon oleifolius</i> (Rosewood) <i>Eucalyptus melanophloia</i> (Silver-leaf Ironbark) <i>Callitris glaucophylla</i> (White Cypress Pine)
3	Undulating Country - Treeless or with Scattered Trees – Cultivated	Tree cover - absent or spaced from 20 to >100 m apart <i>Callitris glaucophylla</i> (White Cypress Pine) <i>Eucalyptus populnea</i> ssp. <i>bimbil</i> (Bimble Box) <i>Eucalyptus melanophloia</i> (Silver-leaf Ironbark) <i>Eucalyptus pilligaensis</i> (Pilliga Grey Box) <i>Schinus areira</i> * (Pepper Tree)
4	Undulating Country - Treeless or with Scattered Trees – Uncultivated	Trees and shrubs were largely absent, with the exception of scattered trees which occurred towards the margins of this community. <i>Alectryon oleifolius</i> (Rosewood) <i>Acacia homalophylla</i> (Yarran)
5	Main Driggle Draggie Creek Channel	Little tree coverage to treeless <i>Alectryon oleifolius</i> (Rosewood) <i>Eucalyptus populnea</i> subsp. <i>bimbil</i> (Bimble Box) <i>Eucalyptus pilligaensis</i> (Pilliga Grey Box) <i>Casuarina cristata</i> (Belah)
6	Dense White Cypress Pine Regeneration	Trees (regenerating <i>Callitris glaucophylla</i> (White Cypress Pine)) are generally spaced between 1-2 m but up to 8 m apart
7	Level Country with Box (<i>Eucalyptus</i> spp.) Communities	Tree cover is spaced from <1 to 20 m apart but can be spaced up to 30 m apart <i>Eucalyptus populnea</i> subsp. <i>bimbil</i> (Bimble Box) <i>Eucalyptus pilligaensis</i> (Pilliga Grey Box) <i>Eucalyptus albens</i> (White Box)
8	Undulating Country with Box or Box / Ironbark (<i>Eucalyptus</i> spp.) / White Cypress Pine Communities	Tree cover varies but spacing ranges from <1 to 20 – 30 m <i>Callitris glaucophylla</i> (White Cypress Pine) <i>Eucalyptus melanophloia</i> (Silver-leaf Ironbark) <i>Eucalyptus albens</i> (White box) <i>Eucalyptus crebra</i> (Narrow leaf Ironbark) <i>Eucalyptus populnea</i> subsp. <i>bimbil</i> (Bimble Box) <i>Eucalyptus melliodora</i> (Yellow Box) <i>Geijera parviflora</i> (Wilga) <i>Eucalyptus pilligaensis</i> (Pilliga Grey Box) <i>Allocasuarina luehmanna</i> (Bull Oak)

COMM. NO.	VEGETATION COMMUNITY	TREE COVER & SPECIES ¹
9	Brigalow (<i>Acacia harpophylla</i>) Community	Isolated patch; tree cover is spaced from 1-5 m apart <i>Acacia harpophylla</i> (Brigalow) <i>Capparis mitchellii</i> (Wild Orange)
10 [#]	Cleared - Cultivated / Uncultivated Pasture Lands (equates to communities 1, 2, 3 and 4)	Tree cover is nearly absent due to the area being generally treeless; some patches of regenerating <i>Callitris glaucophylla</i> (White Cypress Pine) and scattered shrub species
11 [#]	<i>Eucalyptus albens</i> (White Box) Community	Woodland <i>Eucalyptus albens</i> (White Box) <i>Eucalyptus populnea</i> subsp. <i>bimbil</i> (Bimble Box) <i>Eucalyptus crebra</i> (Narrow-leaf Ironbark) <i>Geijera parviflora</i> (Wilga) <i>Callitris glaucophylla</i> (White Cypress Pine)
12 [#]	<i>Eucalyptus crebra</i> (Narrow-leaf Ironbark) – <i>Eucalyptus melanophloia</i> (Silver-leaf Ironbark) – <i>Eucalyptus pilligaensis</i> (Pilliga Grey Box) – <i>Callitris glaucophylla</i> (White Cypress Pine) Community (sub-set of Community 8)	Woodland <i>Eucalyptus crebra</i> (Narrow-leaf Ironbark) <i>Eucalyptus melanophloia</i> (Silver-leaf Ironbark) <i>Eucalyptus pilligaensis</i> (Pilliga Grey Box) <i>Callitris glaucophylla</i> (White Cypress Pine) <i>Allocasuarina luehmannii</i> (Bull Oak) <i>Geijera parviflora</i> (Wilga)
13 [#]	<i>Eucalyptus populnea</i> subsp. <i>bimbil</i> (Bimble Box) – <i>Eucalyptus pilligaensis</i> (Pilliga Grey Box) Community (sub-set of Community 8)	Woodland <i>Eucalyptus populnea</i> subsp. <i>bimbil</i> (Bimble Box) <i>Eucalyptus pilligaensis</i> (Pilliga Grey Box) <i>Callitris glaucophylla</i> (White Cypress Pine) <i>Alectryon oleifolius</i> (Rosewood) <i>Geijera parviflora</i> (Wilga)

¹ For full species list refer to GCNR 2004 *Flora Study of 'The Canyon' Area Extension*

Unless otherwise noted all communities 1-9 were identified in the 2000 assessment (GCNR 2000)

[#] Communities 10-13 were identified in 2004 for the Canyon extension (GCNR 2004)

Source: WCM 2006

The total area disturbed within each vegetation community within ML 1471 and 1464 during the operation of Canyon mine is summarised in **Table 2-3**.

Table 2-3: Area of disturbance of vegetation communities

COMM. NO.	VEGETATION COMMUNITY	TOTAL AREA DISTURBED (ha)
1	Level Plains Country - Treeless or with Scattered Trees – Cultivated	-
2	Level Plains Country - Treeless or with Scattered Trees – Uncultivated	-
3	Undulating Country - Treeless or with Scattered Trees – Cultivated	-
4	Undulating Country - Treeless or with Scattered Trees – Uncultivated	-
5	Main Driggle Draggie Creek Channel	-
6	Dense White Cypress Pine Regeneration	2.2
7	Level Country with Box (<i>Eucalyptus</i> spp.) Communities	-
8	Undulating Country with Box or Box / Ironbark (<i>Eucalyptus</i> spp.) / White Cypress Pine Communities	-
9	Brigalow (<i>Acacia harpophylla</i>) Community	-
10 [#]	Cleared - Cultivated / Uncultivated Pasture Lands (equates to communities 1, 2, 3 and 4)	150.7
11 [#]	<i>Eucalyptus albens</i> (White Box) Community	-
12 [#]	<i>Eucalyptus crebra</i> (Narrow-leaf Ironbark) – <i>Eucalyptus melanophloia</i> (Silver-leaf Ironbark) – <i>Eucalyptus pilligaensis</i> (Pilliga Grey Box) - <i>Callitris glaucophylla</i> (White Cypress Pine) Community (sub-set of Community 8)	65.3
13 [#]	<i>Eucalyptus populnea</i> subsp. <i>bimbil</i> (Bimble Box) – <i>Eucalyptus pilligaensis</i> (Pilliga Grey Box) Community (sub-set of Community 8)	

[#] Communities 10-13 were identified in 2004 for the Canyon extension (GCNRC 2004)
Communities 1-9 were identified in the 2000 assessment (GCNRC 2000)

No records of threatened flora species were found as listed on the Schedules of the NSW *Threatened Species Conservation Act 1995* (TSC Act). Similarly, there were no records of species listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) as being recorded/predicted to occur in the region surrounding the mine.

No Endangered/Threatened Ecological Communities were impacted by the mine.

The remnant native vegetation areas are regarded as potential koala habitat.

Introduced weed and pasture species were found in groundcover species both in cropped areas and areas of remnant native vegetation (GCNRC 2004). Noxious weed species included:

- *Lycium ferocissimum* (African Boxthorn)
- *Sclerolaena birchii* (Galvanised Burr)
- *Xanthium spinosum* (Bathurst Burr)
- *Echium plantagineum* (Paterson's Curse)
- *Opuntia stricta* (Prickly Pear).

2.6 FAUNA

Three broad habitat types were identified on the pre-mining environment (CES 2004):

- Open woodland
- Cleared paddocks (with scattered trees)
- Farm dams.

During the same study the following fauna were recorded:

- Five amphibians
- Five reptiles
- 41 birds
- 29 mammals.

Pomatostomus temporalis temporalis (Grey-crowned Babbler), *Neophema pulchella* (Turquoise Parrot) and *Falco hypoleucos* (Grey Falcon) listed as being vulnerable under the TSC Act were recorded either on the site or in the vicinity. Yellow-bellied Sheath-tail bat (*Saccolaimus flaviventris*) was also recorded; this bat is also listed as vulnerable under the TSC Act. Three of the recorded exotic mammal species are associated with Key Threatening Processes listed in the Schedules of the TSC Act (European Rabbit (*Oryctolagus cuniculus*), European Red Fox (*Vulpes vulpes*) and Feral Cat (*Felis catus*).

3 Rehabilitation history and objectives

3.1 REHABILITATION HISTORY

3.1.1 Rehabilitation of pasture areas

Rehabilitation to pasture involved the following activities:

- Overburden replacement and shaping to create slopes of gradients generally less than 1:10 (V:H), i.e. 6 ° and no greater than 1:5 (V:H), or approximately 11 °
- Friable or weathered materials were placed over the overburden/interburden materials to minimise large rock exposure on the landform surface
- Subsoil and topsoil reinstatement, including:
 - Subsoil and topsoil were redeployed in the reverse order they were stripped. Soil was reinstated preferentially from the areas they were stripped during pre-mining activities, or where unavailable, from previously established stockpiles
 - Soil was reinstated on an even but roughened surface to allow for keying of the soil materials, to encourage water infiltration and to minimise potential for erosion
 - The height of reinstated subsoil and topsoil was based on the availability of these materials and on the surface area of the final footprint
 - Approximately 15-20 cm subsoil and 20 cm topsoil was replaced
- Where possible, topsoil stripped from cleared areas was redeployed on areas rehabilitated to pasture and the same for areas to be rehabilitated to native vegetation
- Topsoil surfaces were scarified to encourage moisture infiltration, inhibit soil erosion and assist pasture seed establishment
- Contour/graded banks were constructed to maintain surface flows below erosive velocities.
- The topsoil surface was sown with a mixture of pasture species, in accordance with the season (**Table 3-1**)
- Scratch or direct drilling techniques in lieu of broadcast seeding in combination with straw mulching, bitumen mulching and hydro mulching was undertaken where rapid soil stabilisation/erosion protection was required
- In sections for pasture establishment and a post-mining grazing land use, tree plantings were undertaken in lots of up to 0.1 ha to provide long term stock shelter. This was undertaken on rip lines using a mix of locally occurring species (Bimble Box, Pilliga Grey Box, Silver-leaf Ironbark, White Box, Narrow-leaf Ironbark, Yellow Box, Wilga, Rosewood, Bull Oak and White Cypress Pine) in appropriate topographic locations. Tree seedling spacing was approximately 5 m. Plastic tree guards were established on transplanted seedlings to inhibit grazing by native animals, rabbits and hares.

Table 3-1: Rehabilitation pasture mix

PASTURE SPECIES	RATE (kg/ha)
Warm Season Grasses	
Bombastic Panic	1 – 2
Green Panic **	2 – 4
Rhodes Grass **	1 – 2
Purple Pigeon Grass	1 – 2
Annual Legumes *	
Subterranean Clover	4 - 5
Cool Season Legumes *	
Barrel (Sephi) Medic	2 – 4
Snail (Sava) Medic **	3 – 5
Woolly Pod Vetch	4 – 6
Serradella (Elgara)	1 – 2
Lucerne	0.5
Cool Season Grasses	
Phalaris (Sirolon or Holdfast)	1 – 2
Wallaby Grass	0.3 - 1

* Inoculated with appropriate rhizobia

** Specific Soil conservation applications

*** Apply 250kg/ha Di-ammonia Phosphate with all seedlings

Reference: Soil Services

Source: WCM 2006

3.1.2 Rehabilitation of native vegetation areas

Rehabilitation of areas to native vegetation involved the following:

- Overburden replacement and shaping to create slopes of gradients generally less than 1:10 (V:H), i.e. 6 ° and no greater than 1:5 (V:H), or approximately 11 °
- Friable or weathered materials were placed over the overburden/interburden materials to minimise large rock exposure on the landform surface
- Subsoil and topsoil reinstatement included:
 - The height of reinstated subsoil and topsoil was based on the availability of these materials and on the surface area of the final footprint
 - Approximately 50 cm subsoil/friable overburden and 7 cm topsoil was replaced in native vegetation areas except in areas assigned to Class II land capability. Subsoil and topsoil thickness in these areas are nominated as 50 cm and 15 cm, respectively.
 - Topsoil surfaces were scarified to encourage moisture infiltration, inhibit soil erosion and assist pasture seed establishment
- Contour/graded banks were constructed to maintain surface flows below erosive velocities
- Seeding of the topsoil surface with a non-persistent exotic cover crop species (e.g. Japanese Millet, Wheat or Barely) to provide surface stability prior to natural regeneration.
- Depending on natural regeneration from the seedbank, seeds and/or seedlings from native tree and shrub species collected from the woodland areas over the life of the mine were sown in continuous belts along the contour following previous rip-lines (topsoil was scarified prior to seeding) as a random mix (4-5 m spacing) at a planting density of around 400 seedlings per ha.
- Debris retained during clearing, or material directly transferred from recently cleared areas, was redeployed over the landscape (biomass transferral) to provide mulch, to encourage the establishment of vegetation, to encourage moisture retention and erosion control, and to provide fauna habitat.
- Native tree and shrub species, grown from locally collected seed, were planted along the contour rip-lines at 4-5 m spacing (or 400 trees per ha). Seedling planting mixes were based on the recommendations provided by Geoff Cunningham Natural Resource Consultant, with differing species and/or proportions of species used on lower slopes / drainage flats; mid-slopes and upper slopes and crests (**Table 3-2**)
- Areas were protected via:
 - Maintenance of perimeter fencing to exclude stock
 - Tree guard installation to prevent wind and frost damage, as well as inhibit rabbit/hare grazing.
 - Temporary fencing around tree lots that will be removed once trees reach a height of 4-5 m and are not susceptible to damage from grazing
 - Exotic vertebrate pest control.

3.2 TIMELINE OF REHABILITATION ACTIVITIES AT CANYON MINE

Progressive rehabilitation and revegetation to pasture and native bushland have been undertaken since early 2003 (**Figure 3-1; Table 3-3**) (WCM 2006).

Table 3-2: Seedling planting mixes for native vegetation rehabilitation areas

SPECIES		UPPER SLOPES / CRESTS (%)	MID-SLOPES (%)	LOWER SLOPES / DRAINAGE FLATS (%)
TREES	<i>Eucalyptus melanophloia</i> Silver-leaf Ironbark	15	4	
	<i>Eucalyptus crebra</i> Narrow-leaf Ironbark	30	15	
	<i>Calitris glaucophylla</i> White Cypress Pine	25	22	10
	<i>Geijera parviflora</i> Wilga	5		
	<i>Euclayptus albens</i> White Box	10	40	
	<i>Eucalyptus melliodora</i> Yellow Box	30		
	<i>Eucalyptus pilligaensis</i> Pilliga Grey Box		10	25
	<i>Eucalyptus populnea</i> Bimble Box			25
	<i>Allocasuarina luehmannii</i> Bull Oak			10
SHRUBS	<i>Eremophila debilis</i> Amulla	3	2	2
	<i>Alectryon oleifolius</i> Rosewood			2
	<i>Acacia homalophylla</i> Yarran			5
	<i>Caparis mitchellii</i> Wild Orange			1
	<i>Notelaea microcarpa</i> Native Olive	8	2	
	<i>Maireana microphylla</i> Eastern Cotton bush	4	2	
	<i>Eremophila mitchellii</i> Budda	5		

Source: WCM 2006

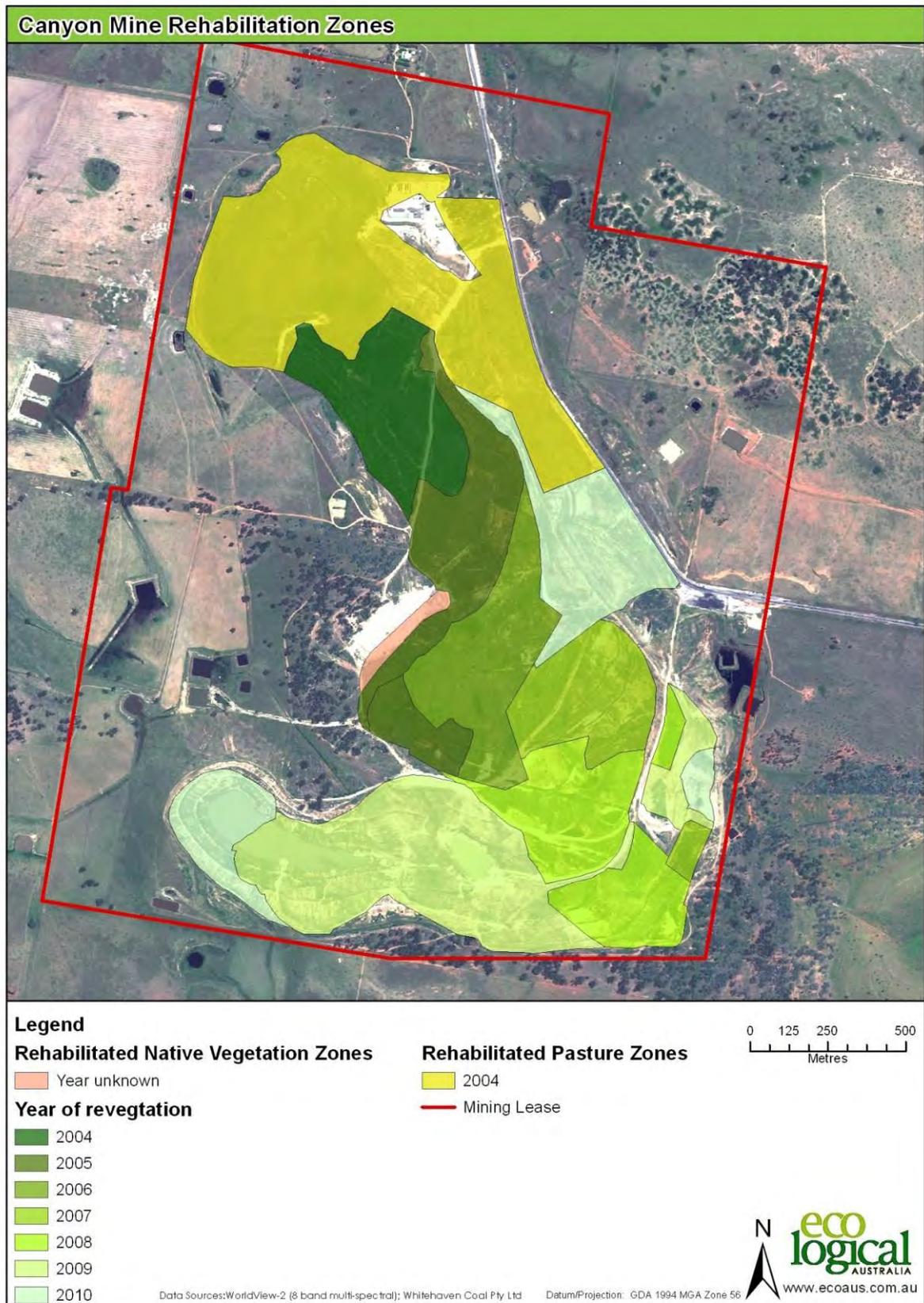


Figure 3-1: Rehabilitation zones (as at 2012)

Table 3-3: Rehabilitation and monitoring history

	CLOSURE DOMAIN	YEAR OF REHAB	REHAB ZONES	REHAB METHOD	LAND CAPABILITY CLASS (POST MINE)	EXISTING MONITORING (QUADRAT NO)	CONTROL (QUADRAT NO)
Infrastructure Areas	1 (a) Infrastructure Areas	2011	1	Pasture (part of 16 ha commitment to re-establish Class II capability land)	2		3
	1 (b) Infrastructure Areas	2011	1	Pasture (part of 16 ha commitment to re-establish Class II capability land)	2		3
	1 (c) Infrastructure Areas	2010	1	Native vegetation (part of 132 ha to return mining areas to native vegetation)	5		1
	1 (d) Infrastructure Areas		1	Pasture (part of 16 ha commitment to re-establish Class II capability land)	2		3
Rehabilitation Zones	2(a) Pasture Zone 1	2004	1	Pasture (part of intended goal to return to 41.4 ha of pasture)	5	2	3
	2(b) Pasture Zone 2	2004	1	Pasture (part of 16 ha commitment to re-establish Class II capability land)	2	4	3
	2(c) Native Vegetation Zone 1	2004	1	Native Vegetation (part of intended goal to return to 132 ha of native vegetation)	3/5		1
	2(d) Native Vegetation Zone 2	2004	1	Native Vegetation (part of intended goal to return to 132 ha of native vegetation)	5	5&6	1
		2005	2				
		2006	3				
	2(e) Native Vegetation Zone 3	2005	1	Native Vegetation (part of intended goal to return to 132 ha of native vegetation)	3/5	7&8	1
		2006	2				
		2007	3				
		2008	4				
2(f) Native Vegetation Zone 4	2007	1	Native Vegetation (part of intended goal to return to 132 ha of native vegetation)	2/3/6			
	2008	2					
	2009	3					
Final Void	3 Final Void	2009	1	To return Void to MOP plan (Native vegetation (on re-shaped banks))	4/5	9&10	
		2010	2				
Emplacement Area	5(a) Emplacement Area 1	2010	1	Pasture (part of 16ha commitment to re-establish Class II capability land)	2		3
	5(a) Emplacement Area 2	2010	1	Pasture (part of intended goal to return to 41.4 ha of pasture)	5		3

3.3 CLOSURE DOMAINS

Five primary closure domains were created for the final landscape (**Table 3-4; Figure 3-2**). Closure domains were chosen to reflect the prior land use and/or rehabilitation type.

