Rehabilitation Monitoring Program for Canyon Coal Mine

Prepared for
Whitehaven Coal Mining Pty Ltd

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Abbreviations

ABBREVIATION	DESCRIPTION
AHD	Australian height datum
CES	Countrywide Ecological Community
DA	Development Approval
EL	Exploration licence
EM	Electromagnetic
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999 (Commonwealth)
GCNRC	Geoff Cunningham Natural Resource Consultants Pty Ltd
H	Horizontal
LiDAR	Light detection and ranging
ML	Mining Lease
MoP	Mining Operations Plan
NSW	New South Wales
SMU	Soil Mapping Unit
Spp	Species
TSC Act	Threatened Species Conservation Act 1995 (NSW)
V	Vertical
WCM	Whitehaven Coal Mining Pty Ltd

1 Introduction

1.1 PROJECT SCOPE

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 east-south-east of Boggabri in the Gunnedah coalfields of NSW (Figure 1-1). The mine lies within 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 subject to agricultural cultivation and grazing.

Progressive rehabilitation to restore landscape functionality was undertaken across the site (WCM 2008, 2009). WCM require the development of a rehabilitation monitoring program (monitoring program) for Canyon that will enable the demonstration of progression towards their rehabilitation aims of returning the land to a combination of native pasture and native vegetation and to ensure the post-mining landscape is sustainable in the long-term. The monitoring program will be designed to enable WCM to document functionality of pasture and woodland areas in comparison to adjacent, unmined landscapes and will permit comparison of rehabilitation methods within rehabilitation zones.

1.2 AIMS AND OBJECTIVES

The aim of this monitoring program is to provide a detailed plan that allows quantitative assessment of rehabilitation performance against nearby unmined landscapes. Specific monitoring program objectives include:

- Draw monitoring objectives from existing plans or develop new objectives if required
- Prescribe separate methods for pasture and woodland rehabilitation areas with appropriate control areas
- Allow quantitative tracking of rehabilitation performance including a feedback loop to assist with rehabilitation or monitoring methods improvement
- For woodland areas, assess key aspects of flora (upper, mid and lower strata), fauna and soil
- Apply remote sensing based methods into the integrated program
- Specify survey locations and survey methods
- Provide detailed methods of analysis including statistical methods
- Analyse data from earlier flora and fauna surveys and where possible integrate sites and methods into the monitoring program.

Figure 1-1: Mine site location

2 Site background

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 all located within the Shire of Narrabri. Mining and associated activities has been contained within the Exploration Licences (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 site is located between the tropical and temperate climatic zones and local climate is influenced by the Nandewar and Great Dividing Ranges to the east. The area is characterised by mild to hot summers and cool winters. Rainfall is highest over the period from November to February. The driest months are May and July. Around 72 rain days occur 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 area 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 Draggle 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.

2.5 GEOLOGY AND SOILS

2.5.1 Soil mapping units

Three soil mapping units (SMU) were identified across the mine site footprint (GCNRC 2000). These units are summarised in Table 2-1.

Table 2-1: Soil mapping units

	SMU-1 SHALLOW SOILS	SMU-2 DUPLEX SOILS	SMU-3 CLAY SOILS
Position in landscape	Upper slopes and crests	Mid slopes, depressions or plains	Plains
Typical gradient	0-5 %	2-5 %	0-2 %
Depth	Shallow (60-75 cm)	Deep (260 cm)	Deep (250 cm)
Topsoil (A horizon)	Sandy loam to silt clay loam; 40-50 % gravel pH 6 Moderate dispersion	Sandy loam, clay loam, sand clay loam; up to 60 % gravel pH 5.0-7.5 Slight to moderate dispersion	Light to medium clay; Highly structured pH 6.5 Low dispersibility
B horizon	Sandy clay/light clay; 60-70 % gravel High dispersion percentage	Medium clay; Gravel content increases with depth pH increases with depth slight to moderate dispersion	Medium clay pH increases with depth Variable amounts of gravel
Soil surface	Hardsetting to loose; Surface crusts, surface stones	Hardsetting to loose	Self-mulching

2.5.2 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 2-2).

Table 2-2: Land capability class descriptions

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 IV	Land not capable of regular cultivation but suitable for grazing with occasional cultivation. Soil conservation practices such as pasture improvement, stock control, application of fertilizer and minimal cultivation for the establishment or re-establishment of permanent pasture.
Class V	Land not capable of regular cultivation but suitable for grazing with occasional cultivation. Structural soil conservation works such as absorption banks, diversion banks and contour ripping are required, together with practices outline as in Class IV.
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*. n.d.

2.6 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 2-3). Note that only dominant tree species are listed below; the original flora assessments are referred to for full species lists.

Table 2-3: 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 *Alectryon oleifolius* (Rosewood) *Eucalyptus populnea* ssp. *bimbil* (Bimble Box) *Eucalyptus pilligaensis* (Pilliga Grey Box) *Casuarina cristata* (Belah)
2	Level Plains Country - Treeless or with Scattered Trees – Uncultivated	Trees are spaced from 15 to >100 m apart (where present) *Eucalyptus populnea* ssp. *bimbil* (Bimble Box) *Alectryon oleifolius* (Rosewood) *Eucalyptus melanophloia* (Silver-leaf Ironbark) *Callitris glaucophylla* (White Cypress Pine)
3	Undulating Country - Treeless or with Scattered Trees – Cultivated	Tree cover - absent or spaced from 20 to >100 m apart *Callitris glaucophylla* (White Cypress Pine) *Eucalyptus populnea* ssp. *bimbil* (Bimble Box) *Eucalyptus melanophloia* (Silver-leaf Ironbark) *Eucalyptus pilligaensis* (Pilliga Grey Box) *Schinus areira** (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.

Comm. no.	VEGETATION COMMUNITY	TREE COVER & SPECIES [1]
		Alectryon oleifolius (Rosewood) *Acacia homalophylla* (Yarran)
5	Main Driggle Draggle Creek Channel	Little tree coverage to treeless *Alectryon oleifolius* (Rosewood) *Eucalyptus populnea* ssp. *bimbil* (Bimble Box) *Eucalyptus pilligaensis* (Pilliga Grey Box) *Casuarina cristata* (Belah)
6	Dense White Cypress Pine Regeneration	Trees (regenerating *Callitris glaucophylla* (White Cypress Pine)) are generally spaced between 1-2 m but up to 8 m apart
7	Level Country with Box (*Eucalyptus* spp.) Communities	Tree cover is spaced from <1 to 20 m apart but can be spaced up to 30 m apart *Eucalyptus populnea ssp. bimbil* (Bimble Box) *Eucalyptus pilligaensis* (Pilliga Grey Box) *Eucalyptus albens* (White Box)
8	Undulating Country with Box or Box / Ironbark (*Eucalyptus* spp.) / White Cypress Pine Communities	Tree cover varies but spacing ranges from <1 to 20 – 30 m *Callitris glaucophylla* (White Cypress Pine) *Eucalyptus melanophloia* (Silver-leaf Ironbark) *Eucalyptus albens* (White box) *Eucalyptus crebra* (Narrow leaf Ironbark) *Eucalyptus populnea* ssp. *bimbil* (Bimble Box) *Eucalyptus melliodora* (Yellow Box) *Geijera parviflora* (Wilga) *Eucalyptus pilligaensis* (Pilliga Grey Box) *Allocasuarina luehmannii* (Bull Oak)
9	Brigalow (*Acacia harpophylla*) Community	Isolated patch; tree cover is spaced from 1-5 m apart *Acacia harpophylla* (Brigalow) *Capparis mitchellii* (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 *Callitris glaucophylla* (White Cypress Pine) and scattered shrub species
11[#]	*Eucalyptus albens* (White Box) Community	Woodland *Eucalyptus albens* (White Box) *Eucalyptus populnea ssp. bimbil* (Bimble Box) *Eucalyptus crebra* (Narrow-leaf Ironbark) *Geijera parviflora* (Wilga) *Callitris glaucophylla* (White Cypress Pine)
12[#]	*Eucalyptus crebra* (Narrow-leaf Ironbark) – *Eucalyptus melanophloia* (Silver-leaf Ironbark) – *Eucalyptus pilligaensis (*Pilliga Grey Box) - *Callitris glaucophylla* (White Cypress Pine) Community (sub-set of Community 8)	Woodland *Eucalyptus crebra* (Narrow-leaf Ironbark) *Eucalyptus melanophloia* (Silver-leaf Ironbark) *Eucalyptus pilligaensis* (Pilliga Grey Box) *Callitris glaucophylla* (White Cypress Pine) *Allocasuarina luehmannii* (Bull Oak) *Geijera parviflora* (Wilga)
13[#]	*Eucalyptus populnea* ssp. *bimbil (*Bimble Box) – *Eucalyptus pilligaensis* (Pilliga Grey Box) Community	Woodland *Eucalyptus populnea* ssp. *bimbil* (Bimble Box) *Eucalyptus pilligaensis* (Pilliga Grey Box)

Comm. no.	VEGETATION COMMUNITY	TREE COVER & SPECIES [1]
	(sub-set of Community 8)	*Callitris glaucophylla* (White Cypress Pine) *Alectryon oleifolius* (Rosewood) *Geijera parviflora* (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 2-4.

Table 2-4: 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 Draggle Creek Channel	-
6	Dense White Cypress Pine Regeneration	2.2
7	Level Country with Box (*Eucalyptus* spp.) Communities	-
8	Undulating Country with Box or Box / Ironbark (*Eucalyptus* spp.) / White Cypress Pine Communities	-
9	Brigalow (*Acacia harpophylla*) Community	-
10[#]	Cleared - Cultivated / Uncultivated Pasture Lands (equates to communities 1, 2, 3 and 4)	150.7
11[#]	*Eucalyptus albens* (White Box) Community	-
12[#]	*Eucalyptus crebra* (Narrow-leaf Ironbark) – *Eucalyptus melanophloia* (Silver-leaf Ironbark) – *Eucalyptus pilligaensis* (Pilliga Grey Box) - *Callitris glaucophylla* (White Cypress Pine) Community (sub-set of Community 8)	65.3
13[#]	*Eucalyptus populnea* ssp. *bimbil* (Bimble Box) – *Eucalyptus pilligaensis* (Pilliga Grey Box) Community (sub-set of Community 8)	

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

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

2.7 FAUNA

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

- Open woodland
- Cleared paddocks (with scattered trees)
- Wetlands (man-made dams).

During the same study the following fauna were recorded:

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

The Grey-crowned Babbler (*Pomatostomus temporalis*) and two other species (Turquoise Parrot (*Neophema pulchella*) and Grey Falcon (*Falco hypoleucos*)) listed as being Vulnerable under the TSC Act were recorded either on the site or in the vicinity. The Yellow-bellied Sheathtail 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*)).

2.8 EXISTING MONITORING DATA

Flora and fauna monitoring has been undertaken in accordance with the flora and fauna management plans since 2004. As such, flora and fauna monitoring quadrats were established in plots over the mine site and within rehabilitated areas to assess rehabilitation success throughout the life of the mine. The quadrats were established by Geoff Cunningham Natural Resource Consultants Pty Ltd (GCNRC), and flora and fauna assessments were undertaken annually by GCNRC and Countrywide Ecological Services (CES), respectively.

Plots were established as rehabilitation progressed leading to a maximum of 10 plots being established

in 2010. Each plot consisted of a 100 m by 100 m quadrat that was searched systematically for a number of parameters. Flora parameters included measures for cover species, cover percent and naturally regenerating trees. Fauna survey included specific searches for birds, amphibians, mammals and reptiles with targeted searches for Grey-crowned Babblers and Yellow-bellied Sheathtail Bat. In 2010, 20 roof tiles were deployed to provide specific habitat (primarily reptiles and amphibians) in plots 3 and 10.

The Grey Falcon, Glossy Black Cockatoo (*Calyptorhynchus lathami*), Grey Crowned Babbler and Yellow-bellied Sheathtail Bat were found within the vicinity. A breeding family and four nests of the Grey Crowned Babbler were located within the rehabilitation area and immediate surrounds.

Further description and analysis of the existing monitoring is found in Appendix 1.

3 Rehabilitation history

Coal extraction at the mine employed a conventional haulback system which involves up to ten sequential activities:

- Drainage installation
- Vegetation removal
- Soil stripping (including separate removal of topsoil and subsoil layers by scrapers)
- Overburden drilling and blasting
- Overburden removal from above the uppermost ply of the coal seam
- Upper coal ply excavation
- Interburden excavation and removal
- Lower coal ply excavation
- Final landform shaping and preparation
- Final landform revegetation.

The total rehabilitated area (post mining operations) is approximately 200 ha, including 52 ha of pasture and grasses and 148 ha of native vegetation.

