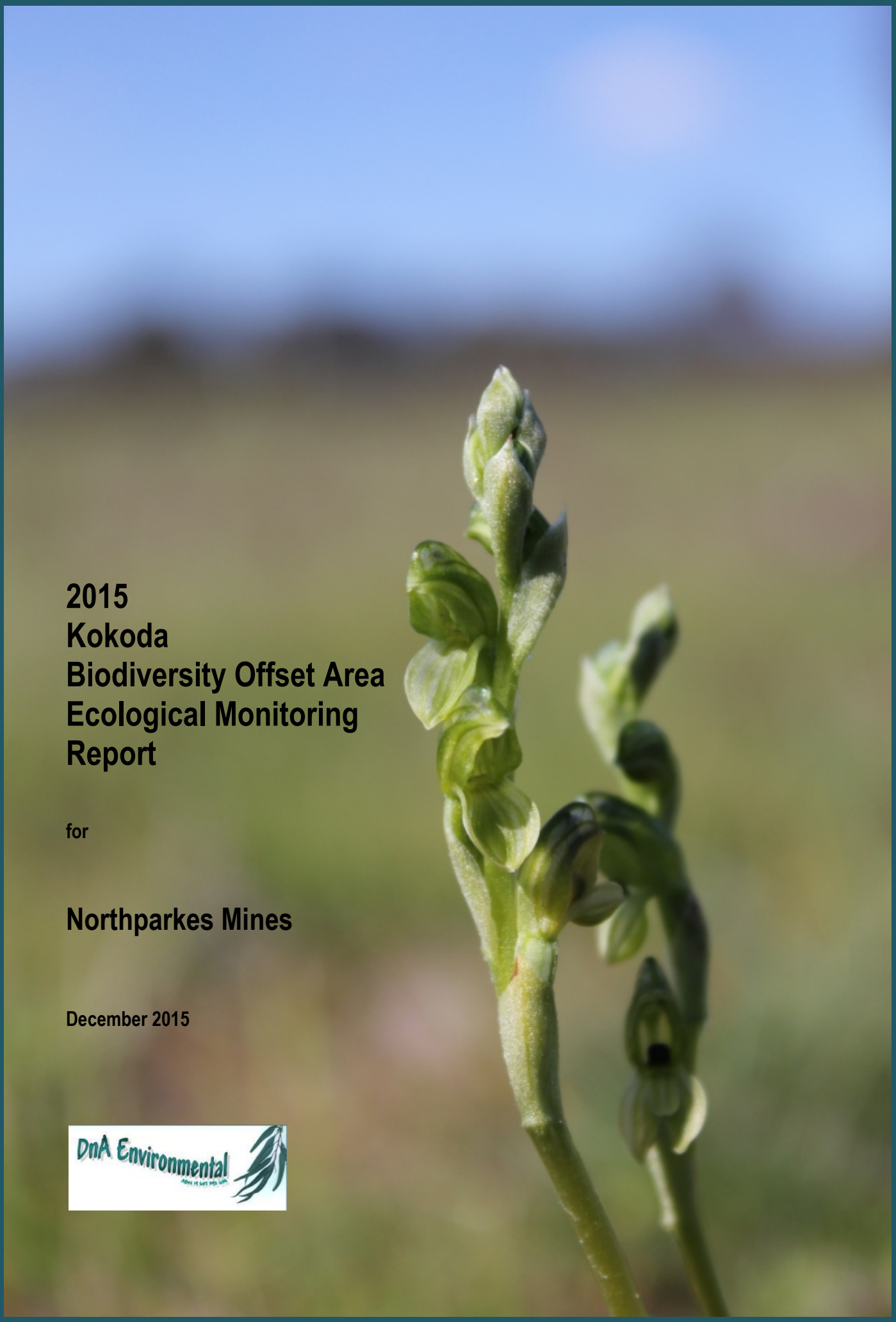


2015 Kokoda Biodiversity Offset Area Ecological Monitoring Report

for

Northparkes Mines

December 2015

DnA Environmental

Disclaimer

This is a report of work carried out by DnA Environmental and on behalf of CMOC Mining Services Pty. Limited, Northparkes Mines (NPM), Parkes and has been prepared according to the brief provided by the client. The information contained herein is complete and correct to the best of my knowledge. The representations, statements, opinions and advice, expressed or implied in this report are produced in good faith but on the basis that DnA Environmental are not liable (whether by reason of negligence, lack of care or otherwise) to any person for any damage or loss whatsoever which has occurred or may occur in relation to that person taking or not taking (as the case may be) action in respect of any or all of the content.

Signed: 

Dr Donna Johnston
Restoration Ecologist
PhD, B.App.Sc (Hons) MEIANZ

Draft submitted: 8th December 2015
Reviewed by: Roisin Feeney, 17th February 2016
Final Report submitted: 29th February 2016

DnA Environmental
417 Mandurama Rd
Mandurama
NSW 2792

Ph/Fax: (02) 63 675 251
Mobile: 0408 221 922
donna@dnaenviro.com.au

ABN 19 607 392 634

Acknowledgements

The field work, data analyses and resultant report were undertaken and prepared by Dr Donna Johnston and Andrew Johnston from DnA Environmental. Roisin Feeney provided escort assistance around the Kokoda property.

Executive summary

The 2015 Kokoda Offset Area (KOA) ecological monitoring report is a result of work carried out by DnA Environmental on behalf of Northparkes Mines (NPM) as part of the Biodiversity Offset Strategy and Voluntary Conservation Agreement with Office of Environment and Heritage (OEH). The Biodiversity Offset Management Plan (BOMP) (Umwelt 2014a) was prepared to guide the ongoing management of the Kokoda Offset Area for biodiversity conservation and enhancement purposes. The BOMP was prepared in accordance with the NSW Project Approval requirements issued for the NPM Step Change Project and provides a framework for the implementation of ecological management actions, regeneration strategies, controls and monitoring programs for the Kokoda Offset Site.

This ecological monitoring report describes the ecological monitoring methodology and presents the results of the annual ecological monitoring program established in 2015. The primary objective of the annual monitoring program is to compare the progress of natural regeneration and/or active revegetation areas by comparing a selection of ecological performance targets or completion criteria against less disturbed areas of remnant vegetation (reference sites) that are representative of the desired vegetation assemblage as described in the BOMP.

The Kokoda Offset Site is 350 hectares and is located in the Mandagery locality of the Central West Slopes of NSW, approximately 52 kilometres south-east of the Northparkes mine. Historically the property has been grazed by sheep and cattle but under the new Conservation Agreement with NPM and OEH, the property will remain free from domestic livestock grazing. Vegetation surveys undertaken by Umwelt indicate the property is comprised of ten different vegetation communities consisting of derived grasslands and a variety of different woodlands communities which vary according to soil type, topography and historical land practices.

The Umwelt surveys indicated there are approximately 96 ha of Derived Native Grasslands (DNG) once thought to have been *Eucalyptus microcarpa* (Grey Box) Grassy Woodland which conform to the TSC Act listed *Inland Grey Box Woodland* EEC and the EPBC Act listed *Grey Box (Grassy Woodlands and Derived Native Grasslands of South-eastern Australia* EEC. As part of the BOMP these DNG areas will be regenerated to their original Grey Box Grassy woodland community. The remaining 15 ha area of DNG are thought to have been dominated by *Eucalyptus dwyeri* (Dwyer's Red Gum) – *E. microcarpa* (Grey Box) – *E. sideroxylon* (Mugga Ironbark) – *Callitris endlicheri* (Black Cypress Pine) community, and these will also be regenerated to the original woodland structure.

There is a very small area (2.2 ha) of *E. albens* (White Box) Grassy Woodland which conforms to the TSC Act listed *E. albens* (White Box) – *E. melliodora* (Yellow Box) – *E. blakelyi* (Blakely's Red Gum) Woodland EEC and the EPBC Act listed *E. albens* (White Box) – *E. melliodora* (Yellow Box) – *E. blakelyi* (Blakely's Red Gum) Grassy Woodland and Derived Native Grassland CEEC. All areas of remnant woodland within the Kokoda Offset Area will be managed to improve wildlife habitat and biodiversity outcomes.

In 2014 Umwelt implemented the first ecological surveys and established 16, 20 x 20m monitoring sites across the range of vegetation communities and management zones at the KOA. The results of these surveys are provided in Umwelt (2014b). In 2015, DnA Environmental was engaged to review the monitoring program and establish a comprehensive range of ecological data which will fulfil the monitoring and reporting requirements of the BOMP. The monitoring programs aim to establish clearly defined, repeatable and consistent methodologies for monitoring changes in various aspects of ecosystem function, succession and long-term sustainability. Part of this process includes:

- Establishing a range of relevant reference sites to compare and track the progress and inherent ecosystem function of revegetation areas;
- Selecting a range of suitable reference sites that reflect the desired final land use, biodiversity targets, historical disturbances and local community expectations; and

- Undertaking a monitoring program that provides simple but informative and reliable information that indicates positive recovery trends or rapid detection of rehabilitation failure.

At Kokoda, a range of Key Performance Indicators (KPI's) were quantified by data obtained from replicated reference sites which were representative of the Grey Box Woodland EEC and Dwyer's Red Gum woodland. All ecological performance indicators are quantified by range values measured from these reference sites which form both an *upper* and *lower* KPI targets. The same ecological performance indicators are also measured in the revegetation/rehabilitation sites and these should equal or exceed these values, or at least demonstrate an increasing trend.

These Key Performance Indicators have been further separated into "*Primary performance indicators*" and "*Secondary performance indicators"*. Primary performance indicators are those chosen as essential completion criteria targets, and have been identified as those that will satisfy requirements identified within the BOMP. The range values of each ecological performance indicator are adapted annually to reflect seasonal conditions and disturbance events. Secondary performance indicators are those that would be desirable to achieve but do not necessarily have a direct affect on consent conditions or meeting biodiversity targets

In 2015, 17 permanent monitoring sites were established across the range of vegetation communities which included:

- three Grey Box Grassy woodland reference sites;
- five DNG sites which will be regenerated back to Grey Box Grassy woodland;
- three Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress woodland reference sites;
- three DNG which will be regenerated back to the Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress woodland community;
- One White Box Grassy Woodland CEEC;
- One Grey Box – Ironbark woodland; and
- One Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress Pine Forest which was mapped as low quality woodland.

The monitoring methodology adopted at Kokoda is consistent with that used in the NPM rehabilitation monitoring program (DnA Environmental 2009 – 2014) and the Estcourt Offset Area ecological monitoring program (DnA Environmental 2010 - 2014). The methodology includes a combination of Landscape Function Analyses (CSIRO Tongway & Hindley 1996), accredited soil analyses and various measurements of ecosystem diversity and habitat values based on and adapted from the Biometric methodology (Gibbons 2002, Gibbons *et al* 2008a, 2008b).

The annual vegetation monitoring will aim to be undertaken during spring where possible and this year was undertaken from 28th September – 1st October.

Grey Box woodlands: Summary of results

The three Grey Box woodland reference sites were characterised by having a mature tree canopy and a well developed decomposing leaf litter layer with a sparse cover of native perennial forbs and grasses. The White Box and Ironbark woodlands also had a mature tree canopy and while both sites had a well developed leaf litter layer, native grasses and forbs were more abundant in the White Box woodland, while in the Ironbark woodland there was an understorey of low and scattered shrubs. While the Grey Box revegetation sites presently existed as degraded pastures and were structurally different to the woodland reference sites, they typically had good ground cover comprised of a combination of annual and perennial plants and cryptogams.

Despite the lack of a mature tree canopy, the Grey Box revegetation sites tended to be more stable than the reference sites due to the higher abundance of perennial ground covers, very hard soil crusts which were usually contained a significant abundance of cryptogam cover and subsequently there tended to be less evidence of erosion or deposition within these sites. The revegetation sites however had a lower infiltration and nutrient recycling capacity largely due to lack of a mature overstorey, undeveloped leaf litter layer and hard surface crusts.

The White Box grassy woodland was the most ecologically functional site with the sum total score of 170.3 out of a possible score of 300. This site contained high patch area, a mature tree canopy and well developed grassy ground cover layer, with high levels of decomposing litter and had very stable soils. The Grey Box woodland sites GBWood3 and GBWood2 were the next most functional communities but did not tend to have such high levels of these attributes and scored 168.4 and 164.3 respectively. The derived grasslands GBReveg1, GBReveg4 and GBReveg3 that will be revegetated to Grey Box woodland were presently more functional than GBWood1 and the Ironbark woodland. These two woodland areas had also been severely degraded through a long grazing history with the herbaceous understorey having been severely depleted and the soils were compacted and these sites scored 159.7 and 159.5 respectively. The least functional communities were presently GBReveg5 which scored 155.6 and GBReveg2 with 151.8.

In the reference sites the density of trees and mature shrubs (>5cm dbh) ranged from 8 – 21 individuals and were dominated by *Eucalyptus microcarpa* (Grey Box). They were typically in good to medium health but all sites contained some individuals in a state of advanced dieback or were stags. The White Box woodland was dominated by *E. albens* but a *Callitris endlicheri* and *E. blakelyi* were also preset with most trees being in good to medium health and a large percentage (63%) of them were bearing reproductive structures. The Ironbark woodland was dominated by a mixture of *E. albens, E. dealbata* and *E. sideroxylon* with several *E. microcarpa* and a single *Callitris endlicheri.* Most individuals were in medium to poor health and there several dead individuals. No trees or mature shrubs were recorded in the Grey Box revegetation areas.

Shrub and juvenile tree densities were relatively low 1 – 18 individuals (25 – 450 stems per hectare) and these were represented by 1- 4 species. Species included juvenile *E. microcarpa, Acacia implexa, A. paradoxa* (Kangaroo Thorn), *Brachyloma daphnoides* (Daphne Heath) or *Cassinia laevis* (Cough Bush). In the White Box woodland there was one small *Acacia implexa*. In the Ironbark woodland, there were 108 individuals which were dominated by *Brachyloma daphnoides.* Most individuals in the reference sites were less than 0.5m in height. No juvenile trees or shrubs were recorded in the Grey Box revegetation areas.

Total ground cover, which is a combination of leaf litter, annual plants, cryptogams, rocks, logs and live perennial plants (<0.5m in height) was relatively high in the woodland reference sites and ranged from 90.5 – 99.5%. In IronWood1 total ground cover was slightly lower with 86.5% while in the White Box woodland and derived grassland revegetation sites there was 98.5 – 100% ground cover.

In the Grey Box woodland reference sites and the White Box and Ironbark woodlands the most dominant form of ground cover was dead leaf litter but there was also a small contribution of cover provided by scattered perennial plants and fallen branches, and there may have been an occasional annual plant or rock. The White Box woodland had a higher cover of perennial ground cover, while in the Ironbark woodland, cryptogams and logs were also important. In comparison the revegetation sites were presently dominated by various proportions of annual plants and dead leaf litter and had a higher cover of perennial ground covers and cryptogams. The reference sites were also characterised by having a mature canopy cover which exceeded 6.0m in height with low hanging braches also providing occasional projected cover in the lower height classes. The White Box woodland had a similar overstorey structure while in Ironwood1, the scattered low shrubs provided some structural diversity 0.5 – 2.0m in height.

In the reference sites total floristic diversity was highly variable with 23 – 39 species recorded. The White Box woodland contained the highest total species diversity with 51 species while there were 35 species recorded in the Ironbark woodland. Floristic diversity in the derived grasslands ranged from a low diversity of 30 species (GBReveg3) to a high of 45 species (GBReveg2). Native species were more diverse than exotic species in sites WBWood1, IronWood1 as well as the derived grasslands GBReveg2 and GBReveg4. While only one exotic species was recorded in IronWood1, all other sites contained more exotic species than were recorded in the woodland reference sites and were therefore weedier than desired.

In IronWood1, 100% of the live ground covers were endemic species but in the White Box woodland native species provided 78.3% cover and was weedier than desired. In the derived grasslands the highest cover of native plants was recorded in GBReveg2 with 61.7% endemic cover, while the lowest was recorded in GBReveg1 and GBReveg3 which had low scores of 27.2% and 27.8% respectively. Therefore all revegetation areas were presently dominated by exotic species and weedier than desired.

The White Box and Ironbark woodlands were comprised of an adequate representation of the major plant groups but there was a slightly low diversity of herbs in IronWood1. In the derived grassland revegetation areas there was also an adequate representation of most growth forms except that there were no tree species. While there were also no shrubs in the grassland areas, no shrubs were recorded in the GBWood01 reference site.

There were 140 species recorded across the Grey Box monitoring sites with 41 (29%) of these being exotic species. The exotic annual *Hypochaeris glabra* (Smooth Catsear) was recorded in all sites including the three reference sites and White Box and Ironbark woodlands. Exotic annuals *Arctotheca calendula* (Capeweed), *Anagallis arvensis* (Scarlet Pimpernel) and *Briza minor* (Shivery Grass) were also very common. Common native species included *Aristida ramosa* (Threeawn Grass), *Austrostipa scabra subsp. falcata* (Speargrass), *Bothriochloa macra* (Red-leg Grass), *Elymus scaber* (Common Wheatgrass) and *Cheilanthes sieberi subsp. sieberi* (Rock Fern).

In the Grey Box woodland reference sites no species was particularly abundant in the understorey with only *Austrostipa scabra subsp. falcata* (Speargrass) meeting the required criteria in one site (GBWood01). *Austrostipa scabra subsp. falcata* was also the most abundant in the White Box woodland along with *Hydrocotyle laxiflora* (Stinking Pennywort). In the Ironbark woodland *Brachyloma daphnoides* (Daphne Heath) provided the most ground cover. The derived grasslands were dominated by a different range of species with most cover provided exotic annual grasses especially *Vulpia muralis* (Rats-tail Fescue) and *Aira cupaniana* (Silvery Hairgrass). Other common species included the exotics *Trifolium angustifolium* (Narrow-leaf Clover) and *Hypochaeris glabra* (Smooth Catsear) and the natives *Bothriochloa macra* (Red-leg Grass) and *Rytidosperma racemosum* (Wallaby Grass).

The soils in the Grey Box reference sites were very strongly acidic, with the remaining sites being similar to or within desirable levels and were non saline and non sodic. Most sites were also low in organic matter, Phosphorous and CEC. The results indicate there were slightly to moderately elevated levels of Potassium and significantly high concentrations of Iron in most of the Grey Box sites, including the three reference sites indicating these may be naturally occurring.

Performance of the woodland revegetation monitoring sites against "proposed" Primary Completion Performance Indicators

The table below indicates the performance of the woodland revegetation monitoring sites against a selection of proposed Primary Completion Performance Indicators. The selection of criteria has been presented in order of rehabilitation phases according to the ESG3 MOP guidelines (*excluding Phase 1: Decommissioning*). The range values of the ecological performance targets are amended annually.

Revegetation sites meeting or exceeding the range values of their representative community type i.e. Grey Box woodland reference sites have been identified with a coloured box and have therefore been deemed to meet these primary completion performance targets this year. Hashed coloured boxes indicate they may be outside of the reference target ranges, but within acceptable agricultural limits.

Performance of the Grey Box revegetation sites against primary completion performance indicators for Grey Box woodland communities in 2015.

Rehabilitation Phase	Aspect or ecosystem component	Performance Indicators	Unit of measurement	Grey Box Woodland ecosystem range 2015		GBReveg 1	GBReveg 2	GBReveg 3	GBReveg 4	GBReveg 5	WBWood 1	IronWood 1
Performance indicators are quantified by the range of values obtained from replicated reference sites				Lower	Upper	2015						
Phase 2: Landform establishment and stability	Active erosion	No. Rills/Gullies	No.	0	0	0	0	0	0	0	0	0
Phase 3: Growth medium development	Soil chemical, physical properties and amelioration	pH	pH (5.6 - 7.3)	4.9	5.2	6.5	5.8	6.1	5.9	6.0	5.8	5.0
		Organic Matter	% (>4.5)	4.7	7.8	2.6	4.6	1.9	1.7	2.2	1.5	4.2
		Nitrate	ppm (>12.5)	1.5	1.8	2.6	2.1	2.3	2.5	2.2	1.8	1.5
Phase 4: Ecosystem & Landuse Establishment	Landscape Function Analysis (LFA): Landform stability and organisation	LFA Stability	%	62.8	65.0	73.6	73.0	72.0	71.0	69.1	62	62.4
		LFA Landscape organisation	%	100	100	100	100	100	100	100	100	100
	Vegetation diversity	Diversity of shrubs and juvenile trees	species/area	1	4	0	0	0	0	0	1	7
			% population	100	100	0	0	0	0	0	100	100
		Exotic species richness	<No./area	6	7	18	13	17	16	18	12	1
	Vegetation density	Density of shrubs and juvenile trees	No./area	1	18	0	0	0	0	0	1	108
	Ecosystem composition	Trees	No./area	1	2	0	0	0	0	0	3	6
		Shrubs	No./area	0	3	0	0	0	0	0	1	6
		Herbs	No./area	14	20	20	32	18	17	21	33	12

Rehabilitation Phase	Aspect or ecosystem component	Performance Indicators	Unit of measurement	Grey Box Woodland ecosystem range 2015		GBReveg 1	GBReveg 2	GBReveg 3	GBReveg 4	GBReveg 5	WBWood 1	IronWood 1
Phase 5: Ecosystem & Landuse Development	Landscape Function Analysis (LFA): Landform function and ecological performance	LFA Infiltration	%	49.7	53.5	46.2	38.4	43.3	44.3	42.9	54.4	51.1
		LFA Nutrient recycling	%	47.2	50.7	41.6	40.4	44.6	46	43.6	53.9	46
	Protective ground cover	Perennial plant cover (< 0.5m)	%	3	7	18	34	25	17	15.5	19.5	5.5
		Total Ground Cover	%	91	100	99	98.5	100	100	100	100	86.5
	Native ground cover abundance	Percent ground cover provided by native vegetation <0.5m tall	%	90.5	97.1	27.2	61.7	27.8	36.5	31.4	78.3	100
	Ecosystem growth and natural recruitment	shrubs and juvenile trees 0 - 0.5m in height	No./area	1	13	0	0	0	0	0	0	78
		shrubs and juvenile trees 1.5 - 2m in height	No./area	0	1	0	0	0	0	0	0	0
	Ecosystem structure	Foliage cover 0.5 - 2 m	% cover	0	0	1	0	0	0	0	0	3
		Foliage cover >6m	% cover	50	52	0	0	0	0	0	28	26
	Tree diversity	Tree diversity	%	100	100	0	0	0	0	0	100	100
	Ecosystem health	Live trees	% population	85	100	0	0	0	0	0	100	82.5
		Healthy trees	% population	5	48	0	0	0	0	0	50	10
		Flowers/fruit: Trees	% population	0	10	0	0	0	0	0	62.5	17.5

Dwyer's Red Gum woodlands

The Dwyer's Red Gum (DRG) woodland reference sites were also characterised by having a mature tree canopy and a well developed decomposing leaf litter layer and a sparse cover of native perennial forbs and grasses. The low quality Dwyer's Red Gum woodland site was characterised with having an open mature tree canopy, moderate cover of annual and perennial ground cover species and typically had a well developed leaf litter layer but this was patchy. The Dwyer's Red Gum revegetation sites presently existed as degraded grasslands but they typically had good ground cover comprised of a combination of annual and perennial plants and cryptogams.

DWood1 was the most ecologically functional site with a total sum of LFA scores of 176.3 out of a possible 300. DReveg1, DReveg2 and the low quality woodland DWoodLQ were the next most functional sites and had a sum of scores which exceeded the reference sites DWood2 and DWood3 which scored 159.6 and 151.9 respectively. The lowest ecological function was recorded in DReveg3 with a sum of indices of 150.2. All DRG revegetation sites did not yet meet many completion targets related to the mature tree and shrub populations and the structural complexity of the sites due to the lack of a well developed canopy and shrub understorey. In most of the revegetation sites there was often an appropriate diversity of native herbs and grasses but the sites also tended to be dominated by exotic species and were weedier than desired.

There were 9 – 25 trees and/or mature shrubs (>5cm dbh) in the DRG reference sites, equating to a density of 225 – 625 stems per hectare. There were nine individuals in the low quality woodland but none were yet present in the derived native grassland sites. They were typically in medium health but there were also a large percentage of stags in DWood1 and DWood2 as a result of self thinning. No mistletoe was recorded however a large percent of the population were bearing reproductive structures such as buds, flowers or fruits in DWood3. There was a very small percentage containing hollows suitable for nesting sites (>10cm). In the low quality woodland all trees were in medium health and almost half (44%) of them were bearing fruit. The DRG reference sites were dominated by *Callitris endlicheri* but there may also have been scattered individuals of *Allocasuarina luehmannii, E. dwyeri, E. dealbata, E. sideroxylon* and/or *E. microcarpa*. The low quality woodland was dominated by *E. dwyeri* and contained one *E. albens*.

There was a large variation on the number of shrubs and juvenile trees (<5cm dbh) recorded in the reference sites with densities ranging from 32 – 598 individuals equating to a density of 800 – 14950 stems per hectare with 87% of these being less than 0.5m in height. In the low quality woodland there were eight small shrubs and juvenile trees. In the woodland reference sites there were 4- 7 species of shrubs and juvenile trees with the most abundant species being young *Callitris endlicheri* seedlings. There were also low occurrences of range of other species including *Acacia doratoxylon* (Spearwood), *Brachyloma daphnoides*, *E. dwyeri*, *E. sideroxylon*, *Allocasuarina verticillata* (Drooping She oak) and *Cassinia laevis* (Cough Bush). In DWood3 there was a relatively high abundance of *Calytrix tetragona* (Fringe Myrtle). In DReveg1 there were nine *E. dwyeri* saplings and while most height classes were represented the majority were less than 1.5m in height. No shrubs or juvenile trees were recorded in the remaining grassland sites.

Total ground cover in the DRG woodland reference sites ranged from 91.0 – 96.5% which was similar in the low quality woodland. In the derived grasslands there was at least 99.5% ground cover. In the reference sites and the low quality woodland the most dominant form of ground cover was dead leaf litter and there was a small contribution of cover provided by scattered perennial and annual plants and cryptogams. There was some cover by provided by fallen branches, and there may have been an occasional rock. The low quality woodland had similar features in similar proportions but did not tend to have fallen branches. The reference sites and the low quality woodland were also characterised by having a mature canopy cover which exceeded 6.0m in height with low hanging braches and scattered shrubs also providing occasional projected cover in the lower height classes. In comparison the revegetation sites were presently dominated by various proportions of annual plants and dead leaf litter

but had similar proportions of perennial ground covers and cryptogam cover. Some taller grass tussocks may have provided a small amount of vertical structure but they did not yet have a shrub or mature tree layer.

Total floristic diversity recorded within the 20 x 20m monitoring sites ranged from 31 – 49 species but the low quality woodland contained the highest total species diversity with 50 species Floristic diversity in the derived grassland sites was variable and ranged from a low diversity of 27 species in DReveg2 to a high of 40 species in DReveg3. In the reference sites there were 2 – 8 exotic species with only eight exotics species also being recorded in DReveg2. The remaining sites had more exotic species than desired.

In the reference sites most of the live plant cover was provided by native species with endemic plants providing 73.6 – 90.1% of the total plant cover. There was a slightly lower abundance of native species in DWoodLQ with 65.8% and was slightly weedier than desired. In the derived grasslands the highest cover of native plants was recorded in DReveg2 with 62.5% endemic cover. In DReveg1 and DReveg3 exotic species dominated the sites with only 33.0% and 32.1% endemic plant covers respectively. Therefore all grassland sites were presently dominated by exotic species and weedier than desired.

In the reference sites herbs were the most diverse plant group with 16 - 28 different species followed by grasses with 5 – 8 species. There were four tree species, 2 – 6 shrub species and one sub-shrub was recorded in all three sites. There were up to 2 reed species and all sites had one species of fern. The low quality DRG woodland had similar composition of the herbaceous ground covers, but it had a low diversity of tree species and no sub – shrubs were recorded. In the grassland revegetation areas there was also an adequate representation of most growth forms in the herbaceous ground covers but there was presently a low diversity of trees and shrubs and no sub-shrubs were recorded.

There were 126 species recorded across the Dwyer's Red Gum monitoring sites with 41 (33%) of these being exotic species. The exotic annual *Hypochaeris glabra* (Smooth Catsear) and *Vulpia muralis* (Rats-tail Fescue) were recorded in all sites including the three reference sites and so was the native fern *Cheilanthes sieberi subsp. sieberi* (Rock Fern). Other common exotic annuals were *Aira cupaniana* (Silvery Hairgrass), *Arctotheca calendula* (Capeweed) and *Briza minor* (Shivery Grass). Some common native species included the native perennial grasses *Aristida ramosa* (Threeawn Grass) and *Bothriochloa macra* (Red-leg Grass). Native herbs *Bulbine bulbosa* (Bulbine Lily), *Drosera peltata* (Pale Sundew), *Stuartina muelleri* (Spoon Cudweed) and *Triptilodiscus pygmaeus* (Austral Sunray) were also relatively common.