Table 3-4: Closure Domains

DOMAIN		REHABILITATED LAND USE
1 Infrastructure Areas		
1(a)	Site Office and Facilities Crib Room First Aid Room Car Park Area Former Orica Hardstand	Pasture
1(b)	Workshop Fuel Farm Hardstand / Storage Area	Pasture
1(c)	Coal loading bin ROM Pad Coal loading facilities and road access area	Native Vegetation
1(d)	Explosives magazine	Pasture
2 Rehabilitation Zones		
2(a)	Pasture Zone	Pasture
2(b)	Pasture Zone	Pasture
2(c)	Native Vegetation Zone 1	Native Vegetation
2(d)	Native Vegetation Zone 2	Native Vegetation
2(e)	Native Vegetation Zone 3	Native Vegetation
2(f)	Native Vegetation Zone 4	Native Vegetation
3	Final Void	Banks – native vegetation
5 Emplacement Areas		
5(a)	Emplacement Area 1	Pasture
5(b)	Emplacement Area 2	Pasture



Figure 3-2: Closure domains

3.4 REHABILITATION GOALS

The rehabilitation goal of the Canyon mine site for closure is to return the land areas to agricultural capability consistent with those that existed pre-mining, as well as provide for improved biodiversity by the establishment of woodland areas on the remainder of the site.

The final rehabilitation outcomes and associated mine closure objectives are linked to commitments identified in the Environmental Management Strategy, Mining Operations Plan and Mine Closure Plan for the site (WCM 2005, 2008, 2009).

4 Management triggers

A two-tiered system of triggers for management was developed in the RMP as a response to any changes identified via remote sensing.

The first tier of response is triggered by changes detected in the remote sensing time series analysis which instigates further investigation including targeted rapid on-ground assessments (**Table 4-1**).

The second tier of response is triggered if changes are confirmed or discovered on-ground (**Table 4-2**). These triggers instigate the development of site specific management responses and remedial actions.

This report documents the baseline collection and analysis of data over this site, hence these monitoring triggers do not apply. However, any potential issues noted either using the remote sensing or field-based survey were documented and reported to WCM.

Table 4-1: Remote sensing monitoring triggers for management

TRIGGER	INVESTIGATION	MANAGEMENT
Remote sensing change detection identifies areas of significant change (> +/-2 std dev from average) in area greater than 0.1 ha	Investigate sources of change via desktop assessment: <ol style="list-style-type: none"> 1. Obvious external influence e.g. fire, major storm, or unrelated development) 2. Potentially due to weed infestation, erosion / sedimentation, poor cover establishment 	Respond to change based on likely source of impact: <ol style="list-style-type: none"> 1. Identify region of change and tag it as non-project specific impact; 2. Undertake directed field investigation via rapid field checking protocol (Table 4-2).

Table 4-2: Rapid field checking protocol and management

PARAMETER	METHOD	MANAGEMENT
Weed invasion	Document key weed species, estimate of % of weed cover in defined impact area Determine if invasive environmental or declared weed Enter location and extent of infestation (within limits of inspection) into GIS database	Weed management will be implemented to limit the spread and colonization of noxious and environmental weeds. 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 (<i>Sclerolaena birchii</i>). Follow-up inspections to assess the effectiveness of the weed management measures implemented and the requirement for any additional management measures.
Erosion or sedimentation	On ground inspection record nature and extent of erosion (location, erosion type, depth of soil loss)	Identify cause / source and refer to Sediment Control Plan and/or seek expert advice to develop site specific management of erosion
Sedimentation (deposition)	On ground inspection record nature and extent of sedimentation (location, extent, depth, sediment calibre)	
Bare soil	On ground inspection to record nature and extent of bare soil Investigate cause of bare soil and document likely reasons (soil testing may be required)	Develop a site specific management plan to ameliorate the bare soil area

The agricultural monitoring provides quantitative data on key pasture and soil attributes as they relate to land agricultural capability. Management response triggers are linked primarily to statistically significant decline in pasture or soils condition or other management issues noted by the field team during sampling (**Table 4-3**).

Table 4-3: Agricultural area monitoring triggers for management

TRIGGER	MANAGEMENT
Statistically significant change detected in either: <ul style="list-style-type: none"> • pasture biomass • pasture species composition • weed cover • soil character (pH, EC, OM, N or P) 	Verify with field assessment and determine appropriate response e.g. assess soil fertility and condition and consider treatment
Weed infestation	Notify WCM
Soil erosion	Notify WCM

The woodland area monitoring program provides quantitative data on woodland habitat condition, fauna species and soil attributes. Management response triggers are linked primarily to statistically significant decline (cover or composition) in vegetation in any strata or other management issues noted by the field team during sampling (**Table 4-4**).

Table 4-4: Woodland area monitoring triggers for management

TRIGGER	MANAGEMENT
Statistically significant decline detected in either: <ul style="list-style-type: none"> • Native overstorey (cover, health, richness, recruitment) • Mid storey (cover, richness) • Ground cover (cover, richness) • Weeds (cover, richness) • % ground cover 	Verify with field assessment and determine appropriate response
Exotic fauna	Notify WCM
Weed infestation	Notify WCM
Soil erosion	Notify WCM

5 Methods

Rehabilitation has taken place in a progressive manner to create areas of pasture and woodland, resulting in eight unique rehabilitation zones (**Figure 3-1**; **Table 5-1**).

Table 5-1: Rehabilitation Monitoring Zones

LANDSCAPE TYPE	REHABILITATION DATE	AREA (ha)
Pasture	2004	46
Woodland	2004	15
Woodland	2005	18
Woodland	2006	15
Woodland	2007	12
Woodland	2008	20
Woodland	2009	32
Woodland	2010	21

Given the size of the area and the different land uses and domains, a multi-scale, multi-data source monitoring approach has been used. Remote sensing has been used to monitor the entire target area including control areas. Targeted field work was implemented for agricultural and native vegetation environments, with surveys directed into control and impact areas.

5.1 REMOTE SENSING

5.1.1 Multi-spectral image processing and analysis

Multi-spectral imagery was captured across the entire target area and control areas on 24 February 2012 using WorldView-2. This image was then processed into a normalised difference vegetation index (NDVI). The image was stratified into the rehabilitation zones and control zones for both the pasture and woodland areas. Point data were extracted from the NDVI from which 1000 points were randomly selected to ensure equal sample size. Comparison was made using MDS plots and ANOVA to determine if data in any of the zones are significantly different from each other ($p < 0.05$). Tukey's HSDs comparison of means was used to identify where the differences occur.

5.1.2 EM38 and EM31 survey

EM38 was used to provide information on the variability in soil surface conductivity in the top 0.5-1.0 m of soils while EM31 was used to provide information in the deep subsoil 2-8 m. The conductivity readings give an indication of soil moisture, soil ions (salt) and soil texture variations.

EM38/31 survey was undertaken on 12 April 2012 over the pasture areas only and processed into soil conductivity maps. These data were assessed to delineate regions of like soil conductivity.

A total of 34.6 mm of rain fell during the seven days preceding and on the day of the EM survey (BoM 2012).

5.2 PASTURE AREA SURVEYS

Surveys were conducted on 6 and 8 December 2011 by ecologist Dr Lachlan Copeland and Damien Smith.

This monitoring procedure assessed parameters related to pasture productivity and soil nutrient status. Eight survey site locations were selected from the pasture rehabilitation zone and eight each from the two adjacent control areas using a targeted design (**Figure 5-1**;

Table 5-2). Survey sites were located to be:

- At least 50 m from a rehabilitation boundary
- Each site a minimum of 100 m from another site.

At each site a 1 m by 1 m quadrat was placed and assessed for pasture biomass (cover % estimate and biomass) and composition including weeds. Following pasture survey a soil sample to 150 mm was taken from the centre of each quadrat location. The soil sample was bagged and stored appropriately for laboratory analysis of pH, EC, N, P and organic matter. Soil analysis was conducted by East-West EnviroAg.

Incidental observations of weed species were made while moving between quadrats. Had significant weed outbreaks been noted, they would have been recorded with a GPS and reported to WCM.

Four soil pits to a depth of 1 m were established, two in the rehabilitation area and one in two of the control areas (**Figure 5-2**). Soil pits were described using standard field measures with particular notice of horizon boundaries and ecological functionality (e.g. root establishment, evidence of soil fauna).

Table 5-2: Pasture monitoring locations and survey dates

TREATMENT	PLOT	EASTING*	NORTHING	DATE
Rehabilitation	1	228719	6596750	6/12/2011
	2	228962	6596709	6/12/2011
	3	229156	6596815	6/12/2011
	4	228929	6596857	6/12/2011
	5	229606	6596393	6/12/2011
	6	228872	6596961	6/12/2011
	7	228951	6597096	6/12/2011
	8	229291	6596701	6/12/2011
Control	9	229569	6597206	6/12/2011
	10	228799	6597351	8/12/2011
	11	229147	6597223	6/12/2011
	12	229566	6597100	8/12/2011
	13	228560	6596357	6/12/2011
	14	228854	6596229	6/12/2011
	15	228984	6596354	8/12/2011
	16	2289445	6596172	6/12/2011
	17	228688	6597035	6/12/2011
	18	228769	6597182	6/12/2011
	19	228561	6596208	6/12/2011
	20	228693	6596215	6/12/2011
	21	229700	6597197	6/12/2011
	22	229680	6597085	6/12/2011
	23	228805	6596334	6/12/2011
	24	228632	6596449	6/12/2011

Datum: GDA 94 Zone 56

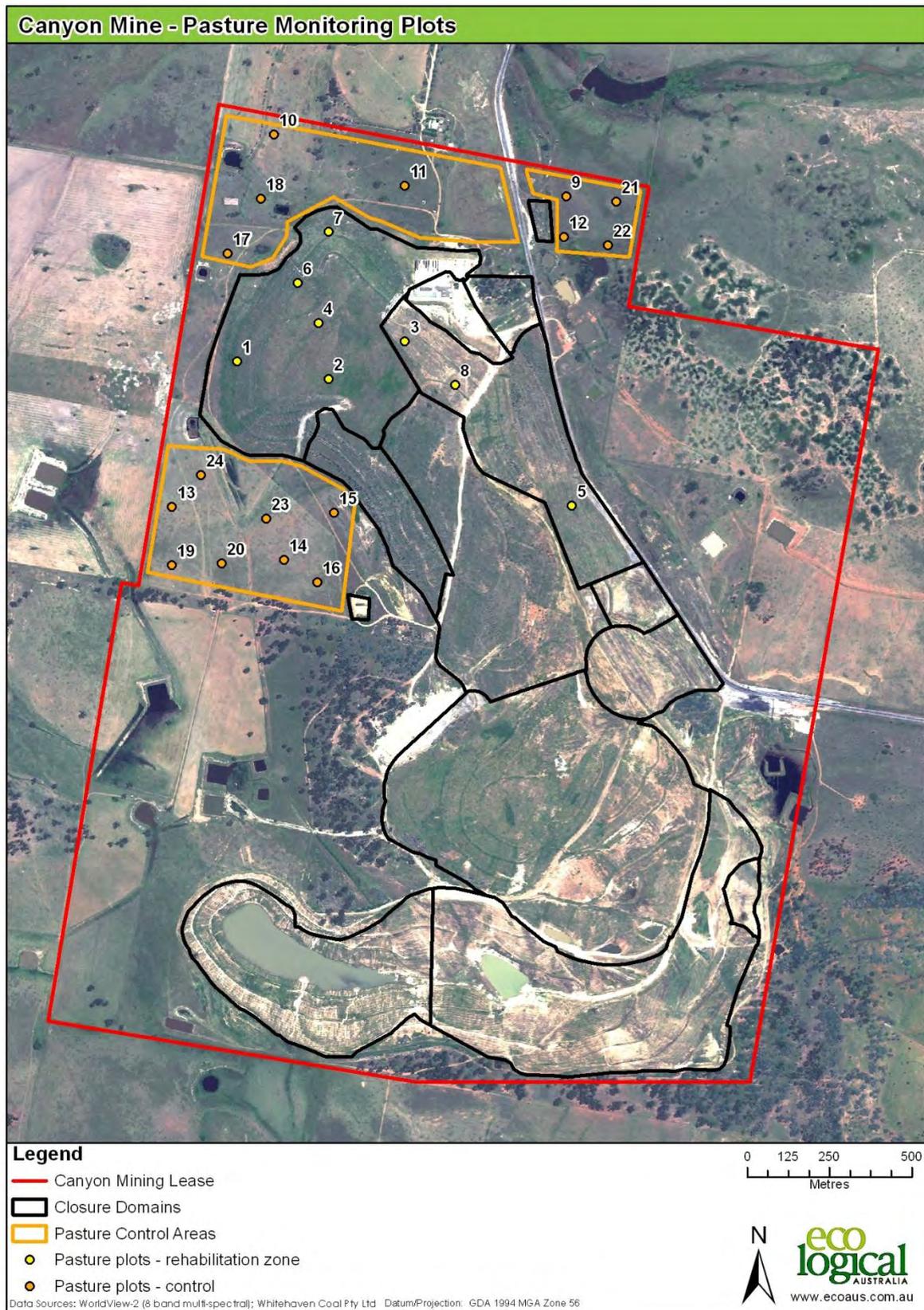


Figure 5-1: Canyon Mine - Pasture Monitoring Plots

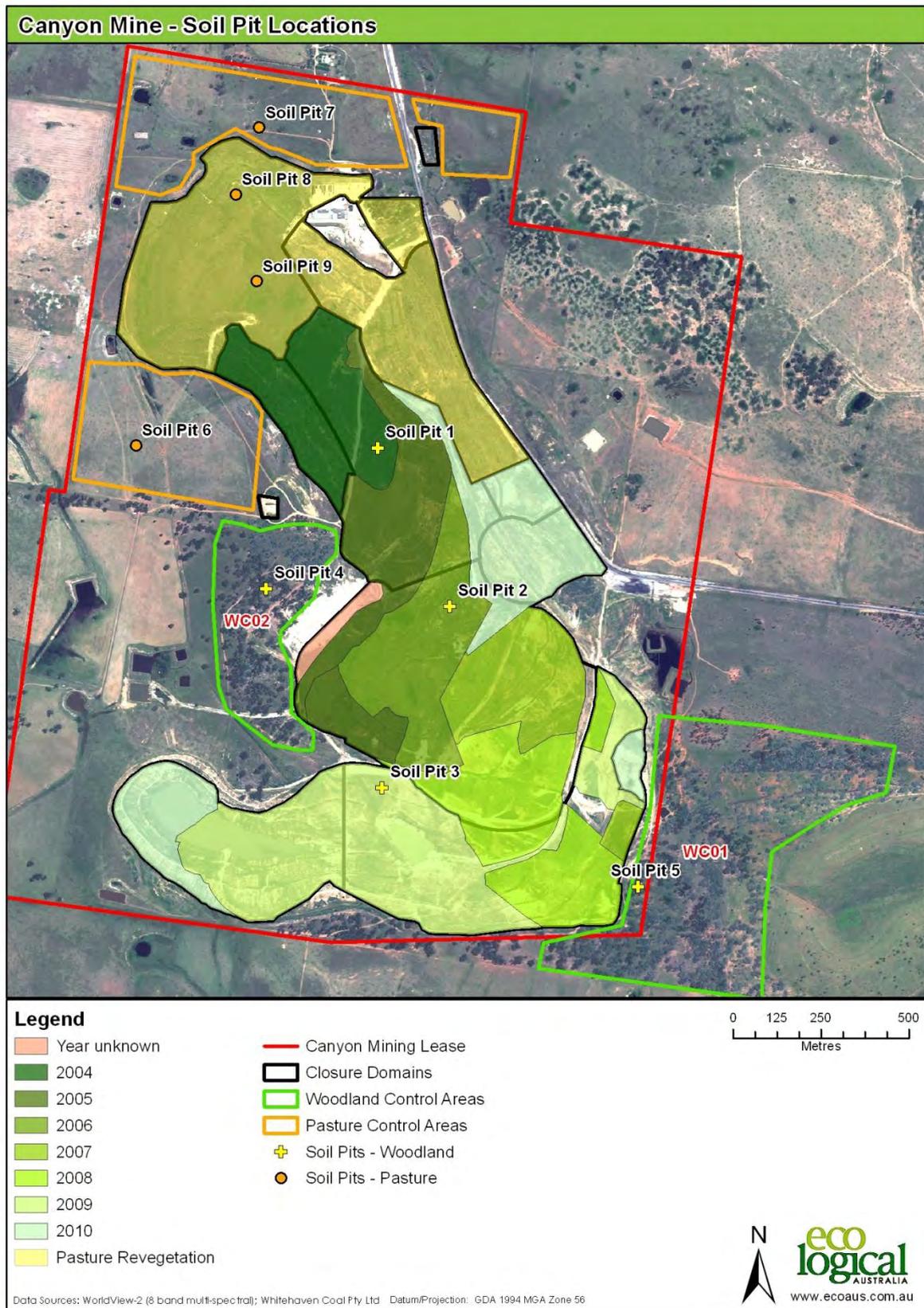


Figure 5-2: Canyon Mine - Soil Pit locations

5.3 WOODLAND SURVEYS

Five survey site locations were selected from each woodland rehabilitation zone and five each from the two adjacent control areas using a targeted design (**Figure 5-3**). Survey sites were located to be:

- At least 50 m from a rehabilitation boundary
- Each site a minimum of 150 m from another site.

No monitoring of enrichment zones (which were part of the original offset strategy) has been included in the monitoring.

In addition, five soil pits to a depth of approximately 1 m were established, three in the rehabilitation area and one in each of the control areas (**Figure 5-2**). Soil pits were described using standard field measures with particular notice to horizon boundaries and ecological functionality (e.g. root establishment, evidence of soil fauna).

5.3.1 Vegetation

Surveys were conducted on various days in December 2011 and January 2012 by ecologist Dr Lachlan Copeland and Damien Smith.

Vegetation monitoring focused on the woodland rehabilitation zones and adjacent control areas. Surveys focused on condition and function of woodland vegetation. The woodland vegetation habitat monitoring sites are identified in **Table 5-3** and **Figure 5-3**.

A suite of parameters related to vegetation health and habitat value were assessed (**Table 5-4**). Key parameters were collected for the upper, mid and ground strata at both impact sites and control sites to enable comparison.

A useful measure of vegetation condition is True Projected Foliage Cover (TPFC) which is effectively the proportion of a given area that is covered by foliage/branches/stems in a given stratum. It is easily visualised as the amount of shade cast by the canopy if the sun was shining directly overhead. The TPFC is calculated by multiplying the mean Projected Foliage Cover (PFC, expressed as a decimal) underneath a canopy, by the Projected Crown Cover (PCC) of each strata within a community. The method of calculating TPFC used in this project provides a more accurate percentage of cover than PFC or PCC alone.

The base vegetation plot was 50 m x 20 m and incorporated a 20 m x 20 m nested subplot, a 50 m centre transect, a photo point, and an alignment point.

Figure 5-4 shows the plot layout and **Table 5-5** summarises the sampling units. The standard plot layout was used in both modules.