Progressive mine rehabilitation was undertaken over the life of the mine. This method was adopted in order to reduce the period of mined-out pit exposure, and therefore minimise potential air quality, erosion and sedimentation impacts and to reduce the visibility of mining activities (GCNRC & CES 2005). Rehabilitation involved reshaping the landscape, soil redeployment (in association with availability of materials and the desired post-mining land capability and land use), drainage control and revegetation with either native vegetation or pasture.

The rehabilitation procedures adopted vary depending on the nature of the disturbance, the final landform, the nature of the existing vegetation, the rehabilitation objectives and the post-mining land use (WCM 2006).

3.1 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 was 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 topsoiled 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

3.2 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.

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

	SPECIES	UPPER SLOPES/CRESTS (%)	MID-SLOPES (%)	LOWER SLOPES / DRAINAGE FLATS (%)
TREES	Silverleaf Ironbark	15	4	
	Narrowleaf Ironbark	30	15	
	White Cypress Pine	25	22	10
	Wilga	5		
	White Box	10	40	
	Yellow Box			30
	Pilliga Grey Box		10	25
	Bimble Box			25
	Bull Oak			10
SHRUBS	Amulla	3	2	2
	Rosewood			2
	Yarran			5
	Wild Orange			1
	Native Olive	8	2	
	Eastern Cottonbush	4	2	
	Budda	5		

Source: WCM 2006

3.3 TIMELINE OF REHABILITATION ACTIVES 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).

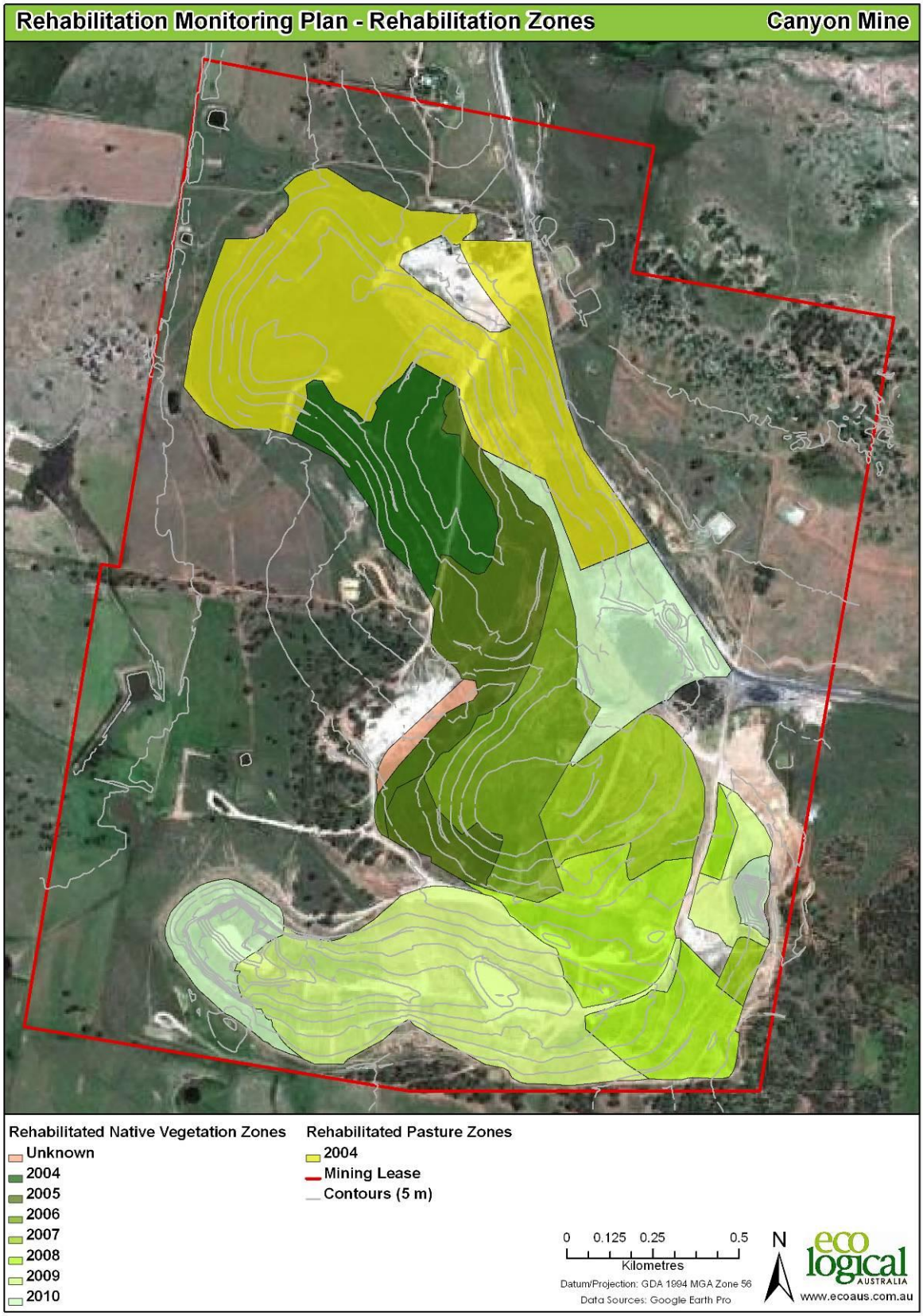

Figure 3-1: Rehabilitation Zones (as at 2011)

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)	Reference (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				
		2010	5				
	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

3.4 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

4 Review of management plans

4.1 RELEVANT MANAGEMENT PLANS

A total of 13 management plans have been identified as providing possible input into an ongoing monitoring strategy (Table 4-1). The plans are currently in place and must be maintained until lease relinquishment.

Table 4-1: Management plans for Canyon Mine

PLAN TITLE	COMMENT
Mining Operations Plan (MLs 1464 & 1471)	Primary site plan Nominal completion date 2008
Mining Operations Plan Amendment	Nominal completion date 2010
Environmental Management Strategy	Guiding Policy document
Environmental Monitoring Program	
Mine Closure Plan	
Air Quality Monitoring Program	Maintained until lease relinquishment
Water Management Plan (including Erosion and Sediment Control Plan)	Maintained until lease relinquishment
Void Management Plan	Maintained until lease relinquishment
Flora and Fauna Management Plan	Maintained until lease relinquishment
Archaeology and Cultural Heritage Management Plan	Maintained until lease relinquishment
Bushfire Management Plan	Maintained until lease relinquishment
Weed Management Strategy	Implemented by WCM following Independent Environmental Audit

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 from 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, 2008b, 2009). These outcomes include:

- To maintain and/or restore biodiversity and ecological integrity of areas affected by mining or agriculture within the mining lease
- To maintain and/or re-establish agricultural land (pasture establishment) of comparable land capability to that of the pre-disturbance environment
- To provide a revegetated post-mining landform which is consistent with surrounding landforms and, with the exception of the final void, provides no obvious evidence of a prior mining land use
- Creation of low maintenance, geotechnically stable final landform
- To minimize visual exposure by ensuring rehabilitation blends with the adjoining landscape
- To minimize erosion and sedimentation

- Rehabilitated areas that will provide habitat for fauna and corridors for fauna movement between rehabilitated areas, regrowth areas and remnant vegetation
- To control vermin, feral animals and noxious weeds
- To ensure successful implementation of the approved biodiversity offset strategy
- To monitor rehabilitation success in terms of physical and biological parameters.

The EMS also identifies a number of other objectives that relate specifically to the key aspects of this monitoring plan (flora, fauna and soils/land capability):

- Native vegetation re-establishment / extension using locally collected seed
- Development and implementation of a flora and fauna monitoring program which provides statistically valid conclusions on rehabilitation success and recommendations for improved outcomes (if required)
- Exclusion of bushfire and control of noxious weeds and feral animals
- Successful development of native vegetation communities within the stock exclusion zone (i.e. rehabilitated areas and remnants) which emulate the structure and floristics of undisturbed areas (as demonstrated by monitoring)
- Successful establishment of more extensive native vegetation communities that currently exist in the area of the mine
- Utilization of offset strategy areas by native fauna (as demonstrated by monitoring)
- Rehabilitation / offset strategy refinement on the basis of monitoring outcomes, site experience and improved technologies
- Re-establishment of approximately 16 ha Class II land capability land (including an area classified as Class III prior to mining) using soils reclaimed from existing Class II areas
- Elsewhere, landform establishment, soil application and vegetation establishment consistent with pre-disturbance land capabilities.

WCM has envisaged that the final land use will encompass (MOP 2006):

- Approximately 52 ha of the area disturbed by mining within the “Whitehaven” and “Merton” properties will function as grazing land, with irregular cultivation of the shallower slopes for fodder crop production. The areas of grazing land use will have patches of woodland primarily attributed a nature conservation land use
- Disturbed areas within the “Womboola” property will be rehabilitated to a native woodland community suitable for nature conservation/low intensity grazing.

Long term rehabilitation objectives include:

- Rehabilitate the landscape to a low maintenance and stable condition suitable for agricultural land uses and/or nature conservation
- Re-create the post-mining landform to blend with the surrounding landscapes (with the exception of the final void) so that the previous mining land use is not evident.
- Revegetate a minimum of 2 ha for each 1 ha of native bushland disturbed and subsequently enhancing the biodiversity and ecological integrity of areas impacted by the mine operations, or by previous agricultural practices. Revegetated areas are to comprise a species composition that replicates those vegetation communities that currently exist or that existed prior to agricultural activities. Rehabilitated lands will provide fauna habitat and extend wildlife corridors between remnant and revegetated areas

Areas not impacted by mining:

- Eradicate grazing pressure from areas of relatively undisturbed native vegetation; resultantly, enhance the quality, diversity and extent of those communities
- To continue the conservative stocking of open grassland communities with cattle to reduce the amount of fire hazardous materials
- To continue the grain production and pasture rotation in previously cultivated areas.

4.2 BIODIVERSITY OFFSET AREAS

Over the life of the mine, a total of approximately 80 ha native bushland was cleared, with the remaining areas comprising agricultural areas (MOP 2006). As per Conditions 28 and 29 of the Developmental Consent (DA 8-1-2005), the 80 ha of cleared native vegetation is to be compensated via offsets (GCNRC & CES 2006). Accordingly, compensation was to be primarily undertaken on the "Womboola" property and was to include:

- Grazing exclusion (134 ha)
- 30 ha of existing woodland where natural regeneration is already occurring since the purchase of the "Womboola" property
- 48 ha of grassland not programmed for enrichment planning
- Enrichment plantings (56 ha)
- Enrichment plantings on open grassland on "Womboola" property to accelerate the extension of native bushland communities and re-establishment and/or extension of vegetation corridors between existing patches of remnant vegetation, areas to be rehabilitated to native vegetation and Vickery State Forest (WCM 2004).

The establishment of a total of 148 ha native bushland on the rehabilitated post-mining landform on "Whitehaven", "Merton" and "Womboola" over the life of the Whitehaven Coal Mine would also assist to compensate for the 80 ha native bushland cleared (WCM 2004).

Following further consideration to appropriate offsets, WCM established its Regional Biobank on the western fall of the Kelvin Range, east of the Canyon site, and obtained in principal support from the DoP to transfer the Canyon offset requirements to this site. The Biobank is currently awaiting registration. As a consequence the original offset proposal identified above is no longer applicable.

5 Monitoring procedures

5.1 MONITORING AIMS AND OBJECTIVES

Following detailed review of the site including the previous land use, rehabilitation landscape and rehabilitation objectives, this monitoring program aims to document landscape capability in the mine rehabilitation area in comparison to the nearby control areas to demonstrate continuing land capability. A summary of the rehabilitation aims and objectives stated in the relevant management plans is listed in Table 5-1.