No species was particularly abundant in the understorey in the Dwyer's Red Gum woodland reference sites DWood2 and DWood3. However in DWood1, the native perennial ground covers *Cheilanthes sieberi subsp. sieberi* and *Gonocarpus elatus* (Hill Raspwort) were relatively abundant but so was the exotic annual *Hypochaeris glabra.* The derived grasslands also tended to have a high abundance of *Hypochaeris glabra,* with other annual species including *Vulpia muralis* and *Aira cupaniana* also being abundant in some sites. The native grasses *Aristida ramosa, Bothriochloa macra* and *Rytidosperma fulvum* were relatively abundant in DReveg1 and/or DReveg2

The soils were moderately to strongly acidic and non saline but the ESP slightly exceeded the 5% threshold in DReveg1 and DWoodLQ and may be sodic. All sites were also low in organic matter, Phosphorous, Nitrate and CEC but were typically quite similar to the DRG woodland reference sites. The results also indicate there are significantly high concentrations of Iron in all of the Dwyer's Red Gum sites, including the three reference sites and are likely to be typical of the area.

Performance of the DRG woodland revegetation monitoring sites against "proposed" Primary Completion Performance Indicators

The table below indicates the performance of the woodland revegetation monitoring sites against a selection of proposed Primary Completion Performance Indicators. The selection of criteria has been presented in order of rehabilitation phases according to the ESG3 MOP guidelines (*excluding Phase 1: Decommissioning*). The range values of the ecological performance targets are amended annually. Revegetation sites meeting or exceeding the range values of their representative community type i.e. Dwyer's Red Gum woodland reference sites have been identified with a coloured box and have therefore been deemed to meet these primary completion performance targets this year. Hashed coloured boxes indicate they may be outside of the reference target ranges, but within acceptable agricultural limits.

Performance of the Dwyer's Red Gum revegetation sites against primary completion performance indicators for Dwyer's Red Gum woodland communities in 2015.

Rehabilitation Phase	Aspect or ecosystem component	Performance Indicators	Unit of measurement	Dwyer's Red Gum Woodland ecosystem range 2015		DReveg 1	DReveg 2	DReveg 3	DWoodLQ
Performance indicators are quantified by the range of values obtained from replicated reference sites				Lower	Upper	2015	2015	2015	2015
Phase 2: Landform establishment and stability	Active erosion	No. Rills/Gullies	No.	0	0	0	0	0	0
Phase 3: Growth medium development	Soil chemical, physical properties and amelioration	pH	pH (5.6 - 7.3)	5.2	5.4	5.5	5.3	5.9	5.2
		Organic Matter	% (>4.5)	2.3	3.5	2.4	2.4	2.9	2.3
		Nitrate	ppm (>12.5)	1.4	2.3	2.3	1.7	2.5	1.6
Phase 4: Ecosystem & Landuse Establishment	Landscape Function Analysis (LFA): Landform stability and organisation	LFA Stability	%	63.1	70.0	75.0	71.3	69.2	66.5
		LFA Landscape organisation	%	100	100	100	100	100	100
	Vegetation diversity	Diversity of shrubs and juvenile trees	species/area	4	7	1	0	0	3
			% population	100	100	100	0	0	100
		Exotic species richness	<No./area	2	8	17	8	22	17
	Vegetation density	Density of shrubs and juvenile trees	No./area	32	598	9	0	0	8
	Ecosystem composition	Trees	No./area	4	4	1	0	0	2

Rehabilitation Phase	Aspect or ecosystem component	Performance Indicators	Unit of measurement	Dwyer's Red Gum Woodland ecosystem range 2015		DReveg 1	DReveg 2	DReveg 3	DWoodLQ
		Shrubs	No./area	2	6	0	0	0	2
		Herbs	No./area	16	28	20	17	26	32
Phase 5: Ecosystem & Landuse Development	Landscape Function Analysis (LFA): Landform function and ecological performance	LFA Infiltration	%	43.6	54.6	47.1	46	40.1	49.9
		LFA Nutrient recycling	%	44.5	51.7	43.4	46.4	40.9	46.9
	Protective ground cover	Perennial plant cover (< 0.5m)	%	4	28	8.5	10.5	9.5	10.5
		Total Ground Cover	%	91	97	99.5	100	100	97
	Native ground cover abundance	Percent ground cover provided by native vegetation <0.5m tall	%	73.6	90.1	33.0	62.5	32.1	65.8
	Ecosystem growth and natural recruitment	shrubs and juvenile trees 0 - 0.5m in height	No./area	31	502	2	0	0	8
		shrubs and juvenile trees 1.5 - 2m in height	No./area	0	0	0	0	0	0
	Ecosystem structure	Foliage cover 0.5 - 2 m	% cover	0	4	6	8	0	0
		Foliage cover >6m	% cover	12	44	0	0	0	34
	Tree diversity	Tree diversity	%	100	100	0	0	0	100
	Ecosystem health	Live trees	% population	30	82	0	0	0	100
		Healthy trees	% population	1	27	0	0	0	0
		Flowers/fruit: Trees	% population	10	82	0	0	0	44

Conclusion and management recommendations

The proposed revegetation activities within the derived grassland areas as described in the BOMP aim to increase biodiversity and habitat values through the removal of livestock grazing to allow natural regeneration, supplemented with tubestock planting. These activities are likely to result in the cleared grassland areas developing into woodland communities and therefore meeting most ecological performance indicators in the medium to longer term. The reference sites at Kokoda are typically degraded and of low quality which subsequently have provided low performance targets. In the Grey Box woodlands in particular, there was limited abundance and diversity of the grassy understorey and there were limited shrubs. Subsequently the revegetation activities proposed should include a range of species known to occur within these communities and not just restricted to those occurring within the existing reference sites.

Strategic grazing is also likely to be a critical management strategy which will be required to maintain biodiversity, encourage tree and shrub regeneration and to reduce fuel loads as part of the integrated and adaptive management strategy for the Kokoda Offset Area. As part of the BOMP it would be beneficial to implement strategic grazing management to manipulate the grassy understorey biomass in order to:

- Promote natural tree and shrub recruitment;
- Reduce cover abundance of exotic annual grasses, in favour of native perennial grasses (grazing late summer/early autumn and/or late winter early spring);
- Promote and maintain diversity in the herbaceous understorey cover;
- Reduce understory growth in preparation for direct seeding and/or tubestock planting;
- Reduce the incidence of bush-fire and bush-fire intensity;
- Prevent invasion from weeds via the maintenance of strong native perennial pastures and high ground cover levels;
- Assist ongoing site maintenance and monitoring by providing better access around the property.

This year several species of orchids were observed at various locations around the property. As part of the management of the Kokoda property, the location of these populations should be considered when undertaking revegetation, weed control and strategic grazing, particularly as most orchids are only identifiable during a limited time period.

Other potential management issues at Kokoda may be related to high density *Callitris endlicheri* regeneration which was observed to be occurring within and adjacent to woodland areas where mature Callitris were present. Strategic grazing may reduce the density of existing seedlings and regulate the degree of Callitris regeneration through manipulation of the herbaceous understorey and germination niches.

Herbivory by feral and pests species may also become an increasingly important management issue which should be regularly monitored as specified in the BOMP. Safe and easy access should always be maintained around main access tracks and boundary fences to facilitate monitoring, property maintenance and bushfire management. Regular inspections should be undertaken with slashing and/or strategic grazing management implemented on a needs basis. There were little other management issues that have not already been addressed in the BOMP.

TABLE OF CONTENTS

1 2015 Kokoda Offset Area Ecological Monitoring Report

1.1 Introduction

The 2015 Kokoda Offset Area (KOA) ecological monitoring report is a result of work carried out by DnA Environmental on behalf of Northparkes Mines (NPM) as part of the Biodiversity Offset Strategy and Voluntary Conservation Agreement with Office of Environment and Heritage (OEH). The Biodiversity Offset Management Plan (BOMP) was prepared to guide the ongoing management of the Kokoda Offset Area for biodiversity conservation and enhancement purposes (Umwelt 2014a). The BOMP was prepared in accordance with the NSW Project Approval requirements (PA11_0060) and Commonwealth Project Approval (EPBC 2013/6788) requirements issued for the NPM Step Change Project and provides a framework for the implementation of ecological management actions, regeneration strategies, controls and monitoring programs for the Kokoda Offset Site.

This ecological monitoring report describes the ecological monitoring methodology and presents the results of the annual ecological monitoring program first established in 2015. The primary objective of the annual monitoring program is to compare the progress of natural regeneration and/or active revegetation areas by comparing a selection of ecological targets or completion criteria against less disturbed areas of remnant vegetation (reference sites) that are representative of the desired vegetation assemblage as described in the BOMP.

2 Kokoda Offset Area

2.1 Landuse

The Kokoda Offset Site is located in the Mandagery locality of the Central West Slopes of NSW, approximately 52 kilometres south-east of the Northparkes mine. The property is 350 hectare in size and is comprised of native grasslands to the north of the property with regrowth eucalypt woodland on the steeper slopes and ridges in the southern part of the property. Historically the property has been grazed by sheep and cattle but under the new Conservation Agreement with NPM and OEH, the property will remain free from domestic livestock grazing (Umwelt 2014).

2.2 Vegetation communities

Vegetation surveys undertaken by Umwelt (2014b) indicate there are ten different vegetation communities consisting of derived grasslands and a variety of different woodlands communities which vary according to soil type, topography and historical land practices (Table 2-1). The remaining 2.5ha is associated with farm infrastructure including farm dams and access tracks.

The Umwelt surveys indicated there are approximately 96 ha of Derived Native Grasslands (DNG) once thought to have been *Eucalyptus microcarpa* (Grey Box) Grassy Woodland which conform to the TSC Act listed *Inland Grey Box Woodland in the Riverina, NSW South Western Slopes, Cobar Peneplain, Nandewar and Brigalow Belt South Bioregions* EEC and the EPBC Act listed *Grey Box (Grassy Woodlands and Derived Native Grasslands of South-eastern Australia* EEC. As part of the BOMP these DNG areas will be regenerated to their original Grey Box Grassy woodland community (Umwelt 2014).

The remaining 15 ha area of DNG are thought to have been dominated by *Eucalyptus dwyeri* (Dwyer's Red Gum) – *E. microcarpa* (Grey Box) – *E. sideroxylon* (Mugga Ironbark) – *Callitris endlicheri* (Black Cypress Pine) community, and these will also be regenerated to the original woodland structure as part of the BOMP (Umwelt 2014).

There is a very small area (2.2 ha) of *E. albens* (White Box) Grassy Woodland which conforms to the TSC Act listed *E. albens* (White Box) – *E. melliodora* (Yellow Box) – *E. blakelyi* (Blakely's Red Gum) Woodland EEC and the EPBC Act listed *E. albens* (White Box) – *E. melliodora* (Yellow Box) – *E. blakelyi* (Blakely's Red Gum) Grassy Woodland and Derived Native Grassland CEEC. All areas of remnant woodland within the Kokoda Offset Area will be managed to improve wildlife habitat and biodiversity outcomes (Umwelt 2014). The distribution of the various vegetation communities as mapped by Umwelt (2014) is provided in Figure 2-1.

Table 2-1. Vegetation communities occurring at the Kokoda Offset Area (Umwelt 2014b).

Vegetation Community	TSC Act Status	EPBC Act Status	Vegetation within Kokoda Offset Site (ha)
Grey Box Grassy Woodland	EEC	EEC	13
Grey Box Grassy DNG	EEC	EEC	96
White Box Grassy Woodland	EEC	CEEC	2.2
Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress Pine Forest			150
Rocky Rise Shrubby Woodland			26
Grey Box – Ironbark Woodland			25

Vegetation Community	TSC Act Status	EPBC Act Status	Vegetation within Kokoda Offset Site (ha)
Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress Pine DNG			15
Dwyer's Red Gum Creekline Woodland			9.4
Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress Pine Woodland Low Quality			8.6
Mugga Ironbark Woodland			1.9
Farm Tracks and Dams – Disturbed Land			2.5
Total			350

2.3 Threatened Species

2.3.1 Flora

No threatened flora species were recorded by Umwelt (2014) in the Kokoda Offset Area.

2.3.2 Fauna

Twelve threatened fauna species were recorded in the Kokoda Offset Site by Umwelt (2014b) and are listed in Table 2-2. The grey-crowned babbler, brown treecreeper and the superb parrot were the most commonly recorded threatened fauna species across the Kokoda Offset Area (Umwelt 2014b). The grey-crowned babbler and the brown treecreeper are both sedentary birds and will utilise the site across all seasons whereas the superb parrot is a seasonally nomadic species which will largely utilise the Kokoda Offset Site for foraging during spring and summer. Given the array of varied habitats within the site, there is a high potential that other threatened fauna species may occur within the Kokoda Offset Area.

Table 2-2. Threatened fauna species recorded at Kokoda (Umwelt 2014b)

Common Name	Scientific Name	Status		No. of Individuals/ Locations
		TSC Act	EPBC Act	
Glossy black-cockatoo	*Calyptorhynchus lathami*	V		2/1
Superb parrot	*Polytelis swainsonii*	V	V	162/23
Little lorikeet	*Glossopsitta pusilla*	V		25/2
Brown treecreeper (eastern subspecies)	*Climacteris picumnus victoriae*	V		18/10
Speckled warbler	*Chthonicola saggitatus*	V		13/9
Hooded robin (south-eastern form)	*Melanodryas cucullata cucullata*	V		1/1
Grey-crowned babbler (eastern subspecies)	*Pomatostomus temporalis temporalis*	V		95/20
Varied sittella	*Daphoenositta chrysoptera*	V		2/2
Diamond firetail	*Stagonopleura guttata*	V		8/3
Eastern bentwing-bat	*Miniopterus schreibersii oceanensis*	V		-/2
Little pied bat	*Chalinolobus picatus*	V		-/2
Yellow-bellied sheath tail-bat	*Saccolaimus flaviventris*	V		-/2

2.4 Management zones

The KOA has been further delineated according the condition of the vegetation and their recovery potential. A conceptual plan of the different management areas according to potential regenerative capacity and active revegetation management requirements is given in Figure 2-2 (Umwelt 2014a). Management zones 1 to 5 are DNG communities that occur on the lower slopes in the northern section of the property. These areas will each receive varying levels of management. The long term goal for each of these zones, including zone 6, is to return them to their former woodland community structure.

Table 2-3. Management Zones at the Kokoda Offset Area. (Umwelt 2014a).

Management Zone	Vegetation Type	Objective	Total Area (ha)
1	Grey Box Grassy Woodland – DNG – Active Revegetation	Restore to woodland	36.3
2	Grey Box Grassy Woodland – DNG – Potential Regeneration	Restore to woodland	21.3
3	Grey Box Grassy Woodland – DNG – Natural Regeneration	Restore to woodland	38.4
4	Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress Pine DNG Active Regeneration	Restore to woodland	1
5	Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress Pine DNG Natural Regeneration	Restore to woodland	13.8
6	Disturbed – Potential Regeneration	Restore to woodland	1.3
7	All Remnant Woodland and Forest	Conserve and maintain	238
		Total	**350**

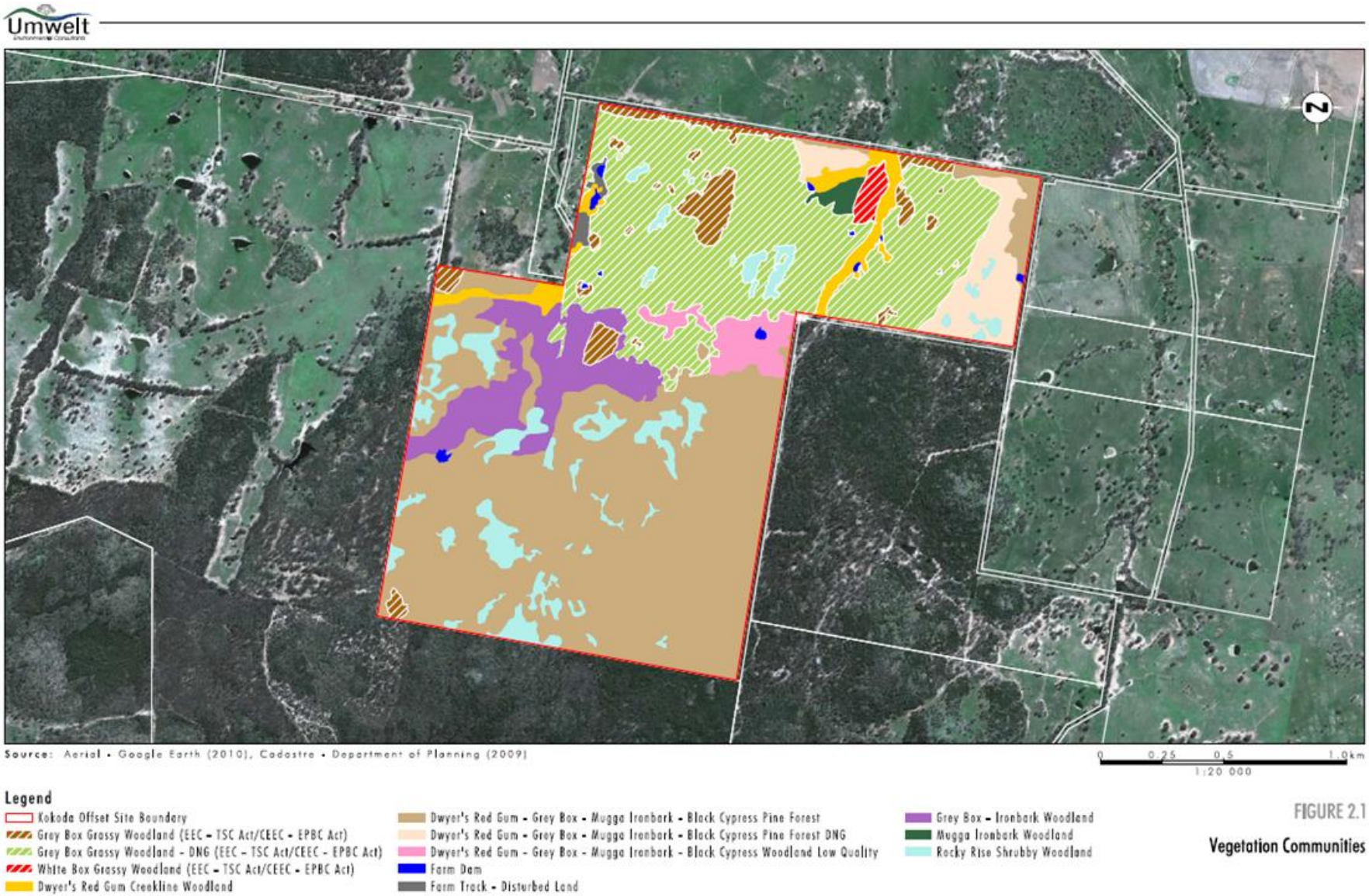


Figure 2-1. Distribution of the various vegetation communities within the Kokoda Offset Area (Umwelt 2014a)

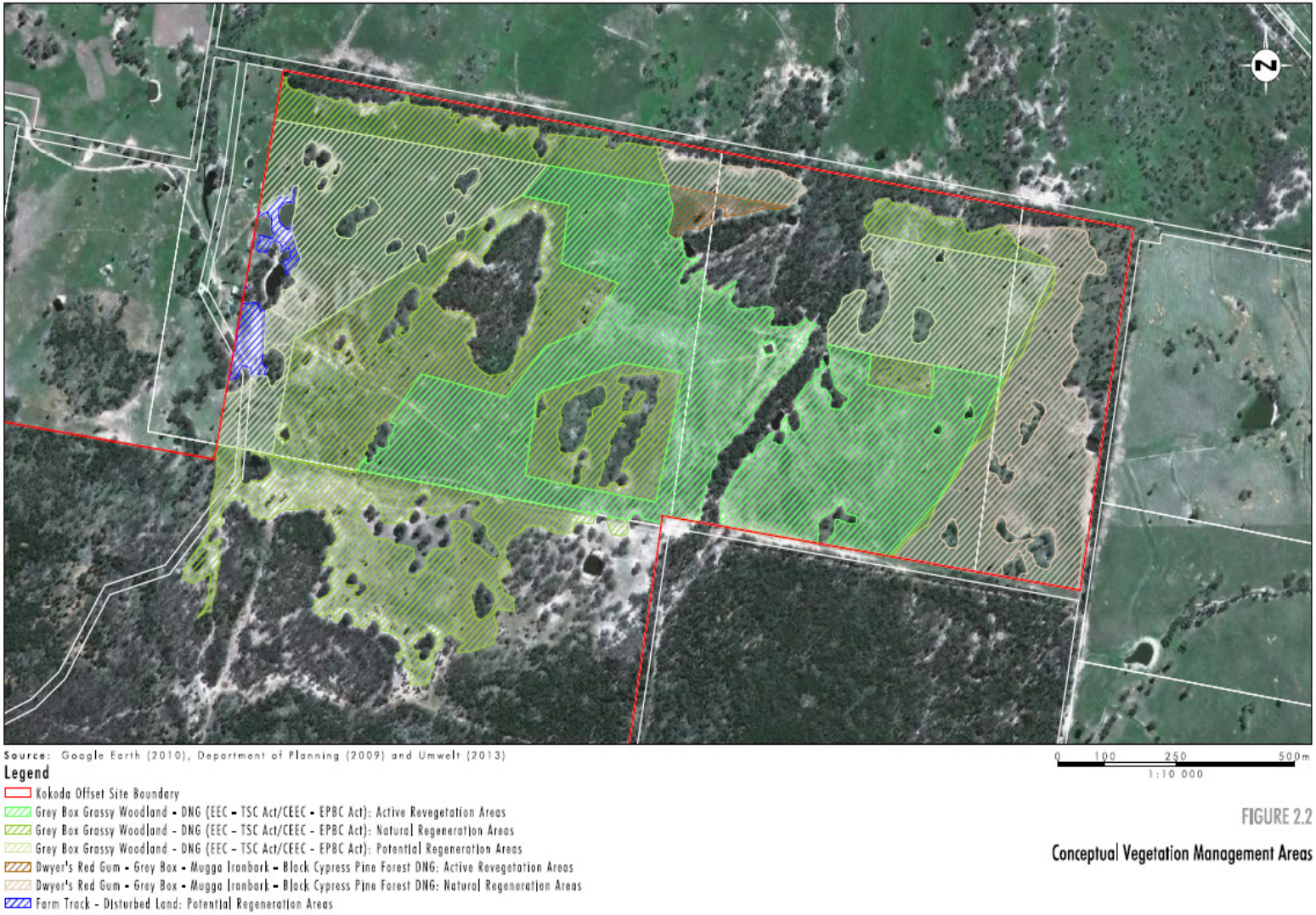


Figure 2-2. Conceptual plan of the different management areas according to potential regenerative capacity and active revegetation management requirements (Umwelt 2014a).

2.5 Biodiversity Management targets

There are a range of biodiversity management targets which will be required to be met as part of the approval conditions. These have been determined by Umwelt (2104a) as short, medium and long-term targets with these being provided below. Specific performance indicators and completion criteria will be used to track the recovery of the woodlands and effectiveness of the proposed management strategies as described in the BOMP.

2.5.1 Short-term objectives

The short term (3 year) biodiversity management targets for the management of the Kokoda Offset Site are to:

- establish signage throughout the Kokoda Offset Site;
- remove stock-grazing activities from the Kokoda Offset Site;
- establish a monitoring program to assess the success of ongoing management and improvement strategies, in particular focusing on the regeneration potential of Grey Box Grassy Woodland DNG areas; and
- commence establishment of Grey Box Grassy Woodland in areas of DNG through assisted natural regeneration principles;
    - include a range of flora species from each vegetation strata represented in the target community (such as trees, shrubs, and ground cover forbs and grasses), even if only as seedlings/juvenile plants initially, as determined through monitoring of selected reference sites in the target community within the Kokoda Offset Site;
    - contain a flora species assemblage trending towards the target communities (i.e. Grey Box Grassy Woodland EEC or Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress Pine Forest) as determined through monitoring of selected reference sites in the target community within the Kokoda Offset Site;
    - support no more than 20 per cent foliage cover of perennial weed species (as a total of all strata, based on monitoring plot data); and
    - support no more than 20 per cent bare ground as part of the ground layer.
- effectively manage weed and pest species;
- implement weed monitoring at 6, 12, 18 and 24 months to assess if weed species are out competing native species once grazing pressure has been removed. Adaptive management practices will be adopted to control weed species as necessary;
- from year 2 onwards, initiate active revegetation methods to establish Grey Box Grassy Woodland in areas of low recovery potential DNG as deemed required through the results of monitoring in years 1 and 2;
- manage the remnant woodland areas to maintain similar or increasing flora and fauna species diversity;
- establish an appropriate long-term conservation mechanism; and
- demonstrate that accurate records are being maintained substantiating all activities and monitoring associated with the BOMP.

2.5.2 Medium-term objectives

The preliminary medium term (6, 10 and 15 years) biodiversity management targets for the Kokoda Offset Site are to:

- effectively monitor, control and reduce weed and pest species populations;

- monitor and document collective trend towards an increase in native flora and fauna species diversity;
- monitor and document DNG areas trending toward woodland communities, containing natives species commensurate with those of the target woodland communities

2.5.3 Long-term objectives

The preliminary long term (i.e. 20 years) biodiversity management targets for the Kokoda Offset Site are to:

- effectively control and reduce weed and pest species populations;
- increase the overall native flora and fauna species diversity compared to conditions during baseline assessments;
- improve the habitat values of the remnant woodland communities in the Kokoda Offset Site compared to conditions during baseline assessments;
- successfully establish an additional 96 hectares of Grey Box Grassy Woodland EEC in areas of existing DNG and demonstrate that the regenerated communities are representative of local reference sites in remnant Grey Box Grassy Woodland EEC.
- regenerate/revegetate management areas contain a minimum of 50 per cent of the native flora species diversity recorded from reference sites in the target community within the Kokoda Offset Site;
- regenerate/revegetate management areas support a vegetation structure that is similar to that recorded for reference sites in the target community within the Kokoda Offset Site;
- demonstrate that second generation trees are present within regeneration/revegetation areas;
- identify that more than 75 per cent of trees are healthy and growing as indicated by long term monitoring;
- ensure that weed species do not dominate any vegetation stratum (i.e. weed species comprise less than 10 per cent of any vegetation stratum);
- ongoing monitoring of soil stability, including implementation of erosion and sediment controls to management significant erosions concerns, as required; and
- regenerate/revegetate areas linked to existing woodland remnants to establish vegetation corridors within the broader landscape and manage excessive edge effects.

2.6 Ecological Monitoring Program

The Kokoda Offset Area will be subject to an ongoing monitoring program to measure the success of management and restoration strategies in meeting the approval conditions, management targets and performance indicators in a timely manner. The monitoring program will incorporate annual systematic monitoring as well as biannual (twice yearly) inspections as indicated in the BOMP (Umwelt 2014a). Primary monitoring objectives as indicated in the BOMP (Umwelt 2014a) include;

- identify any potential loss of biodiversity values over the entire Kokoda Offset Site;
- document the ecological characteristics of remnant woodland vegetation to establish a baseline for developing accurate closure criteria for the regeneration of DNG;
- assess the recovery of DNG areas;
- assess and map the presence of threats such as significant populations of pest fauna species or weed infestations; and
- identify the need for additional or corrective management measures to achieve the performance indicators and completion criteria.

2.7 Ecological monitoring timing and schedules

It has been proposed that the ecological monitoring will be annual for the first five years, then every three years for the following 15 years. Monitoring within the DNG areas will be required every six months in the early recovery/establishment phases (Umwelt 2014a).

The first ecological monitoring survey has been completed within six months of the implementation of the BOMP (Umwelt 2014b). Where possible subsequent monitoring events should occur in the same season and preferentially ecological monitoring surveys should be undertaken in spring or autumn as there tends to be a lower diversity of species detectable in the more extreme weather conditions of winter and summer seasons (except where specific seasons are required for targeted bird surveys).

3 Ecological monitoring methodology

It has been proposed in the BOMP that the monitoring program should incorporate techniques that:

- are relatively simple to measure, can be replicated with limited subjectivity, and are reproducible;
- adopt the SMART principles (specific, measurable, achievable, realistic and timely);
- are targeted towards recording information that provides a good indication of the status of the biodiversity values of the Kokoda Offset Site;
- allow for floristic composition and structure to be monitored over time using basic statistical analysis;
- allow for comparison to reference (control) sites; and
- are cost effective.

3.1 2014 surveys

In 2014 Umwelt implemented the first ecological surveys and established 16, 20 x 20m monitoring sites across the range of vegetation communities and management zones at the KOA. The results of these surveys are provided in Umwelt (2014b).

3.2 2015 vegetation assessments

3.2.1 Conceptual approach

In 2015, DnA Environmental was engaged to review the monitoring program and establish a comprehensive range of ecological data which will fulfil the monitoring and reporting requirements of the BOMP.

The monitoring programs aim to establish clearly defined, repeatable and consistent methodologies for monitoring changes in various aspects of ecosystem function, succession and long-term sustainability. Part of this process includes:

- Establishing a range of relevant reference sites to compare and track the progress and inherent ecosystem function of rehabilitation areas;
- Selecting a range of suitable reference sites that reflect the desired final land use, biodiversity targets, historical disturbances and local community expectations; and
- Undertaking a monitoring program that provides simple but informative and reliable information that indicates positive recovery trends or rapid detection of rehabilitation failure.

At Kokoda, a range of Key Performance Indicators (KPI's) were quantified by data obtained from replicated reference sites which were representative of the Grey Box Woodland EEC and Dwyer's Red Gum woodland. All ecological performance indicators are quantified by range values measured from these reference sites which form both an *upper* and *lower* KPI targets. The same ecological performance indicators are also measured in the revegetation/rehabilitation sites and these should equal or exceed these values, or at least demonstrate an increasing trend.