Table 5-3: Woodland monitoring sites and date of surveys

TREATMENT	PLOT ID	START EASTING	START NORTHING	DATE SURVEYED	TRANSECT BEARING (°)
Rehabilitation 2010	1	228771	6595308	9/01/2012	100
	2	228730	6595157	9/01/2012	120
	3	229771	6596171	8/12/2011	140
	4	229896	6595954	8/12/2011	160
	5	229740	6595863	20/12/2011	330
Rehabilitation 2009	6	229313	6595081	9/01/2012	80
	7	229587	6595023	11/01/2012	350
	8	229061	6595034	9/01/2012	100
	9	228887	6595231	9/01/2012	300
	10	229980	6595344	20/12/2011	50
Rehabilitation 2008	11	229667	6595376	21/12/2011	60
	12	229687	6595161	20/12/2011	280
	13	229816	6595290	20/12/2011	60
	14	229796	6595007	11/01/2012	10
	15	229978	6595080	21/12/2011	40
Rehabilitation 2007	16	229821	6595502	20/12/2011	240
	17	229780	6595743	20/12/2011	170
	18	229616	6595515	11/01/2012	260
	19	229667	6595648	20/12/2011	270
	20	229897	6595639	20/12/2011	200
Rehabilitation 2006	21	229560	6595883	8/12/2011	30
	22	229569	6595737	8/12/2011	350
	23	229398	6595736	8/12/2011	60
	24	229491	6595561	11/01/2012	190
	25	229534	6595400	21/12/2011	250
Rehabilitation 2005	26	229426	6595954	8/12/2011	90
	27	229482	6596119	8/12/2011	230
	28	229483	6596294	8/12/2011	340
	29	229324	6596068	5/12/2011	10
	30	229230	6595533	5/12/2011	350

TREATMENT	PLOT ID	START EASTING	START NORTHING	DATE SURVEYED	TRANSECT BEARING (°)
Rehabilitation 2004	31	228975	6596539	6/12/2011	320
	32	229234	6596607	5/12/2011	20
	33	229232	6596224	8/12/2011	180
	34	229147	6596433	8/12/2011	170
	35	229302	6596389	8/12/2011	200
Control	36	230471	6595217	9/12/2011	270
	37	230521	6595381	9/12/2011	280
	38	230387	6594823	21/12/2011	50
	39	230004	6594823	21/12/2011	120
	40	230264	6595071	21/12/2011	120
	41	229092	6595856	5/12/2011	330
	42	229060	6595481	5/12/2011	170
	43	228970	6595744	5/12/2011	-
	44	229062	6595639	5/12/2011	290
	45	229093	6595989	5/12/2011	300

Datum: GDA 94 Zone 56

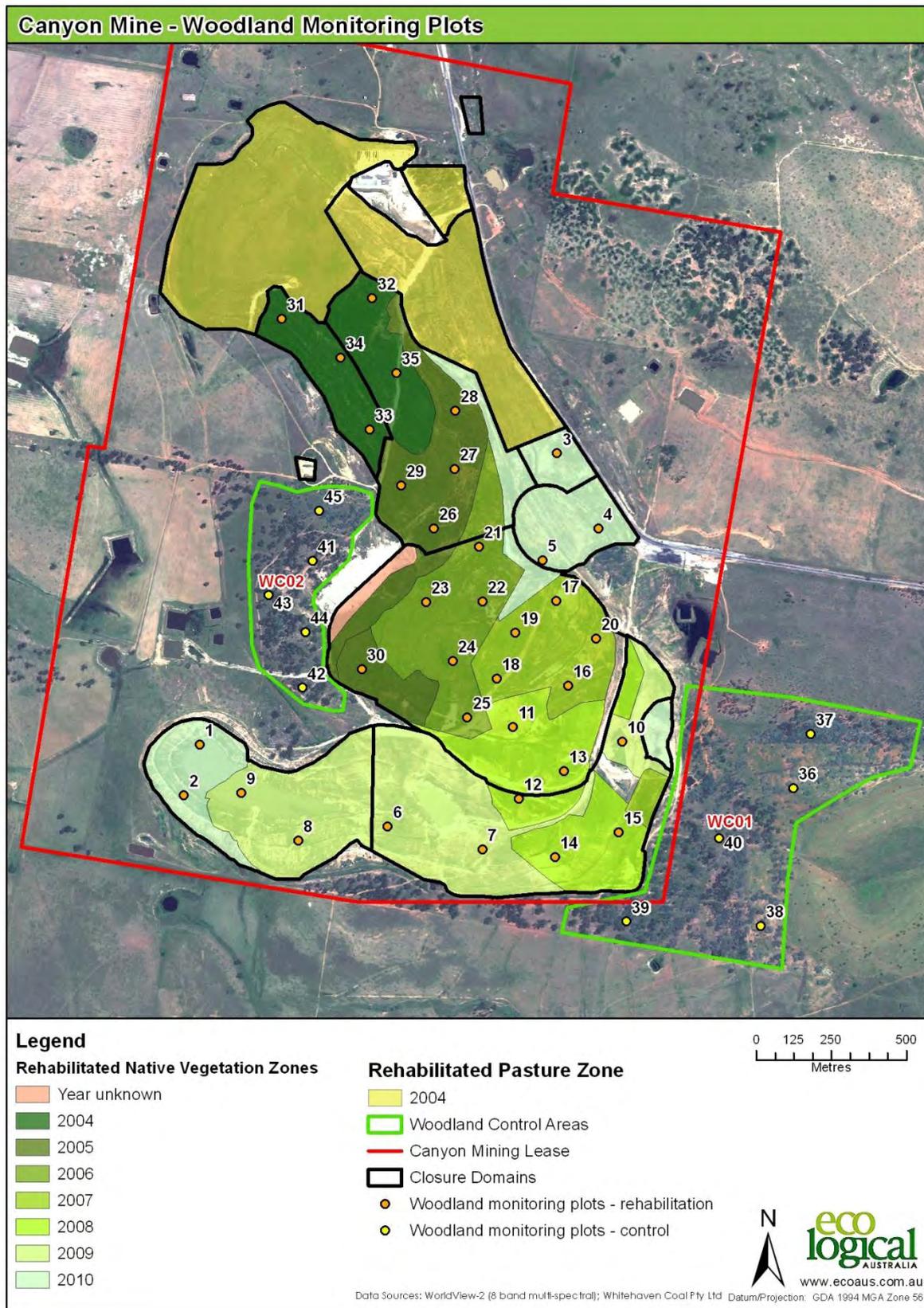


Figure 5-3: Canyon Mine - Woodland Monitoring Plots

Table 5-4: Ecological attributes measured within condition plots

THEME	ATTRIBUTE	DESCRIPTION
Native overstorey (canopy)	Cover	Measured as Projected Crown Cover (PCC) along a 50 m transect Measured as Projected Foliage Cover (PFC) under three canopies
	Health	Categorised into four simple categories based on proportion of canopy dieback
	Richness	List of native overstorey species (including emergents)
	Recruitment	Presence/absence of trees in the juvenile and sapling diameter classes
Native midstorey (shrub and small tree)	Cover	Measured as Projected Crown Cover (PCC) along a 50 m transect
	Richness	List of native midstorey species
Native ground layer	Cover	Measured as Projected Foliage Cover (PFC) of native groundcover plants at each of 50 points along a 50 m transect
	Richness	List of native groundcover species
Exotic species	Cover	Measured as Projected Crown Cover (PCC) along a 50 m transect for exotic canopy and exotic midstorey species. Measured as Projected Foliage Cover (PFC) at each of 50 points along a 50 m transect in exotic ground layer species.
	Richness	List of exotic flora species
Groundcover	Large woody debris	Measured in the sub-plot as the total number and combined length of all sections of dead fallen timber ≥ 10 cm diameter, ≥ 0.5 m in length, and completely detached from living or dead standing trees
	Organic litter	Recorded as a „hit“ or „miss“ at each of 50 points along a 50 m transect, then calculated as % litter cover (OL)
	Cryptogams	Recorded as a „hit“ or „miss“ at each of 50 points along a 50 m transect, then calculated as cryptogam (Cr)
	Bare ground	Recorded as a „hit“ or „miss“ at each of 50 points along a 50 m transect, then calculated as bare ground (BG)
	Rock	Recorded as a „hit“ or „miss“ at each of 50 points along a 50 m transect, then calculated as rock (Ro)

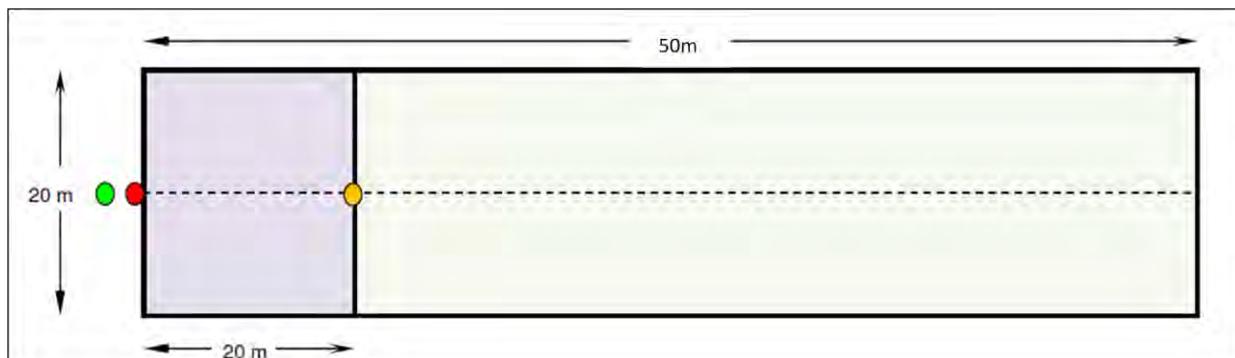


Figure 5-4: Plot design and layout

Table 5-5: Sampling units

Sampling unit	Attributes measured
 Photo Point	Point from which plot is located and oriented, and from which plot image is recorded 5 m back behind reference point (taken after plot laid out)
 Reference Point	Site marker post with ID tag and flagging tape attached
 Alignment Point	Positioned 20 m from reference point along the transect
 Baseplot (50 m x 20 m)	Native canopy health Native and exotic canopy species Native and exotic midstorey species (shrub and small tree) Large tree density (native species only) Recruitment of native canopy species
 Subplot (20 m x 20 m)	Native and exotic ground layer species Coarse woody debris
----- Transect (50 m)	Native canopy cover Native midstorey cover Native groundcover Exotic cover Organic litter Cryptogam Rock Bare ground

5.3.2 Terrestrial fauna and habitat monitoring

Terrestrial fauna and habitat monitoring focused on woodland zones and was conducted on 12 and 13 January 2012 by ecologist Dr Stephen Debus and Damien Smith.

Terrestrial surveys targeted:

- Woodland birds as they are relatively mobile and quick to use the available habitat
- *Phascolarctos cinereus* (Koala), *Neophema pulchella* (Turquoise Parrot) and *Pomatostomus temporalis temporalis* (Grey-crowned Babbler) as they are listed under either the TSC Act and/or the EPBC Act or are locally important
- Reptiles, as specific habitat was established to attract these species.

Terrestrial fauna and habitat monitoring occurred in the surrounding areas of the sites identified in **Figure 5-5** with opportunistic observations in other areas also recorded.

Terrestrial fauna monitoring focused on rapid approaches to species identification and notes on habitat use. Where suitable, proxy measures for fauna (e.g. evidence of usage such as nests, scratching, or scats) were also assessed.

Targeted faunal groups for monitoring and methods used for survey were as per **Table 5-6**.

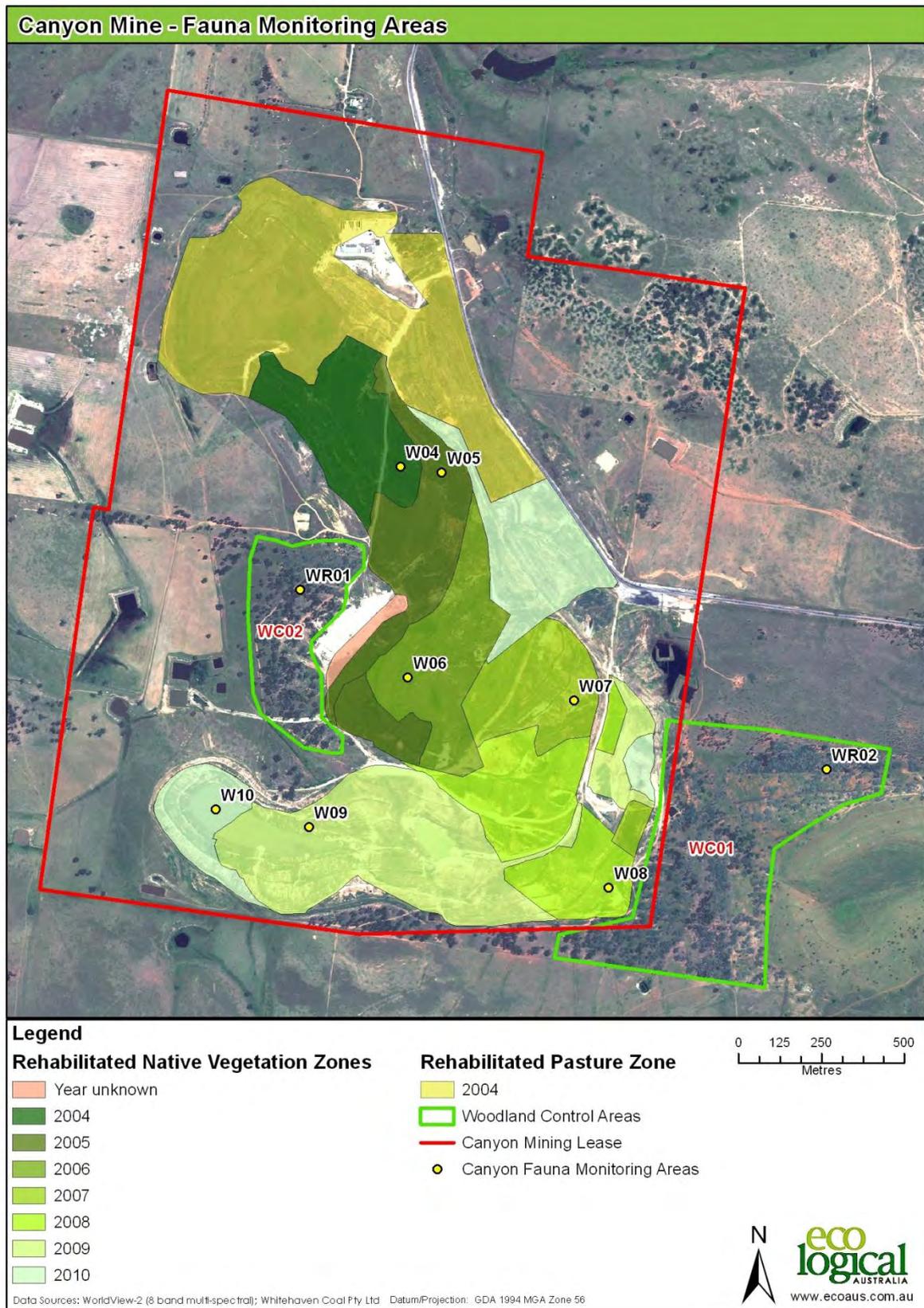


Figure 5-5: Fauna monitoring areas - monitoring conducted in the area around monitoring point, within each zone or control area

Table 5-6: Terrestrial fauna monitoring methods

PARAMETER	ANALYSIS	PURPOSE	SURVEY METHOD
Turquoise Parrot	Presence/absence Habitat usage	Establish presence and habitat usage	A standardised search with a stopping rule as per Watson (2004) was used to survey for woodland birds at dawn and dusk.
Grey-crowned Babbler	Presence/absence Habitat usage	Establish presence and habitat usage	As plot areas were too small to survey in a straight-line transect birds were recorded while walking in a meandering path in the surrounding area of each monitoring point, with all birds recorded either through observation or calls. All birds seen or heard should be recorded in 5 minute intervals and recording continued until no new species are recorded for three consecutive 5 minute periods.
Woodland birds	Presence/absence Habitat usage	Establish presence and habitat usage	
Koala	Presence/absence Habitat usage	Establish presence and habitat usage	
Mammals	Mammal species diversity	Establish presence	A trap line containing a combination of 5 large hair funnels and 5 small hair funnels should be placed on the ground or within habitat trees that may occur along the trap line for a period of 4 nights. Hair funnels should be baited with a mixture of honey, peanut butter and oats (ratio of 1:3:3). Hair funnels were not available for this round of sampling. Upon discussion with WCM staff it was decided to not undertake this aspect of the survey and consider more detailed fauna survey when vegetation community structure and concomitant habitat becomes more complex
Reptile habitat	Species usage of habitat	Identify species diversity and usage	Due to a season of heavy rainfall grass growth was high and dense which along with inaccurate GPS locations mean that artificial habitat was unable to be located. Incidental reptile observations were recorded.

5.4 WEATHER AT THE TIME OF SAMPLING

Temperatures in the three months preceding the monitoring period were mild to warm and consistent with historical averages. Above average rainfall occurred in September through to February while March and April had lower than average rainfall (**Table 5-7**). Climate data were taken from the nearest weather station (Gunnedah Pool Station number 055023) (BoM 2012).

Table 5-7: Weather conditions preceding and during the monitoring period (BoM 2012)

MONTH	ACTUAL MONTHLY MEAN		TOTAL RAINFALL (mm)	HISTORICAL AVERAGES (1876-2011)		
	MIN TEMP (°C)	MAX TEMP (°C)		MIN TEMP (°C)	MAX TEMP (°C)	RAINFALL (mm)
Sep-11	5	23.5	88.8	7	22.8	40.3
Oct-11	9.4	24.4	135	10.8	26.7	55.5
Nov-11	15.7	29.9	176.2	14.2	30.3	62.6
Dec-11	14.3	27.1	94	16.8	32.9	70.1
Jan-12	16.4	30.8	102.2	18.4	34	71.3
Feb-12	16.7	29.4	177.4	18.1	32.9	67.3
Mar-12	14.8	28.4	17.6	15.8	30.7	47.7
Apr-12	10.4	25.8	19.8	11.4	26.4	37.5

Temperatures during the field survey were warm with rain occurring on all but one of the survey days (**Table 5-8**). Climate data were taken from the nearest weather station (Gunnedah Pool Station number 055023) (BoM 2012).

Table 5-8: Weather conditions during the spring 2011 field surveys

DATE	MIN (°C)	MAX (°C)	RAINFALL (mm)	9AM TEMP	3PM TEMP	WIND DIRECTION AND MAXIMUM SPEED (km/h)
5/12/2011	11.5	25.8	7.0	17.7	28.5	SSE 57
6/12/2011	12.9	25	8.0	16.1	23.5	SE 33
8/12/2011	14.9	24.1	12.6	18	20.5	NE 31
9/12/2011	16.1	27.3	2.4	20.7	26.5	E 28
12/12/2011	15.6	24.9	41.8	19.6	23	SSE 33
13/12/2011	12.9	28.3	0.4	19.3	27	WNW 37
20/12/2011	16	29.5	12.0	19.8	27.9	SE 26
21/12/2011	16.6	29.1	1.0	22.6	28.5	SE 41
9/01/2012	21.4	32.1	20.8	23.9	31.1	WSW 33
11/01/2012	14.6	30.4	0.0	23.6	29.7	W 52

5.5 STATISTICAL METHODS

Monitoring plots were compared using non-metric multidimensional scaling (MDS) in Primer 6 (PRIMER-E, Plymouth 2006). MDS plots allow multi-parametric data, such as species presence/absence, species abundance, or % cover, to be displayed in two dimensions. Sites with similar community compositions will appear close to each other on MDS plots, while those that are less similar will appear further apart (Clarke and Warwick 2001). For repeated sampling of quadrats it is possible to then detect and map changes in a community over time (Clarke and Warwick 2001), which is the intention with future monitoring. For the monitoring undertaken for this report this method was used to assess progression of the groundcover characteristics of rehabilitated areas towards control sites. It would be expected that those sites rehabilitated earliest would most resemble the control sites.

MDS plots were constructed for Canyon pasture and groundcover data that was collected in spring 2011, following the calculation of Euclidean Distance similarity matrices for pasture biomass and Bray-Curtis Similarity matrices for woodland vegetation data.

MDS plots were made for the following:

- Pasture biomass
- Pasture species composition
- Soil physical chemistry in pasture zones
- Groundcover species presence/absence
- Groundcover species abundance
- Groundcover composition (rock, bare earth, cryptogam, litter, native species, exotic species).

Analysis of Variance (ANOVA) was also conducted where applicable in order to determine if there was a significant difference in mean values, with a p-value less than 0.05 indicative of there being a significant difference. If significant difference was established Tukey's HSD (honestly significant difference) was conducted to establish where the difference occurred.

The results of these are discussed in the relevant results sub-section.

5.6 DATA REVIEW

Appendix A of the Rehabilitation Monitoring Program (ELA 2011) summarises monitoring data collected between 2004 and 2010. This information has been reviewed in conjunction with spring 2011 survey results to track rehabilitation progress.

6 Results

6.1 REMOTE SENSING

6.1.1 Multi-spectral imagery

WorldView-2 imagery of the rehabilitation zones and control areas was captured on 24 February 2012, assessed for quality and analysed to provide information for future change detection.

The combination of true colour, false colour and NDVI image visualisation products gives an indication of the extent and condition of each land cover type in the area (**Figure 6-1**; **Figure 6-2** and **Figure 6-3**). These images show a pattern of revegetation which is consistent with the rehabilitation zones, i.e. those areas which were planted during 2004 to 2006 indicate greater vegetation cover than those areas rehabilitated since 2007. Infrastructure such as roads and dams are evident.

The NDVI image shows variation in photosynthetically active biomass (green vegetation) over the site with blue areas showing low or no vegetation (e.g. bare soil or water) and red areas showing the highest amounts of green biomass. As expected for a late summer image the control woodland areas show the greatest amount of green biomass with the 2009 and 2010 woodland rehabilitation areas (cyan and yellow) showing relatively less vegetation.

MDS plots of NDVI data for the woodland zones indicate that those areas rehabilitated in 2004 and 2005 are nearing the control sites in terms of green biomass amount (**Figure 6-4**; **Figure 6-5** and **Figure 6-6**). Further analysis using ANOVA and Tukey's HSD comparison of means indicates similarity (no significant difference $p > 0.05$) between rehabilitation areas of a similar age and between the control sites and rehabilitation zones Wood_04 and Wood_05b (**Table 6-1**).

MDS plots of the NDVI data for the Pasture zones indicate that green biomass amounts differ between all zones (**Figure 6-7**). It is likely that differences in management, for example grazing pressure, account for the largest differences between zones. Further analysis using ANOVA and Tukey's HSD comparison of means indicates similarity (no significant difference $p > 0.05$) in green biomass between Ref Past 1 and Ref Past 2 (**Table 6-2**).