Table 5-1: Summary of stated monitoring objectives

STATED OBJECTIVE (EMS, MOP, MCP)	SECTION ADDRESSED
Maintain and/or restore biodiversity and ecological integrity of areas affected by mining or agriculture within the mining lease	Chapter 5, general aim
To maintain and/or re-establish agricultural land (pasture establishment) of comparable land capability to that of the pre-disturbance environment	Sections, 5.4 and 5.5, key outcome of pasture monitoring
To provide a revegetated post-mining landform which is consistent with surrounding landforms and, with the exception of the final void, provides no obvious evidence of a prior mining land use	Section 6.3, secondary outcome of LiDAR topographic assessment
Creation of low maintenance, geotechnically stable final landform	Section 5.4, secondary outcome of LiDAR topographic assessment
To minimize visual exposure by ensuring rehabilitation blends with the adjoining landscape	Section 5.4, secondary outcome of LiDAR topographic assessment
To minimize erosion and sedimentation	Chapter 5, secondary outcome of cover monitoring in all environments
Rehabilitated areas that will provide habitat for fauna and corridors for fauna movement between rehabilitated areas, regrowth areas and remnant vegetation	Section 5.6, primary objective of Woodland monitoring
To control vermin, feral animals and noxious weeds	Section 5.5, 5.6, 5.7 secondary outcome of Pasture monitoring and Vegetation and Fauna monitoring
To ensure successful implementation of the approved biodiversity offset strategy	Offset established in the WCM Regional Biobank Site
To monitor rehabilitation success in terms of physical and biological parameters	Chapter 5, general aim
Native vegetation re-establishment / extension using locally collected seed	Chapter 5.6, primary outcome of Woodland monitoring
Development and implementation of a Flora and Fauna monitoring program which provides statistically valid conclusions on rehabilitation success and recommendations for improved outcomes (if required)	Chapter 5, primary objective of this monitoring program
Exclusion of bushfire and control of noxious weeds and feral animals	Review annual monitoring results

STATED OBJECTIVE (EMS, MOP, MCP)	SECTION ADDRESSED
Successful development of native vegetation communities within the stock exclusion zone (i.e. rehabilitated areas and remnants) which emulate the structure and floristics of undisturbed areas (as demonstrated by monitoring)	Section 5.6, primary outcome of Woodland monitoring
Successful establishment of more extensive native vegetation communities than currently exist in the area of the mine	Section 5.6, primary outcome of Woodland monitoring
Utilization of rehabilitated areas by native fauna (as demonstrated by monitoring)	Section 5.6, primary outcome of Woodland monitoring
Rehabilitation / offset strategy refinement on the basis of monitoring outcomes, site experience and improved technologies	Chapter 5, primary objective of this monitoring program
Re-establishment of approximately 16 ha Class II land capability land (including an area classified as Class III prior to mining) using soils reclaimed from existing Class II areas	Section 5.5, primary outcome of Pasture monitoring
Elsewhere, landform establishment, soil application and vegetation establishment consistent with pre-disturbance land capabilities.	Chapter 5, primary objective of this monitoring program

In many cases the objectives provided in the management plans provide general guidelines. A more specific set of monitoring objectives has been developed with the purpose of providing detailed monitoring results that can be analysed to provide quantitative information on rehabilitation outcomes to document land capability and inform WCM on the most effective rehabilitation procedures. The monitoring objective can be divided into site scale, pasture area and woodland areas objectives, with specific survey methods designed for each main area.

Site scale objectives include to document:

- Landscape stability through comparison of temporal DEM data
- Vegetative cover including bare soil assessment
- Soil conductivity (relates to primarily to moisture and salt).

Pasture areas objectives include to document:

- Pasture productivity (biomass and composition)
- Topsoil character.

Woodland area objectives include to document:

- Woodland vegetation metrics
- Woodland habitat complexity and functionality
- Woodland bird species and community composition
- Koala usage
- Reptile use of artificial habitat
- Mammal species diversity.

5.2 SURVEY LAYOUT

Investigation of the rehabilitation program and history shows that rehabilitation has taken place to create areas of pasture and woodland (Figure 3-1). Since rehabilitation was carried out progressively, rehabilitation zones were established at different times. The combination of rehabilitation landscape (pasture or woodland) and rehabilitation times creates eight unique rehabilitation zones (Figure 3-1;

Table 5-2).

Table 5-2: Rehabilitation Monitoring Zones

ZONE NUMBER	LANDSCAPE TYPE	REHABILITATION DATE	AREA (HA)
1(a)	Pasture	2004	46
2(a)	Woodland	2004	15
2(b)	Woodland	2005	18
2(c)	Woodland	2006	15
2(d)	Woodland	2007	12
2(e)	Woodland	2008	20
2(f)	Woodland	2009	32
2(g)	Woodland	2010	21

5.3 MONITORING APPROACH

Given the size of the target area and the different land uses and domains, a multi-scale, multi-data source monitoring approach has been developed (Table 5-2). It is proposed to use remote sensing data (LiDAR, multi-spectral imaging and EM38/31) to monitor across the entire target area including control areas. The remotely sensed imagery will provide data that provide for quantitative comparison of key land surface condition parameters in agricultural and native vegetation environments. Repeat capture and analysis of the multi-spectral imagery will also highlight areas of changes in land cover beyond those found in control areas. Targeted field work will be implemented to examine the causes of any change highlighted.

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

Table 5-3: Multi-scale monitoring program

DATA SOURCE	TYPE	SCALE	PURPOSE
Remote sensing	LiDAR	Entire site	Topographic form and change Woodland parameters
	Multi-spectral imaging	Entire site	Agricultural pasture cover/biomass Woodland cover/biomass Erosion monitoring Direct field survey
	EM38/31	Pasture zone	Soil moisture and nutrient zones
Agricultural survey	Pasture survey	Pasture zone	Pasture biomass and composition
	Soil Survey	Pasture zone	Soil nutrient status
Woodland survey	Vegetation survey	Within woodland zones	Woodland health and function
	Fauna survey	Within woodland zones	Woodland health and function
	Soil survey	Within woodland zones	Soil condition

5.4 REMOTE SENSING

Whole of site monitoring will be conducted using LiDAR, multi-spectral imagery and EM38 data sources.

The multi-spectral imagery should be captured annually in spring/summer (Sept-Dec) as anniversary capture helps to minimize sun angle and seasonal ground cover changes between captures. The imagery should then be processed into the appropriate vegetation index and assessed visually and statistically.

Table 5-4: Remote Sensing Monitoring Program

DATA SOURCE	PARAMETERS	ANALYSIS	PURPOSE	SAMPLING FREQUENCY
LiDAR	High resolution topography	Comparative statistics Visual assessment	Document baseline landscape morphology Quantify topographic change	Baseline Repeat sampling every 3 years
	Canopy height model	Comparative statistics Visual assessment	Document baseline woodland height Quantify changes in woodland canopy height	
	Projected foliar cover	Comparative statistics Visual assessment	Document baseline woodland foliar cover Quantify changes in woodland foliar cover	
High resolution imagery	NDVI – relative plant biomass and cover	Comparative statistics Visual assessment	Document baseline variability in vegetative cover, both woodland and pasture Direct targeted field survey	Baseline Every year – early spring
EM 38/31 survey	Soil electrical conductivity	Comparative statistics Visual assessment	Document baseline variability in surface soil conductivity, relates to water, ions and texture Document changes in soil surface conductivity	Baseline Every 3-5 years *Best results achieved after saturating rainfall

5.4.1 LiDAR processing and analysis

LiDAR data will be captured across the entire target area and control areas. These data will be processed into a land surface digital elevation model (DEM) across the entire landscape and a canopy height model (CHM) and projected foliar cover (PFC) over the woodland areas.

The initial data capture will be stratified into the different rehabilitation areas and woodland parameters compared using descriptive statistics.

Subsequent LiDAR captures will be processed in to the same products (DEM, CHM and PFC) and each dataset will be subtracted from those produced from earlier captures creating a series of change images (DEM change, CHM change and PFC change). Overall DEM change will be assessed to document landscape stability. Woodland products will be stratified into rehabilitation zones and compared statistically with each other.

In addition areas of significant change in LiDAR metrics will be highlighted and a targeted reconnaissance survey directed to investigate the source of the change and implement any planning, management action or change in management procedures required (Table 5-5).

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

5.4.2 Multi-spectral image processing and analysis

The high-resolution multi-spectral imagery (World View, Geoeye, Quickbird or similar) will be processed into a normalised difference vegetation index (NDVI). The initial data capture will be stratified into the rehabilitation zones and compared using ANOVA to determine if data in any of the zones is significantly different from each other.

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

In addition areas of significant change in NDVI will be highlighted and a targeted reconnaissance survey directed to investigate the source of the change and implement any planning, management action or change in management procedures required (Table 5-5).

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

5.4.3 EM38 and 31 survey

EM survey is widely used in the agricultural industry to assist with soil mapping. EM38 provides information of the variability in surface soil conductivity in top 0.5-1.0 m of soil while EM31 provides information in the deep subsoil 2-8 m. The conductivity readings correspond strongly to soil moisture, soil ions (salt) and soil texture variations.

The EM38/31 data will be captured over the pasture areas only and processed into a soil conductivity map. The data will be assessed to delineate regions of like conductivity and to direct targeted field assessment of soil characteristics.

Subsequent EM38/31 will be processed into conductivity maps and each dataset will be subtracted from

those produced from earlier captures creating a series of change images. Areas of significant change in soil conductivity will be investigated using field assessment.

In addition areas of significant change in EM38 or EM31 will be highlighted and a targeted reconnaissance survey directed to investigate the source of the change and implement any planning, management action or change in management procedures required (Table 5-5).

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

5.4.4 Directed field assessment

Directed field assessment will arise from the specific atypical changes observed in the remote sensing (Section 5.4). Abnormal change will be assessed against the background change found across the site. Generally, atypical change (either loss or gain in value) will be signified by a change in the remote sensing derived metric that is greater than two times the standard deviation away from the mean change.

The directed field assessment methodology will require a site specific rapid assessment based on the impacting factor, on-ground effect, management plan and action (Table 5-5).

Table 5-5: Rapid field checking protocol

REMOTE SENSING INDICATOR	METHOD
CHM	Meandering traverse of the abnormal change area and nearby similar zones that show normal change. Document source of change. Implement appropriate response for change factor (e.g. weeds, erosion, strong growth) as per the relevant management plan
PFC	
NDVI	
EM survey	On-ground inspection that may include soil coring to investigate source of anomaly

5.5 PASTURE AREA SURVEYS

This monitoring procedure will assess parameters that relate to pasture productivity and soil nutrient status. Eight survey site locations will be selected from the pasture rehabilitation zone and eight each from the two adjacent control areas using a targeted design (Figure 5-1). Survey sites were located to be:

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

Where possible, sites already monitored by GCNRC and CES will be included into the monitoring program. However, coordinates for site locations appear to be in another datum or inaccurate as they do not align with site maps. This will be confirmed during survey site establishment.

At each site a 1 m by 1 m quadrat will be placed and assessed for pasture biomass (cover % estimate and biomass) and compositions including weeds. Following pasture survey a soil sample to 150 mm will be taken from the centre of each quadrat location. The soil sample will be bagged, stored appropriately for laboratory analysis of pH, EC, N, P and organic matter. Incidental observations of weed species will be made when moving between quadrats. Significant weed outbreaks will be noted,

recorded with a GPS and reported to WCM (Table 5-6).