These Key Performance Indicators have been further separated into "*Primary performance indicators*" and "*Secondary performance indicators"*. Primary performance indicators are those chosen as essential completion criteria targets, and have been identified as those that will satisfy requirements identified within the BOMP. The range values of each ecological performance indicator are adapted annually to reflect seasonal conditions and disturbance events. Secondary performance indicators are those that

would be desirable to achieve but do not necessarily have a direct affect on consent conditions or meeting biodiversity targets.

The monitoring methodology adopted at Kokoda is consistent with that used in the NPM rehabilitation monitoring program (DnA Environmental 2009 – 2014) and the Estcourt Offset Area ecological monitoring program (DnA Environmental 2010 - 2014). The annual vegetation monitoring will aim to be undertaken during spring where possible and this year was undertaken from 28 September – 1st October.

4 Vegetation monitoring methodology

The methodology includes a combination of Landscape Function Analyses (CSIRO Tongway & Hindley 1996), accredited soil analyses and various measurements of ecosystem diversity and habitat values based on and adapted from the Biometric methodology (Gibbons 2002, Gibbons *et al* 2008a, 2008b) and these have been described in more detail below.

4.1 Landscape Function Analyses

The LFA is a methodology used to assess key indicators of ecosystem function including landscape organisation and soil surface condition as measure of how well the landscape retains and uses vital resources. It was developed by CSIRO scientists Tongway and Hindley (Tongway 1994, Tongway and Hindley 1995, 1996, 2003, 2004). The indicators used quantify the utilisation of the vital landscape resources of water, topsoil, organic matter and perennial vegetation in space and time. Additional information and data spreadsheets are freely available on the internet.

The LFA methodology collects data at two "nested" spatial scales.

1. At coarse scale, **landscape organisation** is characterised. Patches and interpatches, indicators of resource regulation, are mapped at the 0.5 to 100 m scale from a gradient-oriented transect (making sense of landscape heterogeneity); and
2. At fine scale, **soil surface assessment** (soil "quality") examines the status of surface processes at about the 1-m scale, with rapidly assessed indicators on the patches and interpatches identified at coarse scale.

At each scale, parameters are calculated that reflect several aspects of landscape function. In the first stage, we identify and record the patches and interpatches along a line oriented directly down slope. Sometimes there are several different types of each patch/interpatch which provides a measure of heterogeneity or "**landscape organisation**".

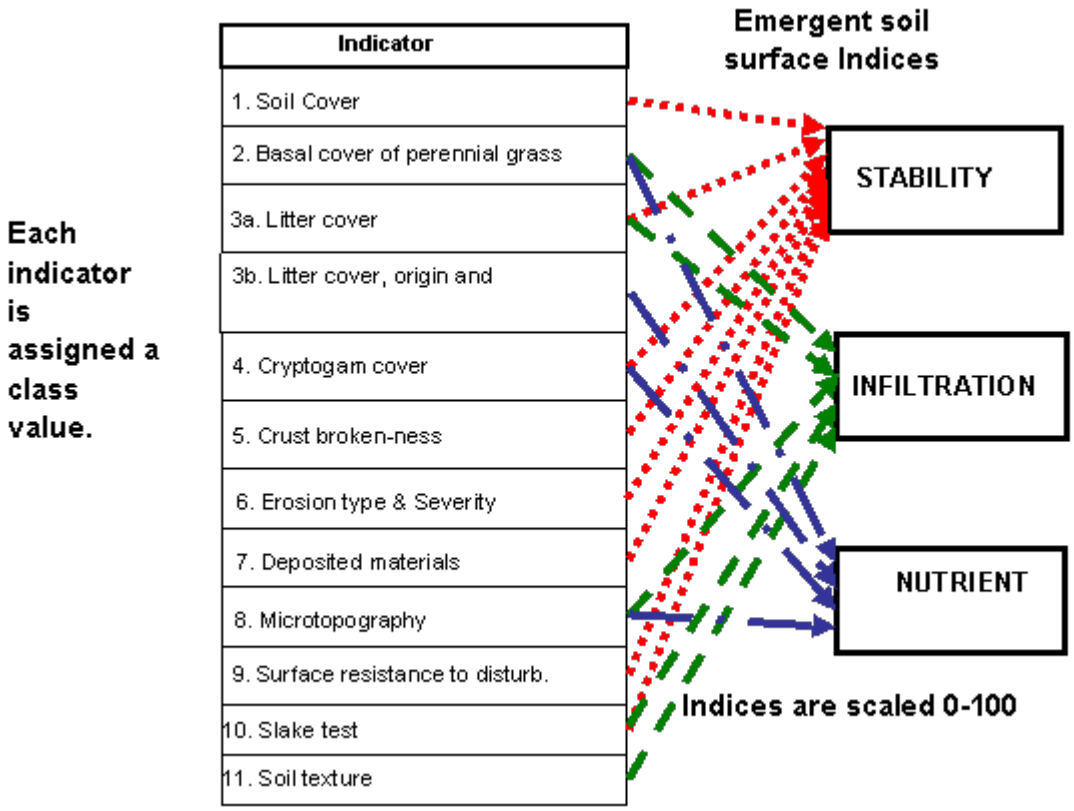
In the second stage, called "**soil surface condition" (SSC)** assessment, it is possible to assess and monitor soil quality using simple indicators including:

- Rain splash protection;
- Perennial vegetation cover;
- Litter;
    - Percent litter cover;
    - Origin of the litter;
    - Extent of decomposition;
- Cryptogam cover;
- Crust Brokenness;
- Soil Erosion Type and Severity;
- Deposited Materials;
- Soil Surface Roughness;
- Surface Nature (resistance to disturbance);
- Slake Test; and
- Soil Surface Texture.

These 11 features are compiled and calculated into three indices of soil quality:

1. **Stability** (that is, resistance to accelerated erosion),
2. **Infiltration** (the rate soil absorbs water) and

3. **Nutrient Cycling** (the way plant litter and roots decompose and become available for use by other plants).



4.2 Soil analyses

Soil samples are undertaken using standard soil sampling techniques within the monitoring quadrat. At least 12 samples are taken at each site and bulked together. Soil samples are sent to Southern Cross University at their National Association of Testing Authorities (NATA) accredited laboratory for analysis. Soil analysis consist of assessing the parameters, pH, Electrical Conductivity (EC), Available Calcium (Ca), Magnesium (Mg), Potassium (K), Nitrate Nitrogen (N), Sulphur (S), Organic Matter (OM), exchangeable Sodium (Na), Ca, Mg, K, Hydrogen (H), Cation Exchange Capacity, available and extractable Phosphorus (P), micronutrients Zinc (Zn), Manganese (Mn), Iron (Fe), Copper (Cu), Boron (B), Silicon (Si), Aluminium (Al), Molybdenum (Mo), Cobalt (Co) and Selenium (Se)) and total Carbon. The heavy metals including Cadmium (Cd), Lead (Pb), Arsenic (As), Chromium (Cr), Nickel (Ni), Mercury (Hg) and Silver (Ag) are also tested.

A report with analysis and desirable levels recommended in the agricultural industry is provided by the laboratory. Exchangeable Sodium Percentages were calculated as a measure of sodicity or dispersion.

4.3 Monitoring structural diversity, floristic and other biodiversity attributes

In addition to LFA, assessments of various biodiversity components must also be made to monitor changes in particular plants and groups of plants through the various successional phases and to document and/or identify critical changes or management actions required.

Some simple and rapid procedures for making these assessments were developed by CSIRO scientists (Gibbons 2002, Gibbons *et al* 2008), and were developed for assessment habitat quality across a range of vegetation types in the southern NSW Murray-Darling Basin. Some adaptations have been made to reduce monitoring effort where possible, and to incorporate aspects of newly formed revegetation sites or sites in the early stages of recovery. For example some habitat features such as the detailed measuring and assessment of decomposition of the logs and branches has been omitted, whilst the understorey assessment included planted tubestock, direct seeding as well as natural recruitment and naturally occurring shrubs.

The rapid ecological assessment provides quantitative data that measures changes in:

- Floristic diversity including species area curves and growth forms;
- Ground cover diversity and abundance;
- Vegetation structure and habitat characteristics (including ground cover, cryptogams, logs, rocks, litter, projected foliage cover at various height increments);
- Understorey density and growth (including established shrubs, direct seeding and tubestock plantings and tree regeneration);
- Overstorey characteristics including tree density, health and survival; and
- Other habitat attributes such as the presence of hollows, mistletoe and the production of buds, flowers and fruit.

Permanent transects and photo-points are established to record changes in these attributes over time.

4.3.1 The permanent monitoring quadrats

The permanent monitoring quadrats are a standard 20 x 20m. The 20m LFA transect must face down slope and this same transect has also used as the vegetation transect, in most cases. In all but one site (DWood1) the left side of the monitoring plot forms both the LFA and vegetation transect with the remaining plot occurring to the right.

Four marker pegs were used to mark out the permanent transect position (using Umwelt marker posts where possible) and these are situated at each corner of the 20 x 20m square plot. GPS readings are taken to ensure quadrats can be relocated over time. Permanent photo-points are also established at various marker pegs of the quadrat to record changes in these attributes over time.

The dimensions and orientation of the 20 x 20m monitoring quadrats is provided in Figure 4-1. Total floristic diversity is recorded in systematic increments within the monitoring plot, beginning at the start of the LFA/veg transect in the 1 x 1m sub-plot as indicated in Figure 4-2. Total shrubs counts are made within the shaded 10 x 20 m subplot as shown in Figure 4-2. Mature tree counts and condition variables are made within the entire 20 x 20m quadrat.

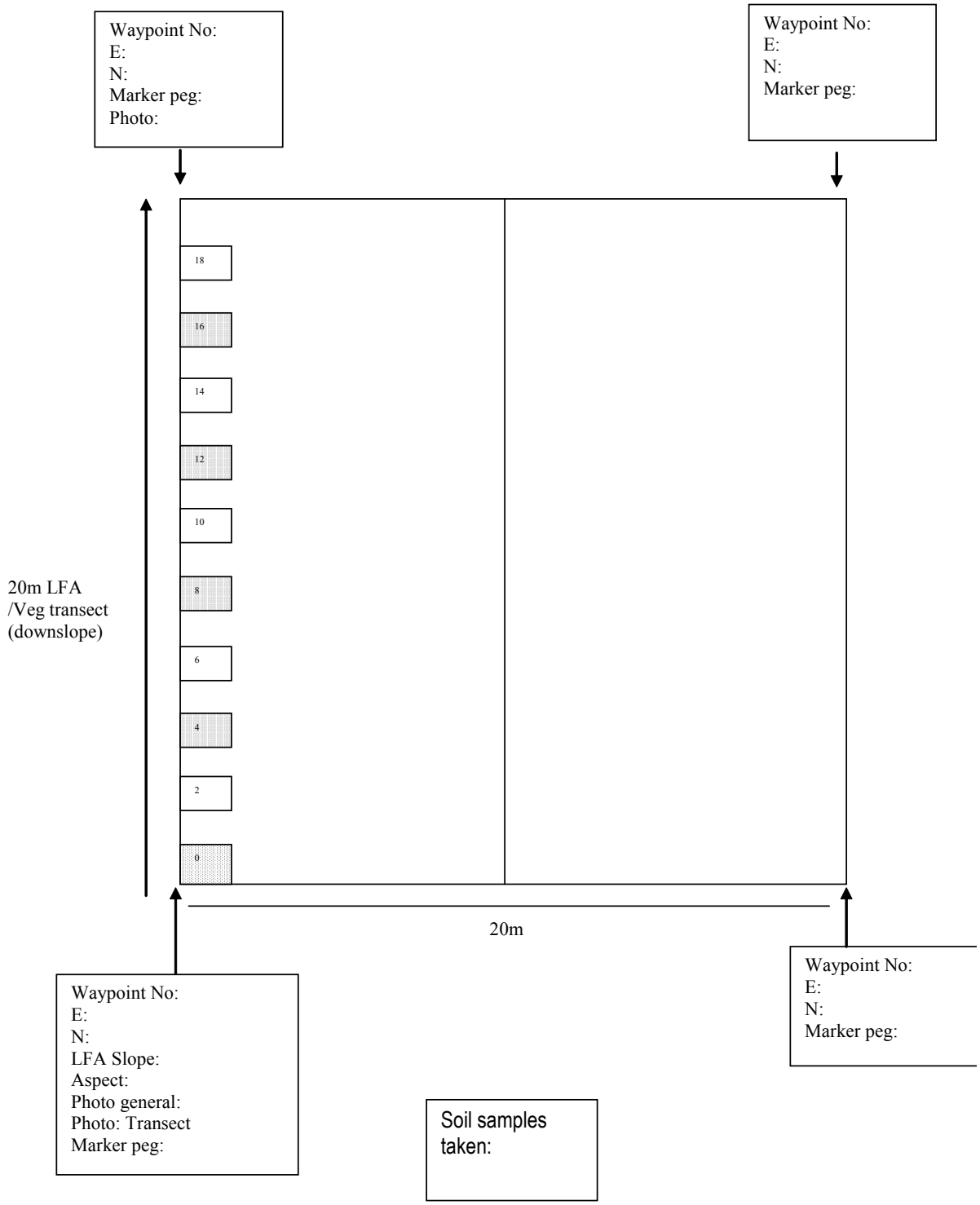


Figure 4-1. Dimensions and orientation of the 20 x 20m monitoring quadrats.

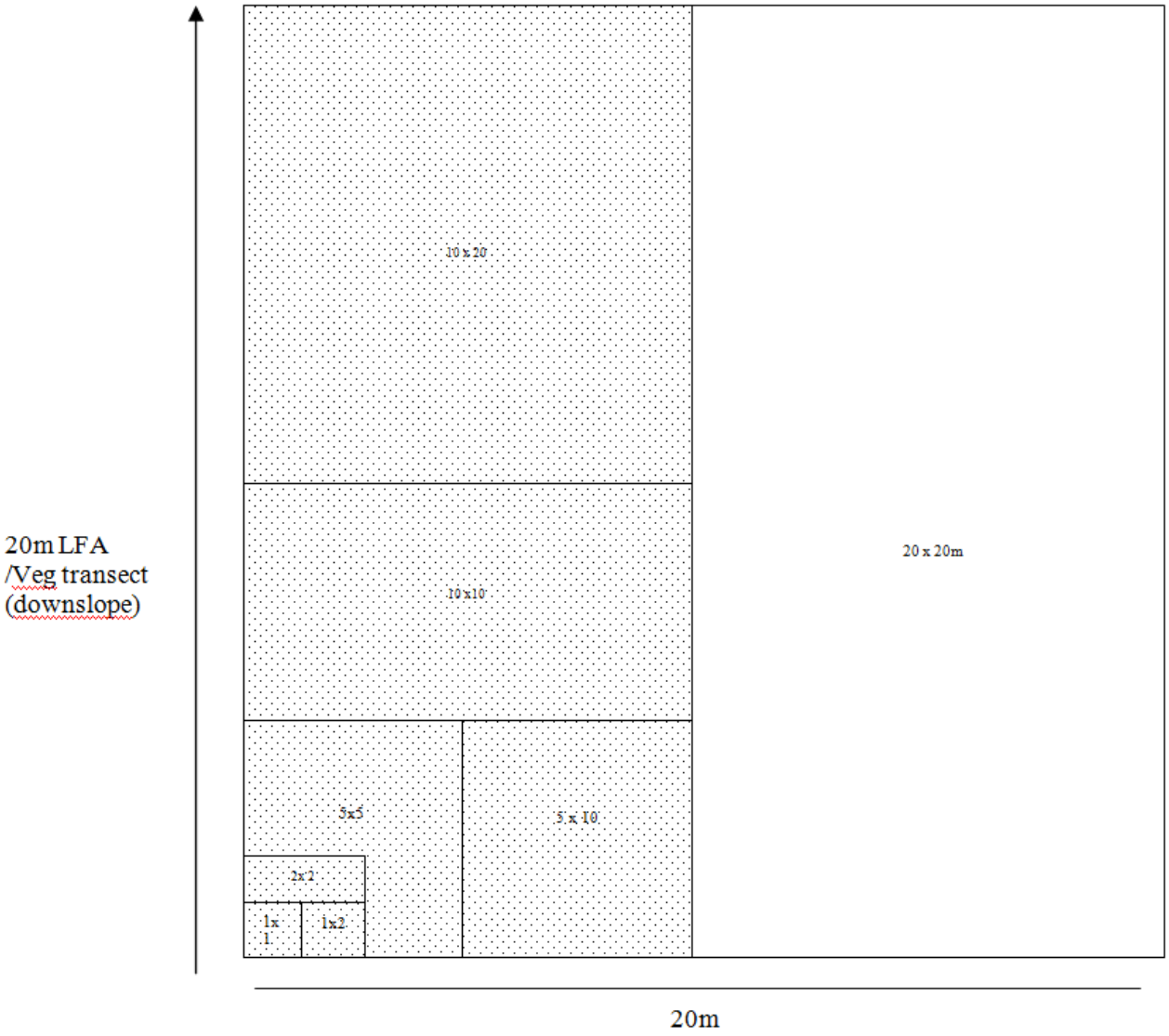


Figure 4-2. Total floristic diversity are recorded in systematic increments within the monitoring plot, beginning at the start of the LFA/veg transect. Total shrubs counts are made within the shaded 10 x 20 m subplot.

4.3.1.1 Information recorded for floristic assessment

The procedure for quantifying floristic diversity and cover abundance is provided in Table 4-1 and Table 4-2.

Table 4-1. Method for collecting data about floristic diversity

Variable	How to record it
New species	Record name of any new species located in the following series of subquadrats starting on the left hand side of the larger 20x20m monitoring quadrat 1x1, 1x2, 2x2, 5x5, 10x10, 10x20, 20x20. This will provide cumulative species diversity
ID	Take a specimen for later identification if required
No species	Number of native and exotic species and growth form
Growth Form	Growth forms as listed on field sheet

Table 4-2. Method for collecting data about cover abundance

Variable	How to record it
Cover abundance	Record species name and allocate a cover abundance score using Braun-blanquet scale within 1m^2 every 4m along the permanent 20m transect
ID	Take a specimen for later identification if required

4.3.1.2 Information recorded for community structure

Variables to measure per 1m^2 at 2m intervals along the 20m line transect are described in Table 4-3.

Table 4-3. Method for collecting data about the structure of the vegetation community

Variable		How to record it
Litter	**NOTE:** these features should add up to 100% i.e. all ground cover, include bare, ground or litter or grasses beneath shrubs, trees.	% cover of litter (<5cm diameter) estimated at each of the 1m lengths every 2m along the permanent 20m transect
Annual Plants		% cover of live annual plants estimated at each of the 1m lengths every 5m along the permanent 50m transect
Cryptogam		% cover estimated at each of the 1m lengths every 2m along the permanent 20m transect – exclude any cryptogam cover that occurs on rock or log (rock and log defined as ≥5cm across)
Bare ground		% cover (including rock <5cm across, but not including cryptogam) estimated at each of the 1m lengths every 2m along the permanent 20m transect
Rock		% cover of rock ≥5cm across estimated at each of the 1m lengths every 2m along the permanent 20m transect
Log		% cover of logs ≥5cm diameter estimated at each of the 1m lengths every 2m along the permanent 20m transect
0-0.5m perennial plant		Projected foliage cover of live perennial plants estimated in vertical stratum from 0-0.5m (regardless of life-form or whether native or introduced) estimated at each of the 1m lengths every 2m along the permanent 20m transect
0.5-2m perennial plant		Projected foliage cover estimated in each vertical stratum from 0.5-2m (regardless of life-form or whether native or introduced) estimated at each of the 1m lengths every 2m along the permanent 20m transect
2-4m perennial plant		Projected foliage cover estimated in each vertical stratum from 2-4m (regardless of life-form or whether native or introduced) estimated at each of the 1m lengths every 2m along the permanent 20m transect
4-6m perennial plant		Projected foliage cover estimated in each vertical stratum 4-6m (regardless of life-form or whether native or introduced) estimated at each of the 1m lengths every 2m along the permanent 20m transect
>6m perennial plant		For overstorey (>6m), estimate projected foliage cover immediately above each of the 1m lengths every 2m along the permanent 20m transect

4.3.1.3 Established shrubs and juvenile trees

Total count of understorey species including tubestock, direct seeding and tree regeneration (<5 cm dbh) is undertaken in the 10 x 20m quadrat as indicated in Figure 4-2 and is recorded as shown in Table 4-4. A tally of individuals representing the different species and their height class category is recorded as the quadrat is systematically searched. In areas with a high density of individuals this process may be more reliably undertaken several times, targeting different species each time. In particularly shrubby areas, smaller representative subplots (eg. 5x5m) may be used and the density of individuals calculated to equate to the total required area (i.e. 0.04ha).

Over time, the number of individuals in each height class should move across the height class categories. Once individuals have reached >5cm dbh, they are then recorded in the tree density and community health data sheets. A sustainable ecosystem should also contain new recruitments, and therefore indicated by the number of individuals recorded in lower height classes.

Table 4-4. Method for obtaining data about understorey diversity, height and recruitment

Species	0 - 0.5m	0.5 - 1.0 m	1.0 - 1.5 m	1.5 – 2.0 m	>2.0 m	Total

4.3.1.4 Information recorded for tree density and health condition

Total number of individuals of trees (>5cm dbh) and their health condition are recorded in the 20 x 20m monitoring quadrat (Table 4-5). Other features such as fire scars, tree hollows or presence of mistletoe are also recorded.

Table 4-5. Method for recording data about overstorey diversity, density, health condition and other habitat features.

Variable	How to record it
Species ID	Record species name
DBH	Record diameter at breast height if >5cm
Dead	Count of dead trees in each dbh class of each species in 50mx20m plot
Living	Count of living trees in each dbh class of each species in 50mx20m plot
Hollows	Count of trees with hollows (>5cm entrance) in each dbh class of each species in 50mx20m plot
Mistletoe	Count of trees with mistletoe in each dbh class of each species in 50mx20m plot
Fire scar	Count of trees with fire scars in each dbh class of each species in 50mx20m plot
Dieback	Count of mature trees with dieback in category class 1 (<30% of estimated original crown is missing due to dieback); class 2 (30-70% of estimated original crown is missing due to dieback) or class 3 (>70% of estimated original crown is missing due to dieback) in 20mx20m

5 Ecological monitoring sites

A preliminary evaluation of the location of the sites established by Umwelt in 2014 via digital mapping suggested that not all main vegetation communities occurring and mapped at Kokoda by Umwelt were represented. In addition, there appeared to be more sites in the cleared DNGs than necessary to fulfil minimum quadrat numbers according to DEC guidelines (2012). Subsequently sites established by Umwelt in 2014 were retained where possible, however in some cases the sites were not required, were not in suitable condition for use as a reference site or new sites were established in unrepresented vegetation communities.

Subsequently, 17 permanent monitoring sites were established in 2015 which included three Grey Box Grassy woodland reference sites and five DNG sites which will be regenerated back to Grey Box Grassy woodland (Table 5-1). There were three Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress woodland reference sites and three DNG which will be regenerated back to the Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress woodland community.

There were also one site established in each of represented examples of White Box Grassy Woodland CEEC, Grey Box – Ironbark woodland and Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress Pine Forest which was mapped as low quality woodland. The remaining two vegetation communities were rather patchy and/or narrow linear corridors and made an overall relatively minor contribution in terms of overall biodiversity significance or influence on biodiversity targets that would not already be reflected within the existing range of monitoring sites.

Table 5-1. The numbers of permanent monitoring sites established in each of the vegetation communities as compared to those mapped by Umwelt and their 2014 surveys.

Community type (as per Umwelt 2014)	Size (ha)	Site description	No sites established by Umwelt 2014	No. sites established by DnA 2015
Grey Box Grassy woodland DNG (EEC)	96	Probable active rehabilitation area	6	5
Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress Pine DNG	15	Probable active rehabilitation area	4	3
Grey Box Grassy woodland EEC	13	reference site	3	3
Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress Pine Forest	150	reference site	3	3
Dwyer's Red Gum – Grey Box – Mugga Ironbark – Black Cypress Pine Forest	8.6	Low quality	0	1
White Box Grassy Woodland CEEC	2.2	CEEC	0	1
Grey Box – Ironbark woodland	25	Non EEC	0	1
Dwyer's Red Gum creek-line woodland	9.4	Non EEC – narrow linear	0	0
Rocky Rise Shrubby woodland	26	Non EEC – Numerous small pockets	0	0
Total No monitoring Sites			**16**	**17**

6 Rainfall

Total annual rainfalls recorded at NPM (2009-2011) and the Parkes Airport (2012-2015) compared to the long-term annual averages recorded at the Parkes Airport are shown in Figure 6-1. Prior to 2010 drought conditions were experienced across most of the state which had a deleterious effect on the native vegetation with the prolonged dry conditions resulting in increased total grazing pressure and further degradation of the environment. In 2010 above average rainfall was received across much of the state and provided excellent growing conditions during spring and summer of 2011 which also initiated recruitment events for numerous plant species but the remainder of 2011 however remained relatively dry. In March 2012 flood conditions were experienced and these were widespread across much of eastern Australia (BoM 2015).

Since March 2012 conditions have been very dry with rainfall often well below the monthly averages with some exceptions occurring June 2013 which were followed by particularly hot dry and unseasonal weather conditions during the spring - summer period of 2013 – 2014. Relief from these conditions came in January and March 2014 however with the exception of above average rainfall being recorded in June, monthly averages during the spring period were very low and these remained low until December 2014 (Figure 6-2).

Following the December rainfall, it continued to be very hot and dry over the summer and autumn periods with little rainfall being recorded with the exception of 87.6mm being recorded in April. July and August 2015 also received above average rainfall and while rainfall was limited in September and October, which provided enough soil moisture to stimulate a flush of germination and sustain good plants growth

Subsequently the extended periods of below average rainfall over the past few years in combination with increased grazing pressure have likely to have a profound effect on the diversity, abundance and composition of the monitoring sites. These adverse conditions have been further compounded by the increased levels of grazing and disturbances associated with domestic livestock (sheep) residing on Kokoda particularly, with high levels of degradation being evident especially within patches of woodland situated within or closest to the cleared grazing paddocks.

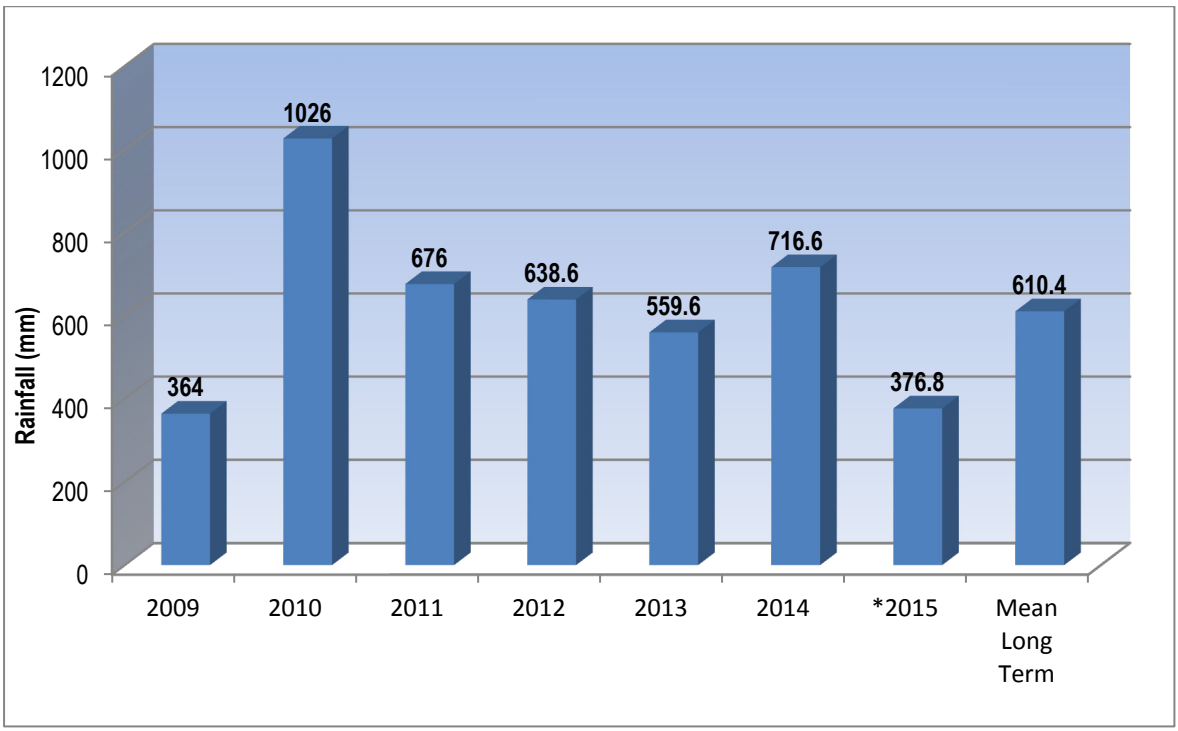


Figure 6-1. Annual rainfall recorded at Parkes Airport 2009 - October 2015 compared to long-term mean annual rainfall.