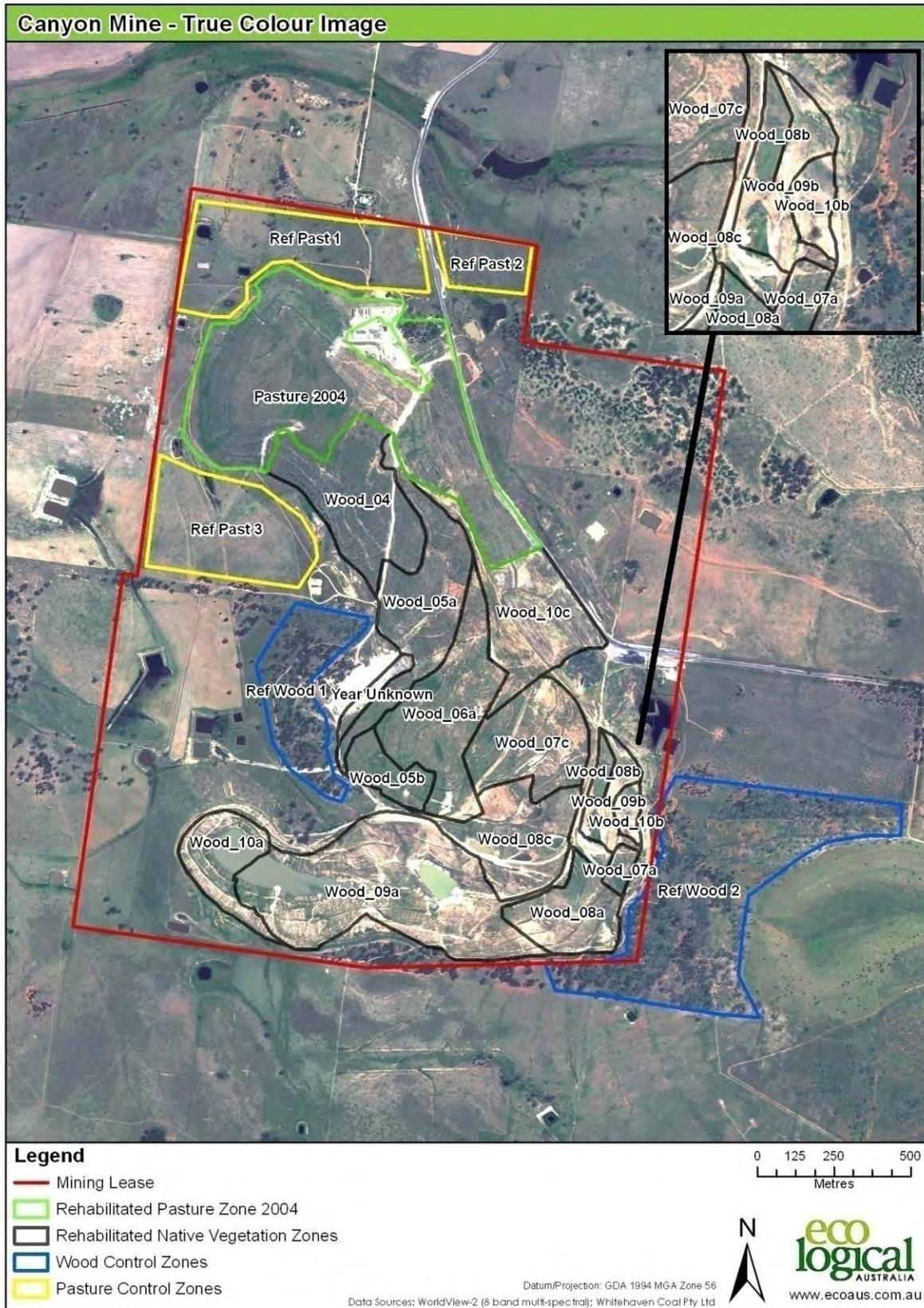


Figure 6-1: Canyon Mine - True Colour Image

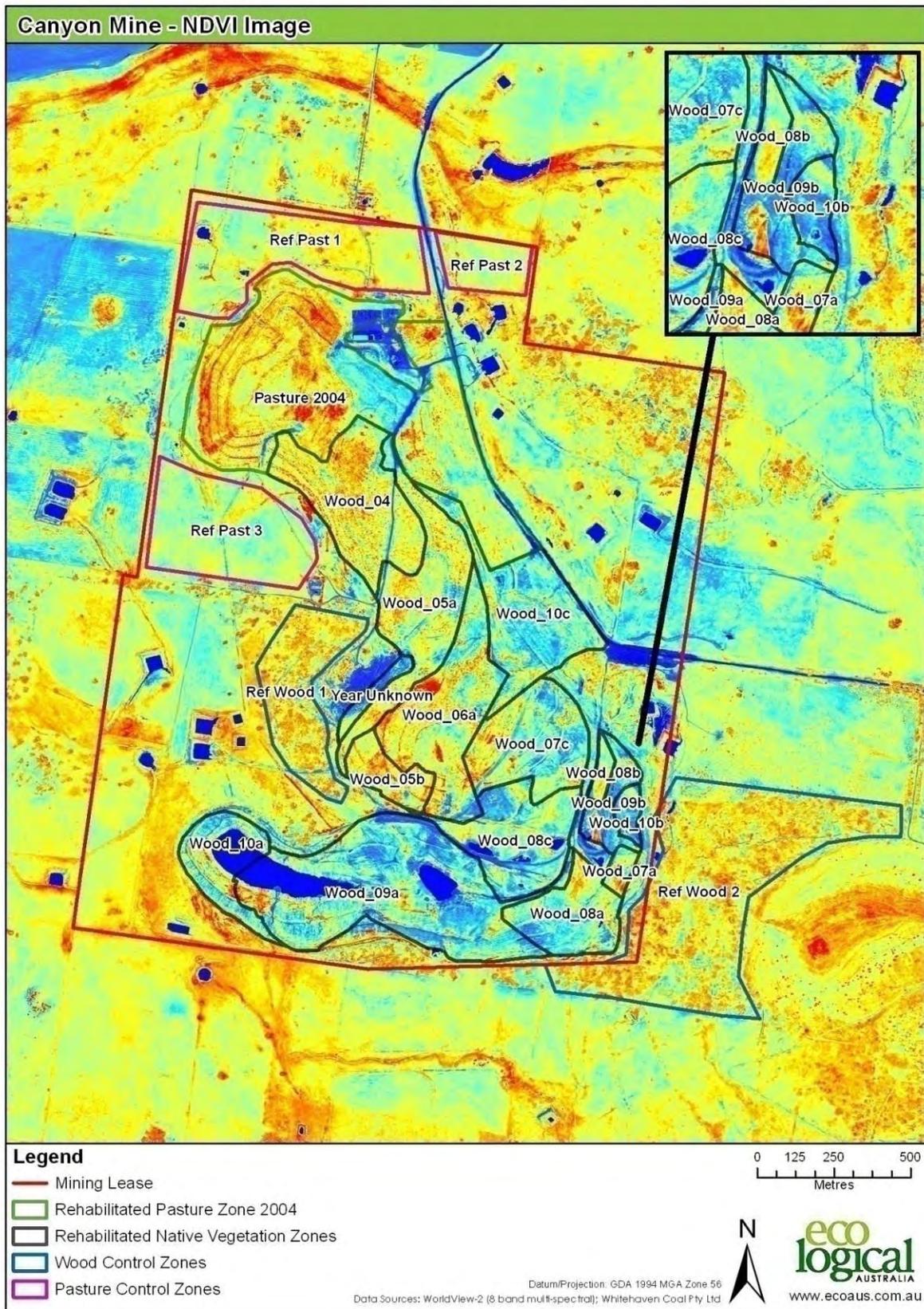


Figure 6-3: Canyon Mine - NDVI Image

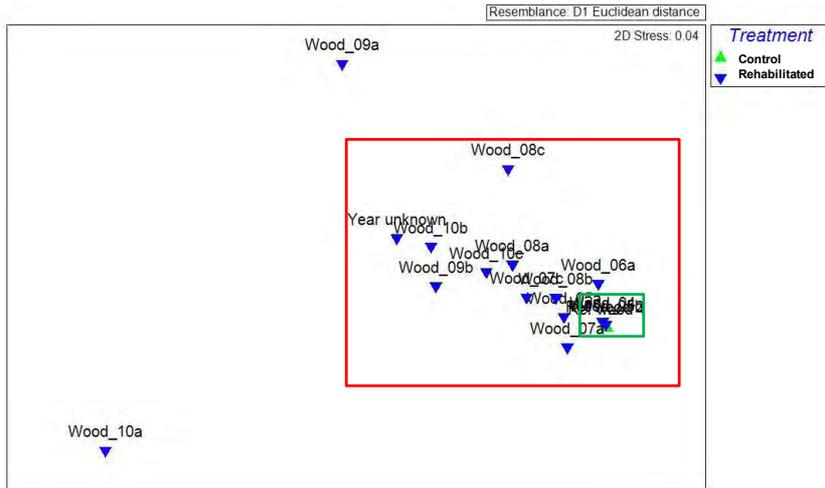


Figure 6-4: MDS of Woodland Zones- NDVI data

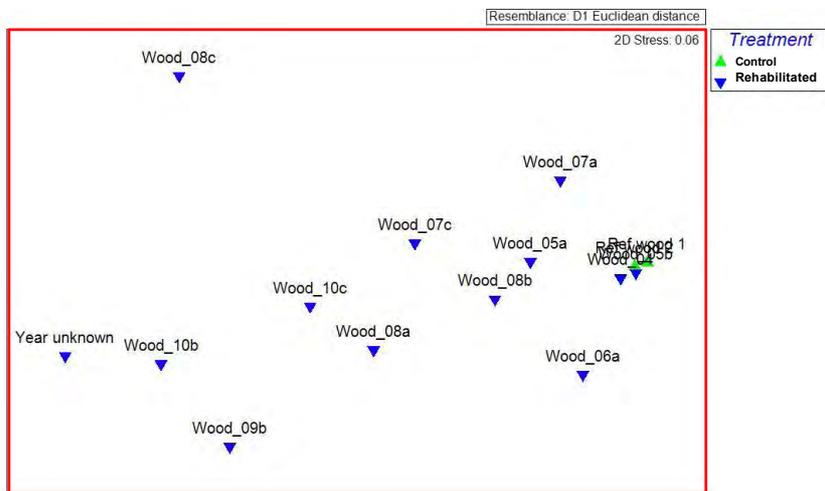


Figure 6-5: Subset of MDS of Woodland NDVI data as indicated by red rectangle in Figure 6-4

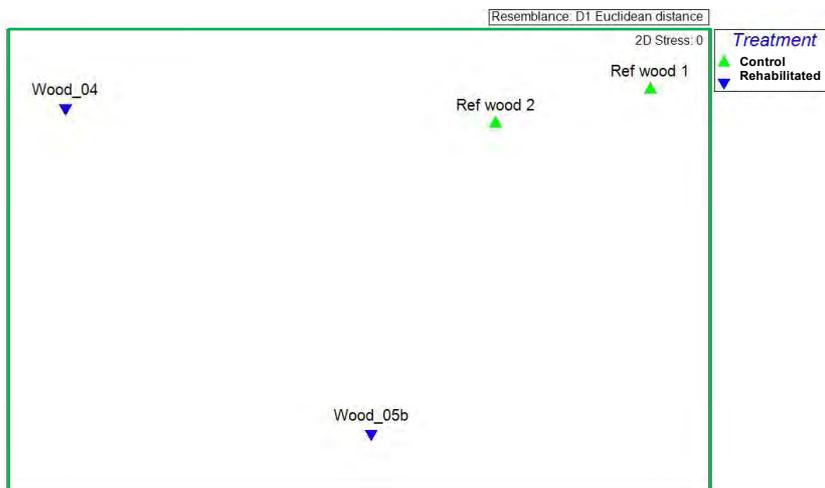


Figure 6-6: Subset of MDS of Woodland NDVI data as indicated by green rectangle in Figure 6-4

Table 6-1: Summary of NDVI statistics of Woodland Zones

NDVI ZONE	SD	MEAN	MODE	MEDIAN	HOMOGENEITY*
Control wood 1	0.103	0.478	0.500	0.487	A
Control wood 2	0.099	0.468	0.500	0.479	A
Wood_04	0.104	0.459	0.444	0.459	A
Wood_05a	0.116	0.417	0.451	0.419	BC
Wood_05b	0.102	0.467	0.417	0.463	A
Wood_06a	0.132	0.425	0.333	0.430	B
Wood_07a	0.129	0.427	0.333	0.419	B
Wood_07c	0.124	0.361	0.333	0.355	-
Wood_08a	0.112	0.329	0.200	0.316	D
Wood_08b	0.096	0.398	0.333	0.403	C
Wood_08c	0.174	0.280	0.146	0.303	E
Wood_09a	0.262	0.206	-0.412	0.251	F
Wood_09b	0.140	0.271	0.200	0.230	E
Wood_10a	0.349	0.157	-0.442	0.273	-
Wood_10b	0.099	0.221	0.162	0.194	F
Wood_10c	0.106	0.308	0.211	0.292	D
Year unknown	0.127	0.207	0.200	0.163	F

* Note zones with the same homogeneity letter are not statistically different

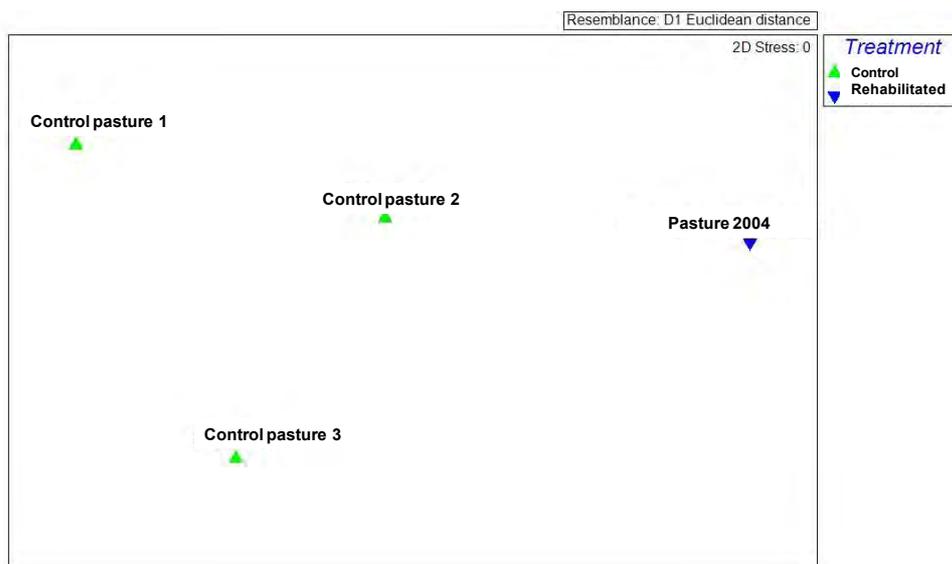
**Figure 6-7: MDS of NDVI data - Pasture Zones**

Table 6-2: Summary of NDVI statistics - Pasture Zones

NDVI ZONE	SD	MEAN	MODE	MEDIAN	HOMOGENEITY
Control past 1	0.101	0.416	0.452	0.419	A
Control past 2	0.059	0.411	0.429	0.403	A
Control past 3	0.063	0.376	0.333	0.370	B
Pasture 2004	0.133	0.441	0.400	0.441	C

6.1.2 EM38 and EM31 survey

Maps of apparent electrical conductivity were generated using the data from the EM31 and EM38 sensors (**Figure 6-8** and **Figure 6-9**). Surveys were conducted across representative areas within the control and rehabilitated areas.

EM31 data ranged from 8 to 201 milliSiemens per m (mS/m) and EM38 ranged from -4 to 136 mS/m. EM signals vary in relation to underlying soil conductivity which in turn relates to soil moisture, ion concentration (salinity) and texture. As the survey area is primarily a reconstructed landscape the EM variation are most likely due to variation in rehabilitation procedures and materials (e.g. subsoil to topsoil ratios, deep fill material etc). In general, rehabilitated landscapes exhibited lower conductivity than the surrounding natural soil landscapes. This lower conductivity may be due to increased soil moisture drainage in the reformed landscapes resulting in lower conductivity. Linear boundaries in EM conductivity zones likely relate to variation caused by physical changes in the material, procedure and time of rehabilitation. These boundaries generally align to the established rehabilitation zones.

Future EM survey will provide for assessment of changes in apparent conductivity that may relate to altered drainage conditions that change soil moisture or ion concentration conditions or general long term changes in soil texture.

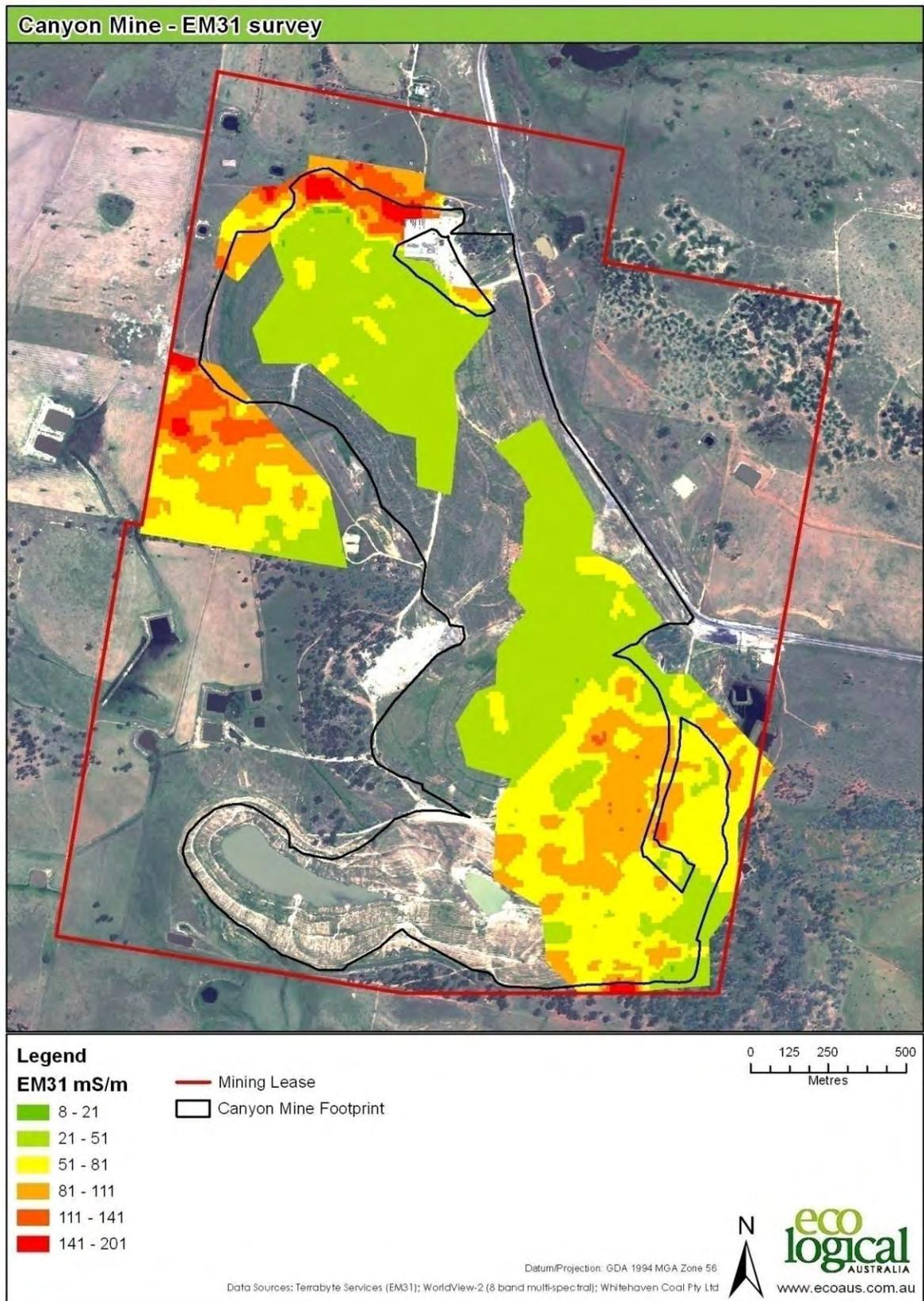


Figure 6-8: Canyon Mine EM31 survey

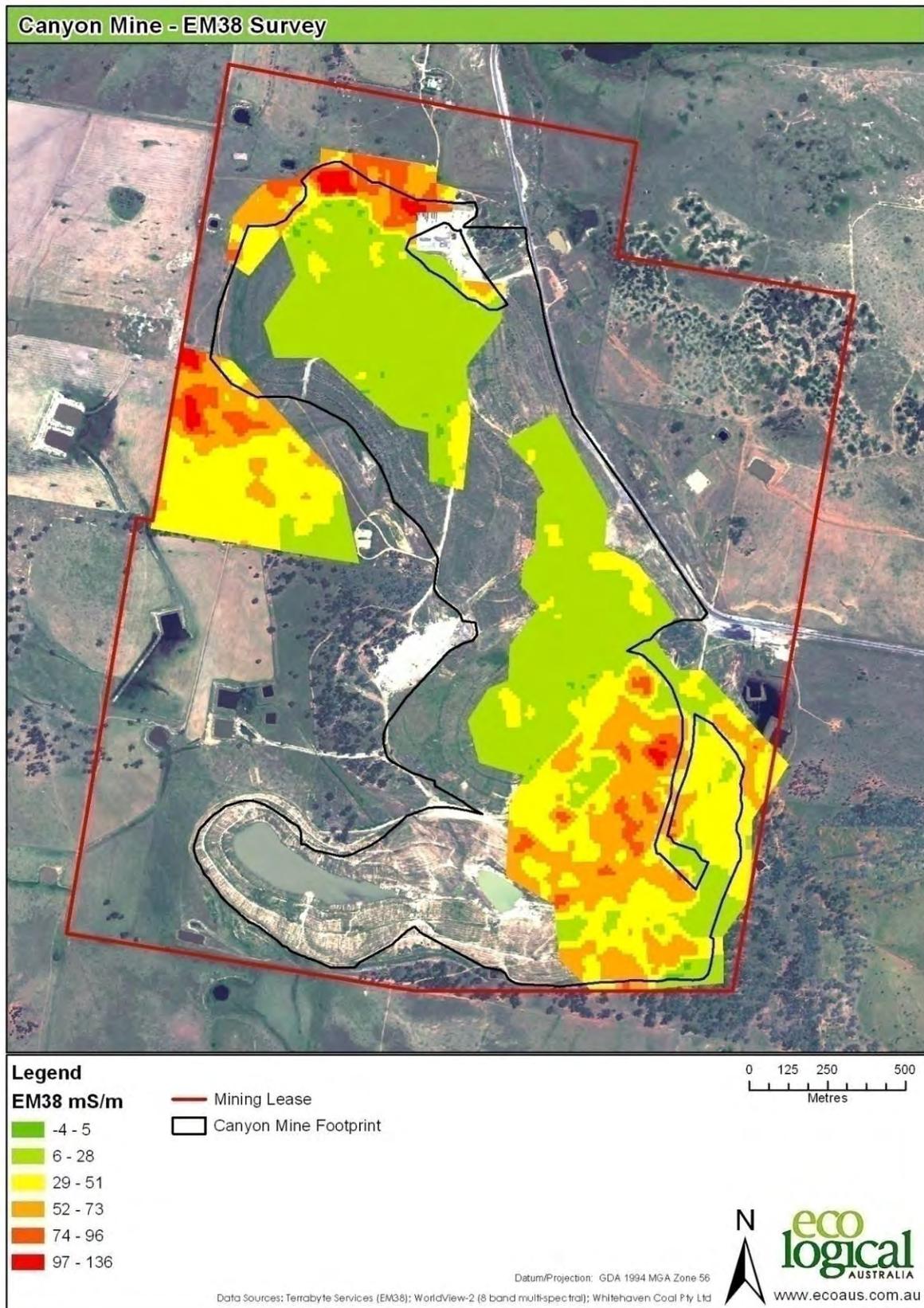


Figure 6-9: Canyon Mine EM 38 survey

6.2 PASTURE AREA SURVEYS

The full suite of results for pasture area surveys is provided in **Appendix A**.