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

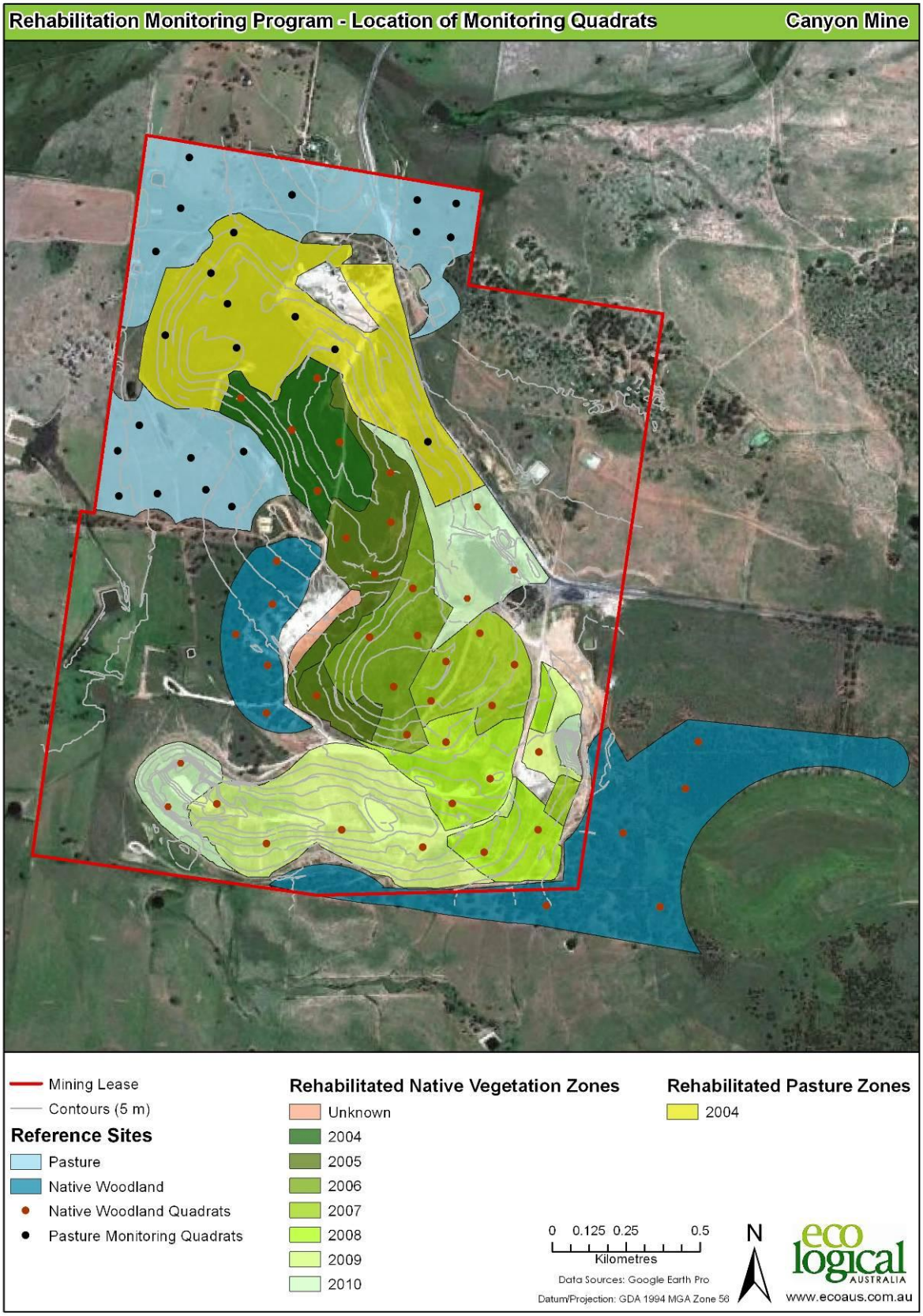

Figure 5-1: Monitoring site locations

Table 5-6: Pasture areas – monitoring program

DATA SOURCE	PARAMETERS	ANALYSIS	PURPOSE	SAMPLING FREQUENCY
Pasture biomass cuts	Pasture biomass	Comparative statistics	Give baseline variability in pasture biomass BACI comparisons	Baseline Every year – early spring
Pasture composition	Pasture species	Descriptive statistics Species list	Establish baseline pasture composition BACI comparisons	Baseline Every year – early spring
Weed survey	Weed species and cover	Descriptive statistics Species list	Establish baseline weed species and % cover BACI comparisons	Baseline Every year – early spring
Soil character (top 15 cm)	pH, EC, Organic matter, N, P	Comparative statistics	Give baseline variability in key soil parameters BACI comparisons	Baseline Every 3 years
Soil Pit	Soil profile	Qualitative assessment	Provide information on soil profile re-establishment and function	Baseline Every 3 years

5.6 WOODLAND SURVEY

Five survey site locations will be selected from each woodland rehabilitation zone and five each from the two adjacent control areas using a targeted design (Figure 5-1). Survey sites were located to be:

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

Where possible, sites already monitored by GCNRC and CES will be included into the monitoring program. However, coordinates for site locations appear to be in another datum or inaccurate as they do not align with site maps. This will be confirmed during survey site establishment. No monitoring of enrichment zones (which were part of the original offset strategy) has been included in this monitoring plan.

Baseline surveys should be conducted in spring 2011 and repeated annually in spring during the monitoring period.

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

5.6.1 Vegetation

The vegetation monitoring will focus on the woodland rehabilitation zones and adjacent control areas. Surveys will focus on the condition and function of the woodland vegetation. The woodland vegetation habitat monitoring sites are identified in Figure 5-1.

Vegetation condition monitoring will include a suite of parameters that relate to woodland vegetation health and habitat value (Table 5-7). Key parameters will be collected for the upper, mid and ground strata at both impact sites and control sites to permit comparison.

Table 5-7: Ecological attributes to be measured within condition plots

THEME	ATTRIBUTE	DESCRIPTION
Native overstorey (canopy)	Cover	Measured as Projected Crown Cover (PCC) along a 100m 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 100m transect
	Richness	List of native midstorey species
Native ground layer	Cover	Measured as Projected Foliage Cover (PFC) of native groundcover plants at each of 100 points along a 100 m transect
	Richness	List of native groundcover species

THEME	ATTRIBUTE	DESCRIPTION
Exotic species	Cover	Measured as Projected Crown Cover (PCC) along a 100m transect for exotic canopy and exotic midstorey species. Measured as Projected Foliage Cover (PFC) at each of 100 points along a 100 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 100 points along a 100 m transect, then calculated as % litter cover (OL)
	Cryptograms	Recorded as a 'hit' or 'miss' at each of 100 points along a 100 m transect, then calculated as cryptogram (Cr)
	Bare ground	Recorded as a 'hit' or 'miss' at each of 100 points along a 100 m transect, then calculated as bare ground (BG)
	Rock	Recorded as a 'hit' or 'miss' at each of 100 points along a 100m transect, then calculated as rock (Ro)

The base plot is to be 100 m x 20 m. It incorporates a 20 m x 20 m nested subplot, a 100 m centre transect, a photo point, and an alignment point.

Figure 5-2 shows the plot layout and Table 5.8 summarises the sampling units. The standard plot layout is to be used in both modules.

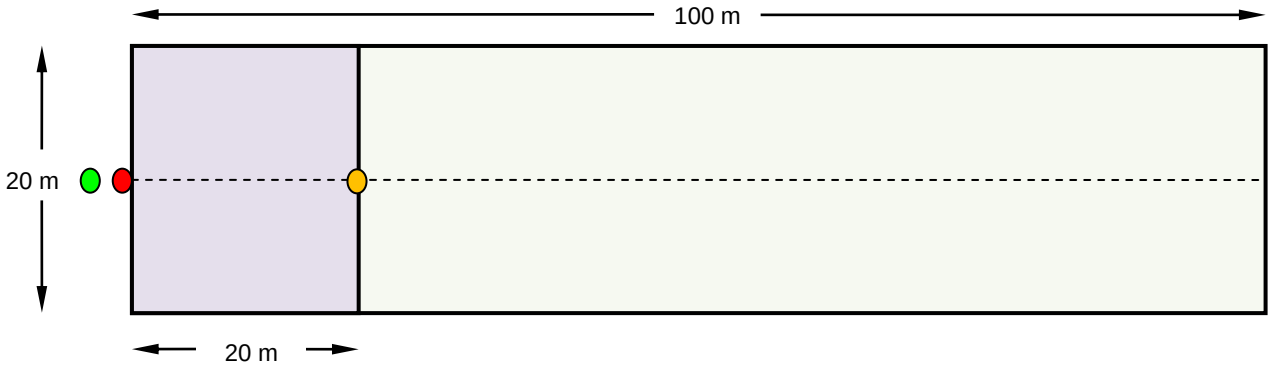

Figure 5-2: Plot design and layout

Table 5-8: 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 photo point along the transect
Baseplot (100 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 (100 m)	Native canopy cover Native midstorey cover Native groundcover Exotic cover Organic litter Cryptogram Rock Bare ground

5.6.2 Terrestrial fauna and habitat monitoring

Terrestrial fauna and habitat monitoring surveys will focus on woodland zones.

The terrestrial fauna surveys will target:

- Woodland birds as they are relatively mobile and quick to use available habitat
- Koalas (*Phascolarctos cinereus*), Turquoise Parrots (*Neophema pulchella*) and grey crowned babblers as they are listed under either the TSC Act and/or EPBC Act or are locally important
- Mammals using non-invasive hair tubes
- Reptiles, as specific habitat was established to attract these species.

The terrestrial fauna and habitat monitoring within woodland areas is to occur at the sites identified in Figure 5-1 although opportunistic observations in other areas will also be recorded.

Terrestrial fauna monitoring will focus 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) will also be assessed.

Targeted faunal groups for monitoring and methodologies for survey will be as per Table 5-9 below.

Table 5-9: Data to be collected for terrestrial fauna

PARAMETER	ANALYSIS	PURPOSE	SURVEY METHOD	SAMPLING FREQUENCY
Turquoise Parrot	Presence/absence Habitat usage	Establish presence and habitat usage	A standardised search with a stopping rule as per Watson (2004) will be used to survey for woodland birds at dawn and dusk. At each site, from a fixed point position, two randomly selected transects should be established. Birds should be recorded while walking in a meandering path along each transect, 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.	Baseline Annual in autumn
Grey-crowned Babblers	Presence/absence Habitat usage	Establish presence and habitat usage		Baseline Annual in spring
Woodland birds	Presence/absence Habitat usage	Establish presence and habitat usage		Baseline Bi-annual in spring & winter
Koalas	Presence/absence Habitat usage	Establish presence and habitat usage	Koala searches should be conducted at each mammal sites and include observations along a transect line, identifying direct sightings, scratching and scats.	Baseline Annual in spring
Hair tubes	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).	Baseline Annual in spring
Reptile habitat	Species usage of habitat	Identify species diversity and usage	Lift artificial habitat (tiles) and record species.	Annual in spring

5.7 STATISTICAL METHODS

The survey design has been established to allow standard ANOVA for all univariate parameters and multi-dimensional scaling (MDS) for multivariate parameters. These statistical tests are appropriate for assessing variation through time and to test the hypotheses required to achieve rehabilitation goals.

ANOVA will be used to test for changes over time and to test for differences between control and rehabilitation sites. For analyses of native vegetation communities, the variables to be analysed will include species richness and % cover, with separate analyses for understorey, overstorey and total community variables. Analyses for changes in the faunal community will be made using species richness and count data.

Multivariate data such as vegetation, woodland bird, reptile, and mammal community assemblages will be analysed using MDS. MDS plots will be used to assess changes in each community relative to the reference sites. Differences through time will be assessed using analyses of similarities (ANOSIM). In the early stages of rehabilitation, MDS plots are expected to show significant differences between rehabilitation communities of fauna and flora and their reference communities. However as time progresses the communities should increase in similarity.

5.8 MONITORING TRIGGERS AND ACTIONS

A two-tiered system of triggers for management is proposed in response to changes identified via remote sensing (Figure 5-3).

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 5-10).

The second tier of response is triggered if changes are confirmed or discovered on-ground (Table 5-11). These triggers instigate the development of site specific management responses and remedial actions

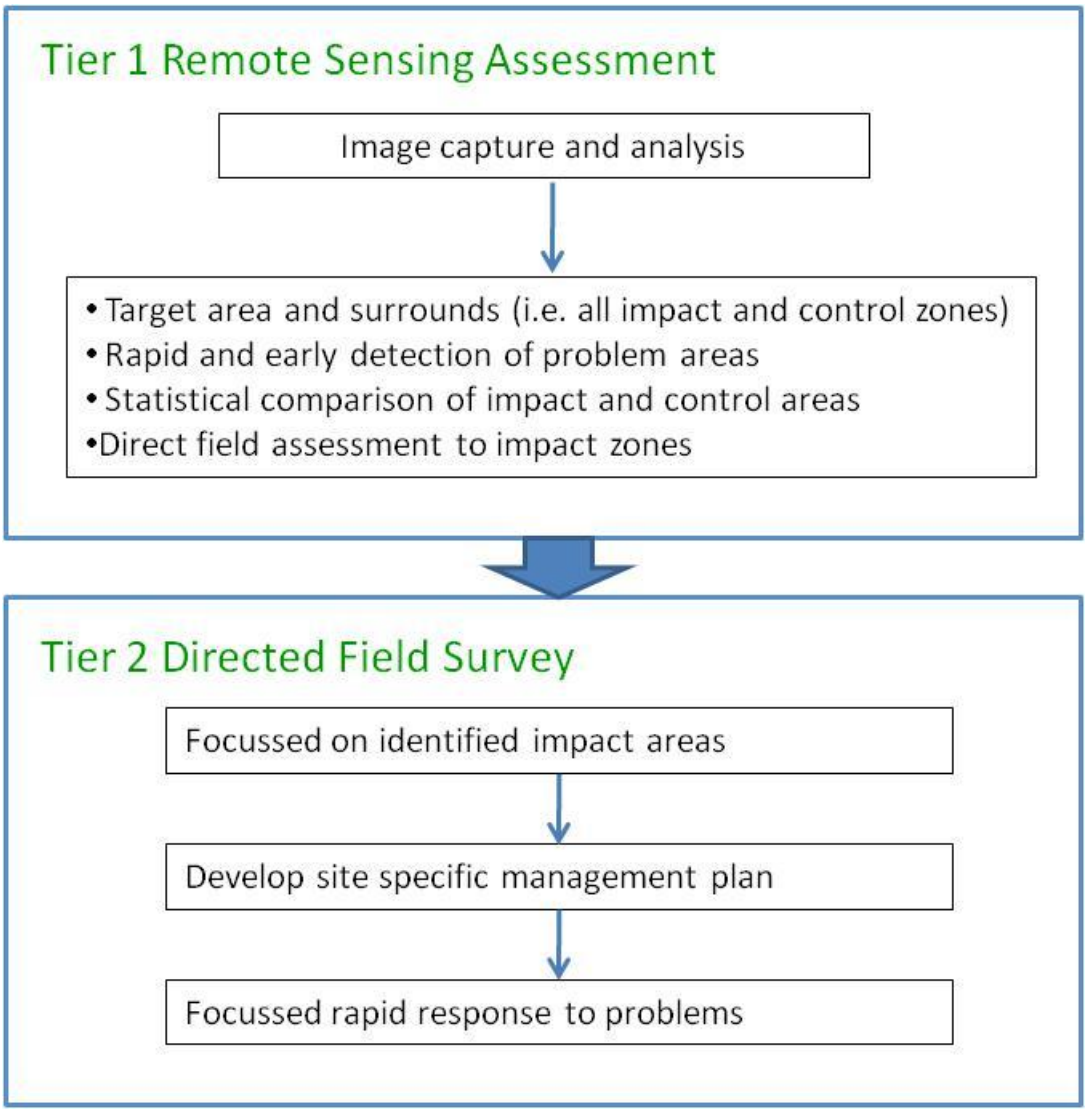

Figure 5-3: Two-tiered remote sensing monitoring and management approach

Table 5-10: 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: 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: 1. Identify region of change and tag it as non-project specific impact; 2. Undertake directed field investigation via rapid field checking protocol (Table 5-11).