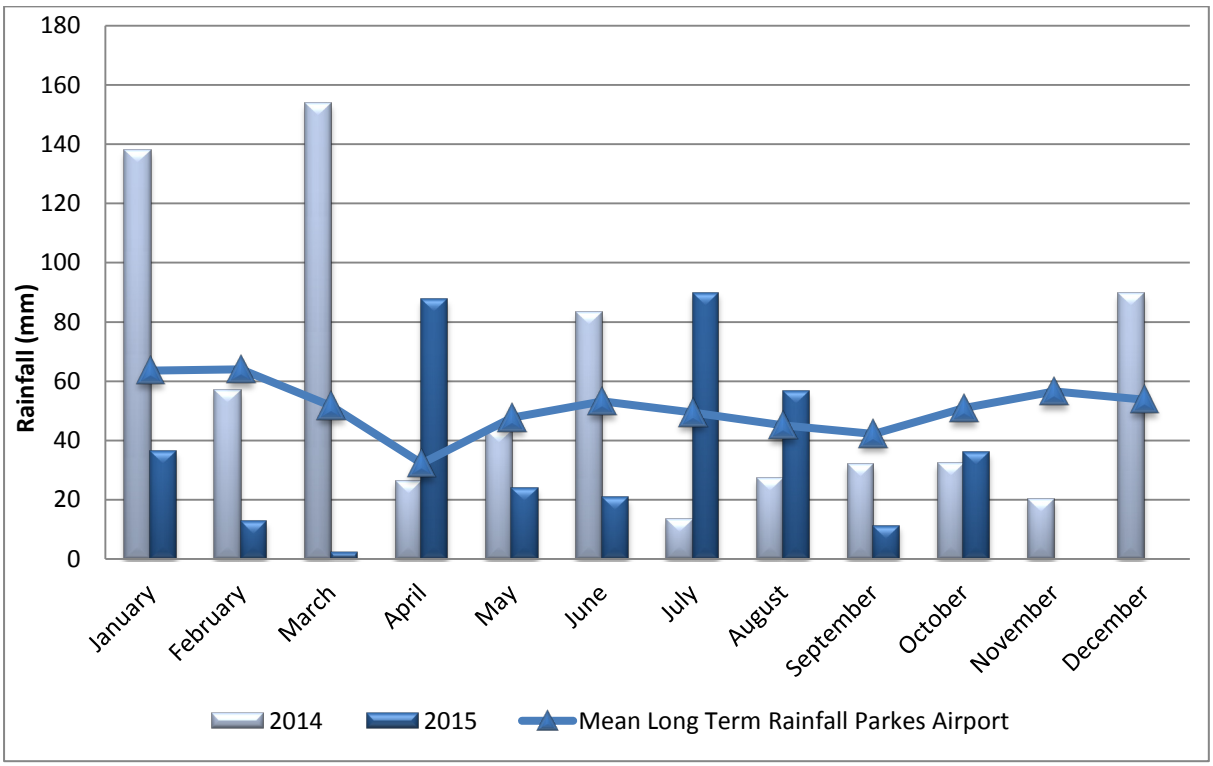


Figure 6-2. Monthly rainfall recorded at the Parkes Airport AWS from January 2014 to October 2015 compared to the long term monthly averages recorded at Parkes Airport AWS. (BoM 2015)

7 Site descriptions and locations

GPS co-ordinates (GDA94), aspects and slopes of the ecological monitoring sites established at Kokoda in 2015 are provided in Table 7-1. The map showing the locations of the monitoring sites is shown in Figure 7-1.

Table 7-1. GPS co-ordinates, aspects and slopes of the offset monitoring sites (GDA94).

Site Reference	LFA/Veg transect Start	LFA/Veg transect Finish	Slope (°)	Bearing (°)	Right bottom marker peg	Right top marker peg
GBReveg1	55635984 6318463	55635965 6318468	5	270 W	55635991 6318478	55635971 6318484
GBReveg2	55636009 6317740	55635990 6317742	4	269 W	55636017 6317758	55635996 6317761
GBReveg3	55636556 6318096	55636575 6318102	3	53 NE	55636563 6318075	55636582 6318083
GBReveg4	55636934 6318008	55636912 6318012	4	270 W	55636939 6318026	55636919 6318031
GBReveg5	55637056 6318287	55637041 6318301	3	303 NW	55637070 6318307	55637057 6318314
WBWood1	55636830 6318372	55636817 6318388	3	325 NW	55636845 6318378	55636836 6318396
IronWood1	55635137 6317458	55635133 6317479	4	337 NW	55635156 6317464	55635147 6317481
GBWood1	55636102 6318312	55636087 6318322	2	273 W	55636111 6318331	55636097 6318337
GBWood2	55635682 6317695	55635668 6317708	3	318 NW	55635696 6317700	55635685 6317714
GBWood3	55635075 6318036	55635090 6318037	1	90 E	55635071 6318019	55635086 6318075
DReveg1	55636561 6318557	55636576 6318552	4	98 E	55636551 6318539	55636571 6318533
DReveg2	55636612 6318473	55636632 6318469	3	90 E	55636610 6318453	55636631 6318447
DReveg3	55637301 6318051	55637319 6318049	4	93 E	55637296 6318031	55637316 6318029
DWoodLQ	55636185 6317769	55636200 6317769	3	82 E	55636179 6317749	55636198 6317751
***DWood1**	*55635679 6316724	*55635661 6316733	4	290 NW	*55635668 6316707	*55635652 6316715
DWood2	55636043 6316811	55636059 6316804	3	95 E	55636035 6316793	55636050 6316788
DWood3	55636166 6317342	55636176 6317357	3	27 NE	55636175 6317329	55636186 6317344

*NB: Transect along right edge, site flips to the left

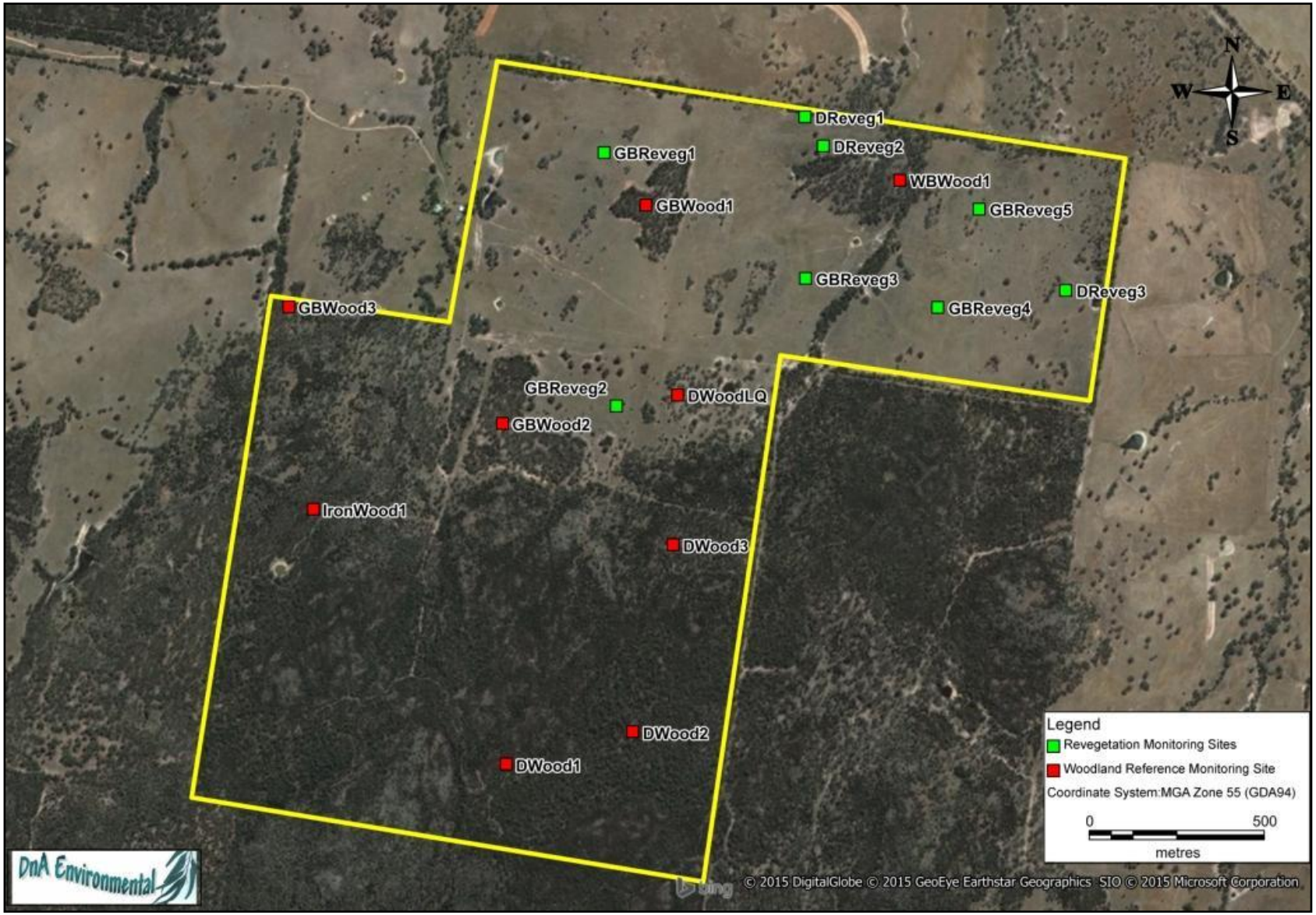
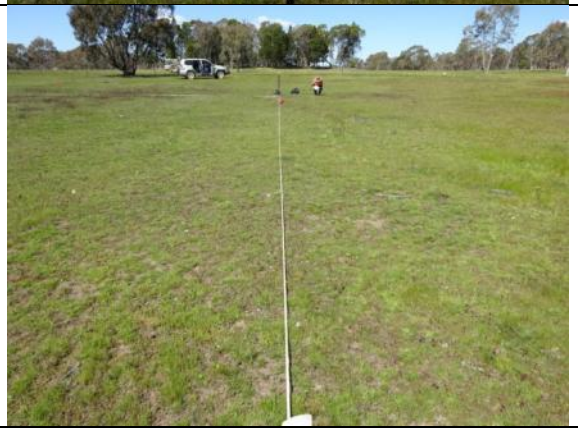


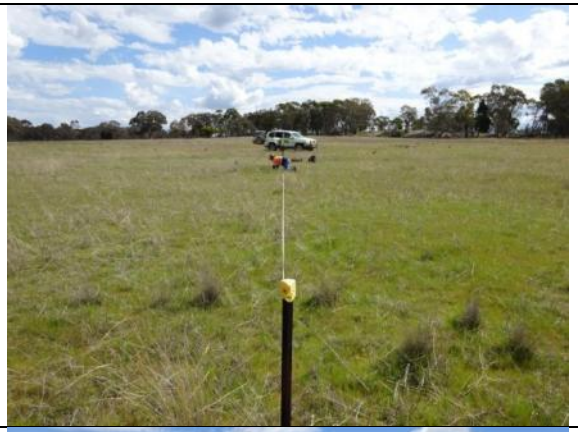
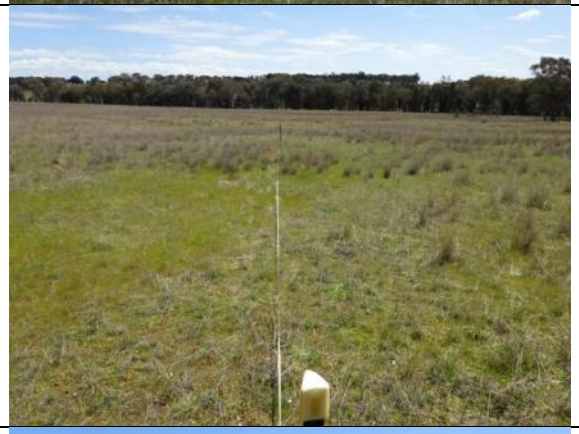
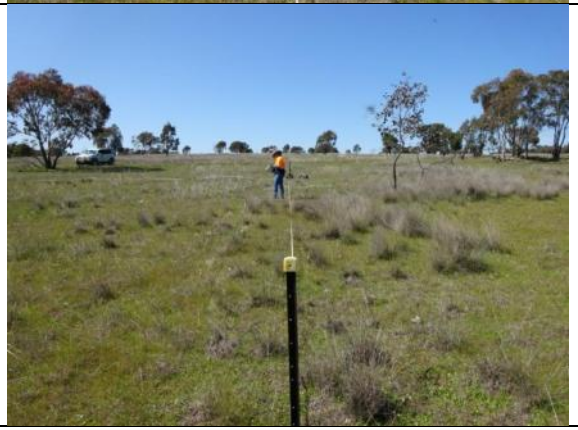
Figure 7-1. Map showing the location of the ecological monitoring sites at Kokoda 2015.

7.1 Grey Box Woodland monitoring sites

General descriptions of the Grey Box Grassy Woodland monitoring sites established at Kokoda in 2015 including photographs taken along the vegetation transect are provided in Table 7-2. This section has also included characteristically similar communities White Box Grassy Woodland CEEC (WBWood1) and Grey Box – Ironbark woodland (IronWood1).

Table 7-2. General site descriptions and permanent photo-points of the Grey Box woodland monitoring sites at Kokoda.

Site Description	2015 (front)	2015 (rear)
GBReveg1: Degraded native pasture dominated by the exotic annuals *Trifolium angustifolium* (Narrow-leaf Clover) and *Vulpia muralis* (Rats-tail Fescue). The site was however relatively diverse and maintained relatively good ground cover. The natives *Bothriochloa macra* Red-leg Grass and *Rytidosperma spp* (Wallaby Grass) were also very common. Presently there was no tree or shrub regeneration.		
GBReveg2: Degraded native pasture dominated by the exotic annuals *Aira cupaniana* (Silvery Hairgrass) and *Vulpia muralis* (Rats-tail Fescue) with large patches of *Parentucellia latifolia* (Red Bartsia). The natives *Bothriochloa macra* (Red-leg Grass), *Rytidosperma racemosa* (Wallaby Grass) and *Wurmbea dioica* (Early Nancy) were also very common. The site was however relatively diverse and maintained relatively good ground cover. Presently there was no tree or shrub regeneration. There were scattered *E. sideroxylon* (Mugga Ironbark) in the vicinity of the site.		

GBReveg3: Native pasture dominated by *Bothriochloa macra* and the exotic annuals *Aira cupaniana, Hypochaeris glabra* (Smooth Catsear) with patches of *Vulpia muralis.* The site was however relatively diverse and maintained relatively good ground cover. Presently there was no tree or shrub regeneration.		
GBReveg 4: Degraded native pasture dominated by *Bothriochloa macra*, but the exotic annuals *Vulpia muralis* (Rats-tail Fescue), *Hypochaeris glabra* (Smooth Catsear) and *Aira cupaniana* were also abundant. The site was relatively diverse and maintained relatively good ground cover. Mosses and cryptogam were scattered throughout. Presently there was no tree or shrub regeneration.		
GBReveg5: Degraded native pasture dominated by *Bothriochloa macra*, but the exotic annuals *Vulpia muralis* (Rats-tail Fescue), *Hypochaeris glabra* (Smooth Catsear) and *Aira cupaniana* were also abundant. The site was relatively diverse and maintained relatively good ground cover. Presently there was no tree or shrub regeneration.		

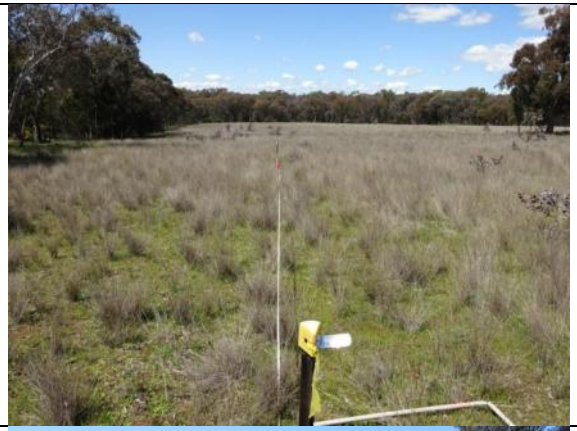
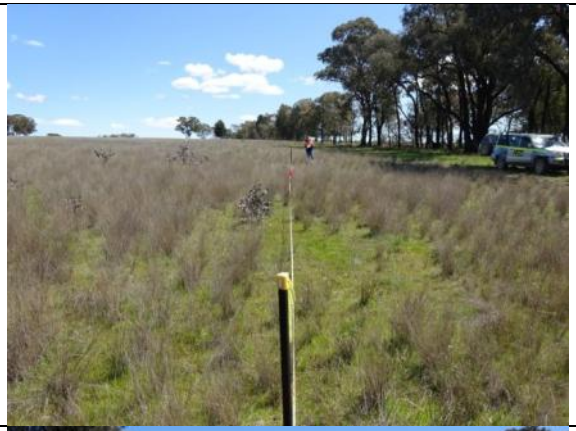
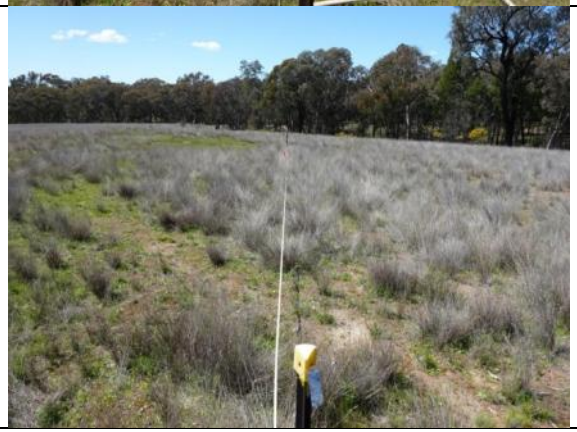
WBWood1: High quality open regrowth woodland dominated *by E. albens* (White Box) with some scattered mature *E. blakelyi* (Blakely's Red Gum) and *Callitris endlicheri*. The trees were represented in varying ages including a few younger saplings, but there was limited recent regeneration. There was a high diversity of native grasses and forbs and a low abundance of exotic annuals. Several species of ground orchids were found. There were also some large patches of the native yam daisy (*Microseris lanceolata*) further up the slope.		
IronWood1: Moderate density regrowth woodland dominated by *E. sideroxylon* (Mugga Ironbark) with scattered *E. microcarpa*, *E. albens, E. dwyeri* and *Callitris endlicheri*. There were scattered mature trees and a moderate density of younger saplings. There were scattered individuals of *Brachyloma daphnoides* (Daphne Heath). There was typically good ground cover provided by dead leaf litter but small bare patches persisted throughout the site. Species diversity was relatively low with the scattered *Gonocarpus tetragynus* and *Brachyloma daphnoides* providing low ground cover values.		
GBWood1: Very degraded regrowth woodland dominated *by E. microcarpa* with some scattered *Callitris endlicheri*. There were some large old regrowth trees, pockets of older regrowth but there was no young regeneration and there were no shrubs. There were some dead stags and fallen branches. There was typically good ground cover provided by dead leaf litter but small bare patches persisted throughout the site. Species diversity was very low with the scattered *Austrostipa scabra subsp. falcata* (Speargrass) and *Einadia nutans subsp. nutans* (Climbing Saltbush) providing very low ground cover value. There were some annual species in old stockcamps under the mature trees. A Tawny Frog mouth was found at this site.		

GBWood2: Degraded regrowth woodland dominated *by E. microcarpa* with some scattered *E. sideroxylon*. There was a moderate density of regrowth trees and some limited but recent recruitment of volunteer shrubs. There were some dead stags and fallen braches were common across the site. There was a high cover of dead leaf litter with a sparse cover of native ground cover species.		
GBWood3: Degraded regrowth woodland dominated *by E. microcarpa* with some scattered *E. sideroxylon*. There was a moderate density of regrowth trees and some limited but recent recruitment of volunteer shrubs. There were no dead stags but some fallen braches occurred across the site. There was a high cover of dead leaf litter with a sparse cover of native ground cover species.		

7.2 Dwyer's Red Gum Woodland monitoring sites

General descriptions of the Dwyer's Red Gum Woodland monitoring sites established at Kokoda in 2015 including photographs taken along the LFA/ vegetation transect are provided Table 7-3. This section also includes the low quality Dwyer's Red Gum Woodland, DWoodLQ.

Table 7-3. General site descriptions and permanent photo-points of the Dwyer's Red Gum monitoring sites at Kokoda.

General site description	2015: Front transect	2015: Rear transect
DReveg1: Degraded native pasture with a moderate abundance of *Aristida racemosa* (three-awn Grass, but the exotic annuals *Hypochaeris glabra* (Smooth Catsear) and *Vulpia muralis* (Rats-tail Fescue) were also abundant. The site was relatively diverse and maintained good ground cover. Mosses and cryptogam were common and there was some scattered *E. dwyeri* regeneration 0.5 – 2.0m in height.		
DReveg2: Degraded native pasture dominated by *Aristida racemosa* (three-awn Grass, but the exotic annuals *Hypochaeris glabra* (Smooth Catsear) and *Vulpia muralis* (Rats-tail Fescue) were also abundant. The site was relatively diverse and maintained relatively good ground cover. Mosses and cryptogam were scattered throughout. Presently there was no tree or shrub regeneration.		

DReveg3: Degraded native pasture dominated by the exotic annuals *Hypochaeris glabra* (Smooth Catsear), *Vulpia muralis* (Rats-tail Fescue), *Aira cupaniana* (Silvery Hairgrass) and *Parentucellia latifolia* (Red Bartsia). The site was however relatively diverse and maintained relatively good ground cover. Mosses and cryptogam were scattered throughout. Presently there was no tree or shrub regeneration.		
DWoodLQ: Open regrowth *E. dwyeri* woodland with occasional *E. albens* on the cleared grazing ecotone. The understorey was diverse but contained an abundance of annual grasses and forbs. The site maintained good ground cover with leaf litter dominant under the mature trees canopies.		
DWood1: Regrowth *E. dwyeri – Callitris* endlicheri woodland with scattered *E. dwyeri* and *E. dealbata* trees and a moderate density of *Callitris endlicheri* saplings. Many saplings have recently died probably over the prolonged summer which has opened up the canopy. *Gonocarpus tetragynus* (Hill Raspwort), *Cheilanthes sieberi* (Rock fern) and *Hypochaeris glabra* (Smooth Catsear) are dominant in the understorey and there is a god cover of leaf litter. There are many fallen branches and Cypress trunks and there is an adjacent rocky granite outcrop. There were numerous *Callitris* seedlings.		

DWood2: Relatively open regrowth woodland of *Callitris endlicheri* and occasional *E. sideroxylon* (Mugga Ironbark). There were many Callitris stags with some having fallen down. There were scattered pockets of *Brachyloma daphnoide*s (Daphne Heath) and a range of sparsely scattered native herbs however *Vulpia muralis* (Rat's Tail Fescue) was also common in pockets. There was extensive Callitris regeneration ~ 5cm in height. Coral Lichen was common throughout the larger woodland area and were present at the end of the vegetation transect. There was an extensive network of ant tunnels.		
DWood3: A grassy clearing with low density *E. dwyeri – Callitris endlicheri* in the bottom of the slope within a major drainage depression. There were scattered patches of *Calytrix tetragona* and a significant number of small *Callitris* and *Calytrix* seedlings. The understorey contained a wide diversity of native herbs. There was extensive sedimentation within the site as a result of extensive overland erosion from the adjacent slopes which had low ground cover.		

8 Results: Grey Box monitoring sites

This section provides the results of the monitoring within the Grey Box monitoring sites and demonstrates ecological trends and performance of the revegetation sites against a selection of primary ecological performance indicators. This section has also included the White Box grassy woodland and Grey Box Ironbark woodland.

8.1 Landscape Function Analyses

8.1.1 Landscape Organisation

A patch is an area within an ecosystem where resources such as soil and litter tend to accumulate, while areas where resources are mobilised and transported away are referred to as interpatches. Landscape Organisation Indices (LOI) are calculated by the length of the patches divided by the length of the transect to provide an index or percent of the transect which is occupied by functional patch areas (Tongway and Hindley 2004).

The three Grey Box woodland reference sites were characterised by having a mature tree canopy and a well developed decomposing leaf litter layer and a sparse cover of native perennial forbs and grasses and collectively provided a highly functional patch area and Landscape Organisation Indices of 100%.

While the Grey Box revegetation sites presently existed as degraded grassland and were structurally different to the woodland reference sites, they typically had good ground cover comprised of a combination of annual and perennial plants and cryptogams. These sites also had a high functional patch areas and subsequently scored LOI's of 100% (Figure 8-1).

The White Box and Ironbark woodland sites were also characterised with having a mature tree canopy and a well developed leaf litter layer. In the White Box woodland, native grasses and forbs were more abundant, while in the Ironbark woodland, there were scattered low shrubs however both sites also had high functional patch areas and LOI's of 100%.

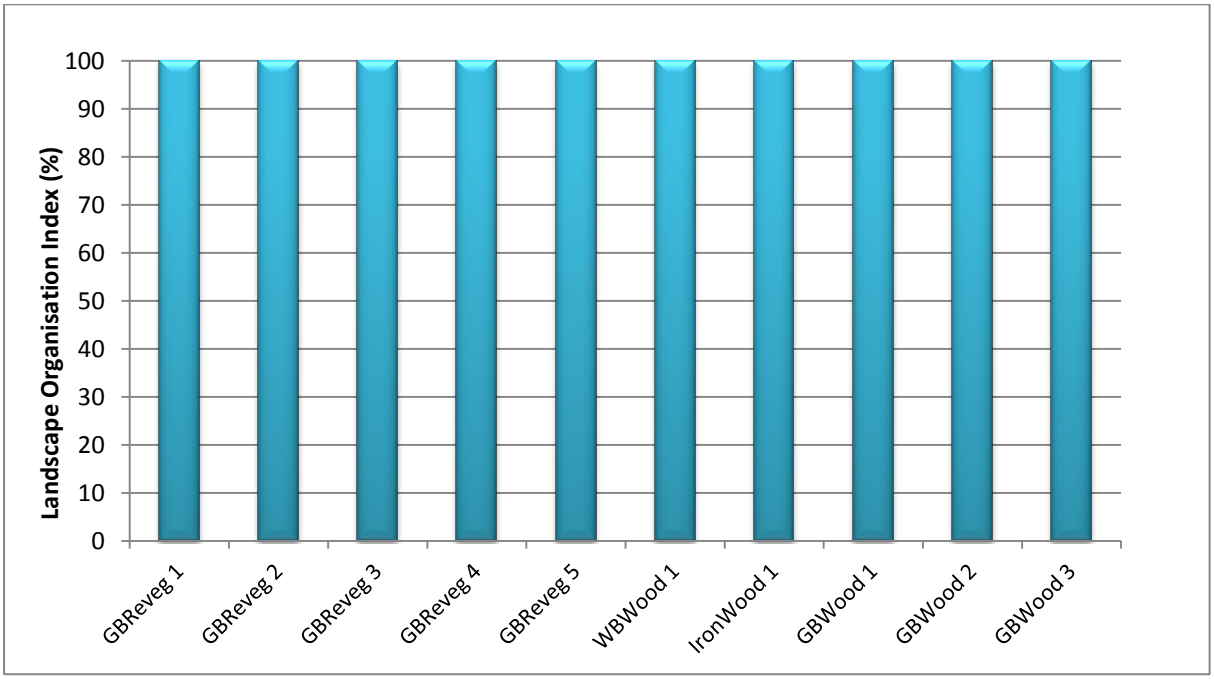


Figure 8-1. Landscape Organisation Indices recorded in the Grey Box woodland monitoring sites.

8.1.2 Soil surface assessments

8.1.2.1 Stability

LFA stability indices in the Grey Box woodland monitoring sites ranged from 62.8 – 65.0 with sites stability being provided by the perennial tree cover, moderately deep litter layers and sandy clay loam soils which were very stable. There was however relatively high rates of deposition evident as leaf litter had become mobilised across the sites during high rainfall events. In the White Box and Ironbark woodlands the stability indices were 62.0 and 62.4 and had similar stability to the Grey Box woodlands (Figure 8-2).

The Grey Box revegetation sites tended to be more stable than the reference sites with stability indices ranging from 69.1 (GBReveg5) – 73.6 (GBReveg1). Despite the lack of a mature tree canopy, higher stability indices can be attributed to the higher abundance of perennial ground covers, very hard soil crusts which were usually contained a significant abundance of cryptogam cover. Subsequently there also tended to be less evidence of erosion or deposition within these sites.

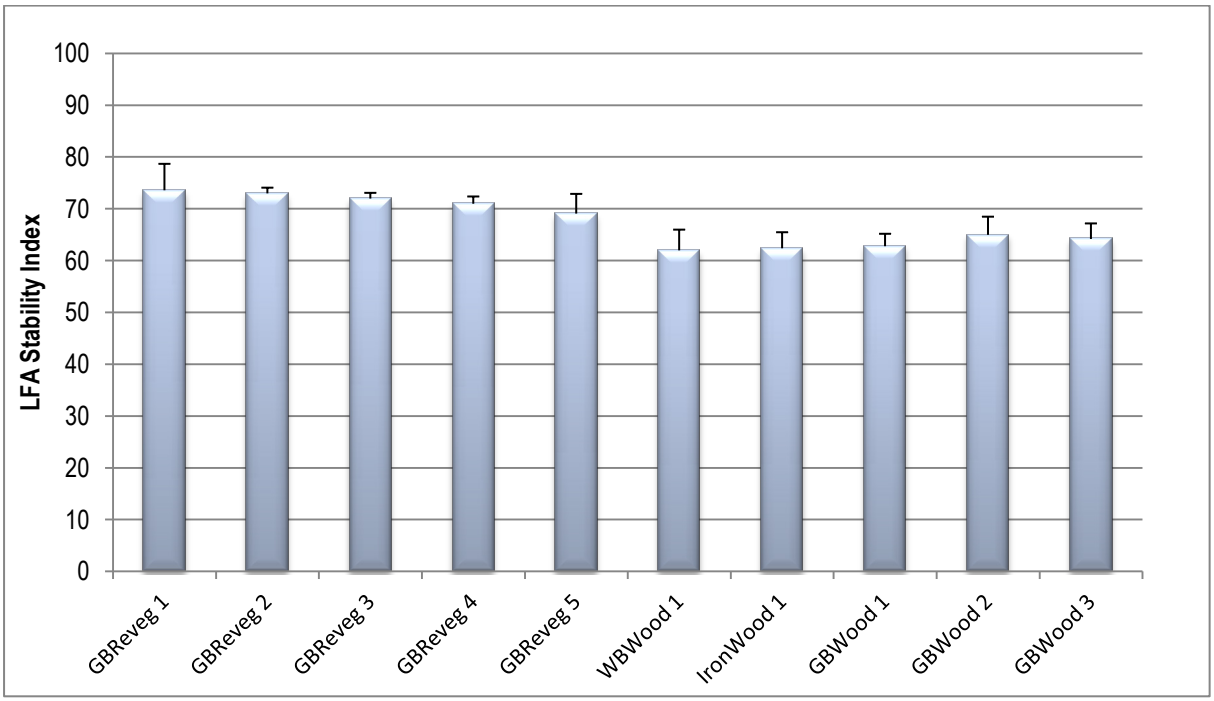


Figure 8-2. LFA stability indices recorded in the Grey Box woodland monitoring sites.