6.2.1 Pasture species

The number of pasture species and species composition did not show any distinct patterns separating the control plots from the rehabilitated plots (**Figure 6-10**). The number of species in the rehabilitated plots ranged from 5 to 11, with the average number of species being 8.5. The number of species in the control plots ranged from 6 to 13, with the average number of species being 9. The most common pasture species across all plots included:

- *Trifolium arvense* (Haresfoot Clover)
- *Chloris truncata* (Windmill Grass)
- *Dichanthium sericeum* (Queensland Bluegrass)
- *Sonchus oleraceus* (Common Sowthistle).

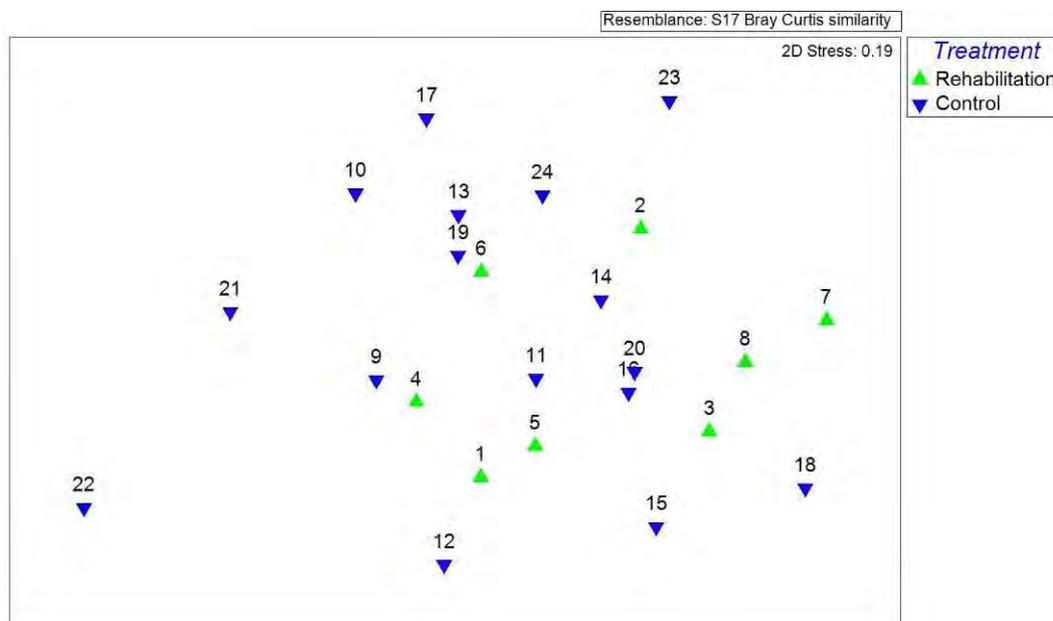


Figure 6-10: Pasture species composition MDS

Pasture cover ranged from 19 to 80% across all rehabilitated pasture plots, with the average being 44%. Pasture cover ranged from 15 to 68%, with an average of 31.9% in the control plots. ANOVA indicated that there was no significant difference in mean percentage pasture cover between the rehabilitated and control sites ($p > 0.05$; $p = 0.72$).

6.2.2 Weed species

For the purposes of rehabilitation monitoring the pasture zones, a weed species was determined to be a species which is undesirable to grazing stock. Three weed species were recorded across the rehabilitation plots, two of which are introduced species.

The number of weed species in the individual rehabilitation plots ranged between 0 and 2 (< 1% cover), the most frequently occurring was *Carthamus lanatus* (Saffron Thistle), an introduced species. A total

of five weed species were recorded across the control plots; two of which are introduced species. The number of weed species in individual control plots also ranged between 0 and 2 (< 2% cover), the most frequently occurring species was *Cheilanthes sieberi* (Poison Mulga Fern), a native species.

6.2.3 Biomass

Biomass in the rehabilitated plots ranged from 950 kg dry matter per hectare (kg DM/ha) up to 3700 kg/ha. Pasture Biomass in the control plots ranged from 250 kg dry matter per hectare (kg DM/ha) up to 4500 kg/ha. ANOVA indicated that there was no significant difference in biomass between rehabilitated plots and control plots ($p > 0.05$; $p = 0.55$).

Biomass was not strongly correlated to pasture cover ($p < 0.05$ Pearson Correlation).

6.2.4 Groundcover composition

Groundcover composition was recorded for each plot (percentage cover of weeds, pasture, bare ground and litter). ANOVA on all parameters indicated no significant difference between rehabilitated plots and control plots. Pasture cover was below the target of 70% for some plots within both the rehabilitation and control zones (**Table 6-3**).

Table 6-3: Summary of groundcover composition

PARAMETER	REHABILITATED PLOTS			CONTROL PLOTS			P VALUE*
	MINIMUM RECORDED	MAXIMUM RECORDED	MEAN	MINIMUM RECORDED	MAXIMUM RECORDED	MEAN	
Weed cover (%)	0	1	0.63	0	2	1.1	0.18
Pasture cover (%)	20	65	41	15	80	45	0.72
Bare ground (%)	0	60	15	0	60	23	0.53
Litter cover (%)	19	80	44	15	68	32	0.15

* $p > 0.05$ indicates no significant difference between means.

It is noted that the spring 2011 monitoring was undertaken after a high rainfall season which may help contribute to abundant native grasses and high plant biomass.

6.2.5 Soil samples

Soil chemistry results for the soil samples taken from the pasture plots did not show any distinct patterns separating the control plots from the rehabilitated plots. There is an indication that the control plots in the southern most zone are more similar than those in the rehabilitated area and other control zones (**Figure 6-11**). ANOVA indicated that there was no significant difference in any of the physical-chemistry parameters between rehabilitated and control plots (**Table 6-4**).

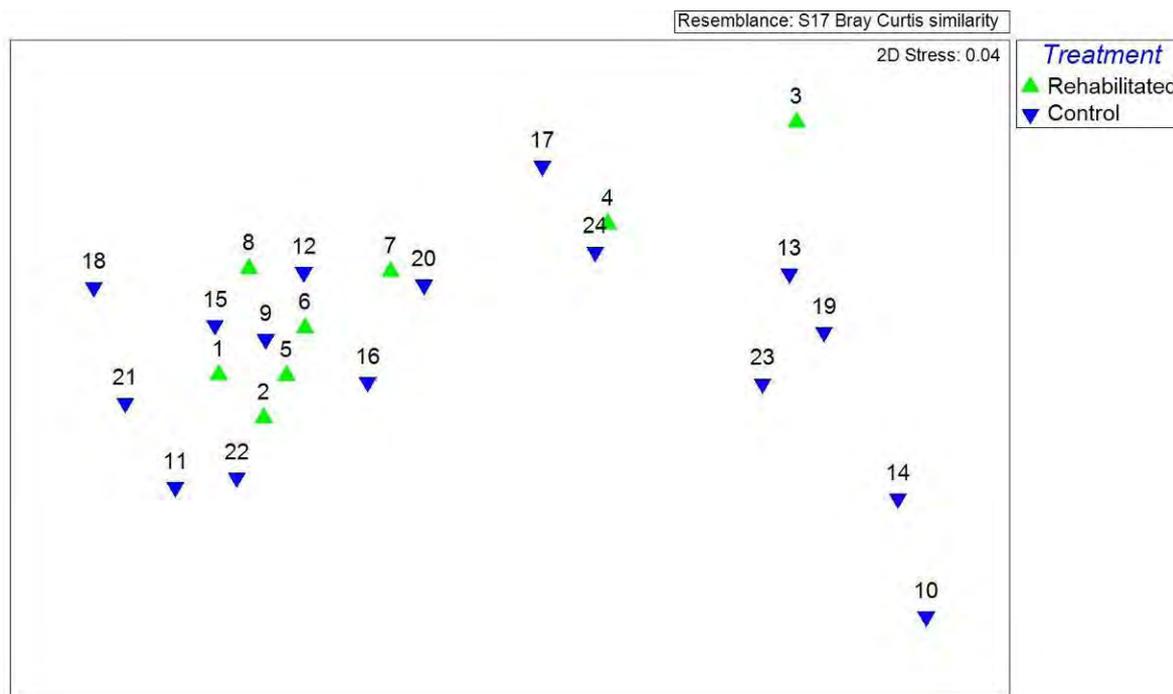


Figure 6-11: MDS of soil physical chemistry of pasture monitoring plots

Table 6-4: Summary of pasture plot soil physical-chemistry data

PARAMETER	REHABILITATED PLOTS			CONTROL PLOTS			P VALUE*
	MIN	MAX	MEAN	MIN	MAX	MEAN	
Electrical Conductivity (dS/m)	0.03	0.14	0.08	0.02	0.23	0.08	0.98
pH (CaCl ₂)	5.66	7.78	6.72	4.9	7.91	6.05	0.12
Total Nitrogen (mg/kg)	352	1176	701	368	1815	837	0.39
Phosphorus Ex (mg/kg)	15.7	34.7	21.58	14.6	35.8	20.45	0.69
Organic Carbon (%)	0.31	1.49	0.80	0.47	2.6	1.07	0.29

* p>0.05 indicates no significant difference between means.

6.2.6 Soil pit descriptions

Soil pits on the rehabilitation areas showed variable profile reconstruction with topsoil depth ranging from 0 cm (Site 1) to 40 cm (Site 9). All rehabilitated soils areas showed good establishment with grass and other vegetation roots penetrating to depths of greater than 25 cm and between horizons (where present).

Full descriptions of soil profiles are provided in **Appendix D**.

6.3 WOODLAND SURVEYS

The full suite of results for woodland vegetation surveys is in **Appendix B**. Results for fauna surveys are in **Appendix C**.

6.3.1 Vegetation

32 canopy and midstorey species were recorded across all monitoring plots; however, in plots 1 to 5 (rehabilitated 2009) and plots 6 to 10 (rehabilitated 2010) no canopy or midstorey species were recorded. Plots 19 and 20, rehabilitated in 2007, had the highest species number with 8 species recorded.

With the exception of areas rehabilitated in 2004 the trees planted in rehabilitation areas are yet to reach a height where they form a canopy layer. However, these trees are forming a midstorey layer in plots rehabilitated during and prior to 2008. The canopy of Plot 32 (rehabilitated in 2004) returned a True Projected Foliage Cover (TPFC) of 1.2%, whilst the TPFC for the control plots ranged between 2.0% and 9.2% (**Table 6-5**). The midstorey for Plots 16 and 20 (rehabilitated in 2007) returned TPFC of 2.0% and 0.2% respectively, those control plots that did have a midstorey had TPFC values ranging between 0.4% and 9.6% (**Table 6-5**).

Table 6-5: True Projected Foliage Cover recorded at Woodland monitoring plots (0% Canopy cover indicates that species yet to reach canopy height; 0% midstorey in control sites indicative of natural variability in woodland strata)

PLOT	16	20	32	36	37	38	39	40	41	42	43	44	45
Year of rehabilitation	2007	2007	2004	Control sites									
Canopy %	0	0	1.2	8.1	2.1	3.0	9.0	6.7	14.8	2.0	2.8	12.7	9.2
Midstorey %	2.0	0.2	0	0	9.6	0	0	4.0	0	0.4	2.4	0.9	1.5

In each 20 m by 20 m quadrat all tree and shrub species greater than 1 m in height were recorded. Planted tree species in plots rehabilitated in 2009 and 2010 were yet to grow to over 1 in height. ANOVA of the mean number of species occurring within each monitoring zone (that being year of rehabilitation or WC01, WC02) shows that there is no significant difference between WC01, WC02 and any of the rehabilitation zones, however, data sets are small (n=5) and may not be indicative of actual trends.

Lycium ferocissimum (African Boxthorn) an invasive tree species was recorded in rehabilitation plots 3, 18 and 19. African Boxthorn is a weed of national significance and Class 4 noxious weed within Gunnedah Shire Council. Noxious weeds are regulated under the *Noxious Weeds Act 1993* which is enforced by the local control authority (usually local government). This species must be managed in a manner that reduces its numbers spread and incidence and continuously inhibits its reproduction. African Boxthorn has an extensive, deep, branched taproot that will produce new growth if broken, therefore control and management generally requires the integration of a number of management techniques for effective control. WCM staff should refer to the site MOP for site weed management procedures. In addition NSW DPI (2012) lists a range of management methods that include:

- Mechanical removal of as much of the top growth and as many of the roots as possible. Removed plant material should then be burnt
- Cultivation after physical removal whereby suitable sites are deep-ripped, bringing most remaining root fragments to the surface to be raked and burnt. Follow up treatment will need to be commenced should there be regrowth
- Chemical control with a registered herbicide and used according to directions on the label, this may require multiple treatments as the plant often regenerates before it dies.

- Foliar spray is the most commonly used control method, application requires strategic timing and it is not an appropriate method for large bushes
- Replacement with appropriate plants, an essential component of managing for boxthorn as seedlings are susceptible to competition from other plants.

Control and management of African Boxthorn is more effective and economical if undertaken when plants are young. The NSW Department of Primary Industries website (<http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/profiles/african-boxthorn>) describes various management actions in detail. Management information can also be obtained from the Gunnedah Shire Council. ELA recommend that these plants are treated as soon as practical.

The mean number of groundcover species recorded generally increased according to rehabilitation age, with the exception of 2006, where total species numbers are relatively low. Low species numbers in the 2006 plots appear to be due to a low number of native species, as the number of exotic species present appear to be consistent with other rehabilitation age zones. The mean number of exotic species present is relatively consistent across all rehabilitation zones and are high relative to the control zones (**Table 6-6**). Both the MDS plot for groundcover species presence/absence and species abundance indicate that those plots rehabilitated earliest are the most similar to the control sites (**Figure 6-12**, **Figure 6-13**). Groundcover composition in terms of native species, exotic species, bare ground, cryptogams and rocks shows a similar trend; with those sites rehabilitated earliest more closely resembling the control sites (**Figure 6-14**, **Figure 6-15**).

Table 6-6: Summary of groundcover species diversity

GROUNDCOVER SPECIES	2010	2009	2008	2007	2006	2005	2004	WC02	WC01
Minimum total species	20	14	26	16	15	33	30	0	30
Maximum total species	35	48	43	29	34	46	46	51	45
Mean number of species	28.6	26.2	35.6	31.6	23.6	38.4	39	41.4	39
Mean number of native species	14.8	14.6	19.6	18	10	23.6	24.4	36.8	33
Mean number of exotic species	13.8	11.6	16	13.6	13.6	14.8	14.6	4.6	6