Table 5-11: 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 (*Sclerolaena birchii*). 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

5.9 FIELD SURVEY MONITORING TRIGGERS

The agricultural monitoring program has been designed to provide 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 soil condition or other management issues noted by the field team during sampling.

Table 5-12: Agricultural area monitoring triggers for management

TRIGGER	MANAGEMENT
Statistically significant change detected in either: • 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 has been designed to provide 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 5-13: Woodland area monitoring triggers for management

TRIGGER	MANAGEMENT
Statistically significant decline detected in either: • 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

5.10 REPORTING AND REVIEW

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

Review of the entire program should be undertaken after the completion of the first round of sampling and analysis to identify particular issues and refine the monitoring program design.

Regular program review should be conducted every 3 years to examine the trends in the data, investigation sampling effort in terms or redundancy or shortfall and to incorporate new monitoring technologies or techniques if appropriate.

The 3 year review should include a stakeholder workshop with key government staff to ensure continued acceptance of the methodology and results.

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Appendix A: Analysis of existing monitoring data

1 Introduction

Flora and fauna monitoring over the Canyon rehabilitation areas has been undertaken in accordance with the Flora and Fauna Management Plan since 2004 (GCNRC 2005a; WCM 2007). Monitoring quadrats were established within land rehabilitated to pasture and native vegetation and within respective reference sites outside of the mine disturbance area to assess the success of rehabilitation throughout the life of the mine. The quadrats were established by Geoff Cunningham Natural Resource Consultants Pty Ltd (GCNRC) and flora and fauna assessments were undertaken by GCNRC and Countrywide Ecological Services (CES) respectively.

It was projected in the flora and fauna management plans that following the establishment of quadrats on revegetated lands, flora and fauna monitoring would be undertaken yearly for 5 years and biennially thereafter until the monitoring program was complete. Monitoring is projected to cease if monitoring data obtained from the treatment sites indicate that revegetated areas are sufficiently established and display a similarity to the species composition and native species cover of the respective reference sites, as per the completion criteria stated in the Mine Closure Plan (WCM 2009).

The purpose of this report is to describe and analyse the flora and fauna monitoring data collected to date. Where possible, statistical methods were implemented to provide quantitative comparisons of the data.

Available flora monitoring data included the years 2005 through to 2010 (GCNRC 2005b, 2006, 2007, 2008, 2009 and 2010). Available fauna monitoring included the years 2007 through to 2010 (CES 2007, 2009a, 2009b and 2010).

2 Monitoring methods and results

2.1 FLORA METHODS

GCNRC commenced flora rehabilitation monitoring at the Canyon Coal Mine on 18 April 2004 and conducted yearly surveys thereafter until 2010.

As per the Flora and Fauna Management Plan, one 100 m x 100 m permanent quadrat and an associated photopoint was established at a reference site for each vegetation community to be impacted by mining operations and an equivalent quadrat was to be established in every 10 ha of

rehabilitated lands. Quadrat surveys and photograph capture were projected to be undertaken at annual intervals for five years, and thereafter every two years until the termination of the monitoring program.

Parameters that were measured in each quadrat included:

- Groundcover species composition and cover using two 100 m step point transects
- Cover abundance of groundcover species using the modified Braun-Blanquet scale
- A count of naturally occurring tree and shrubs to quantify senescent plants and the occurrence of regeneration (planted shrub/tree species were not included in the count).

2.2 FAUNA METHODS

CES commenced fauna monitoring in 2004. Monitoring was projected to be undertaken annually in the spring/early summer period and was to utilise the pre-established flora treatment and control quadrats. Each quadrat was traversed on foot along its length ten times at approximately 10 m intervals to record bird, reptile and mammals species present. Species that occurred within the vicinity of quadrats during the survey period were also recorded.

Additional monitoring included sampling for amphibians, mammals, birds (including the threatened Yellow-bellied Sheathtail Bat (*Saccolaimus flaviventris*) and the Grey-crowned Babbler (*Pomatostomus temporalis*)) in areas outside of the quadrats to assess the impacts of grazing exclusion within the mine site.

Sampling methods identified below were used for the various fauna groupings (WCM 2007):

- **Amphibians**: 10 minute searches and call analysis at selected water bodies within the mining lease
- **Birds**: A count of the number of species over a ten minute period at each quadrat. Grey Crown Babbler surveys were also undertaken and included mapping the nests, and monitoring breeding success, family size, composition and activities.
- **Mammals and nocturnal birds**: Spotlighting was undertaken on fixed 1.0km length drive transects, taken over 2 nights in each habitat type. Call back broadcasts were also conducted. No small mammals were surveyed.
- **Microbats**: Ultrasonic bat call recordings overnight within each habitat type (woodland and pasture).
- **Reptiles**: systematic searches at each of the established 100 x 100 m quadrats, within each habitat type.

2.3 FLORA RESULTS

2.3.1 Quadrats

Ten permanent quadrats and associated photopoints were established over the course of the monitoring period (Figure 2-1; Table 2-1). Eight of which were established within rehabilitated lands and two in native vegetation not impacted by mining operations (reference sites). Eight were positioned within rehabilitated lands located on the original mine footprint and two within the Canyon extension. The location of quadrats was derived from the coordinates provided in the flora monitoring reports (GCNRC). These locations do not align with an existing map, likely due to a datum and/or accuracy error.

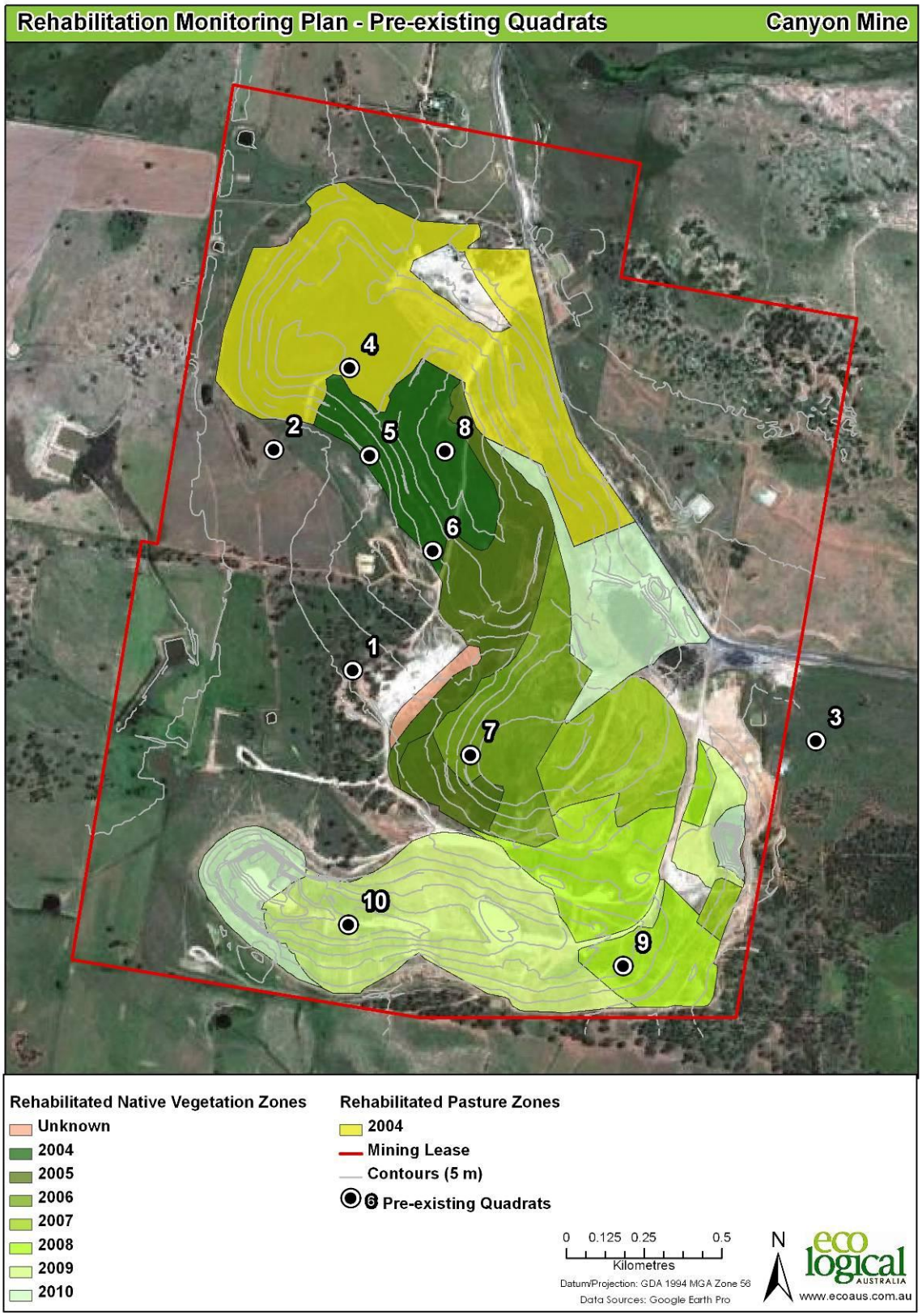

Figure 2-1: Monitoring Quadrats established by GCNRC

Table 2-1: Ecological attributes to be measured within condition plots

QUADRAT	DATE ESTABLISHED	VEGETATION COMMUNITY / SITE DESCRIPTION	LOCATION
1	18th April 2004	Undulating Country with Box or Box/ Ironbark/ White Cypress Pine Communities	Native vegetation (Control Plot 1)
2	18th April 2004	Rehabilitated land – respread with logs	Western section of mine
3	18th April 2004	Undulating Country – Treeless or with Scattered Trees - Uncultivated	Native vegetation (Control Plot 3)
4	6th February 2005	Rehabilitated land – sown to Lucerne Pasture in 2003	Lucrene (*Medicago sativa*) pasture on a crest site.
5	8th February 2005	Rehabilitated land – sown to wheat in 2005 and respread with logs	Upper slope/ crest area sown to wheat
6	16th May 2006	Rehabilitated land – respread with logs and planted out with tree species shortly before May 2006 monitoring	Crest of rehabilitated area along the eastern section of the rehabilitation area
7	20th May 2007	Rehabilitated land – respread with logs	Crest of the rehabilitated area on the southern boundary. Positioned towards the west of the rehabilitation area.
8	20th May 2007	Rehabilitated land – respread with logs	Crest of the rehabilitated area on the southern boundary. Positioned towards the west of the rehabilitation area.
9	March 2009	Rehabilitated land	Sloping land towards the void
10	30th March 2010	Rehabilitated land	Northern batter of the western void.

Due to the staged establishment of quadrats in association with mine decommissioning across the monitoring period, the number of sample years at each quadrat varied (Table 2-2).

Table 2-2: Number of surveys conducted at each quadrat

Quadrat	Tree and Shrub Counts	Step-point Transect Survey		Braun-Blanquet Cover Abundance	
		Number of Surveys	Dates Surveyed	Number of Surveys	Dates Surveyed
1	April 2004	6	Feb 2005, May 2006, May 2007, May 2008, May 2009, March 2010	6	Feb 2005, May 2006, May 2007, May 2008, May 2009, March 2010
2	April 2004	6	Feb 2005, May 2006, May 2007, May 2008, May 2009, March 2010	6	Feb 2005, May 2006, May 2007, May 2008, May 2009, March 2010
3	April 2004	6	Feb 2005, May 2006, May 2007, May 2008, May 2009, March 2010	6	Feb 2005, May 2006, May 2007, May 2008, May 2009, March 2010
4	February 2005	6	Feb 2005, May 2006, May 2007, May 2008, May 2009, March 2010	6	Feb 2005, May 2006, May 2007, May 2008, May 2009, March 2010
5	February 2005	6	Feb 2005, May 2006, May 2007, May 2008, May 2009, March 2010	6	Feb 2005, May 2006, May 2007, May 2008, May 2009, March 2010
6	May 2006	5	May 2006, May 2007, May 2008, May 2009, March 2010	5	May 2006, May 2007, May 2008, May 2009, March 2010
7	May 2007	3	May 2008, May 2009, March 2010	3	May 2008, May 2009, March 2010
8	May 2007	3	May 2008, May 2009, March 2010	3	May 2008, May 2009, March 2010
9	-	2	May 2009, March 2010	2	May 2009, March 2010
10	-	1	March 2010	1	March 2010

2.3.2 Tree and shrub counts

A count of naturally occurring trees and shrubs was undertaken at Quadrats 1 to 8 when the quadrats were first established. All quadrats had zero trees and shrubs, with the exception of the reference sites, Quadrats 1 and 3.