8.1.2.2 Infiltration

The infiltration capacity of the Grey Box, White Box and Ironbark woodland sites were quite similar to each other with the Grey Box sites providing a target range of 49.7 – 53.5 (Figure 8-3). The sites often had a well developed and decomposing litter layer, which had often formed a rich humus layer with lower occurrences of soil surface crusting.

In the revegetation sites, there tended to be an undeveloped litter layer and a hard surface crust which reduces the infiltration capacity of moisture to enter the soil profile, subsequently all revegetation sites presently had lower infiltration capacity which ranged from 38.4 (GBReveg2) – 46.2 (GBReveg1).

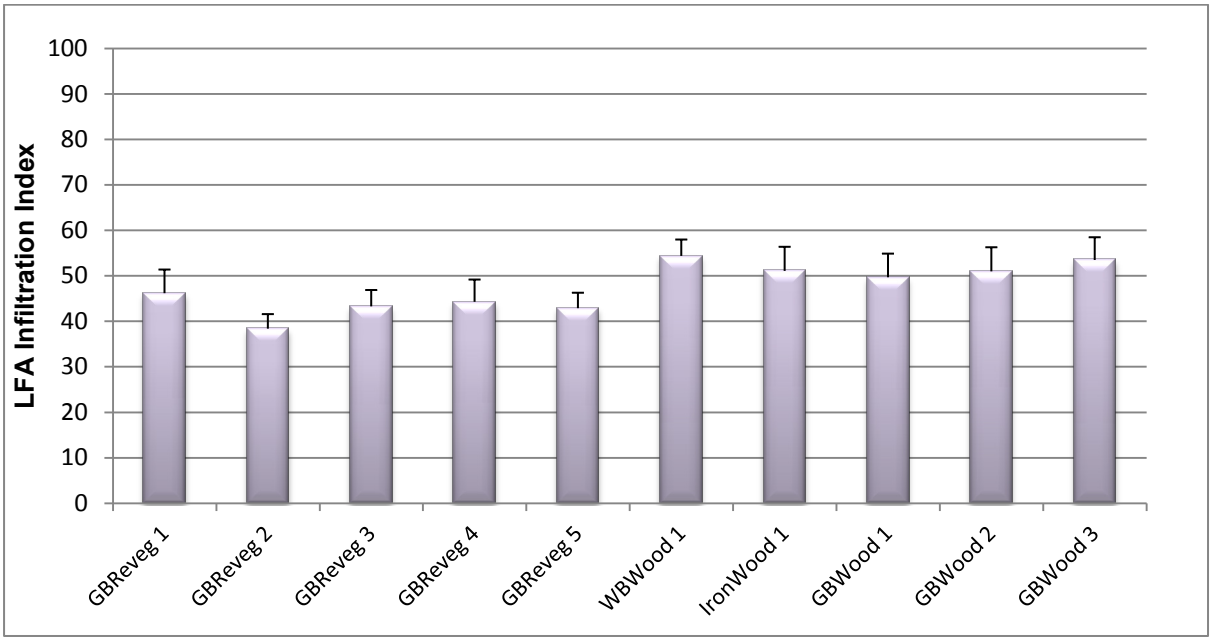


Figure 8-3. LFA infiltration indices recorded in the Grey Box woodland monitoring sites.

8.1.2.3 Nutrient recycling

The nutrient recycling capacity is influenced by the degree of perennial plant cover and accumulation and decomposition of the litter layers, which is in turn influenced by the degree of soil compaction and soil surface crusting. The White Box grassy woodland had the highest nutrient recycling capacity of 53.9. This was largely due to the presence of the mature tree canopy but it also had a higher abundance of perennial ground covers and a deep decomposed litter layer. In the Grey Box woodland reference sites and the Ironbark woodland, there was also a mature overstorey however there was a lower abundance of perennial ground cover and the litter layers were slightly less developed. In the Grey Box woodland reference sites the target nutrient recycling range was 47.2 – 50.7 (Figure 8-4).

In the Grey Box revegetation sites, there was a lack of a mature overstorey and the litter layers were much less developed with the sites having a lower nutrient recycling indices ranging from 40.4 (GBReveg2) to 46.0 (GBReveg4).

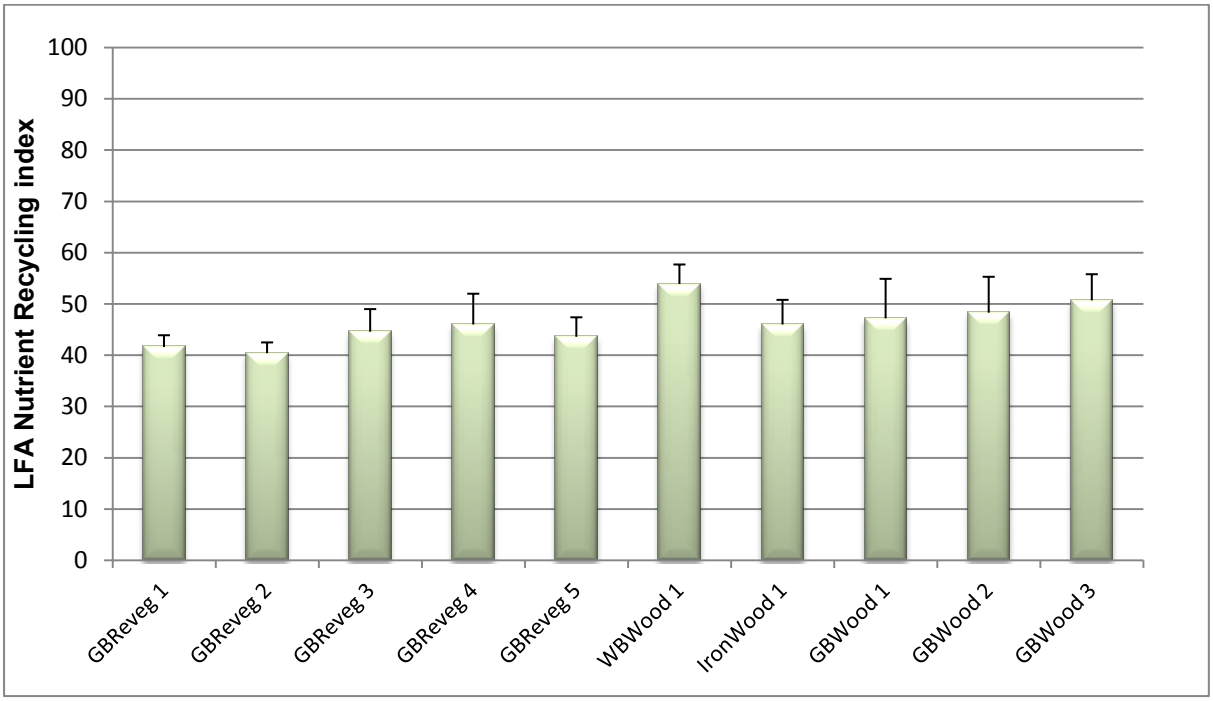


Figure 8-4. LFA nutrient recycling indices recorded in the Grey Box woodland monitoring sites

8.1.3 Most functional sites

The sum of the LFA stability, infiltration and nutrient recycling components provide an indication of the most functional to least functional monitoring sites recorded this year and is provided in Figure 8-5. The maximum score possible is 300 with the White Box grassy woodland being the most ecologically functional site with a total score of 170.3. This site contained high patch area, a mature tree canopy and well developed grassy ground cover layer, with high levels of decomposing litter and had very stable soils.

The Grey Box woodland sites GBWood3 and GBWood2 were the next most functional communities but did not tend to have such high levels of these attributes and scored 168.4 and 164.3 respectively. The derived native grasslands GBReveg1, GBReveg4 and GBReveg3 that will be revegetated to Grey Box woodland were presently more functional than GBWood1 and the Ironbark woodland. These two woodland areas had also been degraded through overgrazing with the herbaceous understorey having been severely depleted and the soils being quite compacted with these sites scoring 159.7 and 159.5 respectively. The least functional communities were presently GBReveg5 which scored 155.6 and GBReveg2 with 151.8.

Examples of the various combinations of ground covers which are critical to overall ecosystem function have been provided in Table 8-1.

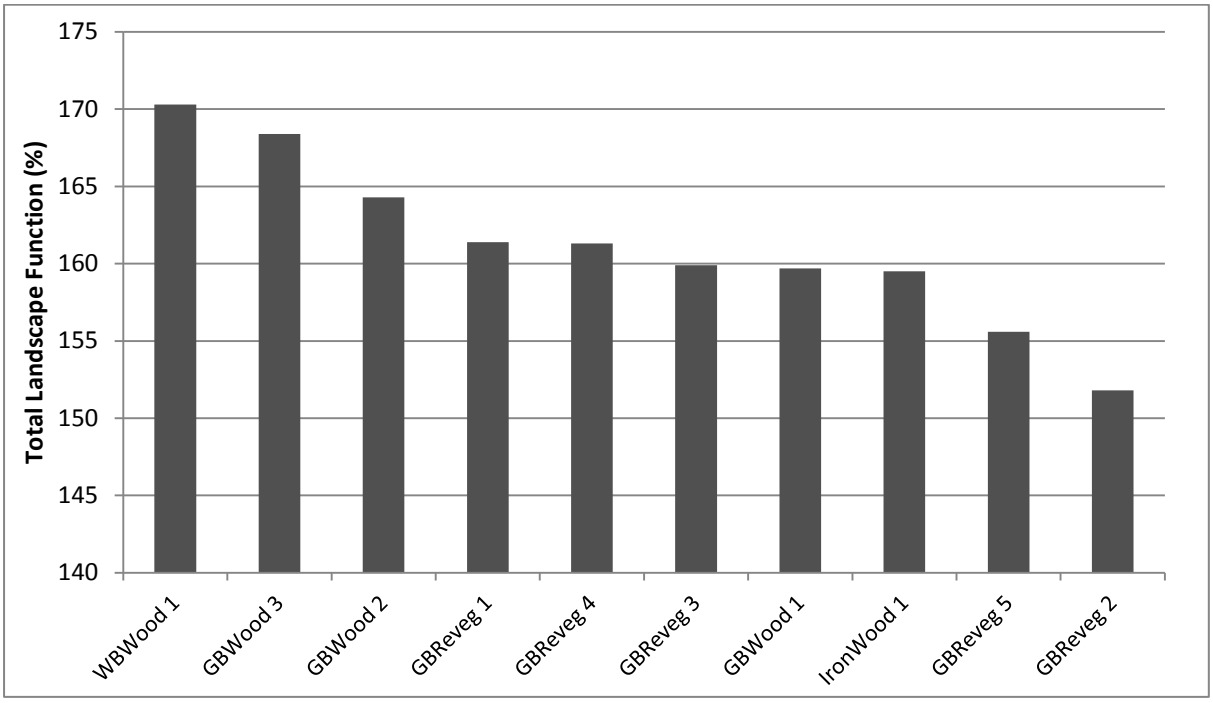
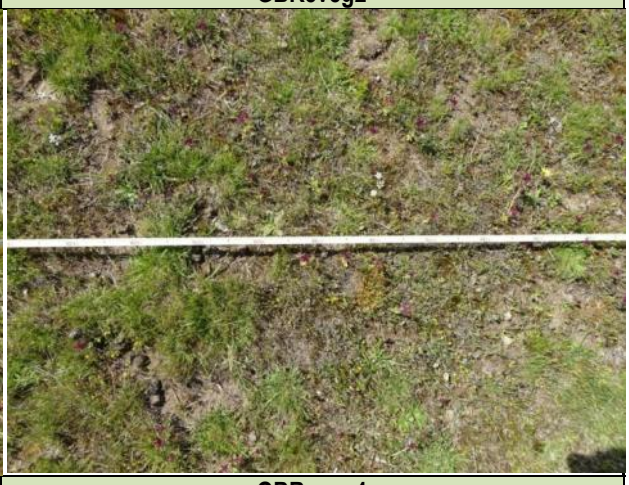


Figure 8-5. Sum of the LFA stability, infiltration and nutrient recycling components indicating the most functional to least functional monitoring site recorded in 2015.

Table 8-1. Examples of the different ground covers in the Kokoda Grey Box monitoring sites.

GBReveg1	GBReveg2
	
GBReveg3	**GBReveg4**
	

8.2 Trees and mature shrubs

8.2.1 Population density

Mature trees and shrubs with a stem diameter >5cm dbh were recorded in the three Grey Box woodland reference sites as well as the White Box and Ironbark woodland sites. There were 8 – 21 individuals in the reference sites, equating to a density of 200 – 525 stems per hectare (Figure 8-6). There were 8 individuals in the White Box site and 33 in the Ironbark woodland. No trees or mature shrubs were yet present in the derived native grassland sites.

8.2.2 Diameter at breast height

The average dbh recorded in the Grey Box reference sites ranged from 18 – 34cm but ranged from 6 – 57cm (Table 8-2). The relatively small trunk diameters indicate the trees are relatively young and indicative of their regrowth status. In the White Box woodland the average dbh was 28 cm with the maximum dbh of 38cm, while in the Ironbark woodland the average dbh was 17 with a maximum of 51cm.

8.2.3 Condition

The trees and mature shrubs in the Grey Box woodland reference sites were typically in good to medium health but all sites contained some individuals in a state of advanced dieback and in GBWood3 there were three stags. No mistletoe was recorded and only a small percent of the populations were bearing reproductive structures such as buds, flowers or fruits or hollows suitable as nesting sites (>10cm). In the White Box woodland most trees were in good to medium health and a large percentage (63%) of them were bearing reproductive structures. In the Ironbark woodland most of the trees were in medium to poor health and there several dead individuals. A small number had reproductive structures and/or hollows.

8.2.4 Species composition

The Grey Box reference sites were dominated by *Eucalyptus microcarpa* (Grey Box). A single mature *Acacia implexa* (Hickory) was also recorded in GBWood2, while a single *E. sideroxylon* (Mugga Ironbark) was recorded in GBWood2 and GBWood3.

The White Box woodland was dominated by *E. albens* but a *Callitris endlicheri* and *E. blakelyi* were also present. The Ironbark woodland was dominated by a mixture of *E. albens, E. dealbata* and *E. sideroxylon* with several *E. microcarpa* and a single *Callitris endlicheri.*

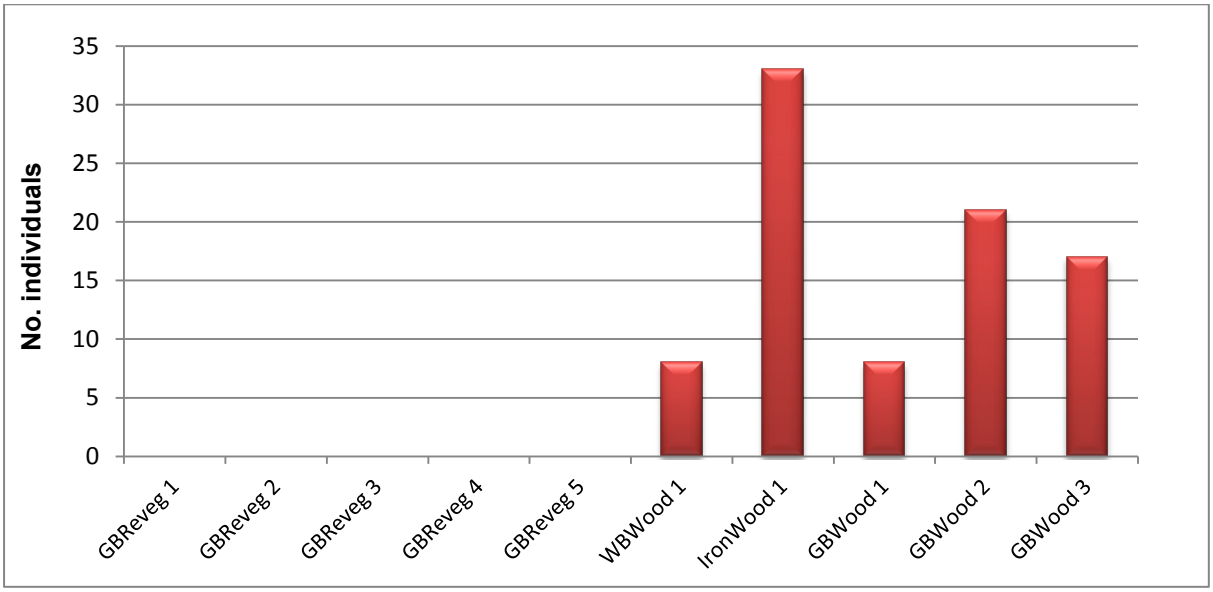


Figure 8-6. Tree and mature shrub densities (>5cm dbh) in the Kokoda Grey Box woodland monitoring sites.

Table 8-2. Trunk diameters and condition of the trees and mature shrubs in the woodland monitoring sites in 2015.

Site Name	No species	Average dbh (cm)	Max dbh (cm)	Min dbh (cm)	Total trees	No. with multiple limbs	% Live	% Healthy	% Medium Health	% Advanced Dieback	% Dead	% Mistletoe	% Flowers / fruit	% with hollows
GBReveg1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GBReveg2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GBReveg3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GBReveg4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
GBReveg5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WBWood1	3	28	38	18	8	4	100	50	38	13	0	0	63	13
IronWood1	5	17	51	7	40	2	83	10	28	45	18	0	18	3
GBWood1	1	34	57	13	8	0	100	13	75	13	0	0	0	38
GBWood2	3	18	29	9	21	5	100	48	38	14	0	0	5	0
GBWood3	2	24	55	6	20	10	85	5	60	20	15	0	10	20

8.3 Shrubs and juvenile trees

8.3.1 Population density

There was a small number of shrubs and juvenile trees (<5cm dbh) in the Grey Box reference sites and 1 – 18 individuals or 25 – 450 stems per hectare were recorded in the monitoring plots (Figure 8-7). There was one shrub in the White Box woodland, while in the Ironbark woodland there were 108 individuals.

8.3.2 Height class

Most individuals in the reference sites were less than 0.5m in height but one or two individuals may have been in the taller height classes (Table 8-3). In the White Box woodland there was one small acacia. In IronWood1 most individuals were less than 1.0m in height.

8.3.3 Species diversity

In the woodland reference sites there were 1- 4 species of shrubs and juvenile trees with the range of species including juvenile *E. microcarpa, Acacia implexa, A. paradoxa* (Kangaroo Thorn), *Brachyloma daphnoides* (Daphne Heath) or *Cassinia laevis* (Cough Bush). In the White Box woodland there was one small *Acacia implexa*. In the Ironbark woodland, the shrubby understorey was much more diverse and was dominated by *Brachyloma daphnoides.* Other species included *Acacia implexa* and *Cassinia laevis with juvenile Brachychiton populneus*, *Callitris endlicheri, Eucalyptus dealbata* and *E. microcarpa.*

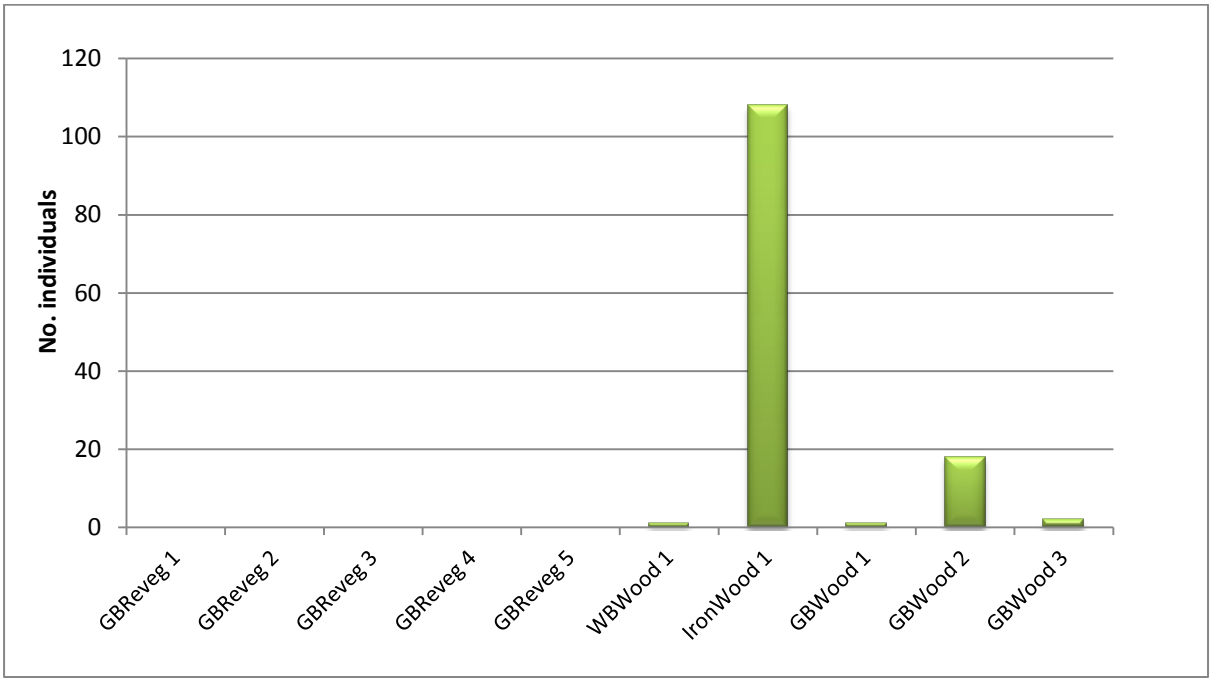


Figure 8-7. Total shrubs and juvenile trees recorded in the Grey Box monitoring sites.

Table 8-3 Number of individuals represented in each height class across the range of monitoring sites.

Site Name	0-0.5m	0.5-1.0m	1.0-1.5m	1.5-2.0m	>2.0m	Total	No. species	% Endemic
GBReveg1	0	0	0	0	0	**0**	0	0
GBReveg2	0	0	0	0	0	**0**	0	0
GBReveg3	0	0	0	0	0	**0**	0	0
GBReveg4	0	0	0	0	0	**0**	0	0
GBReveg5	0	0	0	0	0	**0**	0	0
WBWood1	0	1	0	0	0	**1**	1	100
IronWood1	78	27	2	0	1	**108**	7	100
GBWood1	1	0	0	0	0	**1**	1	100
GBWood2	13	2	2	1	0	**18**	4	100
GBWood3	1	0	0	0	1	**2**	2	100

8.4 Total ground Cover

Total ground cover, which is a combination of leaf litter, annual plants, cryptogams, rocks, logs and live perennial plants (<0.5m in height) was relatively high in the woodland reference sites and ranged from 90.5 – 99.5% (Figure 8-8). In IronWood1 total ground cover was slightly lower with 86.5% while the remaining sites had 98.5 – 100% ground cover.

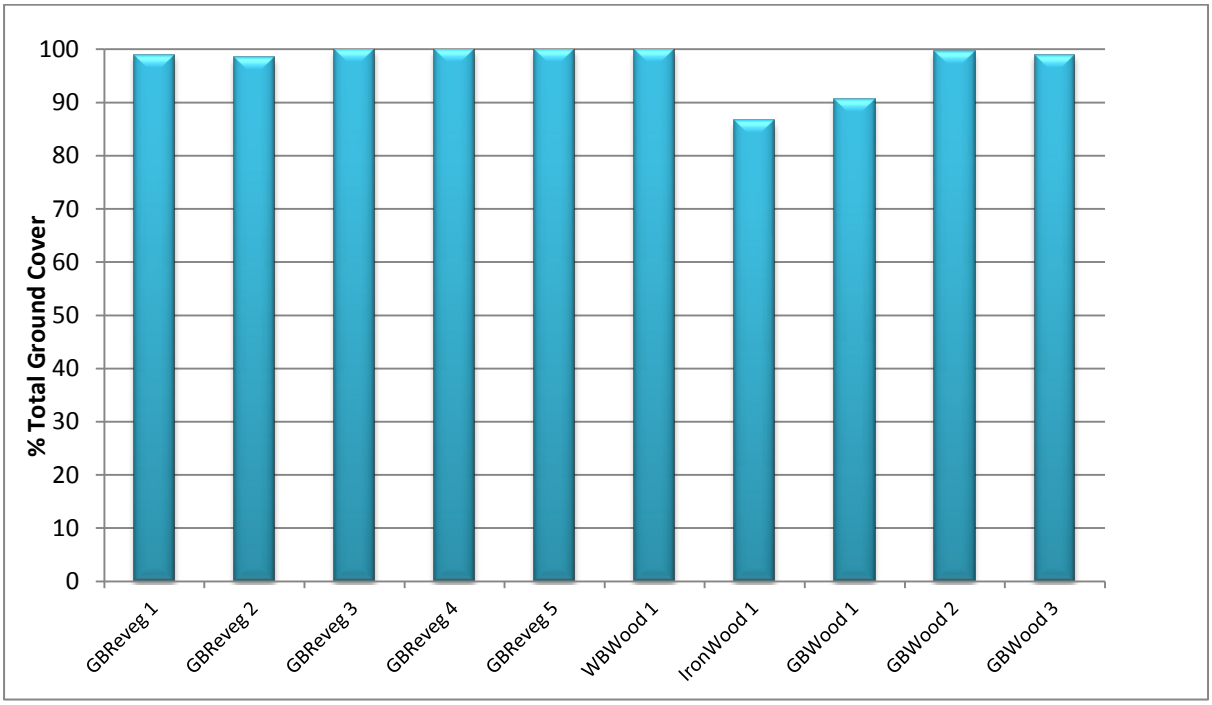


Figure 8-8. Total ground cover recorded in the Grey Box woodland monitoring sites.

8.5 Structural composition

The various combinations of the ground covers and structural compositions of the woodland sites are provided in Figure 8-9. In the Grey Box woodland reference sites and the White Box and Ironbark woodlands the most dominant form of ground cover was dead leaf litter. In the reference sites dead leaf litter provided 82 – 84.4% of the total ground cover. There was a small contribution of cover provided by scattered perennial plants and fallen branches, and there may have been an occasional annual plant or rock. Due to the heavy litter layer, cryptogam cover was presently not an important feature.

The White Box woodland had a higher cover of perennial ground covers, while in the Ironbark woodland, cryptogams and logs were also important. In comparison the revegetation sites were presently dominated by various proportions of annual plants and dead leaf litter and a higher cover of perennial ground covers. Cryptogams were also important in most of these sites.

The reference sites were also characterised by having a mature canopy cover which exceeded 6.0m in height with low hanging braches also providing occasional projected cover in the lower height classes. The White Box woodland had a similar overstorey structure while in Ironwood1, the scattered low shrubs provided some structural diversity 0.5 – 2.0m in height.

Examples of the various structural compositions of the individual sites have been provided in Table 8-4.