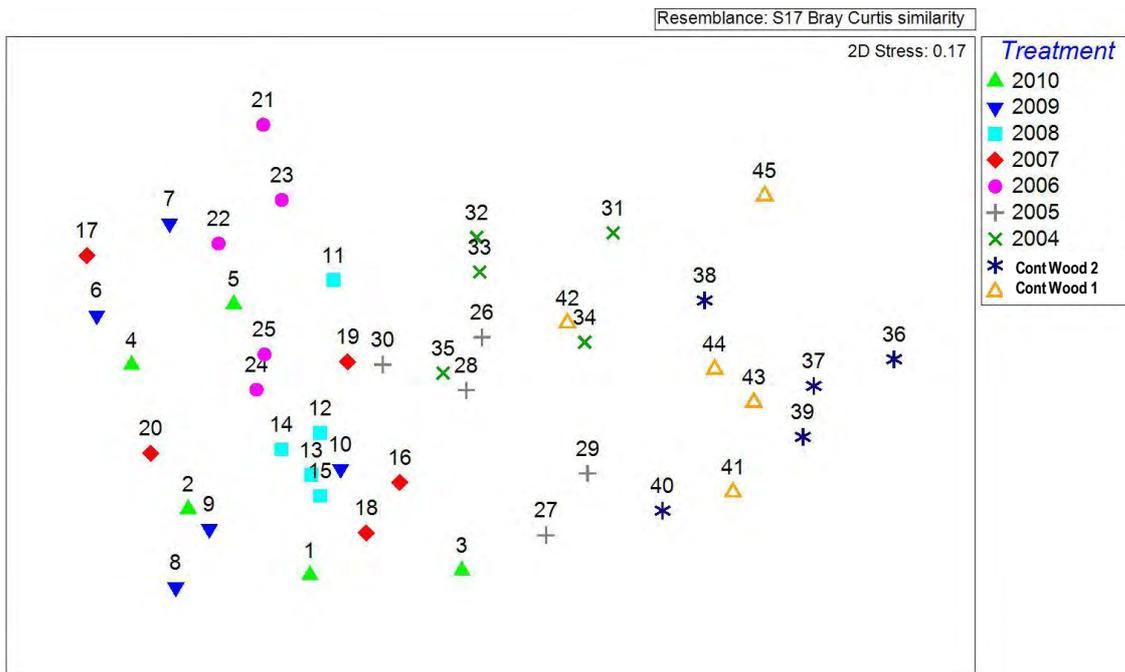


Figure 6-12: MDS plot of groundcover species composition

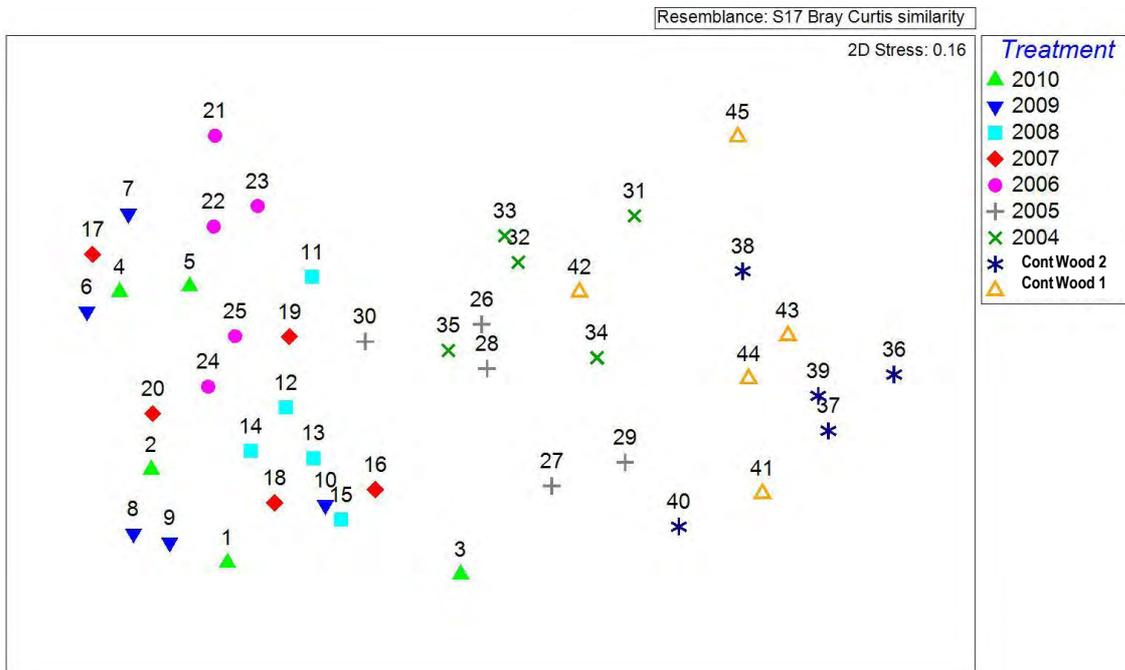


Figure 6-13: MDS plot of groundcover species abundance

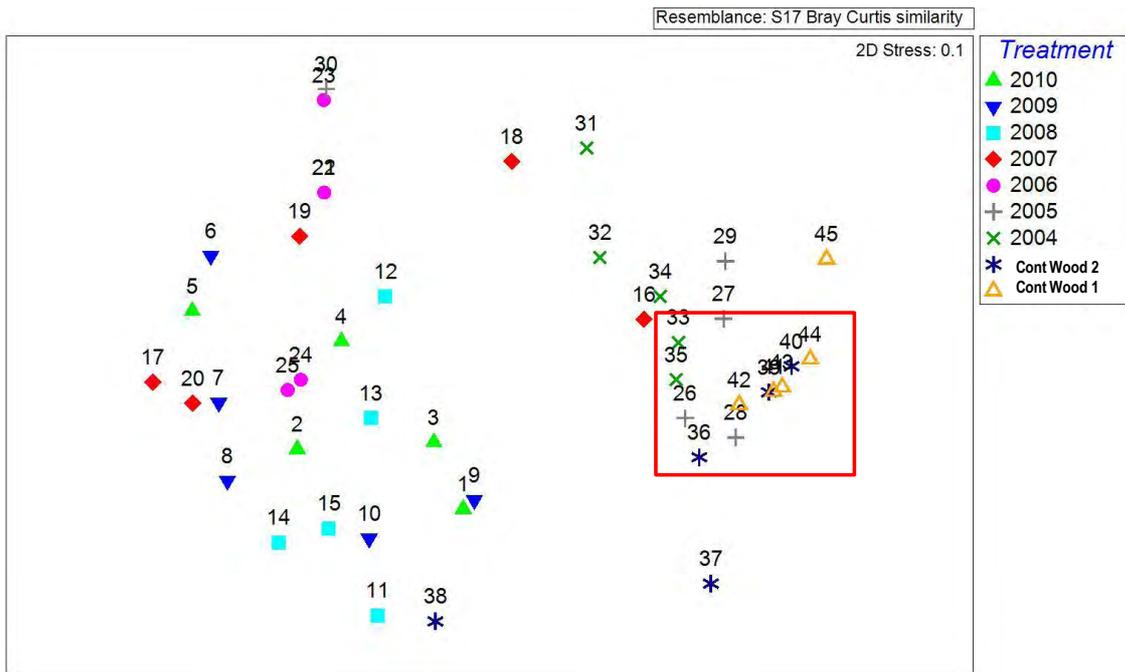


Figure 6-14: MDS plot of groundcover composition

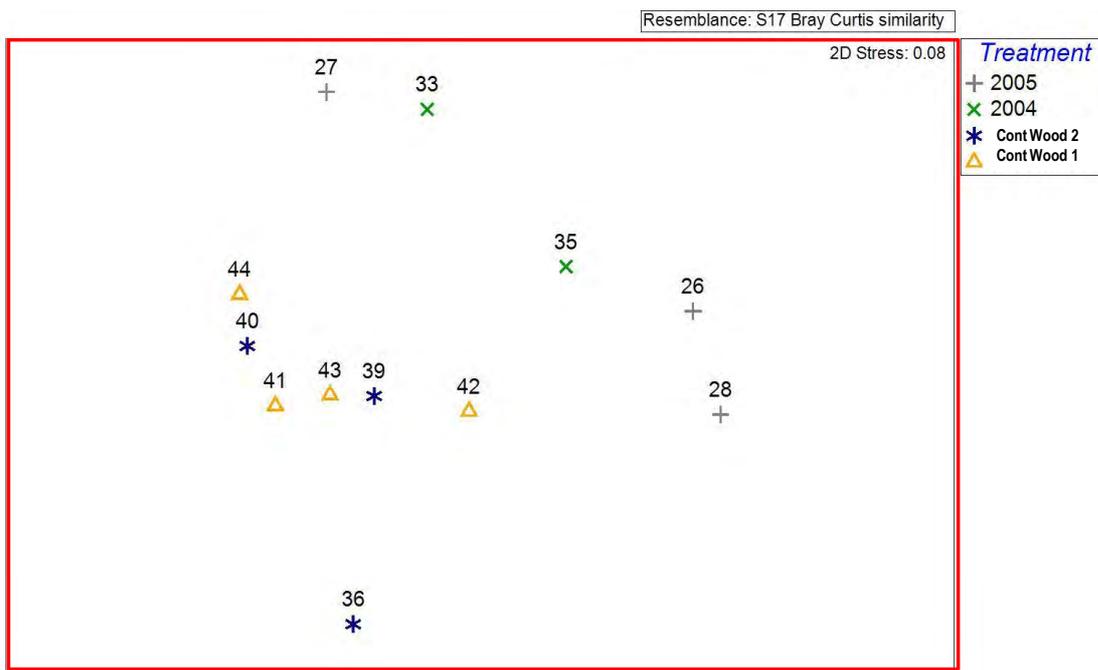


Figure 6-15: Subset of MDS plot of groundcover composition (as indicated by red rectangle in Figure 6-15)

Parameters such as canopy DBH thresholds, canopy species and age classes and coarse woody debris are indicators of self-sustaining vegetation communities. Coarse woody debris was recorded in some of the rehabilitated plots and it is assumed that these have been introduced as habitat elements to the sites. The rehabilitated sites do not yet have a mature canopy and so DBH thresholds, canopy species and age classes were not recorded, however, it is expected that over time these sites will return similar measurements to those recorded at the control sites (**Appendix B5**).

6.3.2 Terrestrial fauna and habitat

As with the vegetation data, those sites rehabilitated earliest had the greater number of bird species and were approaching numbers recorded in the control sites (**Figure 6-16**). *Hirundapus caudacutus* (White-throated Needletail), listed as migratory under the EPBC Act, was recorded on one occasion at rehabilitated site W06. *Pyrholaemus sagittata* (Speckled Warbler), *Hieraaetus morphnoides* (Little Eagle) and *Pomatostomus temporalis temporalis* (Grey-crowned Babbler), listed as vulnerable under the TSC Act were recorded at WR02, WR01, and WR01 and WR02 respectively.

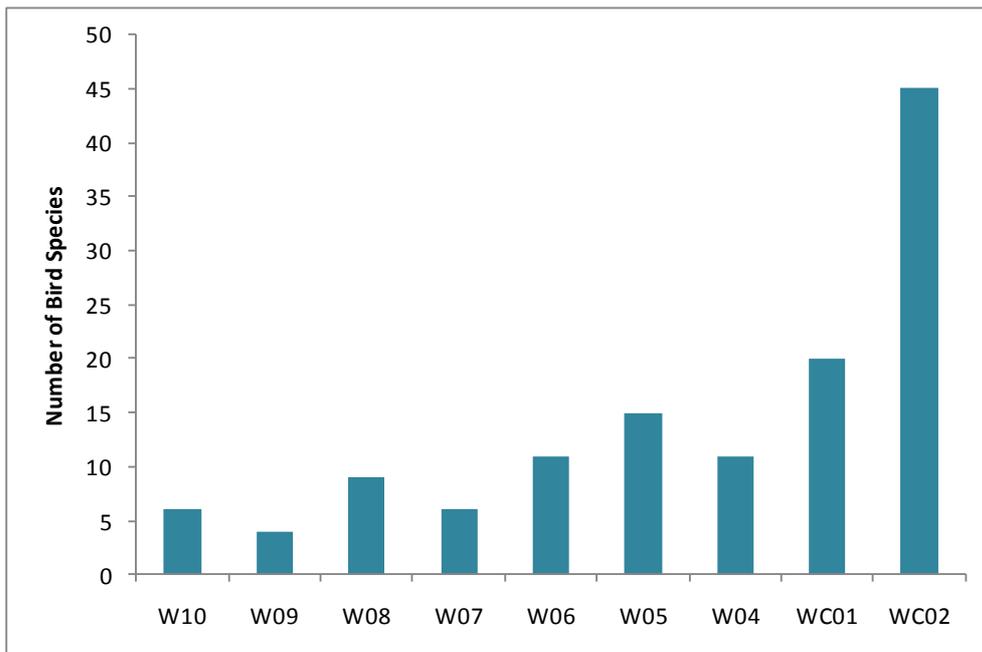


Figure 6-16: Number of bird species recorded within fauna monitoring sites

Other fauna recorded during the spring survey include six species of frog, three species of skink, a tortoise and seven species of mammal of which four were exotic. Number species per site ranged between 1 and 8, the site with the most species was W08 which is close to control site WR02 (**Appendix C** for full results).

Due to substantial rainfall in the period preceding the fauna survey, grass growth was high and dense. In addition GPS locations of artificial reptile habitat were inaccurate, therefore, artificial reptile habitats were unable to be located and visibility for fauna observations was reduced.

6.4 COMPARISON TO PREVIOUS SURVEYS

While new monitoring quadrats for both pasture and woodland areas have been established at Canyon, general comparisons can be made on the progression of rehabilitation.

6.4.1 Pasture areas

Historical data indicated that species composition was progressing towards the reference sites. ANOVA of the spring 2011 data indicates that there is no significant difference in species composition or groundcover composition (rocks, bare earth, native species, weed species and cryptogams) between the rehabilitated areas and the control areas.

6.4.2 Woodland areas

As with the historical data, current results pertaining to the groundcover in the woodland areas indicate a progression towards the control sites, with those areas rehabilitated earliest resembling the control areas more closely. As growth of planted trees and shrubs progresses in the rehabilitated areas a similar trend is expected to appear.

7 Discussion

This project set out to establish a quantitative set of baseline information for ongoing monitoring of the effectiveness of rehabilitation over the Canyon site. Rehabilitated landscapes include areas returned to agricultural and native woodland land uses. A multi-scale, multi-data source monitoring program was designed and implemented to quantify the performance of the rehabilitation works against control areas.

7.1 REMOTE SENSING

Multi-spectral remote sensing provides information relating to land cover and condition across the entire area including rehabilitation and control areas. These data are readily accessible and provide an inexpensive means of documenting land cover change and directing targeted field work.

EM survey data are derived from vehicle mounted survey equipment. Mine site access and accreditation of the survey vehicle and team delayed capture of this survey dataset. In addition the data capture area was limited to areas navigable by 4wd vehicle. These data provide useful information on the spatial variability of shallow sub-surface conductivity, in places rehabilitation zones were clearly delineated with changes in conductivity. Repeat capture of EM data would provide a means of investigating changes in soil moisture, ion and texture zones over time. In addition comparisons to surrounding areas can be used to demonstrate the pattern and range of EM data in natural landscapes in comparison to the rehabilitated areas.

LiDAR data were not captured or processed for this survey period. These data are capable of providing high resolution information across the entire site for topography, tree canopy height and tree foliar density. Longitudinal capture and analysis of LiDAR data would be useful for documenting landscape scale change in these three important parameters.

7.2 PASTURE AREA SURVEYS

Field surveys in pasture areas included collection and analysis of information relating to pasture composition and biomass, pasture weeds and soil character including horizon recreation. For this baseline collection patterns and trends in the rehabilitation area were consistent with those in the control areas.

7.3 WOODLAND SURVEYS

Woodland monitoring including flora and fauna parameters (canopy species composition, abundance, cover, woodland bird numbers etc) showed a trend of rehabilitation area functionality becoming more similar to control sites as establishment age increased.

Hair tube traps were not used during this round of monitoring as equipment availability was limited. Upon discussion with WCM staff it was decided to not undertake this aspect of the survey and consider more detailed fauna survey when vegetation community structure and concomitant habitat becomes more complex.

8 Recommendations

The results of this survey show that the rehabilitation of the Canyon site has been successful to date. Landscape functionality is continuing to trend towards that found in the nearby control areas.

It is recommended that WCM staff consider the results of this survey round and refine the monitoring design for ongoing survey and reporting. Key ongoing monitoring recommendations include:

- Capture and analysis of LiDAR information in 2012
- Capture of multi-spectral imagery in early spring 2012 for change detection and directed field survey as prescribed in the monitoring plan
 - A rapid letter style report to be provided to WCM immediately following analysis to permit timely directed field survey if required
- EM survey to be repeated in 3-5 years or as part of a closure process
- Repeat pasture and woodland flora survey for 2012 to confirm trends and patterns
- Beyond 2012 it is expected that survey effort can be reduced especially in regard to many aspects of vegetation structure (DBH, canopy composition etc) as these parameters are unlikely to change significantly in a 12 month period. Other key functionality parameters such as woodland bird surveys should be conducted annually in conjunction with rapid traverse habitat surveys for general flora condition.
- Soil survey to be repeated in 3 years or as part of a closure process.
- Capture habitat usage data
- Find reptile tiles (should have done this when grass was low) or possibly replace.
- Use Hair tubes

References

- Bureau of Meteorology (BoM). 2012, Daily Weather Observations, Gunnedah Pool: <http://www.bom.gov.au/climate>.
- Clarke K.R., Gorley R.N. 2006. *Primer v6: User Manual/Tutorial*. Primer-E, Plymouth.
- Clarke K.R., Warwick R.M. 2001. *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation* (2nd edn.). Primer-E Ltd, Plymouth.
- Cunningham G.M., Higginson F.R., Riddler A.M.H. & Emery K.A. 1988. *Systems used to classify rural lands in New South Wales*. Available: <http://www.environment.nsw.gov.au/resources/soils/systemsclassifylands.pdf>
- Eco Logical Australia. 2011. *Rehabilitation Monitoring Program for Canyon Coal Mine*. Prepared for Whitehaven Coal Mining Limited.
- Geoff Cunningham Natural Resource Consultants Pty Ltd 2000. *Soil Survey and Land Capability Report*, Whitehaven Coal Mine via Gunnedah.
- Geoff Cunningham Natural Resource Consultants Pty Ltd. 2004. *Flora Study of 'The Canyon' Area Extension Whitehaven Coal Mine via Gunnedah NSW, September 2004*.
- Whitehaven Coal Mining Pty Ltd, December 2004. *Statement of Environmental Effects for the Proposed Canyon Extension to the Whitehaven Coal Mine*.
- NSW DPI. 2012. *Noxious weed declarations – Noxious weed declarations for the Gunnedah Shire Council*: <http://www.dpi.nsw.gov.au/agriculture/pests-weeds/weeds/profiles/african-boxthorn>.
- Whitehaven Coal Mining Pty Ltd 2005. *Environmental Management Strategy for the Whitehaven Coal Mine December 2005*.
- Whitehaven Coal Mining Pty Ltd 2006. *Mining Operations Plan February 2006*.
- Whitehaven Coal Mining Pty Ltd 2008. *Mining Operations Plan Amendment Canyon Open Cut Coal Mine Extension August 2008*.
- Whitehaven Coal Mining Pty Ltd 2009. *Canyon Open Cut Coal Mine Closure Plan July 2009*.

Appendix A1: Pasture plot photographs



Figure A 1: Pasture monitoring plots. Plots 1 to 6 (ordered Left to Right; Top to Bottom)



Figure A 2: Pasture monitoring plots. Plots 7 to 12 (ordered Left to Right; Top to Bottom)



Figure A 3: Pasture monitoring plots. Plots 13 to 18 (ordered Left to Right; Top to Bottom)



Figure A 4: Pasture monitoring plots. Plots 19 to 24 (ordered Left to Right; Top to Bottom)

Appendix A2: Pasture species

SPECIES	REHABILITATED ZONES												CONTROL ZONES												NUMBER OF TIMES SPECIES OCCURS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
<i>Alternanthera denticulata</i> Lesser Joyweed														X			X							X	3
* <i>Ammi majus</i> Bishop's-weed					X																				1
* <i>Anagallis arvensis</i> Scarlet Pimpernel	X		X			X										X			X	X					6
<i>Aristida personata</i> Purple Wire-grass					X											X									2
<i>Aristida</i> sp. Wire-Grass	X																X						X	3	
<i>Austrodanthonia</i> sp. Wallaby Grass																					X				1
<i>Austrostipa scabra</i> Speargrass		X		X		X					X	X	X							X					7
* <i>Avena</i> sp. Wild Oats		X																						X	2
* <i>Bidens subalternans</i> Greater Beggar's Ticks												X										X			2

SPECIES	REHABILITATED ZONES												CONTROL ZONES												NUMER OF TIMES SPECIES OCCURS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
<i>Bothriochloa decipiens</i> Red Grass				X																					1
<i>Bothriochloa</i> sp. Red Grass							X	X															X		3
<i>Brachyscome chrysoglossa</i> Yellow-tongue daisy																					X				1
* <i>Bromus molliformis</i> Soft Brome												X													1
<i>Calotis lappulacea</i> Yellow Burr-daisy		X				X				X															3
<i>Carex inversa</i> Knob Sedge									X													X			2
* <i>Centaurium</i> sp.													X	X		X									3
* <i>Chloris gayana</i> Rhodes Grass							X											X							2
<i>Chloris truncata</i> Windmill Grass				X		X			X	X			X	X			X		X				X		9
* <i>Conyza bonariensis</i> Flaxleaf Fleabane	X			X	X	X																			4
* <i>Conyza</i> sp. Fleabane																		X							1
* <i>Cyclosporum leptophyllum</i>												X			X						X			X	4

SPECIES	REHABILITATED ZONES												CONTROL ZONES												NUMER OF TIMES SPECIES OCCURS	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24		
Slender Celery																										
<i>Cynodon dactylon</i> Couch																					X			X		2
* <i>Cyperus rotundis</i> Nut Grass																						X				1
<i>Dichanthium sericeum</i> Queensland Bluegrass			X				X	X							X	X	X		X		X			X		9
<i>Dichondra</i> sp. A	X																									1
<i>Digitaria divaricatissima</i> Umbrella Grass		X				X							X				X		X					X		6
<i>Einadia polygonoides</i>										X																1
<i>Einadia trigonus</i> Fishweed																					X					1
<i>Eleocharis pusilla</i> Spike-rush																						X				1
<i>Enneapogon</i> sp. Nineawns								X																		1
<i>Enteropogon acicularis</i> Curly windmill Grass	X					X						X														3
<i>Eragrostis leptostachya</i> Paddock Lovegrass									X		X															2
<i>Euchiton</i> sp.							X											X								2

SPECIES	REHABILITATED ZONES												CONTROL ZONES												NUMER OF TIMES SPECIES OCCURS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
<i>Euchiton sphaericus</i> Cudweed				X																				X	2
<i>Evolvulus alsinoides</i>				X												X									2
<i>Fimbristylis dichotoma</i> Common Fringe-sedge									X																1
* <i>Gomphrena celosioides</i> Gomphrena Weed																								X	1
<i>Goodenia fascicularis</i>										X								X		X					3
<i>Haloragis heterophylla</i> Rough Raspwort																							X		1
* <i>Hypochaeris microcephala</i> White Flatweed																					X				1
<i>Juncus usitatus</i> Pin Rush									X																1
* <i>Lactuca serriola</i> Prickly Lettuce				X							X				X										3
<i>Leiocarpa panaetioides</i> Woolly Buttons							X																		1
* <i>Lepidium africanum</i>											X														1
* <i>Lolium perenne</i> Perennial Ryegrass					X						X														2
* <i>Lolium sp.</i> Ryegrass	X										X										X	X			4

SPECIES	REHABILITATED ZONES												CONTROL ZONES												NUMER OF TIMES SPECIES OCCURS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
<i>Malvastrum americanum</i> Spiked Malvastrum																							X		1
<i>Marsilea drummondii</i> Common Nardoo								X														X			2
* <i>Medicago minima</i> Woolly Burr Medic							X											X							2
* <i>Medicago sativa</i> Lucerne	X		X			X																			3
* <i>Mellilotus indicus</i> Hexham Scent															X										1
* <i>Misopates orontium</i> Lesser Snapdragon		X				X								X						X				X	5
<i>Oxalis</i> sp. Soursob					X	X				X			X						X		X		X		7
<i>Panicum buncei</i>	X	X																							2
<i>Panicum effusum</i> Hairy Panic														X		X				X					3
<i>Panicum maximum</i>					X													X							2
<i>Panicum</i> sp.		X																							1
* <i>Petrorhagia nanteuilii</i> Proliferous Pink		X						X		X				X	X					X					6
* <i>Polygonum aviculare</i> Wireweed										X															1

SPECIES	REHABILITATED ZONES												CONTROL ZONES												NUMER OF TIMES SPECIES OCCURS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
<i>Portulaca oleracea</i> Pigweed													X				X							X	3
* <i>Schkuhria pinnata</i> Dwarf Marigold																							X		1
<i>Senecio quadridentatus</i> Cotton Fireweed		X																							1
<i>Sida corrugata</i> Corrugated Sida											X			X											2
<i>Solanum esuriale</i> Quena																								X	1
* <i>Solanum nigrum</i> Black-berry Nightshade	X																								1
* <i>Sonchus oleraceus</i> Common Sowthistle	X				X						X	X		X	X	X		X		X					9
<i>Sporobolus caroli</i> Fairy Grass																								X	1
* <i>Tragopogon porrifolius</i> Salsify												X													1
* <i>Trifolium arvense</i> Haresfoot Clover	X	X	X	X	X			X	X		X					X				X					10
* <i>Trifolium campestre</i> Hop Clover			X					X	X					X									X		5
* <i>Trifolium dubium</i> Yellow Suckling Clover							X			X	X			X		X			X	X					7

SPECIES	REHABILITATED ZONES												CONTROL ZONES												NUMER OF TIMES SPECIES OCCURS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
<i>Trifolium</i> sp. Clover																	X							1	
* <i>Urochloa panicoides</i> Urochloa Grass																							X	1	
<i>Vittadinia</i> sp. Fuzzweed					X	X				X			X	X			X						X	7	
<i>Vulpia</i> sp. Fescue									X		X		X			X			X					5	
<i>Wahlenbergia communis</i> Tufted Bluebell										X											X			2	
<i>Xerochrysum bracteatum</i> Golden Everlasting				X					X							X			X	X				5	
TOTAL SPECIES (77)	11	10	5	9	9	11	7	6	10	9	11	8	8	11	6	12	8	7	9	10	8	6	9	13	