2.3.3 Step-point transect

Two step-point transects were undertaken in each quadrat when they were established, and yearly thereafter until 2010. Quadrats 7 and 8 were not surveyed in the year of establishment due to the recent timing of the rehabilitation works.

In each transect, cover was recorded for individual groundcover species, leaf litter, bare ground, total non-living, and perennial and annual living plants. Results for both transects were collated and mean cover scores for the quadrat were calculated. Species present within the quadrat that were not 'hit' in the step-point transect were noted as additional species, (and were given a Braun Blanquet Cover Abundance score). In the yearly monitoring reports, change detection (in absolute terms) from the survey conducted the previous year was recorded for total living vegetation cover, total perennial and annual plant cover, litter cover and bare surface.

2.3.4 Braun Blanquet cover abundance assessment

The Braun Blanquet cover abundance assessment was undertaken yearly. In the yearly monitoring reports, no comparisons were made between previous survey years.

2.4 FAUNA RESULTS

Monitoring was undertaken at 10 quadrats in November 2007, February 2009, October 2009 and November 2010. A quadrat established within the final void (Quadrat 11) was also monitored in October 2009 and November 2010. (Note: No coordinates were provided for this quadrat and therefore it was not located on the map). In 2009, plots were re-established in areas where star pickets had been accidentally removed during rehabilitation works. Survey methods were generally uniform over the sampling years, with the exception of call playback broadcasts, which were only undertaken near quadrats 1, 2 and 5 in November 2007. Additionally, 20 roof tiles were deployed in Quadrats 3 and 10 in autumn 2010 in an attempt to increase the availability of refuge for ground dwelling vertebrates (Table 2-3). The number of birds, mammals, reptiles, amphibians and microbats recorded within each quadrat and within the vicinity of the mine per survey year is provided in Table 2-4 and Table 2-5.

Table 2-3: Survey methods used across sampling years

Year of Survey	Survey Method						
	Quadrats traversed	**Nocturnal amphibian surveys of dams and suitable habitat across the mining lease**	**Daylight amphibian/reptile surveys of dams and suitable habitat across the mining lease**	**Spotlight transects along access tracks within the mining lease**	**Microbats surveyed using ultrasonic bat recording equipment**	**Call playback broadcasts**	**Roof tiles deployed**
November 2007	Quadrats 1-10 (2 additional quadrats from 2006)	√	√	√	Quadrats 1 and 5	Near Quadrats 1, 2 and 5	
February 2009 (December 2008 surveys were abandoned due to heavy rain).	Quadrats 1-10	√	√	√	Quadrats 1 and 3		
October 2009	Quadrats 1-11 (addition of quadrat 11 in the final void)	√	√	√	Quadrats 1 and 3		
November 2010	Quadrats 1-11	√	√	√	Quadrats 1, 3, 5 and 11		20 in each Quadrat 3 and 10 (autumn 2010)

Table 2-4: The number of fauna species recorded within each quadrat per sampling year

Year of Survey	November 2007											February 2009											October 2009												November 2010											
Fauna Group	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**O***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**O***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**O***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**O***	**A***
Birds	3	3	3	3	5	0	3	1	1	3	2	5	0	1	5	1	3	1	1	0	1	2	6	3	2	2	2	2	1	1	1	1	1	10	6	3	5	5	7	5	7	4	4	5	5	22	4
Mammals	2	0	2	1	2	1	1	0	1	0	1	3	2	0	2	1	1	1	2	0	2	2	2	1	0	1	1	2	1	2	1	2	2	6	3	1	3	2	2	4	1	4	2	3	2	8	0
Reptiles	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	3	2	1	2	3	1	4	1	2	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0
Amphibians	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	6	2
Total	6	4	6	5	8	2	5	2	3	10	4	9	3	2	8	3	5	3	4	1	4	5	11	6	3	5	6	5	6	4	4	4	3	16	11	5	9	8	10	10	9	9	7	9	8	36	6
Threatened Birds	**0**	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	1	0
Introduced Birds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1
Introduced Mammals	1	0	1	0	1	1	0	0	0	0	0	2	1	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	4	1	0	1	1	1	2	1	1	0	2	0	4	0

*O=Recorded outside of quadrats; A=Adjacent to lease

Table 2-5: The number of microbat species recorded within each quadrat per sampling year

Year of Survey	November 2007		February 2009		October 2009		November 2010			
	Quadrat 1	**Quadrat 5**	**Quadrat 1**	**Quadrat 5**	**Quadrat 1**	**Quadrat 3**	**Quadrat 1**	**Quadrat 3**	**Quadrat 5**	**Void**
Microbats	6	6	6	5	5	4	7	7	7	9
Threatened Microbats	1	0	1	2	1	1	1	1	1	1

3 Statistical assessment of existing monitoring data

3.1 METHODS

Treatment quadrat community assemblages were compared to reference quadrats with nonmetric multidimensional scaling (MDS) plots developed using Primer 6 (PRIMER-E, Plymouth 2006). MDS plots allow multi-dimensional data, such as species presence/absence 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. For repeated sampling of quadrats it is possible to map changes in community over time (Clarke and Warwick 2001), and this is the approach taken with the Canyon floristic data and bird species data where the trajectory of quadrat community through MDS space over time was compared to reference plots. If rehabilitation is successful, then treatment quadrat communities will move toward the reference plot communities. As an example, the points on the MDS plots representing the community of Quadrat 4 (a treatment site sown with pasture species) will move through time to be closer to the points that represent Quadrat 3 (the native pasture reference site).

Four separate MDS plots were constructed for Canyon floristic data that has been previously collected by GCNRC, following the calculation of Bray-Curtis similarity matrices. First, an MDS plot was made of square root transformed % cover data. The data were transformed to create normally distributed data. This allowed the relative contribution of each species in the community to be considered. Separate plots were made of 'woodland' quadrats (1 as reference and 5, 6, 7, 8, 9, and 10 as treatments), and 'pasture' quadrats (3 as control and 2, and 4) as treatments). Additional plots were made of the data for each habitat type following presence/absence transformations. These latter plots removed any bias that may have been held by dominant or rare species.

In addition, total % groundcover and native species % groundcover as well as total species diversity and native species diversity were graphed to compare treatment sites to the respective reference sites and the completion criteria target of 70% groundcover.

One MDS plot was constructed as above for the presence/absence of bird species occurring in each quadrat over the respective monitoring periods. This included both the 'woodland' quadrats (1 as reference, and 5, 6, 7, 8, 9, and 10 as treatments), and 'pasture' quadrats (3 as control, and 2 and 5 as treatments). Bird species were used in the analysis as they are indicative of habitat complexity. They are also highly mobile and are able to readily occupy regenerating areas, and are therefore the most appropriate faunal group to use as indicators of the progression of rehabilitation.

3.2 RESULTS

3.2.1 Woodland

The MDS plot of woodland community composition (presence/absence) and total per cent cover in Quadrats 5, 6, 7 and 8 displays a general progression towards the reference site (Quadrat 1) over the respective monitoring periods (Figure 3-1 and Figure 3-2). The proximity of Quadrats 7 and 8, as well as Quadrats 5 and 6, indicate a similar species diversity and % cover at these two respective quadrats, although at Quadrats 7 & 8, there is a divergence in the communities in the '% cover' data in 2010.

The MDS for the presence/absence data (Figure 3-2) of these two sites follows similar trajectories when moving from 2009 to 2010, suggesting that the main changes observed in Figure 3-1 are due to differences in the % cover of a small number of species. Examination of data indicates that the weed species *Chloris gayana* (Rhodes Grass) had 27.5% cover at Quadrat 7 and 19.5% at Quadrat 8 in 2009, but this shifted to 79% and 29% respectively by 2010. During this same period, the native species cover of Quadrat 7 was reduced from 37.5% in 2009 to 6% in 2010 (Figure 3-13).

Groundcover in Quadrats 5 and 6 have exceeded the target of 70% and also display a general progression towards the native species % groundcover and species diversity of the reference site (Control 1) (Figure 3-3 through to Figure 3-6). Additionally, the native species % cover increased, while exotic species decreased over the respective monitoring periods. In Quadrat 5 native species cover progressed from 40% in 2005 to 96.5% in 2010 and in Quadrat 6 native species cover was 39% in 2006 and increased to 92.5% in 2010. Conversely, native species diversity also increased over the same monitoring periods (from 11 to 26 at Quadrat 5 and from 11 to 27 at Quadrat 6). Sampling points in the MDS plots for Quadrats 5 and 6 appear to be progressing closer to each other with each sampling occasion, suggesting that the community is becoming more stable over time (Figure 3-1 and Figure 3-2).

Quadrats 7 and 8 have both reached 70% groundcover, although, this is mostly comprised of exotic species (Figure 3-7 and Figure 3-9). In Quadrat 8, species cover and diversity display a general trend towards the reference site (Control 1) (Figure 3-10). In Quadrat 7, species diversity also displays a general trend towards the reference site (Figure 3-8).

Quadrat 9 and 10 were established in 2009 and 2010 respectively and at present monitoring data for these sites is insufficient for interpretation.

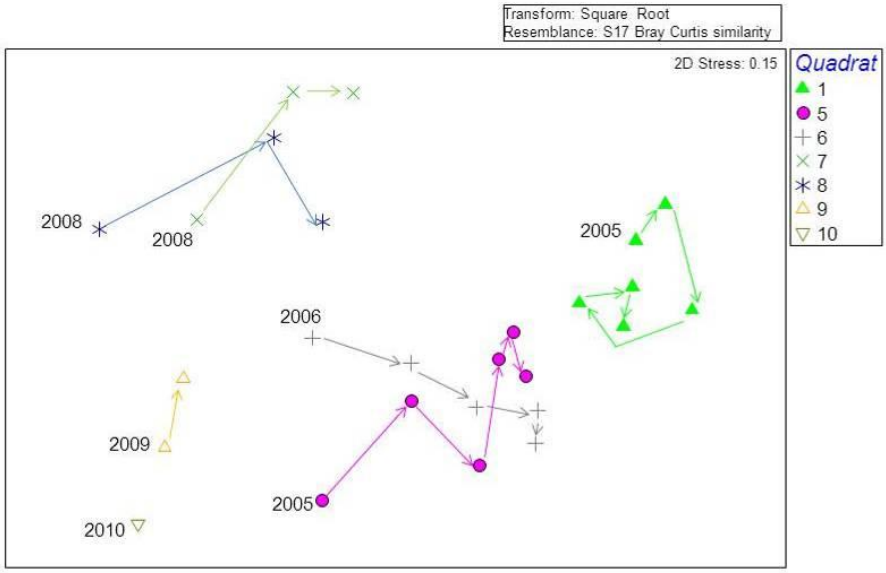

Figure 3-1: Comparison of % groundcover between the rehabilitated woodland quadrats

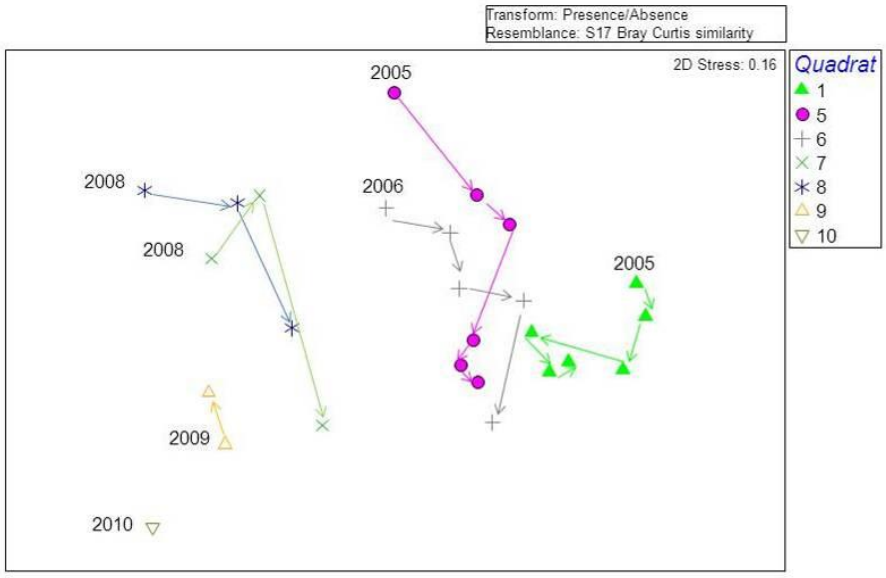

Figure 3-2: Comparison of groundcover species presence/absence between the rehabilitated woodland quadrats