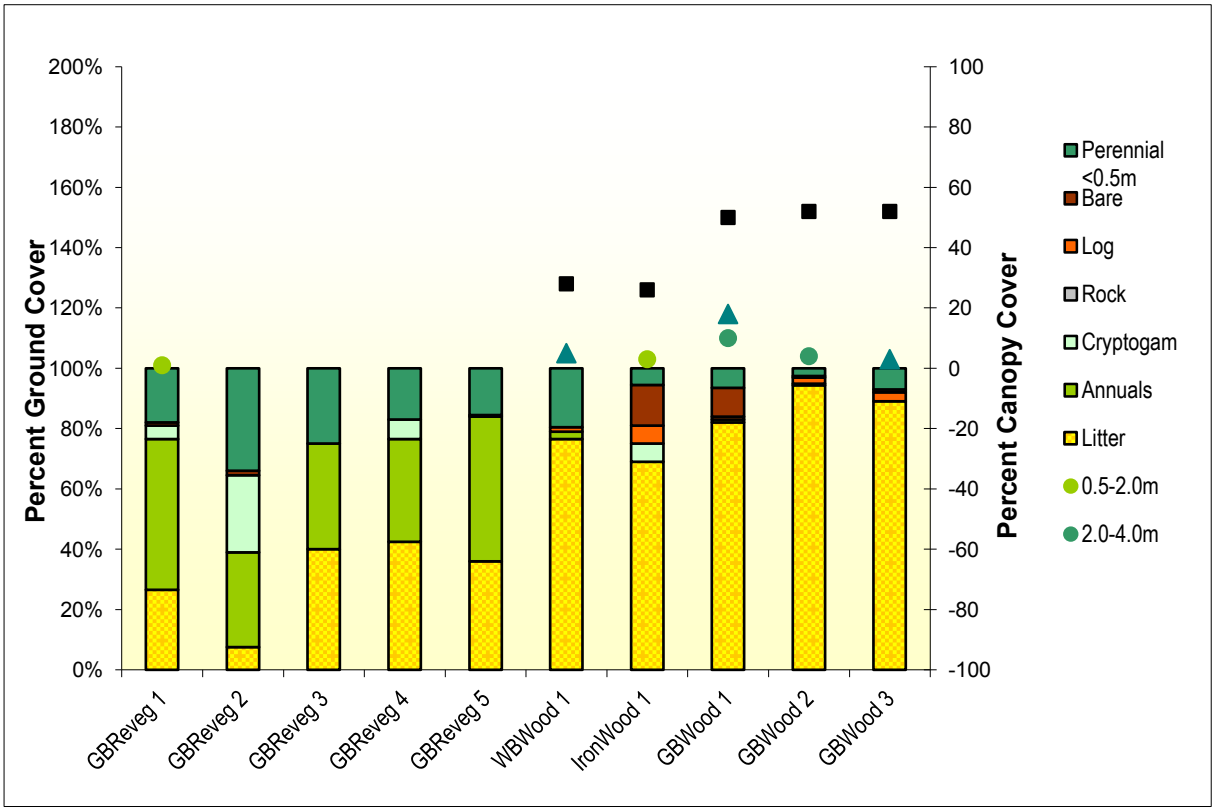


Figure 8-9. Average percent ground cover and projected foliage cover recorded in the Grey Box monitoring sites in 2015.

Table 8-4. Structural compositions of the Grey Box monitoring sites.

GBReveg1	GBReveg2
	
GBReveg3	**GBReveg4**
	

GBReveg5	WBWood1
	
IronWood1	**GBWood1**
	
GBWood2	**GBWood3**
	

8.6 Floristic Diversity

Total floristic diversity recorded within the 20 x 20m Grey Box monitoring sites was highly variable with 23 – 39 species recorded in the reference sites (Figure 8-10). The White Box woodland contained the highest total species diversity with 51 species, while there were 35 species recorded in the Ironbark woodland. Total floristic diversity in the derived grasslands was also variable and ranged from a low diversity of 30 species in GBReveg3 to a high of 45 species in GBReveg2.

In the woodland reference sites, native species were far more diverse than exotic species with 16 – 33 native species being recorded and there were 34 and 39 natives in the White Box and Ironbark woodlands respectively (Figure 8-11). In the derived grasslands, native species were more diverse than exotic species in GBReveg2 and GBReveg4 which had 32 and 18 native species respectively. Site GBReveg3 had the lowest diversity of native species with only 13 species.

While only one exotic species was recorded in IronWood1, all other sites contained more exotic species than were recorded in the woodland reference sites and were therefore weedier than desired. In the revegetation areas, the lowest number of exotic species was recorded in GBReveg2 with 13 species, while the highest was recorded in GBReveg1 and GBReveg5 with 18 exotic species each (Figure 8-12).

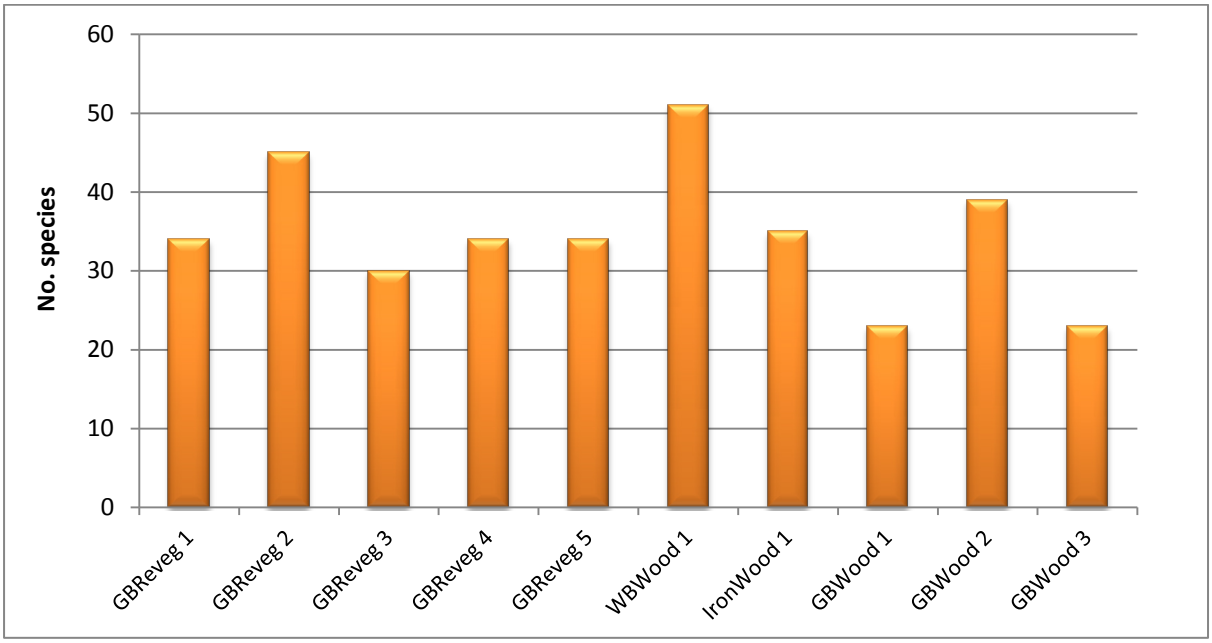


Figure 8-10. Total species diversity recorded in the Grey Box monitoring sites.

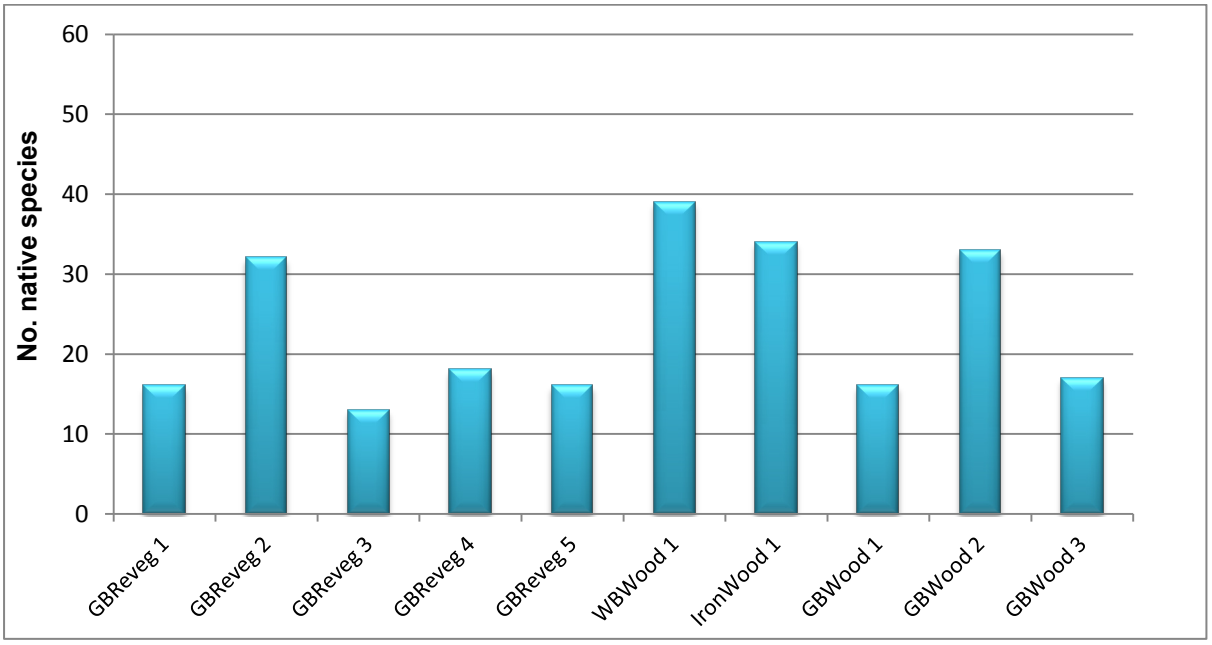


Figure 8-11. Total native species recorded in the Grey Box monitoring sites.

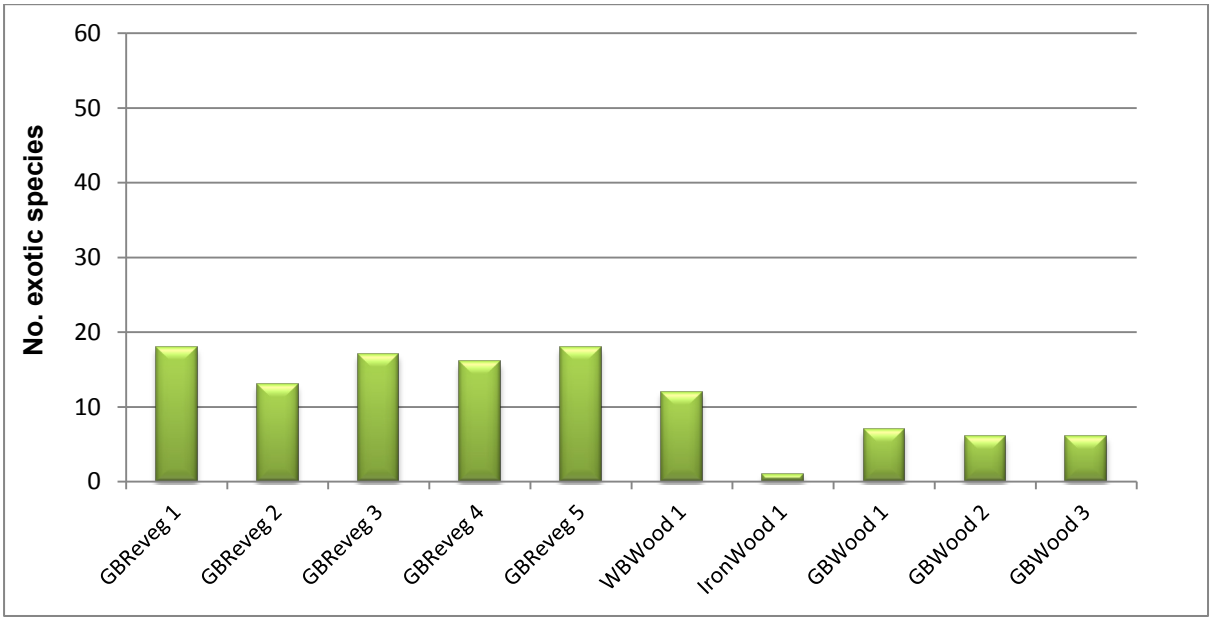


Figure 8-12. Total exotic species recorded in the Grey Box monitoring sites.

8.6.1 Percent endemic ground cover

The percent endemic ground cover is an ecological indicator used to provide some measure of the cover abundance of the live native vegetation along the vegetation transect and therefore indicates the level of weediness at the monitoring sites. While it is only estimation the percent cover of endemic ground cover species has been derived by the following equation.

Percent cover endemic species = sum of the five Braun- blanquet scores for native species / (sum of the five Braun- blanquet scores of exotic species + native species) x 100

In the Grey Box woodland reference sites most of the live plant cover was provided by native species with endemic plant cover scores of 96.2 – 100% (Figure 8-13). There was also 100% endemic plant cover in IronWood1, but in the White Box woodland native species only 78.3% of the live plant cover

and was weedier than desired. In the derived grasslands the highest cover of native plants was recorded in GBReveg2 with 61.7% endemic cover, while the lowest was recorded in GBReveg1 and GBReveg3 which had low scores of 27.2% and 27.8% respectively. Therefore all revegetation areas were presently dominated by exotic species and weedier than desired.

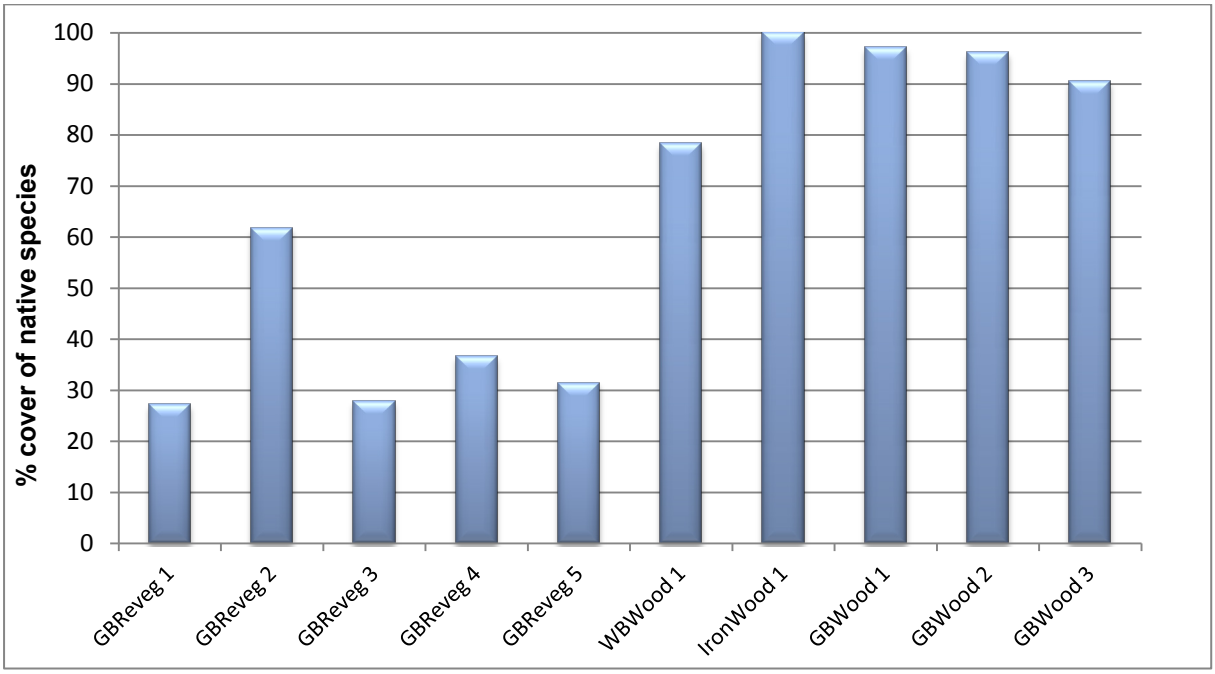


Figure 8-13. Percent endemic ground cover recorded in the Grey Box monitoring sites.

8.7 Vegetation composition

The composition of the vegetation as categorised by seven different growth forms is given in Figure 8-14. In the Grey Box woodland reference sites herbs were the most diverse plant group with 14 - 20 different species followed by grasses with 5 – 11 species. There were 1 - 2 tree species and only up to one shrub, one sub-shrub, one reed and one fern species.

The White Box and Ironbark woodland were comprised of an adequate representation of the major plant groups but there was a slightly low diversity of herbs in IronWood1. In the grassland revegetation areas there was also an adequate representation of most growth forms except that there were no trees. While there were also no shrubs in the grassland areas, no shrubs were recorded in the GBWood01 reference site.

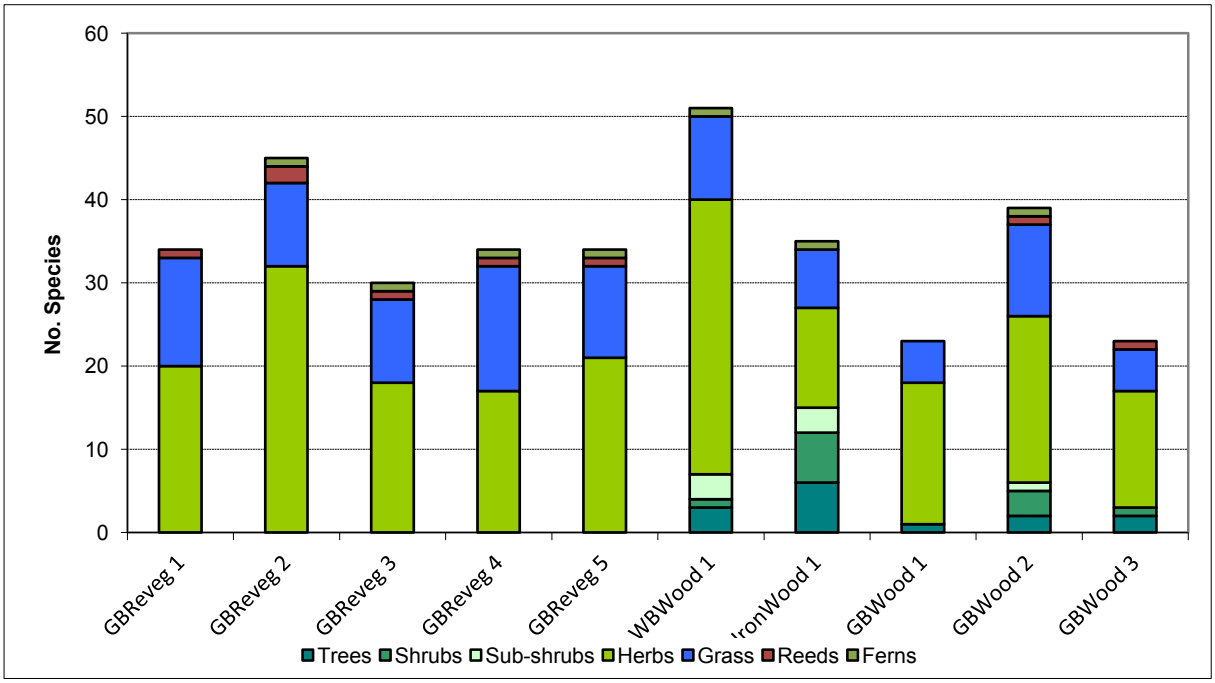


Figure 8-14. Composition of the vegetation recorded in the Grey Box monitoring sites.

8.8 Most common species

There were 140 species recorded across the Grey Box monitoring sites with 41 (29%) of these being exotic species (Appendix 1). The exotic annual *Hypochaeris glabra* (Smooth Catsear) was recorded in all sites including the three reference sites and White Box and Ironbark woodlands. Exotic annuals *Arctotheca calendula* (Capeweed), *Anagallis arvensis* (Scarlet Pimpernel) and *Briza minor* (Shivery Grass) were also very common (Table 8-5).

There were four native perennial grasses which were common to at least six of the ten monitoring sites and these included *Aristida ramosa* (Threeawn Grass), *Austrostipa scabra subsp. falcata* (Speargrass), *Bothriochloa macra* (Red-leg Grass) and *Elymus scaber* (Common Wheatgrass), while the native fern *Cheilanthes sieberi subsp. sieberi* (Rock Fern) was recorded in seven sites. A comprehensive list of species recorded in all monitoring sites has been included in Appendix 1.

Table 8-5. The most common species recorded in the Grey Box monitoring sites.

Family	exotic	Scientific Name	Common Name	Habit	GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5	WBWood1	IronWood1	GBWood1	GBWood2	GBWood3	Total
Asteraceae	*	*Hypochaeris glabra*	Smooth Catsear	h	1	1	1	1	1	1	1	1	1	1	**10**
Asteraceae	*	*Arctotheca calendula*	Capeweed	h	1	1	1	1	1			1	1	1	**8**
Poaceae		*Aristida ramosa*	Threeawn Grass	g	1	1	1	1	1	1	1		1		**8**
Poaceae		*Austrostipa scabra subsp. falcata*	Speargrass	g		1	1		1	1	1	1	1	1	**8**
Poaceae		*Bothriochloa macra*	Red-leg Grass	g	1	1	1	1	1	1		1	1		**8**
Primulaceae	*	*Anagallis arvensis*	Scarlet Pimpernel	h	1	1	1		1	1			1	1	**7**
Adiantaceae		*Cheilanthes sieberi subsp. sieberi*	Rock Fern	f		1	1	1	1	1	1		1		**7**
Poaceae	*	*Briza minor*	Shivery Grass	g	1	1	1	1	1	1					**6**
Poaceae		*Elymus scaber*	Common Wheatgrass	g	1		1	1	1	1			1		**6**

8.9 Most abundant species

The most abundant species recorded in each of the Grey Box monitoring sites this year are provided in Table 8-6. The most abundant species were those that collectively summed to a Braun-blanquet total of 10 or more from the five replicated sub-plots along the vegetation transect. The maximum score that can be obtained by an individual species is 30.

No species was particularly abundant in the understorey in the Grey Box woodland reference sites with only *Austrostipa scabra subsp. falcata* (Speargrass) meeting the required criteria in GBWood01. *Austrostipa scabra subsp. falcata* was also the most abundant in the White Box woodland along with *Hydrocotyle laxiflora* (Stinking Pennywort). In the Ironbark woodland *Brachyloma daphnoides* (Daphne Heath) provided the most ground cover.

The derived grasslands were dominated by a different range of species with most cover provided exotic annual grasses especially *Vulpia muralis* (Rats-tail Fescue) and *Aira cupaniana* (Silvery Hairgrass). Other exotic annuals which were dominant included *Trifolium angustifolium* (Narrow-leaf Clover) and *Hypochaeris glabra* (Smooth Catsear). The native perennial grasses *Bothriochloa macra* (Red-leg Grass) had persisted in numerous grassland sites and provided adequate ground cover, while *Rytidosperma racemosum* (Wallaby Grass) provided the most ground cover in GReveg2.

Table 8-6. The most abundant species recorded in the Grey Box monitoring sites.

Scientific Name	Common Name	GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5	WBWood1	IronWood1	GBWood1	GBWood2	GBWood3
**Trifolium angustifolium*	Narrow-leaf Clover	16									
**Vulpia muralis*	Rats-tail Fescue	24			23	11					
Bothriochloa macra	Red-leg Grass	10		19	13	13					
**Aira cupaniana*	Silvery Hairgrass		16	14		10					
Rytidosperma racemosum	Wallaby Grass		18								
**Bromus molliformis*	Soft Brome			11							
**Hypochaeris glabra*	Smooth Catsear				11	22					
Austrostipa scabra subsp. falcata	Speargrass						13		12		
Hydrocotyle laxiflora	Stinking Pennywort						10				
Brachyloma daphnoides	Daphne Heath							11			

8.10 Soil analyses

8.10.1 pH

Figure 8-15 shows the pH recorded in the Grey Box monitoring sites compared to the "desirable" range in medium or clay loam soils as prescribed by the agricultural industry for growing introduced pastures and crops. The pH range recorded in the woodland reference sites was somewhat lower than desirable agricultural ranges and with a soil pH ranging from 4.94 – 5.16 the soils very strongly acidic (Bruce & Rayment 1982). In the Ironbark woodland, the soil pH was similar to the reference sites with a pH of 5.0. The White Box woodland and derived grassland areas had a slightly higher pH which ranged from 5.80 – 6.45 with these soils being slightly to moderately acidic.

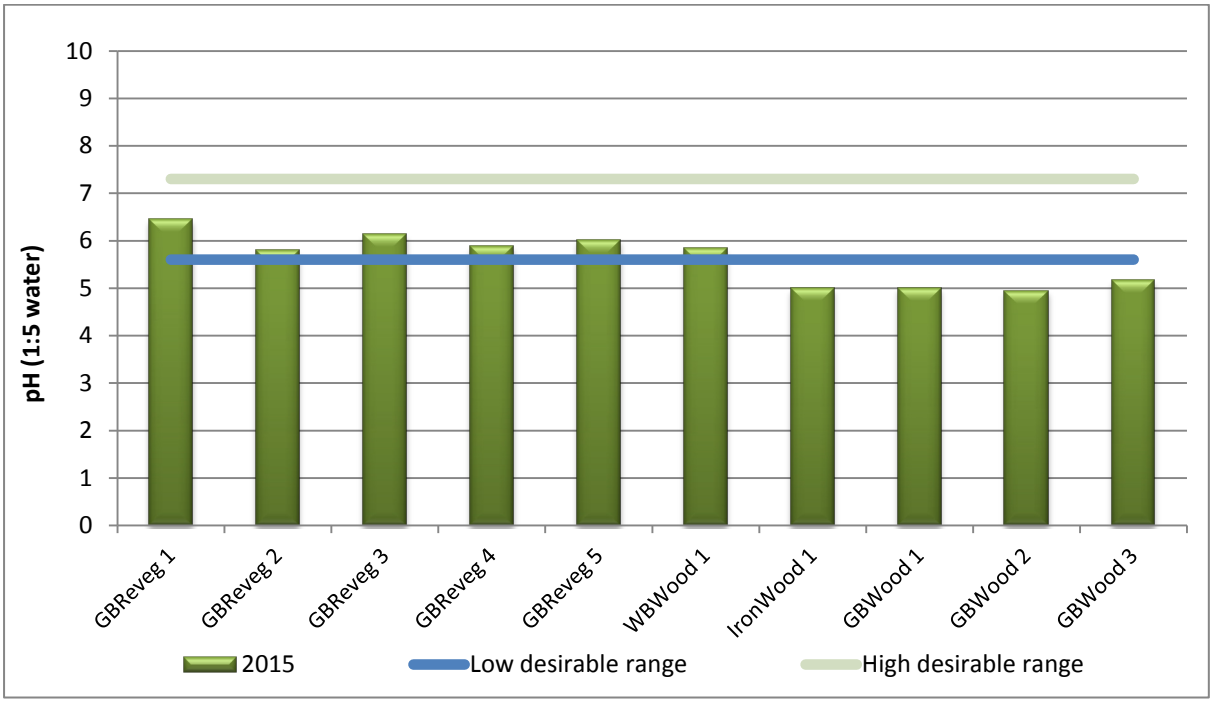


Figure 8-15. Soil pH recorded in the Grey Box monitoring sites compared to the desirable agricultural range.

8.10.2 Conductivity

Figure 8-16 shows the Electrical Conductivity (EC) recorded in the Grey Box monitoring sites compared to the "desirable" range in medium or clay loam soils as prescribed by the agricultural industry for growing introduced pastures and crops. The EC recorded across the range of sites was well below the agricultural threshold indicating there are very low levels of soluble salts in the soil profile and that they are non saline. The highest EC readings were recorded in the reference sites which ranged from 0.069 – 0.077 dS/m. In the remaining sites EC ranged from a low of 0.019 dS/m in GBReveg4 to a high of 0.038 dS/m in IronWood1.

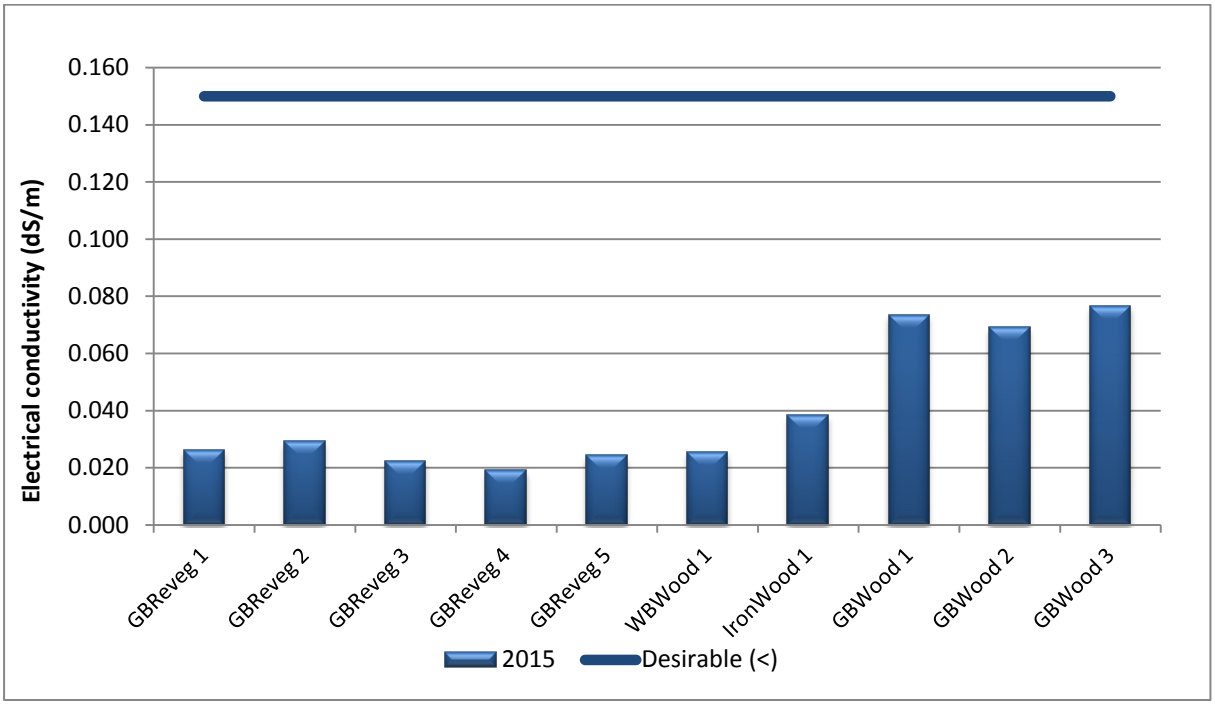


Figure 8-16. Electrical Conductivity recorded in the Grey Box monitoring sites compared to the desirable agricultural levels.