*Denotes introduced species

Appendix A3: Weed species

SPECIES	REHABILITATION ZONES												CONTROL ZONES												NUMBER OF TIMES SPECIES OCCURS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
* <i>Carthamus lanatus</i> Saffron Thistle			X	X		X		X							X										5
* <i>Centaurea melitensis</i> Maltese Cockspur	X											X													2
<i>Chamaesyce</i> sp. Caustic Weed			X							X				X										X	4
<i>Cheilanthes sieberi</i> Poison Mulga Fern									X		X			X		X			X						5
<i>Sclerolaena muricata</i> Black Rolypoly										X									X						2
Total species (6)	1	0	2	1	0	1	0	1	1	2	1	1	0	2	1	1	0	1	1	0	0	0	0	1	

Appendix A4: Pasture plot results

TREATMENT	PLOT	EASTING	NORTHING	GROUND COVER COMPOSITION				SOIL CHEMISTRY					PASTURE BIOMASS
				Weed Species (%)	Pasture Species (%)	Bare Ground (%)	Litter (%)	Electrical Conductivity (dS/m)	pH (CaCl ₂)	Total Nitrogen (mg/kg)	Phosphorus Ex (mg/kg)	Organic Carbon (%)	kg DM/ha
Rehabilitated	1	228719	6596750	1	50	4	45	0.05	5.82	834	24.6	1.49	3700
	2	228962	6596709	0	20	0	80	0.04	6.06	1176	22.4	1.11	3300
	3	229156	6596815	1	20	60	19	0.11	7.77	352	16.4	0.31	950
	4	228929	6596857	1	30	14	55	0.12	7.54	603	19.9	0.58	1450
	5	229606	6596393	0	40	0	60	0.04	5.66	892	34.7	1.01	3200
	6	228872	6596961	1	65	14	20	0.03	5.84	694	18.9	0.79	3050
	7	228951	6597096	0	55	15	30	0.14	7.78	631	20	0.66	2450
	8	229291	6596701	1	50	10	39	0.09	7.32	426	15.7	0.48	3150
Control	9	229569	6597206	1	60	0	39	0.03	4.96	677	33.4	0.87	3300
	10	228799	6597351	2	15	60	33	0.09	6.27	845	26.6	1.35	250
	11	229147	6597223	2	40	0	58	0.03	5.24	1815	23.9	2.45	3700
	12	229566	6597100	2	30	0	68	0.23	7.91	558	15.8	0.47	2900
	13	228560	6596357	0	20	55	25	0.05	5.71	622	17.5	0.71	850
	14	228854	6596229	2	23	50	25	0.02	5.15	825	15.3	0.96	450
	15	228984	6596354	2	30	8	60	0.13	7.71	598	16.3	0.62	3650
	16	2289445	6596172	2	60	5	33	0.03	5.2	970	15.4	1.17	2650
	17	228688	6597035	0	30	50	20	0.03	5.25	514	16.4	0.74	1650
	18	228769	6597182	2	80	0	18	0.16	7.89	368	17.4	0.53	4400
	19	228561	6596208	2	30	50	18	0.02	4.9	697	18.1	0.85	750
	20	228693	6596215	0	70	5	25	0.02	5.52	675	21.4	0.71	2300
	21	229700	6597197	0	80	0	20	0.08	5.67	1025	20.8	1.33	4500
	22	229680	6597085	0	70	0	30	0.15	6.62	1657	35.8	2.6	3300
	23	228805	6596334	1	50	25	24	0.03	6.47	883	18.5	1.11	900
	24	228632	6596449	0	25	60	15	0.13	6.35	668	14.6	0.59	1500
	Max			2	80	60	80	0.23	7.91	1815	35.8	2.6	4500
	Min			0	15	0	15	0.02	4.9	352	14.6	0.31	250

Appendix B1: Woodland monitoring plot photographs

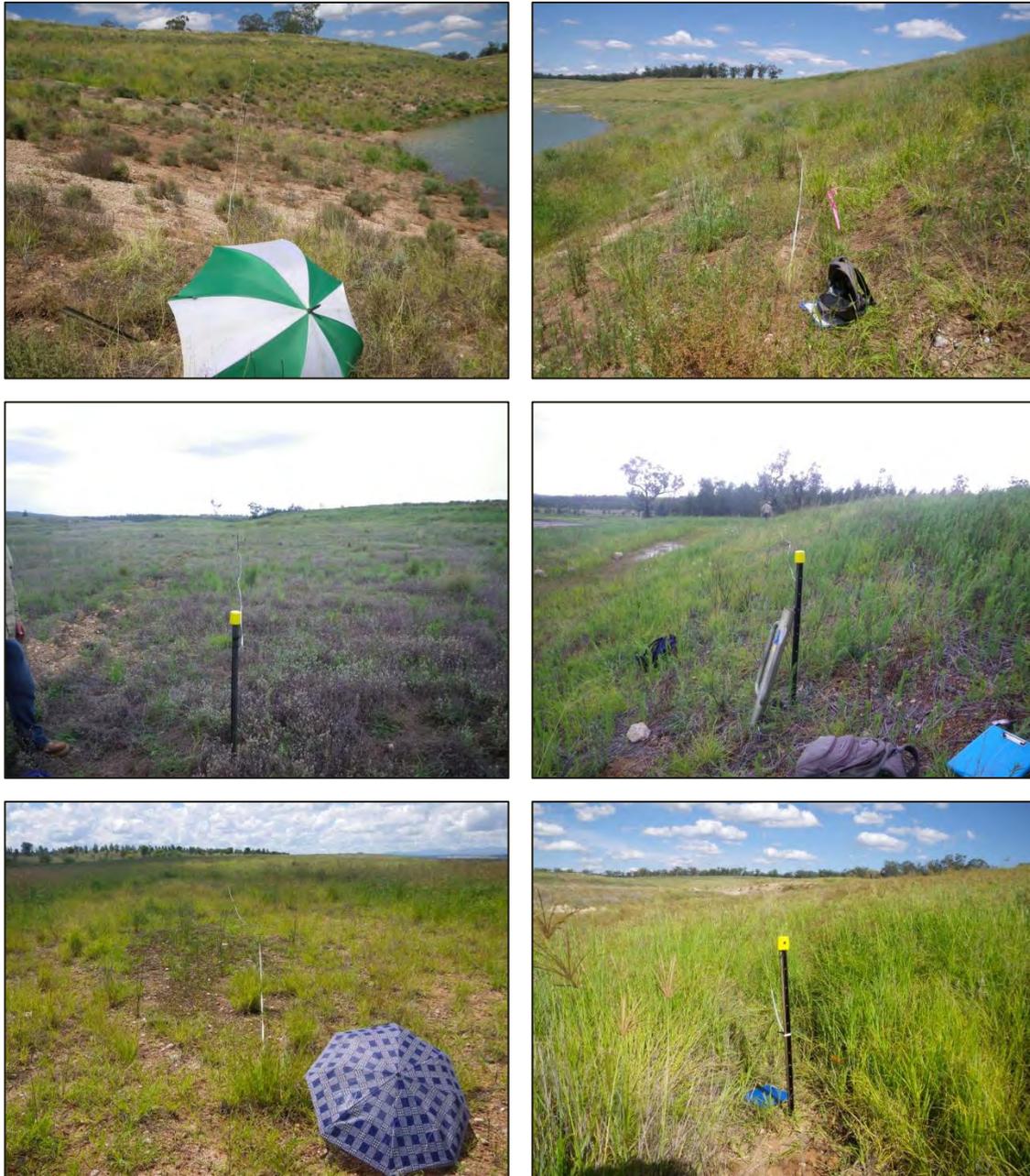


Figure B 1: Woodland monitoring plots. Plots 1 to 6 (ordered Left to Right; Top to Bottom)

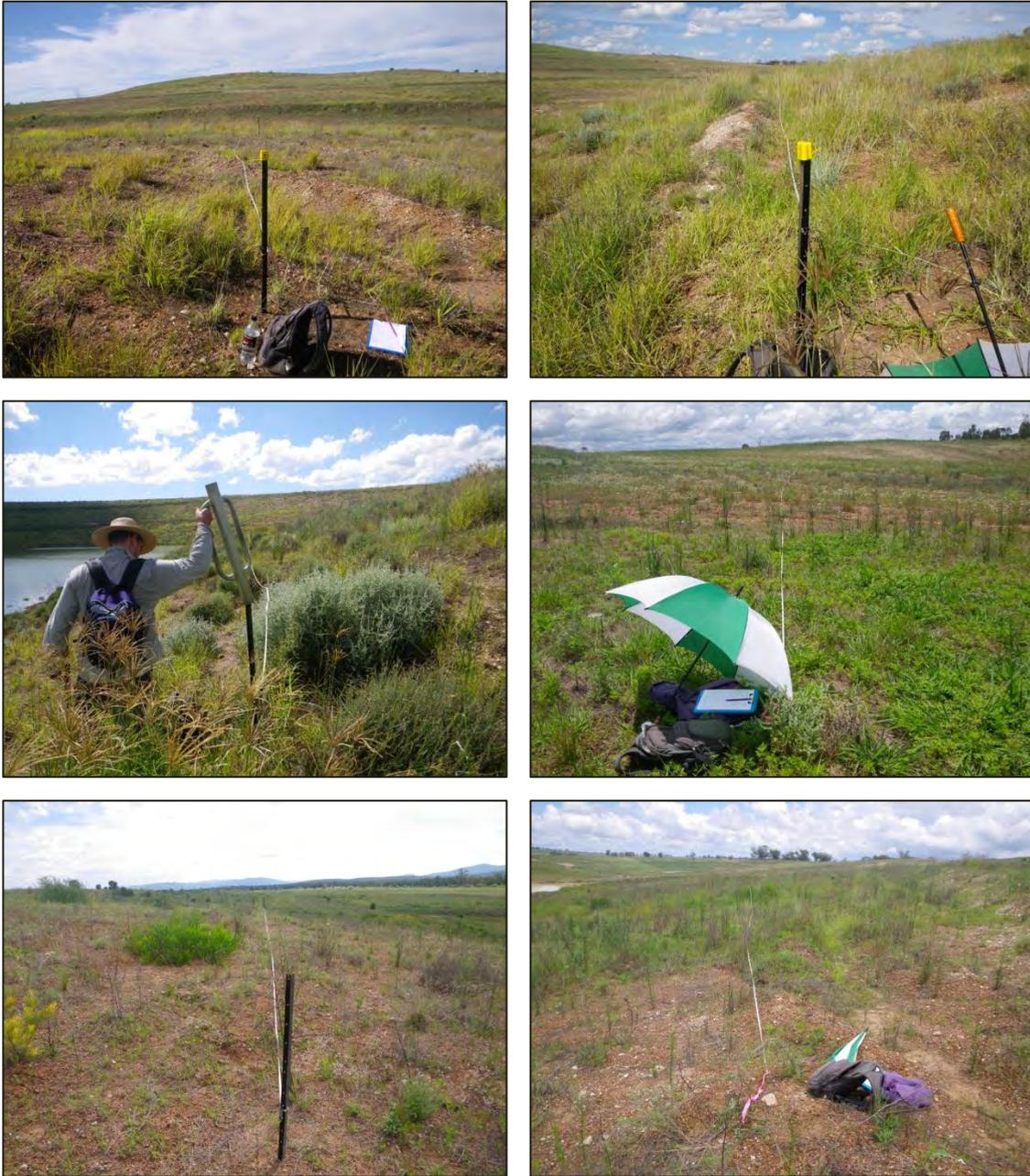


Figure B 2: Woodland monitoring plots. Plots 7 to 12 (ordered Left to Right; Top to Bottom)

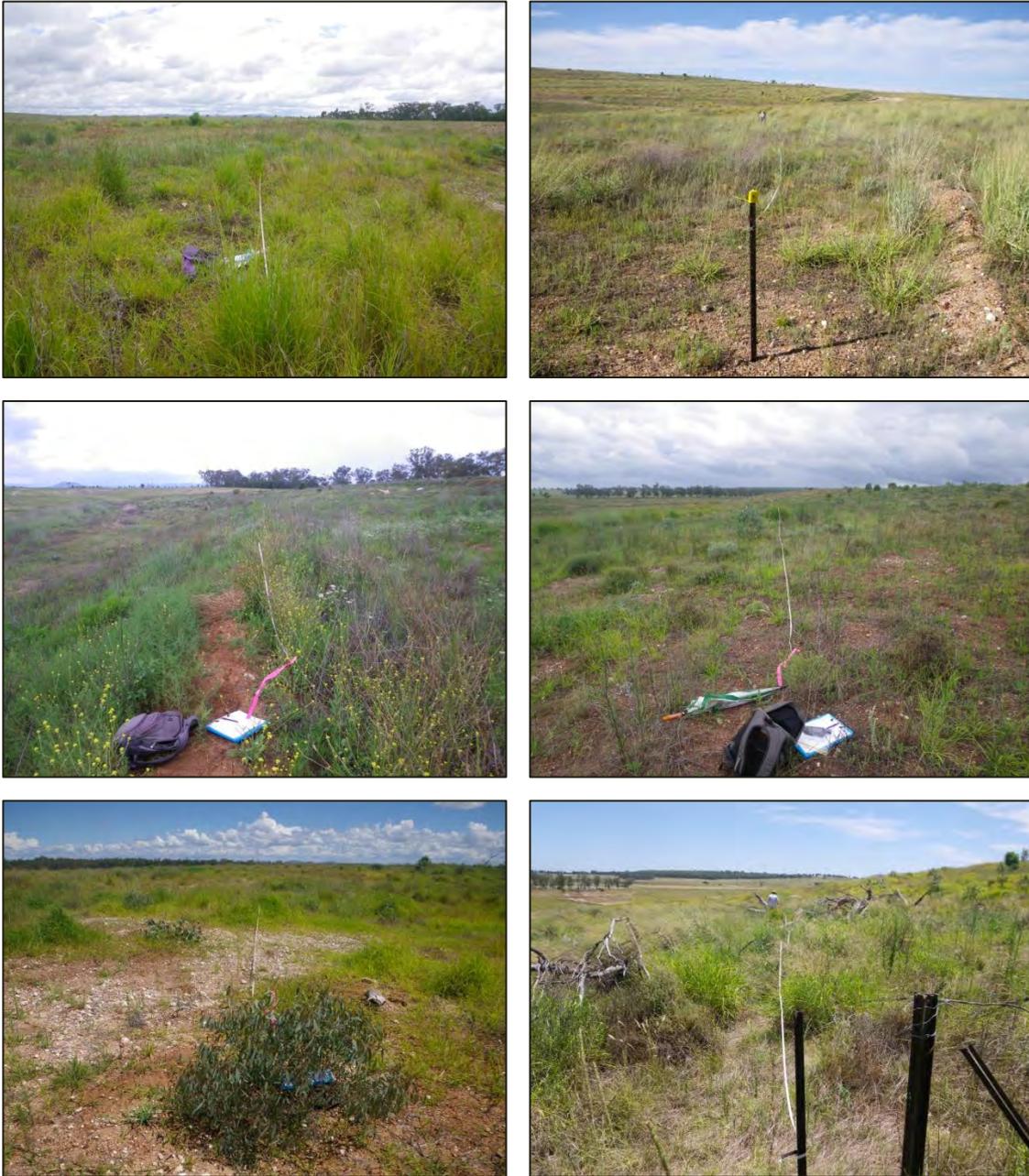


Figure B 3: Woodland monitoring plots. Plots 13 to 18 (ordered Left to Right; Top to Bottom)



Figure B 4: Woodland monitoring plots. Plots 19 to 24 (ordered Left to Right; Top to Bottom)



Figure B 5: Woodland monitoring plots. Plots 25 to 30 (ordered Left to Right; Top to Bottom)



Figure B 6: Woodland monitoring Plots. Plots 31-36 (ordered Left to Right; Top to Bottom)



Figure B 7: Woodland monitoring plots. Plots 37 to 42 (ordered Left to Right; Top to Bottom)



Figure B 8: Woodland monitoring plots. Plots 43 to 45 (ordered Left to Right; Top to Bottom)

Appendix B2: Overstorey and midstorey species in Woodland plots

SPECIES	COMMON NAME	2008				2007					2006			2005			2004					WOOD CONTROL 2					WOOD CONTROL 1				
		11	13	14	15	16	17	18	19	20	21	22	24	26	28	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
<i>Acacia deanei</i>	Green Wattle				X				X			X										X									
<i>Acacia decora</i>	Western Silver Wattle																						X	X							
<i>Acacia floribunda</i>	White Sally Wattle	X																													
<i>Acacia longifolia</i>	Sydney Golden Wattle	X																													
<i>Acacia pendula</i>	Weeping Myall					X	X			X																					
<i>Acacia salicina</i>	Cooba									X																					
<i>Acacia ? saligna</i>	Golden Wreath Wattle											X																			
<i>Acacia</i> sp.																					X										
<i>Alectryon oleifolius</i>	Western Rosewood		X			X			X	X									X	X				X							
<i>Brachychiton populneus</i>	Kurrajong					X				X																					
<i>Callitris glaucophylla</i>	White Cypress Pine									X											X	X	X	X	X			X	X	y	
<i>Casuarina cristata</i>	Belah								X	X																					
<i>Dodonaea viscosa</i>	Sticky Hop-bush									X											X										
<i>Dodonaea viscosa subsp. angustifolia</i>												X																			
<i>Dodonaea viscosa subsp. cuneata</i>	Wedge-leaf Hop-bush															X															
<i>Eucalyptus albens</i>	White Box					X	X		X	X											X		X	X	X						
<i>Eucalyptus blakelyi</i>	Blakely's Red Gum					X	X		X			X																			
<i>Eucalyptus ? blakelyi</i>	Blakely's Red Gum									X				X				X	X												
<i>Eucalyptus crebra</i>	Narrow-leaved Ironbark	X					X		X	X									X	X				X							
<i>Eucalyptus melanophloia</i>	Silver-leaved Ironbark										X		X	X				X		X	X	X	X	X				X	X		
<i>Eucalyptus melliodora</i>	Yellow Box								X			X																			
<i>Eucalyptus microcarpa</i>	Grey Box																											X			
<i>Eucalyptus populnea subsp. bimbil</i>	Bimble Box	X		X			X			X	X											X				X	X	X	X		
<i>Eucalyptus</i> sp. (unknown)						X		X	X				X	X																	
<i>Geijera parviflora</i>	Wilga																					X			X						
* <i>Lycium ferocissimum</i>	African Boxthorn					X			X			X																	X		
<i>Myoporum montanum</i>	Western Boobialla																							X							
<i>Notelaea microcarpa</i>	Native Olive																													X	
<i>Pimelea neo-anglica</i>	Poison Pimelea												X																		
Various planted eucalypt species																X	X														
	Total number of species	4	1	1	1	7	5	1	8	8	5	2	5	3	3	1	1	1	2	3	6	2	5	4	6	3	1	1	3	4	3

*Denotes exotic species; between order and family denotes uncertain identification

SPECIES	2010					2009					2008					2007					2006					2005					2004					WOOD CONTROL 2					WOOD CONTROL 1									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45					
<i>Linum marginale</i> Native Flax																																																		
* <i>Lolium</i> sp. Ryegrass									1																1	1																								
<i>Lomandra filiformis</i> Wattle Mat-rush																																																		
<i>Lomandra longifolia</i> Spiny-headed Mat-rush																																																		
<i>Lomandra multiflora</i> Many-flowered Mat-rush																																																		
* <i>Lycium ferocissimum</i> African Boxthorn																																																		
<i>Lythrum hyssopifolia</i> Hyssop Loosestrife										1																																								
<i>Maireana decalvans</i> Black Cotton Bush														1																																				
<i>Maireana enchylaenoides</i> Wingless Bluebush																																																		
<i>Maireana microphylla</i> Small-leaf Bluebush																																																		
* <i>Malvastrum americanum</i> Spiked Malvastrum																																																		
<i>Malvastrum coromandelianum</i> Prickly Malvastrum																																																		
* <i>Medicago minima</i> Woolly Burr Medic																																																		
* <i>Medicago polymorpha</i> Burr Medic		2	2																																															
* <i>Medicago sativa</i> Lucerne																																																		
* <i>Medicago</i> sp.			1																																															
* <i>Medicago truncatula</i> Barrel Medic																																																		
* <i>Melilotus indicus</i> Hexham Scent																																																		
<i>Mentha satureioides</i> Creeping Mint																																																		

SPECIES	2010					2009					2008					2007					2006					2005					2004					WOOD CONTROL 2					WOOD CONTROL 1				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
<i>*Trifolium glomeratum</i> Clustered Clover					2		2	2			2									2				2	2					1															
<i>*Trifolium repens</i> White Clover							1			1																																			
<i>*Urochloa panicoides</i> Urochloa Grass																																						2							
<i>*Verbascum thapsus</i> Great Mullein																														1															
<i>*Verbascum virgatum</i> Twiggy Mullein																										1																			
<i>*Verbena bonariensis</i> Purpletop										1																																			
<i>Verbena gaudichaudii</i>				1					1		1	1	1	2	1				1							2	1	1	2	1	2	2			2	1			1		1	1		1	
<i>Vicia</i> sp. Vetch														2																															
<i>Vittadinia cuneata</i> Fuzzweed		1			1																									1										1				1	
<i>Vittadinia dissecta</i> Dissected New Holland Daisy											1			1														1														2			
<i>Vittadinia muelleri</i>							1																1							2		1													
<i>Vittadinia</i> sp.	1		2						2	2		2	2		2	2		1	2	2		2	1	2	2		2	1			1	2	2	2	2		2			2				1	
<i>Wahlenbergia communis</i> Tufted Bluebell	1			1	1				1		1	1			1		1	1			1	2			1	2			2	2	2	2	2	2			2	2	2	2	2	2	2	2	
<i>Wahlenbergia gracilis</i> Sprawling Bluebell																																			1		1								
<i>Wahlenbergia luteola</i> Bluebell																																	1												
<i>Walwhalleya prolata</i>																																			2										
<i>*Xanthium occidentale</i> Noogoora Burr													1																									1							
<i>*Xanthium spinosum</i> Bathurst Burr		1																																				1							
<i>Xerochrysum bracteatum</i> Golden Everlasting		1		1					1	1		1	1					1	1					1				1							1				1	2					
<i>Xerochrysum viscosum</i> Sticky Everlasting																												1	1	2									2						1