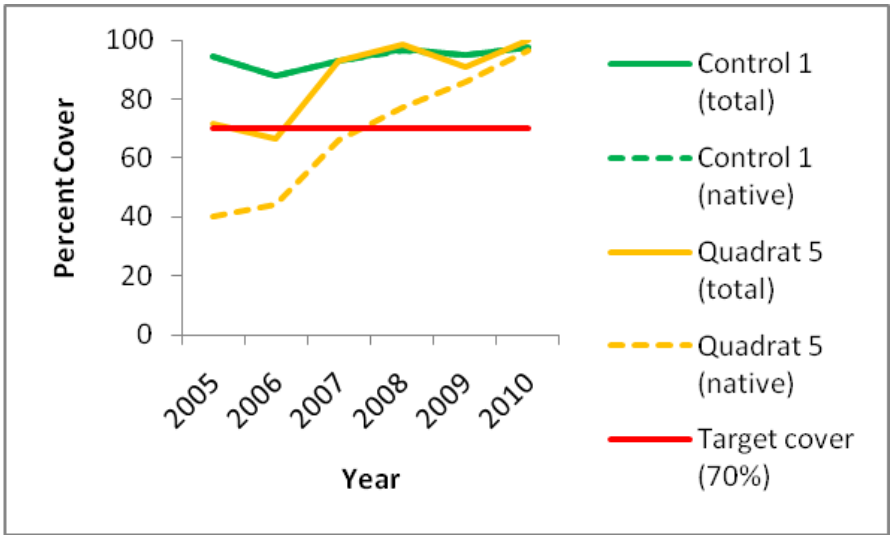

Figure 3-3: Total % groundcover and native species % groundcover in comparison to the target groundcover (70%) and the reference site (Control 1) for Quadrat 5.

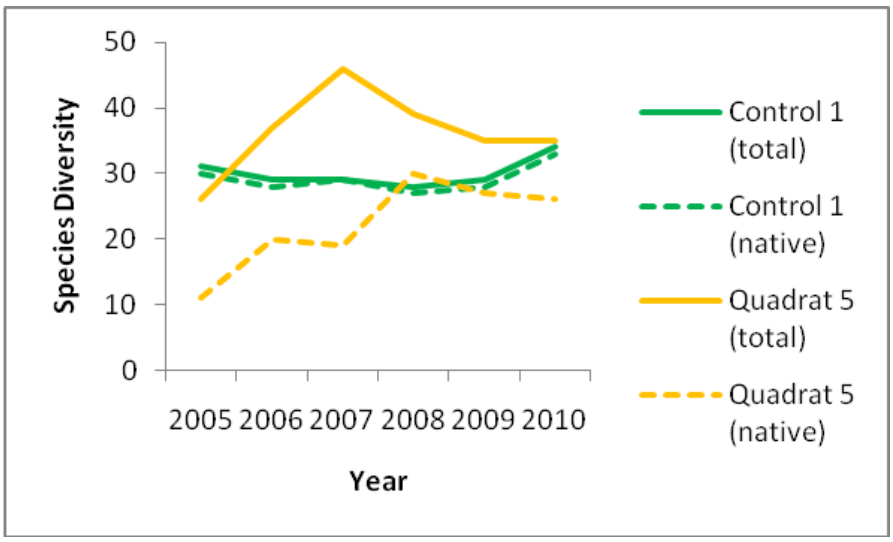

Figure 3-4: Total and native species diversity of Quadrat 5 in comparison to the control quadrat.

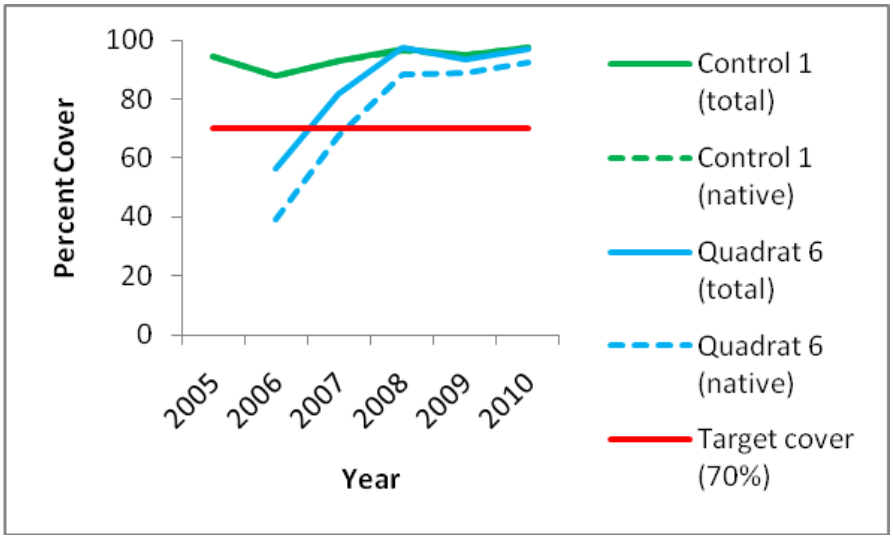

Figure 3-5: Total % groundcover and native species % groundcover in comparison to the target groundcover (70%) and the reference site (Control 1) for Quadrat 6.

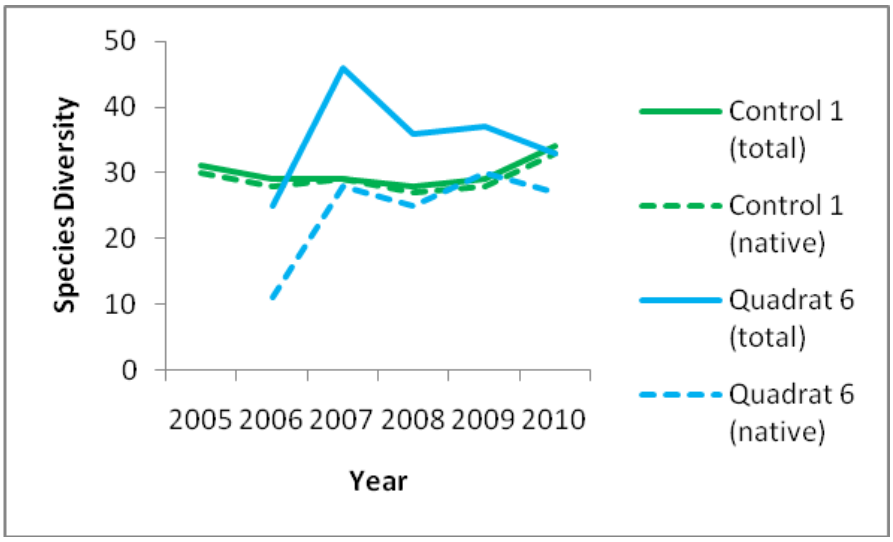

Figure 3-6: Total and native species diversity of Quadrat 6 in comparison to the control quadrat.

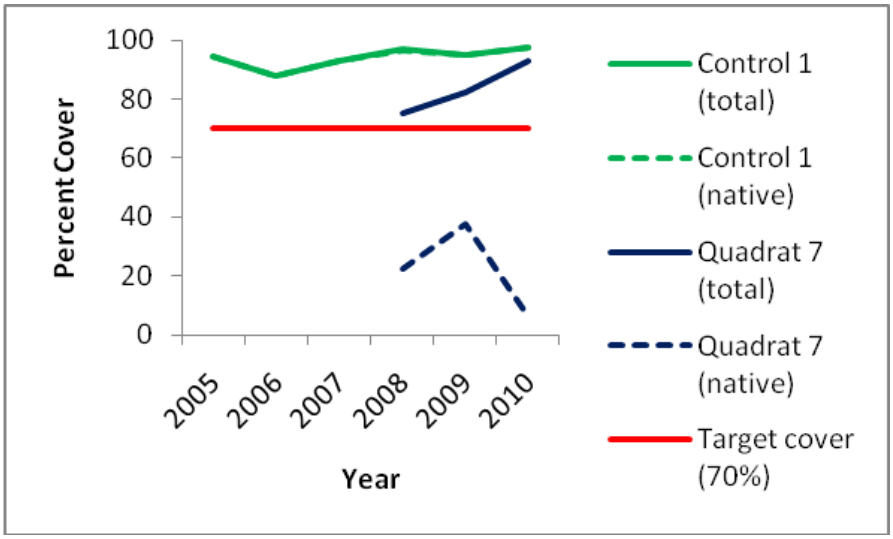

Figure 3-7: Total % groundcover and native species % groundcover in comparison to the target groundcover (70%) and the reference site (Control 1) for Quadrat 7.

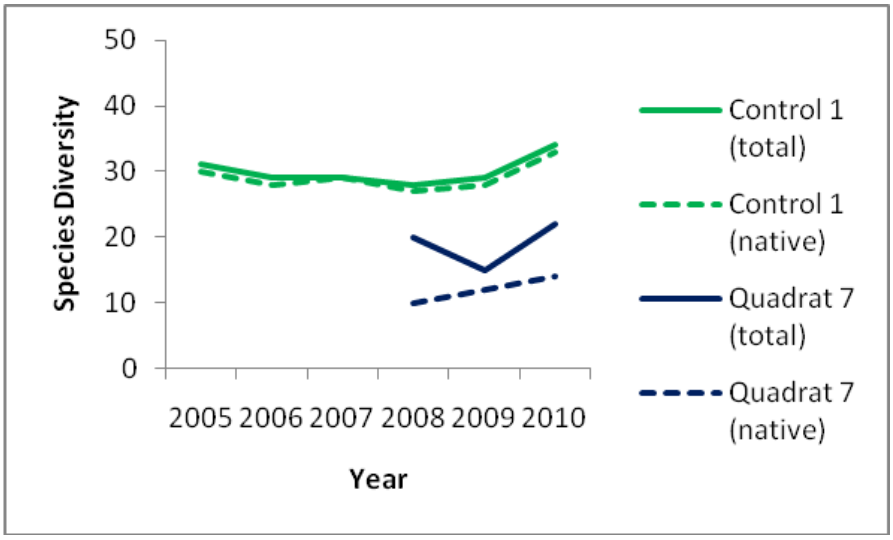

Figure 3-8: Total and native species diversity of Quadrat 7 in comparison to the control quadrat.

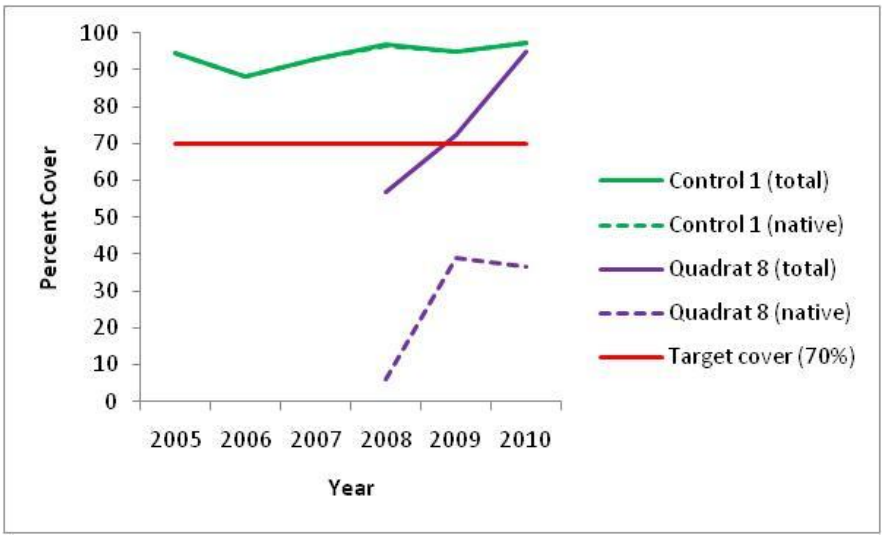

Figure 3-9: Total % groundcover and native species % groundcover in comparison to the target groundcover (70%) and the reference site (Control 1) for Quadrat 8.