8.10.3 Organic Matter

In the Grey Box woodland reference sites OM levels were elevated in comparison to the desirable threshold of 4.5%, with OM concentrations up to 6.3% in GBWood1 (Figure 8-17). These high concentrations are probably related to high manure deposits as a result of livestock camps. In the grassland site GBReveg2 OM levels were 4.6% and at desirable levels, while in Ironwood1 they were slightly lower and at 4.2%. In the remaining sites OM levels were very low and ranged between 1.5% in WBWood1 to 2.6% in GBReveg1.

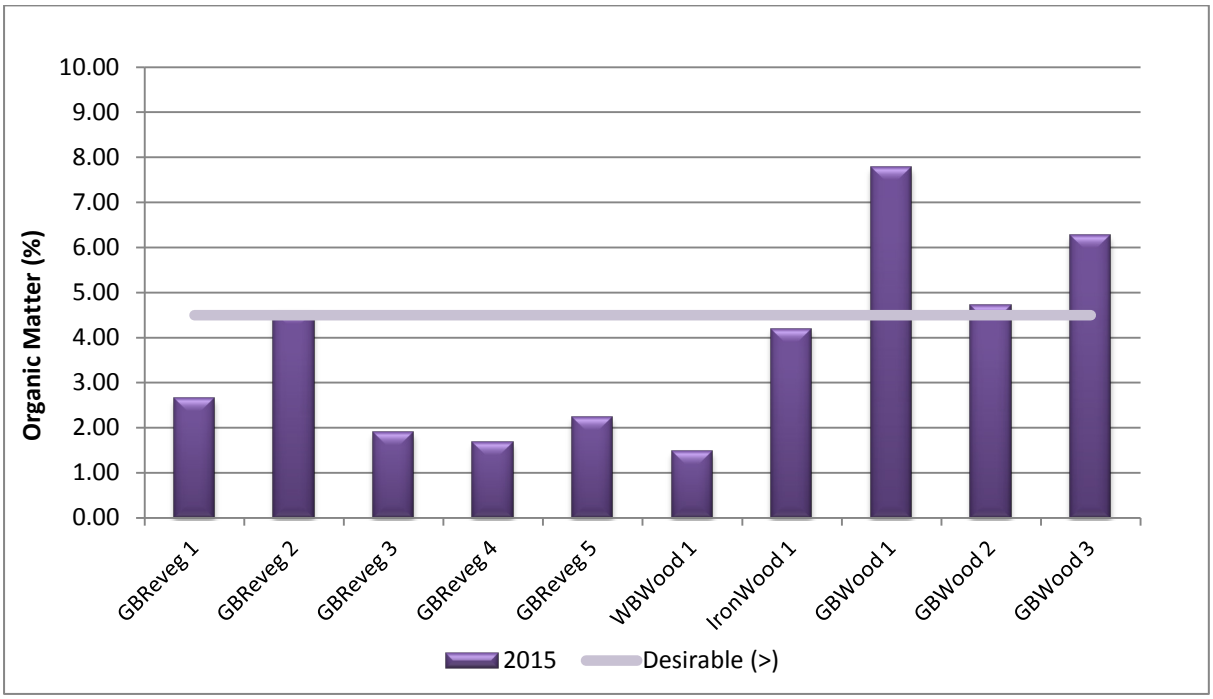


Figure 8-17. Organic Matter concentrations recorded in the Grey Box monitoring sites compared to desirable agricultural levels.

8.10.4 Phosphorous

Phosphorous levels were lower than the agricultural standards across all Grey Box monitoring sites, but were the highest within the woodland reference sites which had a P range of 21 – 40mg/kg. There were minor differences in P across the other Grey Box monitoring sites which ranged from a low of 16 mg/kg in GBReveg1 to a high of 20 mg/kg in IronWood1(Figure 8-18).

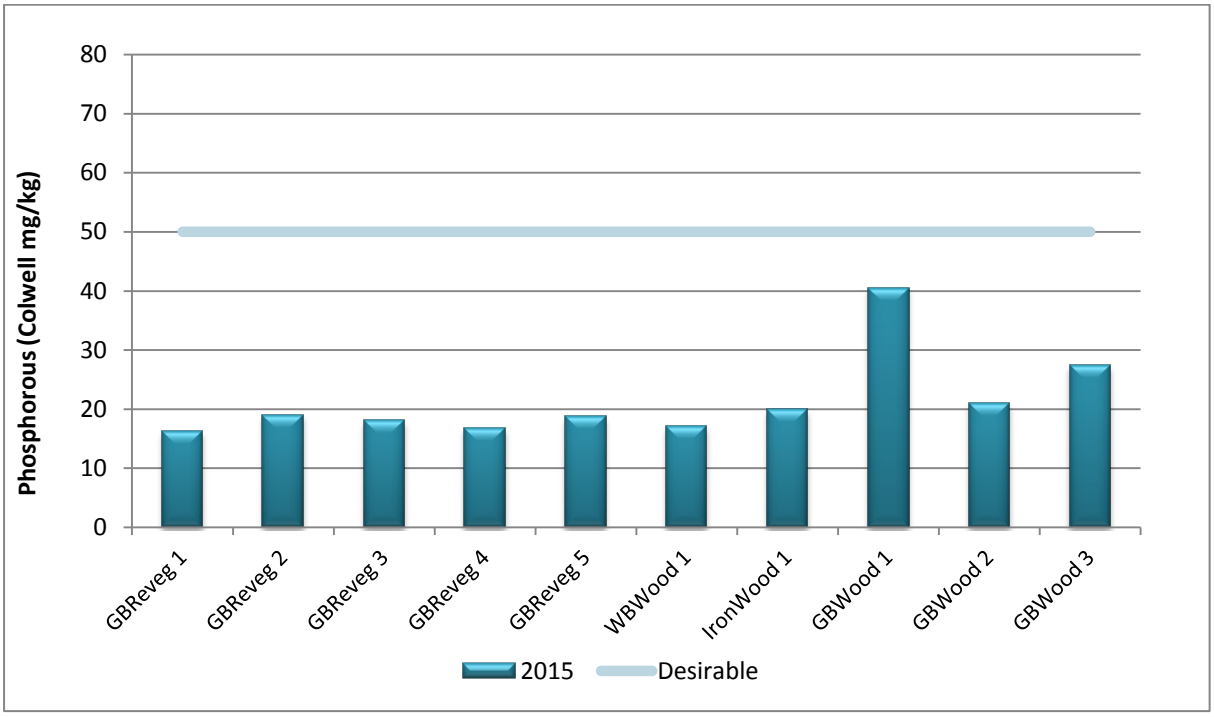


Figure 8-18. Phosphorous concentrations recorded in the Grey Box monitoring sites compared to desirable agricultural levels.

8.10.5 Nitrate

Nitrate levels were lower than the agricultural standards across all Grey Box monitoring sites and there were little differences between the sites. In the reference sites N ranged from 15. – 1.8 mg/kg and most of the other sites were slightly higher and had N concentration up to 2.6 mg/kg in GBReveg1 (Figure 8-19).

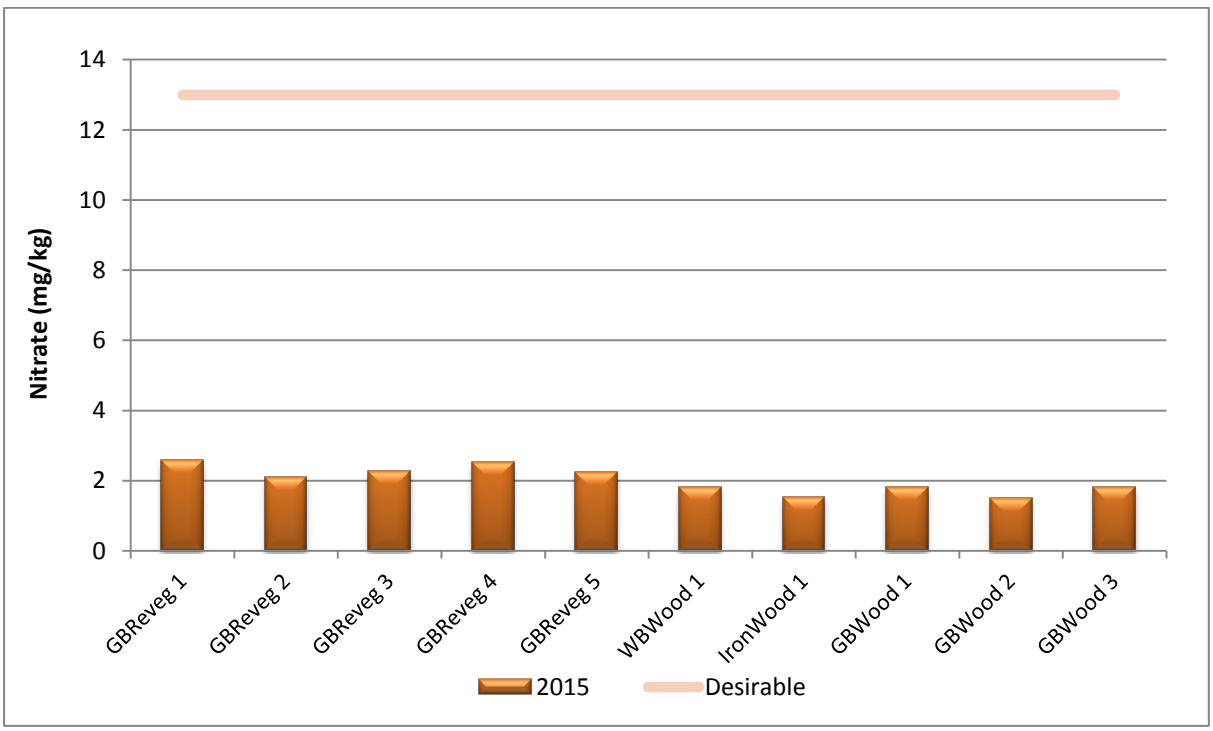


Figure 8-19. Nitrate concentrations recorded in the Grey Box monitoring sites compared to desirable agricultural levels.

8.10.6 Cation Exchange Capacity

Cation Exchange Capacity (CEC) is the capacity of the soil to hold the major cations (calcium, magnesium, sodium and potassium) and is also a measure of the potential fertility of the soil. All of the Grey Box monitoring sites had a low CEC and in the reference CEC ranged from 6.0 – 8.0 cmol/kg. In the remaining sites CEC ranged from a low of 3.4 cmol/kg in GBReveg4 to a high of 5.9 cmol/kg in GB Reveg1 (Figure 8-20).

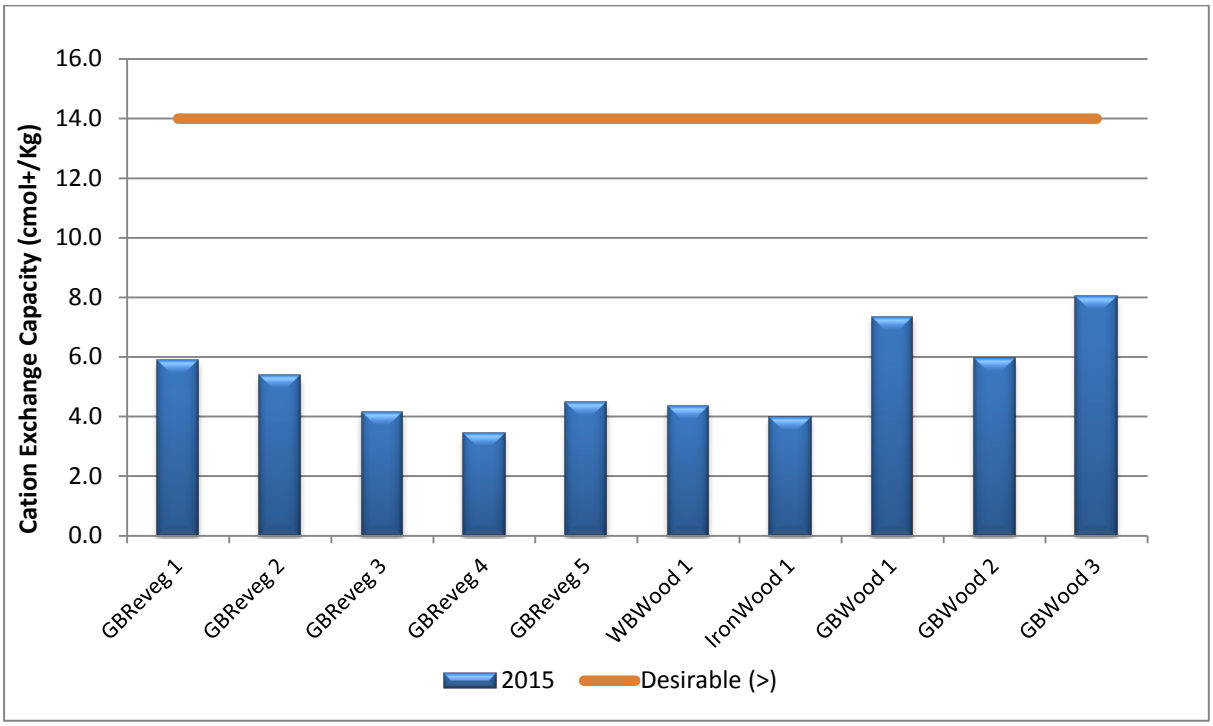


Figure 8-20. Cation Exchange Capacity recorded in the Grey Box monitoring sites compared to desirable agricultural levels.

8.10.7 Exchangeable Sodium Percentage

Sodicity refers to a significant proportion of sodium in the soil compared to other cations with soil considered to be sodic when there is sufficient sodium to interfere with its structural stability which often interferes with plant growth. Sodic soils tend to suffer from poor soil structure including hard soil, hardpans, surface crusting and rain pooling on the surface, which can affect water infiltration, drainage, plant growth, cultivation and site accessibility.

ESP recorded in the woodland reference sites was highly variable and ranged from 1.5 – 4.6% (Figure 8-21). In GBReveg1 and the white Box and Ironbark woodlands ESP was very low and was less than 1.4%. GBReveg2 and GBReveg4 had the highest ESPs of 4.4% and 4.2% respectively. All sites therefore had and ESP which remained below the 5% threshold indicating the soils are non sodic (Isbell 1996).

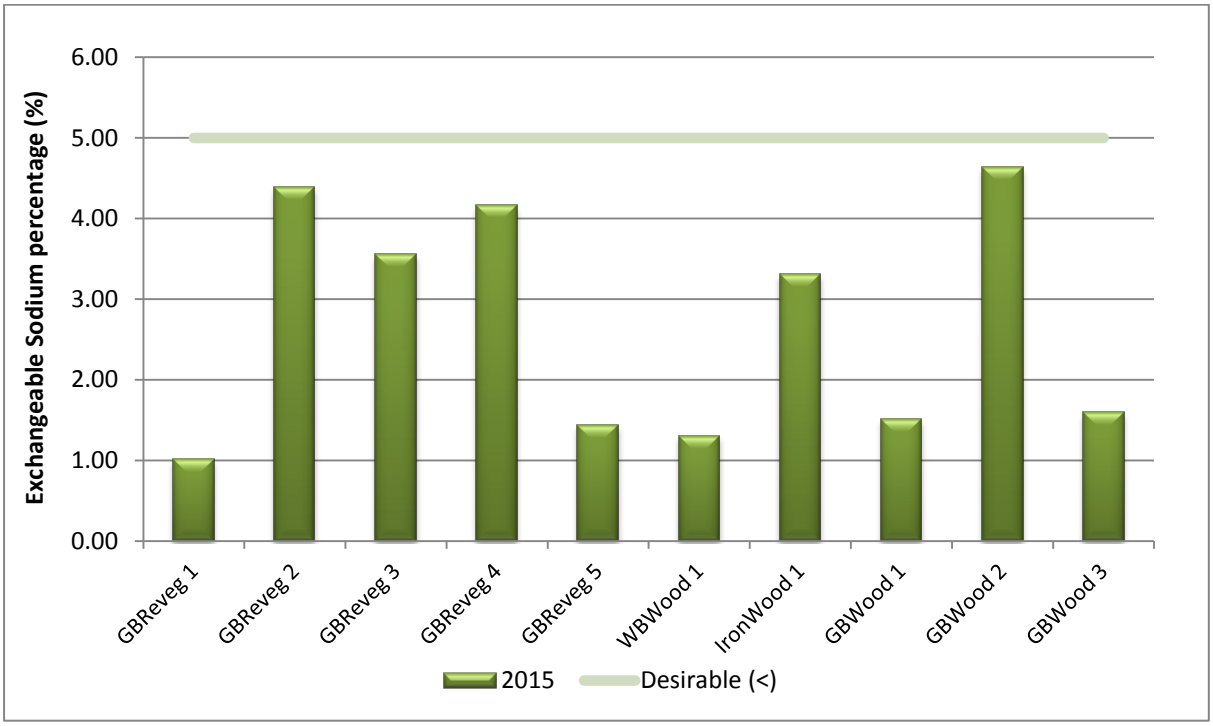


Figure 8-21. ESP recorded in the Grey Box monitoring sites compared to desirable agricultural levels.

8.10.8 Other soil tests

The full results of the soil analysis are provided in Appendix 2 but a summarised version highlighting elevated test results is provided in Table 8-7. The results indicate there are slightly to moderately elevated levels of Potassium and significantly high concentrations of Iron in most of the Grey Box sites, including the three reference sites. These data indicate that the soils at Kokoda are likely to be naturally high in both Potassium and Iron and/or are implicated with the long agricultural history. In the reference sites there may also be slightly elevated levels of Magnesium (GBWood3) and Chromium (GBWood2), and all three sites had elevated Sulfur concentrations.

Table 8-7. Summarised soil analyses highlighting elevated test results.

Method		*Nutrient*		*Units*	GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5	WBWood1	IronWood1	GBWood1	GBWood2	GBWood3	*Indicative guidelines only- refer Note 6*
	Morgan 1	Magnesium	Mg	mg/kg	65	97	71	56	66	73	42	161	101	155	*105*
		Potassium	K		79	73	58	77	112	77	66	145	87	115	*75*
	KCl	Sulfur	S	mg/kg	3.4	3.6	4.2	3.9	3.2	3.8	4.4	8.4	9.2	12.4	*8.0*
	DTPA	Iron	Fe	mg/kg	49	172	116	105	113	93	268	332	407	282	*22*
	Total Acid Extractable	Chromium	Cr	mg/kg	6	4	7	9	8	10	5	8	42	8	*<25 Cr*

Purple = Excessively high; Brown =significantly high; Red = very high; Yellow = moderately high; Green = slightly high

8.11 Grey Box woodland site performance towards meeting woodland completion criteria targets

Table 8-8 indicates the performance of the Kokoda Grey Box monitoring sites against a selection of proposed Completion Performance Indicators during the 2015 monitoring period. The selection of criteria has been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) and ending with indicators of ecosystem and landuse development (blue). The range values are amended annually.

Monitoring sites meeting or exceeding the range values of the Grey Box woodland reference sites have been identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2015. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 8-8. Performance of the Grey Box revegetation monitoring sites against the Primary and Secondary Performance Indicators obtained from the Grey Box woodlands.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	GBWood1	GBWood2	GBWood3	Grey Box Woodland ecosystem range 2015		GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5	WBWood1	IronWood1
Performance indicators are quantified by the range of values obtained from replicated reference sites							2015	2015	2015	Lower	Upper	2015	2015	2015	2015	2015	2015	2015
Phase 2: Landform establishment and stability	**Landform slope, gradient**	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	2	3	1	**1**	**3**	**5**	**4**	**3**	**4**	**3**	**3**	**4**
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Number of gullies or rills >0.3m in width or depth in a 50m transect are limited and stabilising		No.	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Phase 3: Growth medium development	**Soil chemical, physical properties**	Soil properties are suitable for the	pH	pH is typical of that of the surrounding landscape or falls within desirable ranges		pH (5.6 - 7.3)	**5.0**	**4.9**	**5.2**	**4.9**	**5.2**	**6.5**	**5.8**	**6.1**	**5.9**	**6.0**	**5.8**	**5.0**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	GBWood1	GBWood2	GBWood3	Grey Box Woodland ecosystem range 2015		GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5	WBWood1	IronWood1
	and amelioration	establishment and maintenance of selected vegetation species		provided by the agricultural industry														
			EC		Electrical Conductivity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	< dS/m (<0.150)	**0.074**	**0.069**	**0.077**	**0.069**	**0.077**	**0.026**	**0.029**	**0.022**	**0.019**	**0.024**	**0.026**	**0.038**
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	**7.8**	**4.7**	**6.3**	**4.7**	**7.8**	**2.6**	**4.6**	**1.9**	**1.7**	**2.2**	**1.5**	**4.2**
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	**40.5**	**20.9**	**27.4**	**20.9**	**40.5**	**16.2**	**19.0**	**18.1**	**16.8**	**18.7**	**17.1**	**19.9**
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	**1.8**	**1.5**	**1.8**	**1.5**	**1.8**	**2.6**	**2.1**	**2.3**	**2.5**	**2.2**	**1.8**	**1.5**
			CEC		Cation Exchange Capacity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	Cmol+/kg (>14)	**7.3**	**6.0**	**8.0**	**6.0**	**8.0**	**5.9**	**5.4**	**4.1**	**3.4**	**4.5**	**4.4**	**4.0**
			ESP		Exchangeable Sodium Percentage (a measure of sodicity) is typical of the surrounding landscape or is less than the 5% threshold for sodicity	% (<5)	**1.5**	**4.6**	**1.6**	**1.5**	**4.6**	**1.0**	**4.4**	**3.6**	**4.2**	**1.4**	**1.3**	**3.3**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	GBWood1	GBWood2	GBWood3	Grey Box Woodland ecosystem range 2015		GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5	WBWood1	IronWood1
Phase 4: Ecosystem & Landuse Establishment	**Landscape Function Analysis (LFA): Landform stability and organisation**	Landform is stable and performing as it was designed to do	LFA Stability	The LFA stability index provides an indication of the sites stability and is comparable to or trending towards that of the local remnant vegetation		%	**62.8**	**65.0**	**64.2**	**62.8**	**65.0**	**73.6**	**73.0**	**72.0**	**71.0**	**69.1**	**62**	**62.4**
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and is comparable to that of the local remnant vegetation		%	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees	The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.		species/area	**1**	**4**	**2**	**1**	**4**	**0**	**0**	**0**	**0**	**0**	**1**	**7**
				The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		% population	**100**	**100**	**100**	**100**	**100**	**0**	**0**	**0**	**0**	**0**	**100**	**100**
			Total species richness		The total number of live plant species provides an indication of the floristic diversity of the site and is comparable to the local remnant vegetation	No./area	**23**	**39**	**23**	**23**	**39**	**34**	**45**	**30**	**34**	**34**	**51**	**35**
			Native species richness		The total number of live native plant species provides an indication of the native plant diversity of the site and that it is greater than or comparable to the local remnant vegetation	>No./area	**16**	**33**	**17**	**16**	**33**	**16**	**32**	**13**	**18**	**16**	**39**	**34**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	GBWood1	GBWood2	GBWood3	Grey Box Woodland ecosystem range 2015		GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5	WBWood1	IronWood1
			Exotic species richness	The total number of live exotic plant species provides an indication of the exotic plant diversity of the site and that it is less than or comparable to the local remnant vegetation		<No./area	7	6	6	6	7	18	13	17	16	18	12	1
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees	The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation		No./area	1	18	2	1	18	0	0	0	0	0	1	108
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees	The number of tree species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	1	2	2	1	2	0	0	0	0	0	3	6
			Shrubs	The number of shrub species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	0	3	1	0	3	0	0	0	0	0	1	6
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	1	0	0	1	0	0	0	0	0	3	3
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	17	20	14	14	20	20	32	18	17	21	33	12

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	GBWood1	GBWood2	GBWood3	Grey Box Woodland ecosystem range 2015		GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5	WBWood1	IronWood1
			Grasses		The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	5	11	5	5	11	13	10	10	15	11	10	7
			Reeds		The number of reed, sedge or rush species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	1	1	0	1	1	2	1	1	1	0	0
			Ferns		The number of ferns comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	1	0	0	1	0	1	1	1	1	1	1
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0	0	0	0	0	0
Phase 5: Ecosystem & Landuse Development	**Landscape Function Analysis (LFA): Landform function and ecological performance**	Landform is ecologically functional and performing as it was designed to do	LFA Infiltration	LFA infiltration index provides an indication of the sites infiltration capacity and is comparable to or trending towards that of the local remnant vegetation		%	49.7	51.0	53.5	49.7	53.5	46.2	38.4	43.3	44.3	42.9	54.4	51.1
			LFA Nutrient recycling	LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and is comparable to or trending towards that of the local remnant vegetation		%	47.2	48.3	50.7	47.2	50.7	41.6	40.4	44.6	46	43.6	53.9	46

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	GBWood1	GBWood2	GBWood3	Grey Box Woodland ecosystem range 2015		GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5	WBWood1	IronWood1
	Protective ground cover	Ground layer contains protective ground cover and habitat structure comparable with the local remnant vegetation	Litter cover		Percent ground cover provided by dead plant material is comparable to that of the local remnant vegetation	%	82	94.4	89	82	94	26.5	7.5	40	42.5	36	76.5	69
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	1	0.0	0	0	1	50	31.5	35	34	48	2.5	0
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	0.0	0	0	0	4.5	25.5	0	6.5	0.5	0	6
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0	0.5	0	0	1	0	0	0	0	0	0	0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	1	2.0	3	1	3	0	0	0	0	0	1.5	6
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	10	0.5	1	1	10	1	1.5	0	0	0	0	13.5
			Perennial plant cover (< 0.5m)	Percent ground cover provided by live perennial vegetation (< 0.5m in height) is comparable to that of the local remnant vegetation		%	7	2.6	7	3	7	18	34	25	17	15.5	19.5	5.5
			Total Ground Cover	Total groundcover is the sum of protective ground cover components (as described above) and		%	91	99.5	99	91	100	99	98.5	100	100	100	100	86.5

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	GBWood1	GBWood2	GBWood3	Grey Box Woodland ecosystem range 2015		GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5	WBWood1	IronWood1
				that it is comparable to that of the local remnant vegetation														
	Ground cover diversity	Vegetation contains a diversity of species per square meter comparable to that of the local remnant vegetation	Native understorey abundance		The abundance of native species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has more than or an equal number of native species as the local remnant vegetation	> species/m^2	**4.6**	**3.8**	**5.2**	**3.8**	**5.2**	**3**	**9.4**	**2.6**	**5.2**	**3.8**	**9.4**	**5.4**
			Exotic understorey abundance		The abundance of exotic species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has less than or an equal number of exotic species as the local remnant vegetation	< species/m^2	**0.2**	**0.2**	**0.8**	**0.2**	**0.8**	**7.2**	**5.2**	**8**	**6.4**	**6.6**	**3**	**0**
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation		%	**97.1**	**96.2**	**90.5**	**90.5**	**97.1**	**27.2**	**61.7**	**27.8**	**36.5**	**31.4**	**78.3**	**100**
	Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	shrubs and juvenile trees 0 - 0.5m in height	The number of shrubs or juvenile trees < 0.5m in height provides an indication of establishment success and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation		No./area	**1**	**13**	**1**	**1**	**13**	**0**	**0**	**0**	**0**	**0**	**0**	**78**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	GBWood1	GBWood2	GBWood3	Grey Box Woodland ecosystem range 2015		GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5	WBWood1	IronWood1
			shrubs and juvenile trees 0.5 - 1m in height		The number of shrubs or juvenile trees 0.5-1m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	2	0	0	2	0	0	0	0	0	1	27
			shrubs and juvenile trees 1 - 1.5m in height		The number of shrubs or juvenile trees 1-1.5m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	2	0	0	2	0	0	0	0	0	0	2
			shrubs and juvenile trees 1.5 - 2m in height	The number of shrubs or juvenile trees 1.5-2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation		No./area	0	1	0	0	1	0	0	0	0	0	0	0
			shrubs and juvenile trees >2m in height		The number of shrubs or juvenile trees > 2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	1	0	1	0	0	0	0	0	0	1

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	GBWood1	GBWood2	GBWood3	Grey Box Woodland ecosystem range 2015		GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5	WBWood1	IronWood1
	Ecosystem structure	The vegetation is developing in structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5 - 2 m	Projected foliage cover provided by perennial plants in the 0.5 - 2m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**3**
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	**10**	**4**	**0**	**0**	**10**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 -6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	**18**	**0**	**3**	**0**	**18**	**0**	**0**	**0**	**0**	**0**	**5**	**0**
			Foliage cover >6m	Projected foliage cover provided by perennial plants > 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover	**50**	**52**	**52**	**50**	**52**	**0**	**0**	**0**	**0**	**0**	**28**	**26**
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	**1**	**3**	**2**	**1**	**3**	**0**	**0**	**0**	**0**	**0**	**3**	**5**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	GBWood1	GBWood2	GBWood3	Grey Box Woodland ecosystem range 2015		GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5	WBWood1	IronWood1
		vegetation		The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	100	100	100	100	100	0	0	0	0	0	100	100
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	8	21	20	8	21	0	0	0	0	0	8	40
			Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	34	18	24	18	34	0	0	0	0	0	28	17
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees	The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation		% population	100	100	85	85	100	0	0	0	0	0	100	82.5
			Healthy trees	The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation		% population	13	48	5	5	48	0	0	0	0	0	50	10
			Medium health		The percentage of the tree population which are in a medium health condition and that the percentage is comparable to the local remnant vegetation	% population	75	38	60	38	75	0	0	0	0	0	37.5	27.5

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	GBWood1	GBWood2	GBWood3	Grey Box Woodland ecosystem range 2015		GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5	WBWood1	IronWood1
			Advanced dieback		The percentage of the tree population which are in a state of advanced dieback and that the percentage is comparable to the local remnant vegetation	<% population	13	14	20	13	20	0	0	0	0	0	12.5	45
			Dead Trees		The percentage of the tree population which are dead (stags) and that the percentage is comparable to the local remnant vegetation	% population	0	0	15	0	15	0	0	0	0	0	0	17.5
			Mistletoe		The percentage of the tree population which have mistletoe provides an indication of community health and habitat value and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0	0	0	0	0	0
			Flowers/fruit: Trees	The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation		% population	0	5	10	0	10	0	0	0	0	0	62.5	17.5
			Hollows: Trees		The percentage of the tree population which have hollows provides an indication of the habitat value and that the percentage is comparable to the local remnant vegetation	% population	38	0	20	0	38	0	0	0	0	0	12.5	2.5

9 Results: Dwyer's Red Gum monitoring sites

This section provides the results of the monitoring within the Dwyer's Red Gum monitoring sites and demonstrates ecological trends and performance of the revegetation sites against a selection of primary ecological performance indicators. This section has also included the Low Quality Dwyer's Red Gum woodland.