SPECIES	2010					2009					2008					2007					2006					2005					2004					WOOD CONTROL 2					WOOD CONTROL 1									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45					
<i>Zornia dyctiocarpa</i>																																																		
Zornia																																																		
Total Number	27	35	32	29	20	14	21	22	26	48	26	43	36	32	41	46	16	41	29	26	15	17	24	28	34	40	33	38	46	35	46	30	39	43	37	40	40	51	36	40	39	45	30	40	41					

*Denotes exotic species

Add your Braun-Blanquet scale 1=?, 2=?, etc

SPECIES	2010					2009					2008					2007					2006					2005					2004					WOOD CONTROL 2					WOOD CONTROL 1									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45					
<i>Eucalyptus blakelyi</i> Blakely's Red Gum																X	X		X					X																										
<i>Eucalyptus ? albens</i> White Box																															X				X															
<i>Eucalyptus ? blakelyi</i> Blakely's Red Gum																					X						X	X				X	X	X																
<i>Eucalyptus crebra</i>											X						X		X	X														X					X											
<i>Eucalyptus ? crebra</i> Narrow-leaved Ironbark																															X	X			X															
<i>Eucalyptus ? fibrosa</i> Red Ironbark																											X																							
<i>Eucalyptus melanophloia</i> Silver-leaved Ironbark																										X	X	X			X	X	X			X	X	X						X	X					
<i>Eucalyptus melliodora</i> Yellow Box																			X					X																										
<i>Eucalyptus populnea</i> Poplar Box											X									X	X																													
<i>Eucalyptus populnea</i> subsp. <i>bimbil</i> Poplar Box																																					X				X	X	X	X						
<i>Eucalyptus</i> sp. (unknown)																													X	X																				
* <i>Lycium ferocissimum</i> African Boxthorn			X															X	X																															
Total Number of Species	0	0	1	0	4	0	1	0	1	4	3	1	5	6	3	1	0	2	0	1	3	3	1	1	3	3	2	3	5	2	3	4	5	0	1	1	2	5	3											

*Denotes exotic species; ? between order and family denotes species uncertain at present growth stage

Appendix B5: Rehabilitated woodland and control woodland habitat characteristics

PLOT NUMBER:		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Canopy DBH Thresholds:	Large Tree ≥:	-	-	-	-	-	-	-	-	-	-	Planted trees 0.5 m tall covering ~1% of plot; more than one stratum	-	-	No planted trees yet	-	
	Mature Tree ≥:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Advanced Regrowth (xcm to x cm):	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Sapling ≤ xcm to xcm:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Seedlings < xcm dbh:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Canopy ≥ xm:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Midstorey xm to xm:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Ground layer ≤ xm:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Canopy Species and Age Classes:	No. of native canopy species:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	No. of large trees:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Juveniles present (Y/N):	n	n	n	n	n	n	n	n	n	n	n	y	n	y	n	n
	Mature trees present (Y/N):	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	Seedlings present (Y/N):	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	Advanced regrowth present (Y/N):	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Coarse Woody Debris:	Total length of CWD (m):	-	-	-	-	-	-	-	-	-	-	none	none	none		none	
	No. of sections of CWD:	-	-	-	-	-	-	-	-	-	-						
Midstorey, Understorey Species:	No. of native midstorey species:	-	-	-	-	-	-	-	-	-	-	2		1 (natural)		1	
	No. of native species in ground layer:	19	20	-	9	8	4	5	11	16	27	12	20	20	17	23	
Transect:	% Projected Crown Cover- Canopy Species:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	% Projected Crown Cover - Midstorey Species:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

	PLOT NUMBER:	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
Canopy DBH Thresholds:	Large Tree ≥:	Overall tree cover is ~2%	Overall tree cover is ~2%	One planted tree 2 m tall	-	Overall tree cover ~5 %	-	-	Note: Very weedy site and no trees planted in plot	Planted trees on site 1.5 - 2 m tall, covers ~2% of plot	No planted trees	Note: Cover of trees in plot is ~ 1%	Note: Cover of trees in plot is ~ 3%	-	-	-	
	Mature Tree ≥:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Advanced Regrowth (xcm to x cm):	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Sapling ≤ xcm to xcm:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Seedlings < xcm dbh:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Canopy ≥ xm:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Midstorey xm to xm:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Ground layer ≤ xm:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Canopy Species and Age Classes:	No. of native canopy species:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	No. of large trees:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Juveniles present (Y/N):	y	y	n	y	y	y	y	y	y	y	n	y	y	y	n	n
	Mature trees present (Y/N):	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
	Seedlings present (Y/N):	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
Advanced regrowth present (Y/N):	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	
Coarse Woody Debris:	Total length of CWD (m):		7	91	none	1	0	22	22	19	4	37	64	72	10	15	
	No. of sections of CWD:		1	19		1	0	5	5	5	3	13	17	21	8	4	
Midstorey, Understorey Species:	No. of native midstorey species:	1 (planted)	0	1 (planted)	1 (planted)	1 (planted?)	-	1	0	15	0	1, plus planted eucs	-	0	3	1	
	No. of native species in ground layer:	29	4	23	16	11	4	5	8	2	14	24	19	22	35	-	
Transect:	% Projected Crown Cover- Canopy Species:		-	-	-		-	-		-	-	-	-	-	-	-	
	% Projected Crown Cover - Midstorey Species:	4	-	-	-	2	-	-		-	-	-	-	-	-	-	

	PLOT NUMBER:	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
Canopy DBH Thresholds:	Large Tree ≥:	Note: No trees along transect but 2 rows of young trees within plot	-	Note: Estimated cover for 20 x 50 m plot 3%	Note: Estimated planted tree cover for 20 x 50 m plot 2%	Note: Estimated planted tree cover for 20 x 50 m plot 5%	50	50	50	50	50	50	60	50	50	50
	Mature Tree ≥:	-	-	-	-	-	-	-	30	30	30	-	30	-	30	-
	Advanced Regrowth (xcm to x cm):	-	-	-	-	-	-	-	-	-	-	-	10 x 30	-	-	-
	Sapling ≤ xcm to xcm:	-	-	-	-	-	-	-	-	-	-	-	1 to 10	-	-	-
	Seedlings < xcm dbh:	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
	Canopy ≥ xm:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Midstorey xm to xm:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ground layer ≤ xm:	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Canopy Species and Age Classes:	No. of native canopy species:	No canopy yet	0	0	0	0	1	2	3	2	1	1	1	2	2	1
	No. of large trees:	0	0	0	0	0	2	0	1	1	1	0	0	0	2	2
	Juveniles present (Y/N):	y	y	y	y	y	y	y	y	n	y	n	y	y	n	y
	Mature trees present (Y/N):	n	n	n	n	n	y	y	y	y	y	y	y	y	y	y
	Seedlings present (Y/N):	n	n	n	n	n	y	n	y	n	n	n	-	y	n	-
	Advanced regrowth present (Y/N):	n	n	n	n	n	y	y	y	y	y	y	y	y	y	y
Coarse Woody Debris:	Total length of CWD (m):	14, deliberately imported	113	53	51	none	none	27	4	62	99	24	86	3	105	15
	No. of sections of CWD:	8	30	6	14	none	none	8	3	15	42	13	35	3	24	7
Midstorey, Understorey Species:	No. of native midstorey species:	none - but young trees sort of making a midstorey	-	0	3 (inc. sml trees)	5 -planted	1	3	1	4	2	0	1	-	3	2
	No. of native species in ground layer:	0	14	25	31	22	36	39	35	35	39	34	35	-	37	35
Transect:	% Projected Crown Cover- Canopy Species:	-	6	-	-	-	42	16	22	52	28	72	20	12	58	38
	% Projected Crown Cover - Midstorey Species:	-	-	-	-	-	-	52	-	-	20	0	4	12	6	10

Appendix C: Fauna data

SPECIES	COMMON NAME	REHABILITATED SITES								CONTROL SITES	
		W04	W05	W06	W07	W08	W09	W10	WC01	WC02	
BIRDS											
<i>Acanthagenys rufogularis</i>	Spiny-cheeked Honeyeater	X	X								X
<i>Acanthiza apicalis</i>	Inland Thornbill										X
<i>Acanthiza chrysorrhoa</i>	Yellow-rumped Thornbill	X	X								X
<i>Acanthiza nana</i>	Yellow Thornbill										X
<i>Aprosmictus erythropterus</i>	Red-winged Parrot		X								
<i>Aquila audax</i>	Wedge-tailed Eagle										X
<i>Cacatua galerita</i>	Sulphur-crested Cockatoo									X	X
<i>Cacatua sanguinea</i>	Little Corella		X					X		X	X
<i>Chenonetta jubata</i>	Australian Wood Duck									X	X
<i>#Chthonicola sagittata</i>	Speckled Warbler										X
<i>Cincloramphus mathewsi</i>	Rufous Songlark	X	X								X
<i>Cisticola exilis</i>	Golden-headed Cisticola			X	X	X	X	X			
<i>Coracina novaehollandiae</i>	Black-faced Cuckoo-shrike		X								
<i>Corcorax melanorhamphos</i>	White-winged Chough									X	X
<i>Corvus coronoides</i>	Australian Raven									X	X
<i>Coturnix ypsilophora</i>	Brown Quail	X	X	X	X	X	X	X	X		X
<i>Cracticus nigrogularis</i>	Pied Butcherbird			X							X
<i>Cracticus tibicen</i>	Australian Magpie	X	X		X					X	X
<i>Cracticus torquatus</i>	Grey Butcherbird									X	X

SPECIES	COMMON NAME	REHABILITATED SITES							CONTROL SITES	
		W04	W05	W06	W07	W08	W09	W10	WC01	WC02
<i>Dacelo novaeguineae</i>	Laughing Kookaburra									X
<i>Egretta novaehollandiae</i>	White-faced Heron								X	
<i>Elanus axillaris</i>	Black-shouldered Kite			X						
<i>Eolophus roseicapillus</i>	Galah							X	X	X
<i>Eopsaltria australis</i>	Eastern Yellow Robin									X
<i>Eurystomus orientalis</i>	Dollarbird									X
<i>Falco cenchroides</i>	Nankeen Kestrel			X	X			X	X	
<i>Falco longipennis</i>	Australian Hobby			X					X	
<i>Falco peregrinus</i>	Peregrine Falcon			X						
<i>Geopelia striata</i>	Peaceful Dove									X
<i>Gerygone fusca</i>	Western Gerygone									X
<i>Glossopsitta concinna</i>	Musk Lorikeet								X	
<i>Grallina cyanoleuca</i>	Magpie-lark					X		X	X	X
<i>#Hieraetus morphnoides</i>	Little Eagle								X	
<i>^Hirundapus caudacutus</i>	White-throated Needletail			X						
<i>Lalage sueurii</i>	White-winged Triller									X
<i>Lichenostomus penicillatus</i>	White-plumed Honeyeater									X
<i>Lichenostomus virescens</i>	Singing Honeyeater	X	X							
<i>Malurus cyaneus</i>	Superb Fairy-wren	X	X							X
<i>Malurus leucopterus</i>	White-winged Fairy-wren	X	X	X	X	X	X	X		
<i>Manorina melanocephala</i>	Noisy Miner					X			X	X
<i>Megalurus timoriensis</i>	Tawny Grassbird		X	X	X	X				
<i>Neochmia modesta</i>	Plum-headed Finch	X								X
<i>Northiella haematogaster</i>	Blue Bonnet									X
<i>Nymphicus hollandicus</i>	Cockatiel								X	

SPECIES	COMMON NAME	REHABILITATED SITES							CONTROL SITES	
		W04	W05	W06	W07	W08	W09	W10	WC01	WC02
<i>Ocyphaps lophotes</i>	Crested Pigeon	X	X			X			X	X
<i>Pachycephala rufiventris</i>	Rufous Whistler									X
<i>Pardalotus striatus</i>	Striated Pardalote									X
<i>Petrochelidon ariel</i>	Fairy Martin									X
<i>Petroica goodenovii</i>	Red-capped Robin									X
<i>Phaps chalcoptera</i>	Common Bronzewing					X				X
<i>Platycercus eximius</i>	Eastern Rosella								X	X
<i>Plectorhyncha lanceolata</i>	Striped Honeyeater									X
<i>#Pomatostomus temporalis</i>	Grey-crowned Babbler								X	X
<i>Psephotus haematonotus</i>	Red-rumped Parrot					X				X
<i>Rhipidura albiscapa</i>	Grey Fantail									X
<i>Rhipidura leucophrys</i>	Willie Wagtail	X	X							X
<i>Smicronis brevirostris</i>	Weebill		X							X
<i>Struthidea cinerea</i>	Apostlebird								X	X
<i>*Sturnus vulgaris</i>	Common Starling			X						
<i>Taeniopygia bichenovii</i>	Double-barred Finch									X
<i>Todiramphus sanctus</i>	Sacred Kingfisher									X
<i>Turnix varia</i>	Painted Button-quail								X	X
Total		11	15	11	6	9	4	6	20	45
AMPHIBIANS										
<i>Limnodynastes fletcheri</i>	Barking Marsh-Frog					X	X	X		
<i>Limnodynastes tasmaniensis</i>	Spotted Grass-Frog						X	X		
<i>Litoria caerulea</i>	Green Tree-Frog		X							
<i>Litoria dentata</i>	Bleating Tree-Frog					X				

SPECIES	COMMON NAME	REHABILITATED SITES							CONTROL SITES	
		W04	W05	W06	W07	W08	W09	W10	WC01	WC02
<i>Litoria latopalmata</i>	Broad-palmed Frog					X		X		
<i>Litoria peronii</i>	Peron's Tree-Frog					X				X
Total		0	1	0	0	4	2	3	0	1
REPTILES										
<i>Chelodina longicollis</i>	Eastern Snake-necked Tortoise					X				
<i>Cryptoblepharus virgatus</i>	Wall Skink								X	
<i>Egernia striolata</i>	Tree Skink								X	X
<i>Morethia boulengeri</i>	Boulanger's Skink								X	
Total		0	0	0	0	1	0	0	3	1
Mammals										
<i>Macropus giganteus</i>	Eastern Grey Kangaroo	X	X		X	X	X			X
<i>Macropus robustus</i>	Common Wallaroo		X	X		X			X	
<i>Wallabia bicolor</i>	Swamp Wallaby					X				X
* <i>Lepus capensis</i>	Hare	X								X
* <i>Oryctolagus cuniculus</i>	Rabbit								X	X
* <i>Felis catus</i>	Cat							X		
* <i>Vulpes vulpes</i>	Fox							X		
	Total	2	2	1	1	3	1	2	2	4

^Denotes Migratory under the EPBC Act; # Denotes listed as threatened under the TSC Act; *Denotes exotic species

Appendix D: Soil pit summaries

Soil Pit 1 Woodland Rehabilitation Zone (north) (E: 229364; N: 6596274)



HORIZON AND DEPTH	SOIL DESCRIPTION
1: 0 – 0.15 m	Light clay-clayey gravel (wet) with fine-medium gravels (1-5 mm) Grass roots throughout
2: 0.15 – 0.60 m	0.15-0.60 m Sandy clay loam-light clay (lower gravel content than A1) Light chocolate Amount of roots decreases with depth
3: 0.60 – 0.95 m	Sandy clay-gravel mixture (dark grey) with coarse gravels No roots present Mine overburden encountered at 0.95 m

Soil Pit 2 Woodland Rehabilitation Zone (mid) (E: 229569; N: 6595820)



HORIZON AND DEPTH	SOIL DESCRIPTION
1: 0 – 0.70 m	Medium clay with fine gravels (chocolate) Large portion gravels (up to 50%) 1-5 mm diameter Roots present
2: 0.70 – 0.80 m	Medium-heavy clay (brown-chocolate) with fine-medium gravels (approx 10-20%) No roots
3: 0.80 -1.00 m	Sandy clay-gravel mixture (dark grey) Coarse gravels and cobbles (size increases with depth)

Soil Pit 3 Woodland Rehabilitation Zone (south) (E: 229377; N: 6595302)



HORIZON AND DEPTH	SOIL DESCRIPTION
1: 0 – 0.25 m	Medium clay with fine gravels (chocolate) Roots throughout horizon
2: 0.25 – 0.55 m	Medium-heavy clay (dark brown-chocolate) Fine-medium gravels (approx 5-10%) No roots
3: 0.55 – 0.80 m	Sandy clay-gravel mixture (light grey-light brown) with gravel and rock chip fragments Mine overburden encountered at 0.80 m

Note:

Presence of red rock fragments on surface (did not present in soil profile)

Mine overburden encountered at 0.80 m

Soil Pit 4 Woodland Control (north) (E: 229048; N: 6595871)



HORIZON AND DEPTH	SOIL DESCRIPTION
1: 0 – 0.20 m	Sandy loam - sandy clay loam (dark brown) 10-20% gravels (10-15 mm) Root activity throughout horizon
2: 0.20 – 0.50 m	Sandy loam - sandy clay loam (light red-brown) 15-25% gravels (5-20 mm) Roots present but less than above horizon
3: 0.50 – 0.60 m	Heavy clay (chocolate-dark brown) 10-20% gravels (10-15 mm) Few roots
4: 0.60 – 0.75 m	Horizon boundary Sandy clay loam-light clay (dark chocolate) 20-30% gravels up to 25 mm Roots present
5: 0.75 – 1.00 m	Medium-heavy clay (chocolate) Some tree roots present

Note:

Located at foot of a 100 m gentle slope with mostly Inland Grey Box

Soil Pit 5 Woodland Control (south) (E: 230102; N: 6595019)



HORIZON AND DEPTH	SOIL DESCRIPTION
1: 0 – 0.15 m	Light clay with coarse gravels (chocolate-grey) (10mm- 70 mm) Roots present (grass and tree species)
2: 0.15 – 0.35 m	Sandy loam (light grey) with medium gravels Roots present
3: 0.35 – 0.60 m	Sandy loam (light grey) with medium to coarse gravels Rock fragments up to 150 mm Tree roots present
4: 0.60 – 0.85 m	Gravel-sand-silt mixture with predominantly coarse gravels

Note:

Site located on top of a ridge with large stones found throughout the profile

Greater amounts of stones found at 0.60 m

Refusal at 0.75 m

Soil Pit 6 Pasture Control (south) (E: 229678; N: 6596283)



HORIZON AND DEPTH	SOIL DESCRIPTION
1: 0 – 0.20 m	Sandy clay loam-light clay No gravels Roots present
2: 0.20 – 0.40 m	Medium-heavy clay with fine gravel Roots throughout profile
3: 0.40 – 0.60 m	Gravel seam with more than 50% fine gravel (dark red-brown)
4: 0.60 – 1.00 m	Light clay (red-brown) Much less gravel, mottled No roots

Soil Pit 7 Pasture Control (north) (E: 229028; N: 6597192)



HORIZON AND DEPTH	SOIL DESCRIPTION
1: 0 – 0.20 m	Light-medium clay (chocolate) with some fine-coarse gravel Roots throughout profile
2: 0.20 – 0.40	Light -medium clay (light chocolate) with coarse gravels Roots throughout profile but decreases with depth Transitional boundary
3: 0.40 – 1.00	Heavy clay (grey) with small amounts of gravel Roots to depth of 75 cm only

Note:

Some charcoal observed in top 20 cm

Inland grey box trees only trees within a 100m radius of soil pit. Roots reach a depth of around 75 cm but roots were significantly less after top 20 cm.

Soil Pit 8 Pasture Rehabilitation Zone (E: 228961; N: 6597001)



HORIZON AND DEPTH	SOIL DESCRIPTION
1: 0 – 0.15 m	Medium-heavy clay (dark chocolate) with high portion of fine gravel Roots throughout depth of profile
2: 0.15 – 0.60 m	Medium clay (dark brown) with fine-medium gravels Roots to depth of 45cm and decrease with depth
3: 0.60 – 1.00 m	Gravel-sand-clay mixture (mine overburden) (grey) Coarse gravels increasing in size and abundance with depth No roots

Note:

No trees

A1 horizon almost same as control site (north) although higher in portion of gravels

Soil Pit 9 Pasture Rehabilitation Zone (E: 229020; N: 6595752)



HORIZON AND DEPTH	SOIL DESCRIPTION
1: 0 – 0.40 m	Sandy loam-light clay (dark red-chocolate) with high proportion of fine gravel Roots to 35 cm (although sparse after 20 cm depth)
2: 0.40 – 0.60 m	Light-medium clay (chocolate-light grey) High proportion of fine gravels (thin gravel seams) No roots
3: 0.60 – 1.00 m	Medium-heavy clay (dark red-chocolate) Little to no gravels No roots

Note:

No trees

A1 horizon almost same as control site (north) although higher in portion of gravels

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PERTH

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Sydney NSW 2000
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NEWCASTLE

Suites 28 & 29, Level 7
19 Bolton Street
Newcastle NSW 2300
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ARMIDALE

92 Taylor Street
Armidale NSW 2350
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Austinmer NSW 2515
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T 0400 494 366

ST GEORGES BASIN

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St Georges Basin NSW 2540
T 02 4443 5555
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T 02 4476 1151
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MUDGEES

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Mudgee NSW 2850
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F 02 6372 9230

GOSFORD

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