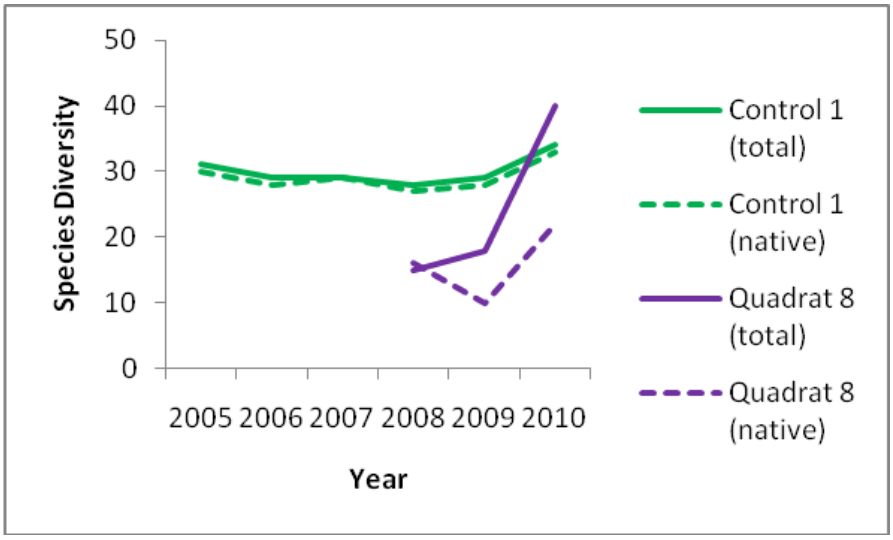

Figure 3-10: Total and native species diversity of Quadrat 8 in comparison to the control quadrat.

3.2.2 Pasture

Pasture community composition (presence/absence) and total per cent cover in Quadrats 2 and 4 display a general progression towards the reference site (Quadrat 3) over the respective monitoring periods. Additionally sampling points of these two quadrats appear to be getting closer to each other with each sampling occasion, suggesting that the community is becoming more stable over time. (Figure 3-11 and Figure 3-12).

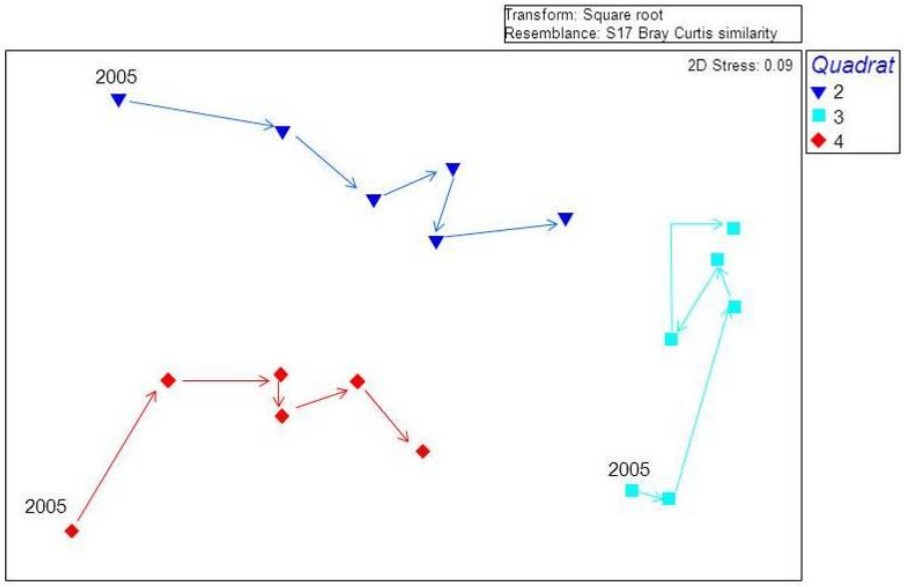

Figure 3-11: Comparison of % groundcover between the rehabilitated pasture quadrats

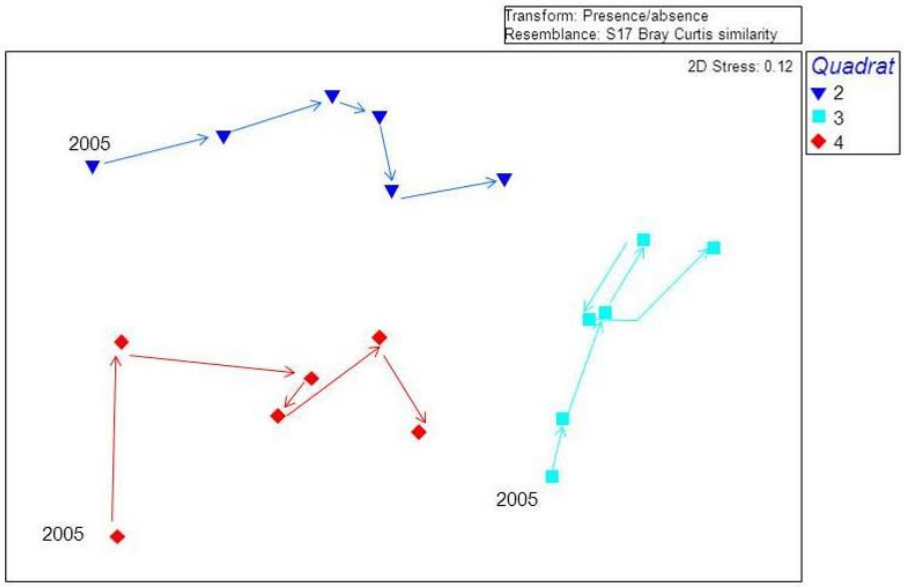

Figure 3-12: Comparison of groundcover species presence/absence between the rehabilitated pasture quadrats

Both Quadrats 2 and 4 have reached beyond the target groundcover (70%), and are both progressing towards the control quadrat in regards to total % groundcover and native species % groundcover (Figure 3-13). At quadrat 2, total and native species diversity has increased beyond the control site, while at Quadrat 3, total species diversity is at a similar level to the control and native species diveristy appears to have increased over the monitoring period (Figure 3-14).

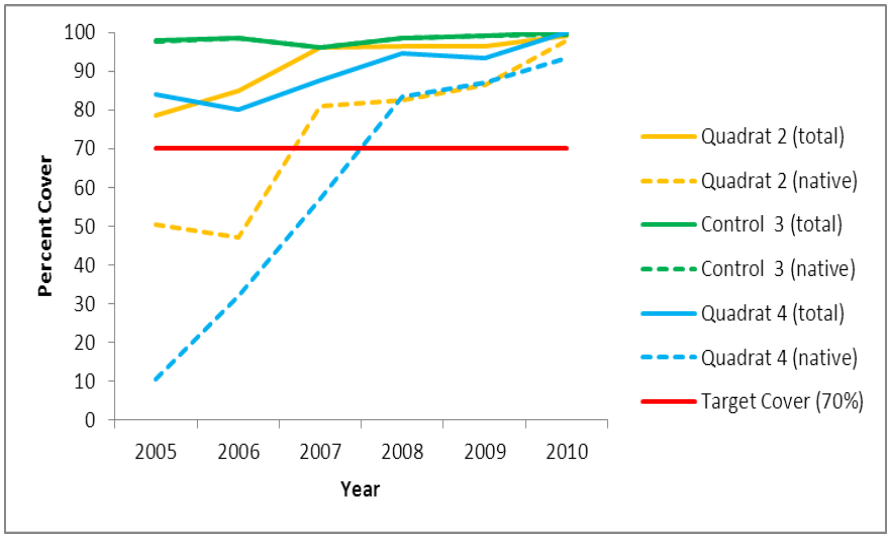

Figure 3-13: Total % groundcover and native species % groundcover in comparison to the target groundcover (70%) and the reference site (Control 1) for Quadrat 2 and Quadrat 4.

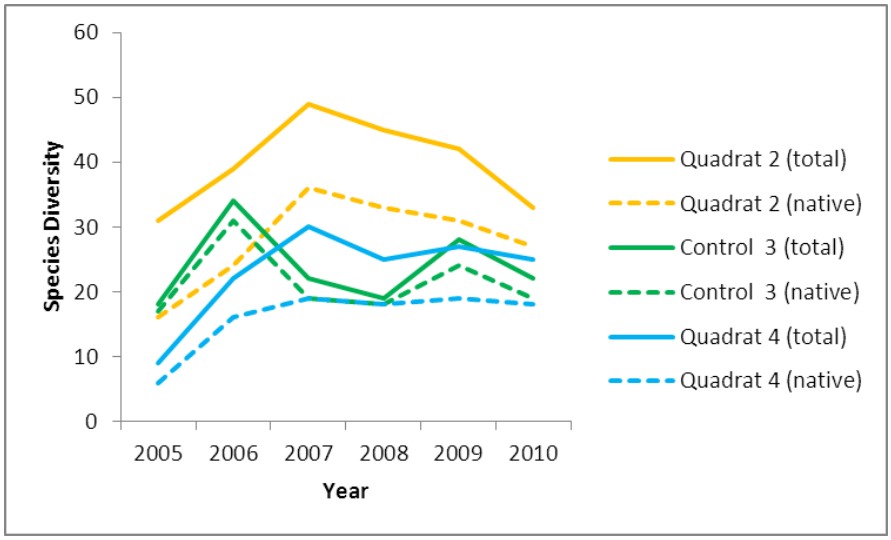

Figure 3-14: Total and native species diversity of Quadrats 2 and 3 in comparison to the control quadrat.

3.2.3 Birds

The quadrats with no birds recorded were not included in the MDS plot and Quadrats 8 and 9 over the years 2008-2009 were also not included in the analyses as they were considered outliers (one species recorded). There is significant overlap between quadrats over monitoring periods, indicating that there are many shared species between the two habitats (pasture and native woodland) (Figure 3-15). However, due to the minimal data available, the interpretation is largely inconclusive.

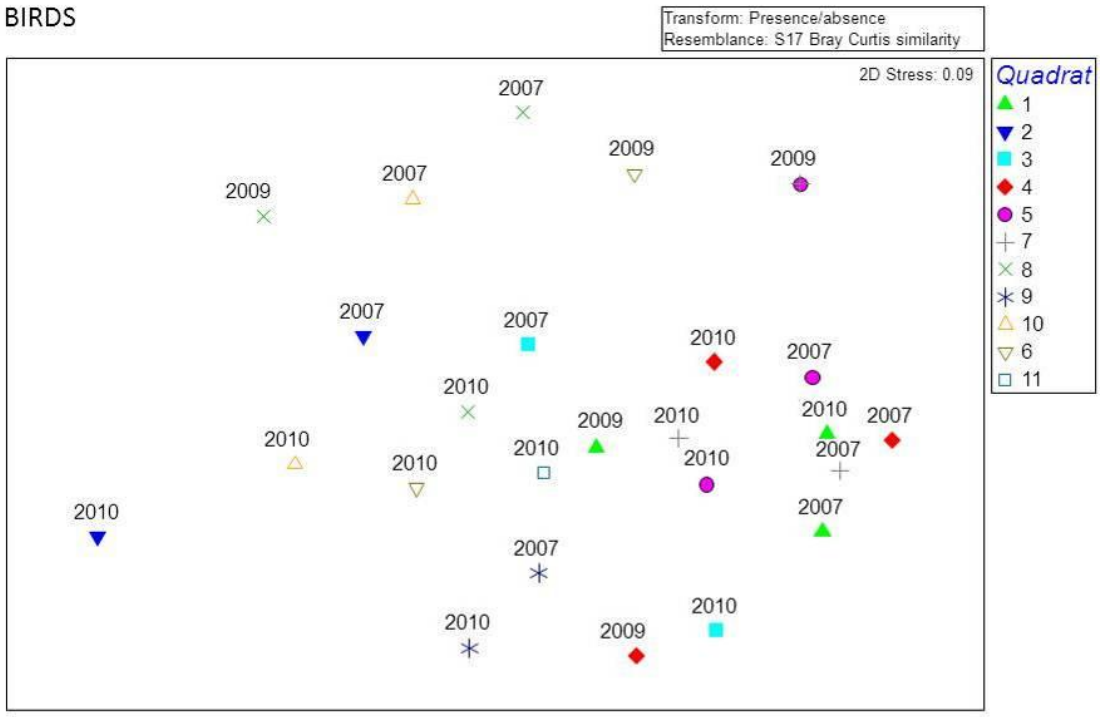

Figure 3-15: Comparison of bird species presence/absence between the rehabilitated pasture and woodland quadrats

3.3 DISCUSSION

The analysis of the existing monitoring data suggests that ecological succession is occurring in both of the rehabilitated pasture quadrats (Quadrats 2 and 4) and two of the rehabilitated native woodland quadrats (5 and 7). For example, Quadrat 2 displays a gradual progression towards the reference site (control Quadrat 3) over the monitoring period. Groundcover within this quadrat has exceeded the target of 70% and native species cover continues to move toward the reference site. Furthermore, total and native species diversity has succeeded the reference site, and the gap between total and native species diversity is steadily decreasing. However, rehabilitated lands are still in the early stages of ecological succession and show minimal stratification compared to the respective reference sites. Monitoring thus far has focused on groundcover species, although, as these ecological communities continue to mature, monitoring will also examine the developing strata.

Additionally, the majority of quadrats have reached the target groundcover of 70%; however, continued monitoring is required to ensure native species diversity and cover increase, while exotic species and cover decrease, as per the respective reference sites.

Monitoring for Quadrats 7, 8, 9 and 10 is still in its early stages and therefore the analysis undertaken is largely inconclusive for these quadrats.

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