9.1 Landscape Function Analyses

9.1.1 Landscape Organisation

A patch is an area within an ecosystem where resources such as soil and litter tend to accumulate, while areas where resources are mobilised and transported away are referred to as interpatches. Landscape Organisation Indices (LOI) are calculated by the length of the patches divided by the length of the transect to provide an index or percent of the transect which is occupied by functional patch areas (Tongway and Hindley 2004).

The three Dwyer's Red Gum woodland reference sites were characterised by having a mature tree canopy and a well developed decomposing leaf litter layer and a sparse cover of native perennial forbs and grasses and collectively provided a highly functional patch area and Landscape Organisation Indices of 100%.

While the Dwyer's Red Gum revegetation sites presently existed as degraded pastures and were structurally different to the woodland reference sites, they typically had good ground cover comprised of a combination of annual and perennial plants and cryptogams. These sites also had a high functional patch areas and subsequently scored LOI's of 100% (Figure 9-1).

The low quality Dwyer's Red Gum woodland site was characterised with having an open mature tree canopy, moderate cover of annual and perennial ground cover species and typically had a well developed leaf litter layer but this was patchy. This site however also had a high functional patch area and scored an LOI of 100%.

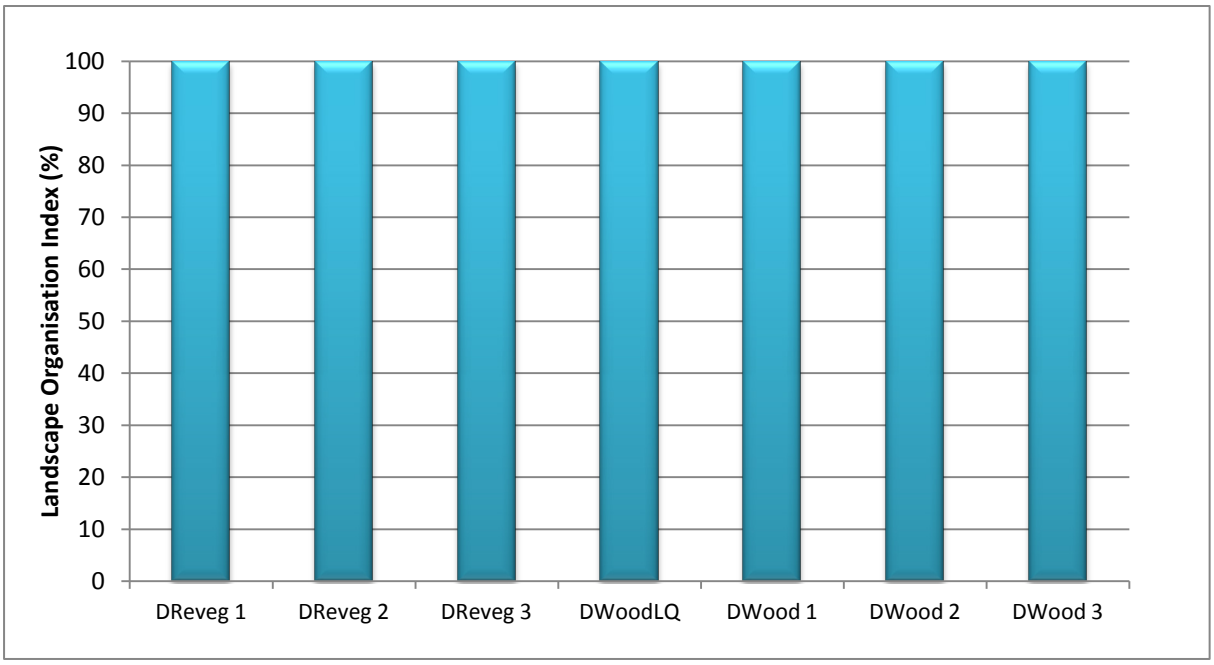


Figure 9-1. Landscape Organisation Indices recorded in the Dwyer's Red Gum woodland monitoring sites.

9.1.2 Soil surface assessments

9.1.2.1 Stability

LFA stability indices in the Dwyer's Red Gum woodland monitoring sites ranged from 63.1 – 70.0 with sites stability being provided by the perennial tree cover, moderately deep litter layers and the sandy loam soils were very stable. There was however relatively high rates of deposition in some sites as leaf litter had become mobilised across the sites during high rainfall events. In the low quality woodland the stability index was 66.5 and thus had similar stability to the woodland reference sites (Figure 9-2).

The Dwyer's Red Gum derived native grasslands also tended to have a stability which was similar to or more stable than the reference sites with stability indices ranging from 69.2 (DReveg3) – 75.0 (DReveg1). Despite the lack of a mature tree canopy, higher stability indices can be attributed to the higher abundance of perennial ground covers, very hard soil crusts which usually contained a significant abundance of cryptogam cover. The sandy clay soils were subjected to some slaking but there tended to be less recent evidence of erosion or deposition within these sites.

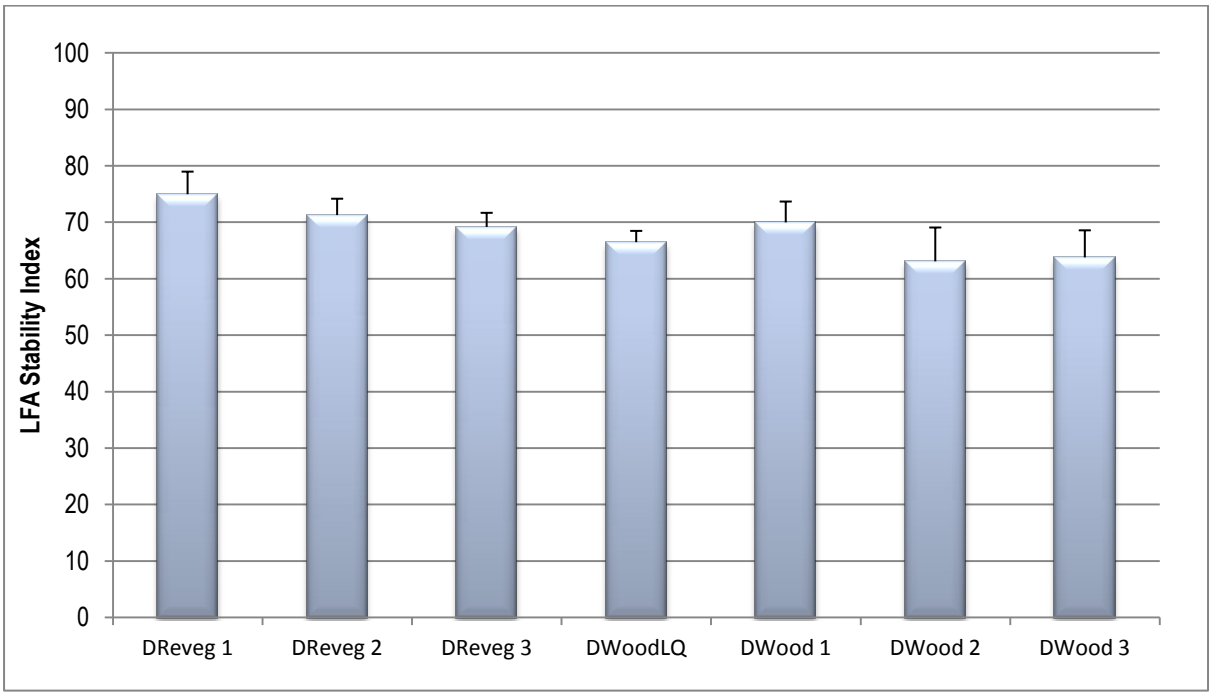


Figure 9-2. LFA stability indices recorded in the Dwyer's Red Gum woodland monitoring sites.

9.1.2.2 Infiltration

The infiltration capacity of the Dwyer's Red Gum and the low quality woodland (DWoodLQ) were quite similar to each other with the Dwyer's Red Gum reference sites providing a target range of 43.6 – 54.6 (Figure 9-3). The sites often had a well developed and decomposing litter layer, which had often formed a rich humus layer with lower occurrences of soil surface crusting but this tended to be quite patchy.

In the derived grassland revegetation sites, there tended to be an undeveloped litter layer and a hard surface crust which reduces the infiltration capacity of moisture to enter the soil profile but DReveg1 and DReveg2 fell within the targets range with infiltration indices of 47.1 and 46.0 respectively. DReveg3 had a slightly lower index of 40.1.

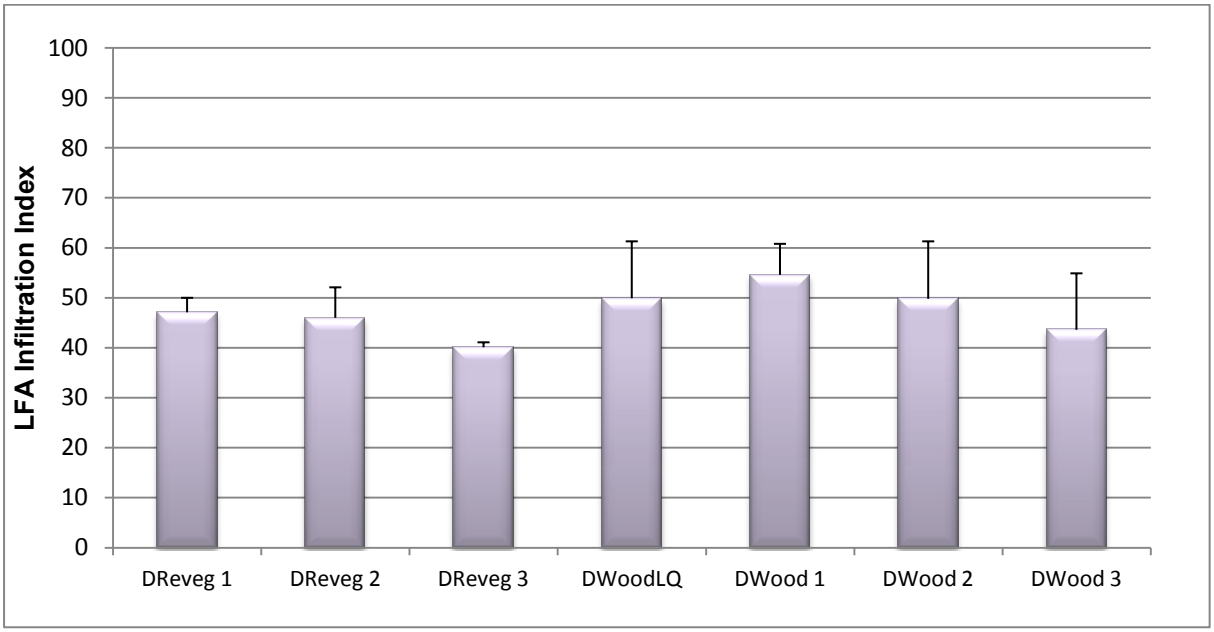


Figure 9-3. LFA infiltration indices recorded in the Dwyer's Red Gum woodland monitoring sites.

9.1.2.3 Nutrient recycling

The nutrient recycling capacity is influenced by the degree of perennial plant cover and accumulation and decomposition of the litter layers, which is in turn influenced by the degree of soil compaction and soil surface crusting. In the Dwyer's Red Gum woodland reference sites and the low quality woodland, there was a mature overstorey and there tended to be a low abundance of perennial ground cover but there were well developed litter layers but the site was patchy. In the Dwyer's Red Gum woodland reference sites the target nutrient recycling range was 44.5 – 51.7 with the low quality woodland scoring 46.9 (Figure 9-4).

In the Dwyer's Red Gum revegetation sites, there was a lack of a mature overstorey however due to the scattered perennial plant cover, relatively good litter cover and extensive abundance of cryptogams the site DReveg2 had similar nutrient recycling indices of 46.4. Nutrient recycling capacity in DReveg1 and DReveg3 were slightly lower with 43.4 and 40.9 respectively.

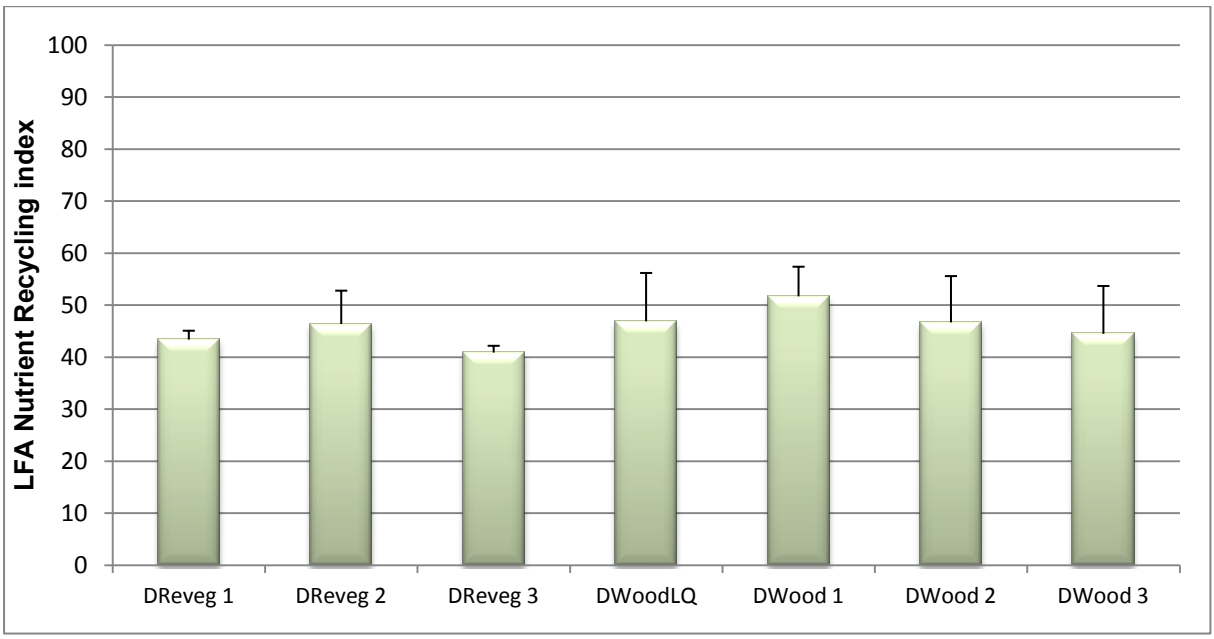


Figure 9-4. LFA nutrient recycling indices recorded in the Dwyer's Red Gum woodland monitoring sites

9.1.3 Most functional sites

The sum of the LFA stability, infiltration and nutrient recycling components provide an indication of the most functional to least functional monitoring sites recorded this year and is provided in Figure 9-5. The maximum score possible is 300 with the Dwyer's Red Gum reference site DWood1 being the most ecologically functional site with a total score of 176.3. This site contained high patch area, a mature tree canopy and well developed grassy ground cover layer, with high levels of decomposing litter and had very stable soils.

DReveg 1, DReveg2 and the low quality woodland DWoodLQ were the next most functional sites and had a sum of scores which exceeded the reference sites DWood2 and DWood3 which scored a relatively low score of 159.6 and 151.9 respectively. The lowest ecological function was recorded in DReveg3 which was only slightly lower than DWood3 with a sum of indices of 150.2. Examples of the various combinations of ground covers which are critical to overall ecosystem function have been provided in Table 9-1.

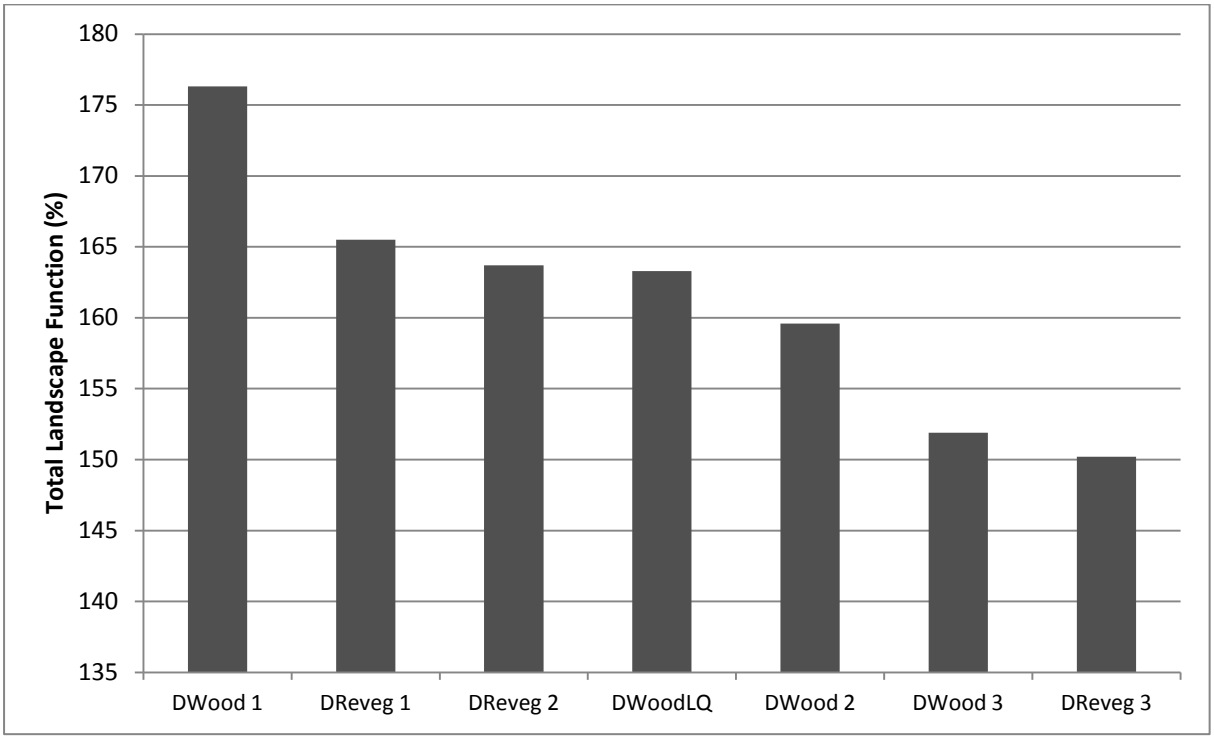


Figure 9-5. Sum of the LFA stability, infiltration and nutrient recycling components indicating the most functional to least functional monitoring site recorded in 2015.

Table 9-1. Examples of the different ground covers in the Kokoda Dwyer's Red Gum monitoring sites.

DReveg1	DReveg2
	

DReveg3	DWoodLQ
	
DWood1	**DWood2**
	
DWood3	
	

9.2 Trees and mature shrubs

9.2.1 Population density

Trees and mature shrubs with a stem diameter >5cm dbh were recorded in the three Dwyer's Red Gum woodland reference sites as well as the low quality Dwyer's Red Gum woodland. There were 9 – 25 individuals in the reference sites, equating to a density of 225 – 625 stems per hectare (Figure 9-6). There were nine individuals in the low quality woodland. No trees or mature shrubs were yet present in the derived native grassland sites.

9.2.2 Diameter at breast height

The average dbh recorded in the Dwyer's Red Gum reference sites ranged from 11 – 23cm but ranged from 5 – 49cm (Table 9-2). The small trunk diameters indicate the trees are relatively young and indicative of their regrowth status. In the low quality woodland the average dbh was 22 cm with the maximum dbh of 27cm.

9.2.3 Condition

The trees and mature shrubs in the Dwyer's Red Gum woodland reference sites were typically in moderate health but there were also a large percentage of stags in DWood1 and DWood2. No mistletoe was recorded and in DWood3 a large percent of the population were bearing reproductive structures such as buds, flowers or fruits. There was a very small percentage containing hollows suitable for nesting sites (>10cm) in the three woodland sites. In the low quality woodland all trees were in medium health and almost half (44%) of them were bearing fruit.

9.2.4 Species composition

The Dwyer's Red Gum reference sites were dominated by *Callitris endlicheri* but there may also have been scattered individuals of *Allocasuarina luehmannii, E. dwyeri, E. dealbata, E. sideroxylon* and/or *E. microcarpa*. The low quality woodland was dominated by *E. dwyeri* and contained one *E. albens*.

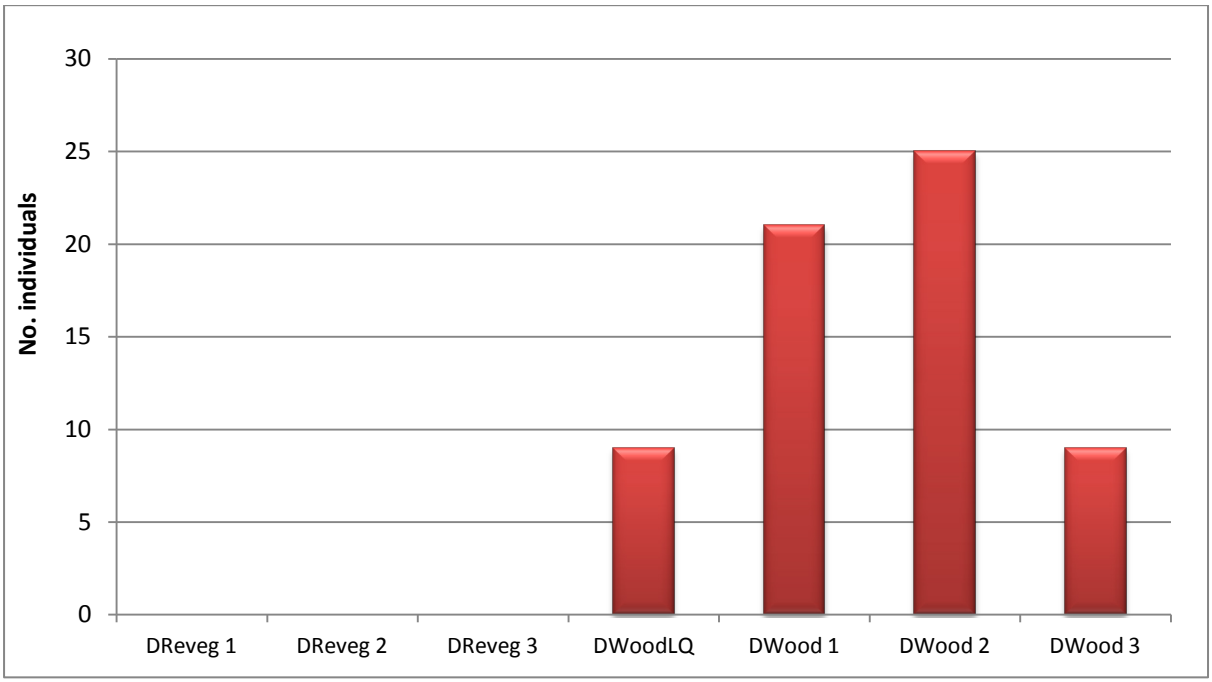


Figure 9-6. Tree and mature shrub densities (>5cm dbh) in the Kokoda Dwyer's Red Gum woodland monitoring sites.

Table 9-2. Trunk diameters and condition of the trees and mature shrubs in the Dwyer's Red Gum monitoring sites.

Site Name	No species	Average dbh (cm)	Max dbh (cm)	Min dbh (cm)	Total trees	No. with multiple limbs	% Live trees	% Healthy	% Medium Health	% Advanced Dieback	% Dead	% Mistletoe	% Flowers / fruit	%. Trees with hollows
DReveg1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DReveg2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DReveg3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DWoodLQ	2	22	27	16	9	7	100	0	100	0	0	0	44	0
DWood1	4	11	28	5	70	2	30	1	24	4	70	0	10	9
DWood2	3	18	49	5	32	4	78	6	53	19	22	0	28	3
DWood3	3	23	31	7	11	2	82	27	27	27	18	0	82	9

9.3 Shrubs and juvenile trees

9.3.1 Population density

There was a large variation on the number of shrubs and juvenile trees (<5cm dbh) recorded in the Dwyer's Red Gum reference sites with densities ranging from 32 – 598 individuals equating to a density of 800 – 14,950 stems per hectare (Figure 9-7). In the low quality woodland eight shrubs and juvenile trees were recorded, while nine eucalypt seedlings were recorded in DReveg1.

9.3.2 Height class

In the reference sites the vast majority (87%) of individuals were less than 0.5m in height, with 10% being 0.5 – 1.0m in height and 3% were 1.0 – 1.5m (Table 9-3). In the low quality woodland all individuals were less than 0.5m in height. In DReveg1 almost all height classes were represented but most were less than 1.5m in height.

9.3.3 Species diversity

In the woodland reference sites there were 4 - 7 species of shrubs and juvenile trees with the most abundant species being young *Callitris endlicheri* seedlings. There were also low occurrences of a range of other species including *Acacia doratoxylon* (Spearwood), *Brachyloma daphnoides*, *E. dwyeri*, *E. sideroxylon*, *Allocasuarina verticillata* (Drooping She oak) and *Cassinia laevis* (Cough Bush). In DWood3 there was a relatively high abundance of *Calytrix tetragona* (Fringe Myrtle). In DReveg1 all individuals were *E. dwyeri* saplings.

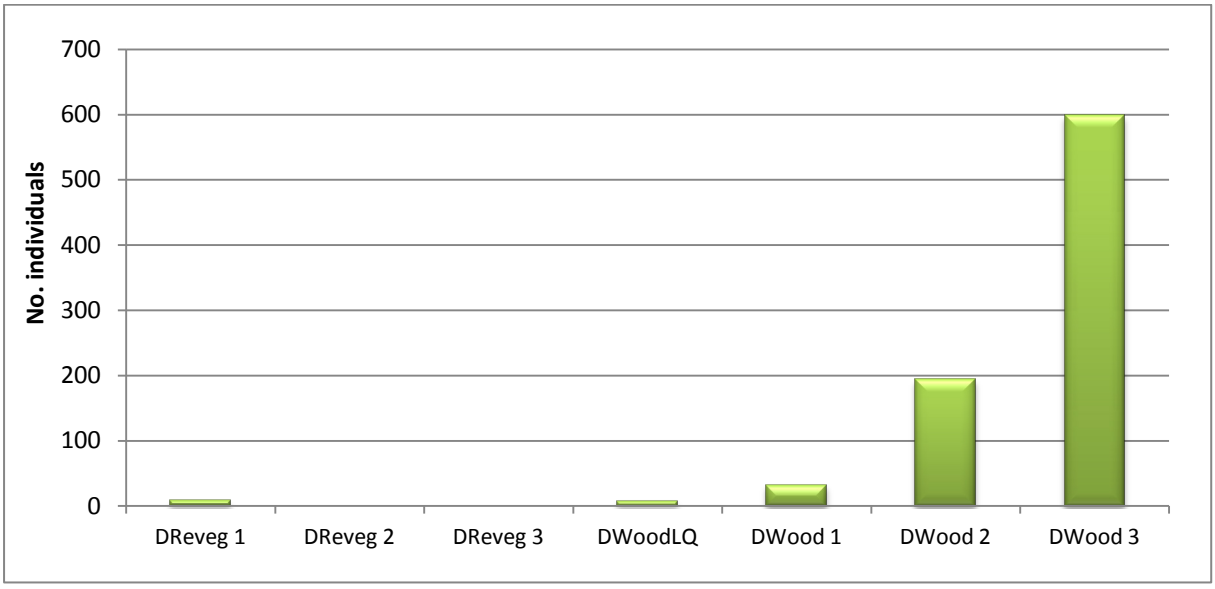


Figure 9-7. Total shrubs and juvenile trees recorded in the Dwyer's Red Gum monitoring sites.

Table 9-3 Number of individuals represented in each height class across the range of monitoring sites.

Site Name	0-0.5m	0.5-1.0m	1.0-1.5m	1.5-2.0m	>2.0m	Total	No. species	% Endemic
DReveg1	2	4	2	0	1	9	1	100
DReveg2	0	0	0	0	0	0	0	0
DReveg3	0	0	0	0	0	0	0	0
DWoodLQ	8	0	0	0	0	8	3	100
DWood1	31	1	0	0	0	32	4	100
DWood2	180	14	0	0	0	194	4	100
DWood3	502	68	26	0	2	598	7	100

9.4 Total ground Cover

Total ground cover, which is a combination of leaf litter, annual plants, cryptogams, rocks, logs and live perennial plants (<0.5m in height) was relatively high in the Dwyer's Red Gum woodland reference sites and ranged from 91.0 – 96.5% (Figure 9-8). In the low quality woodland total ground cover was similar with 97.0%. In the derived grasslands, ground cover was at least 99.5%.

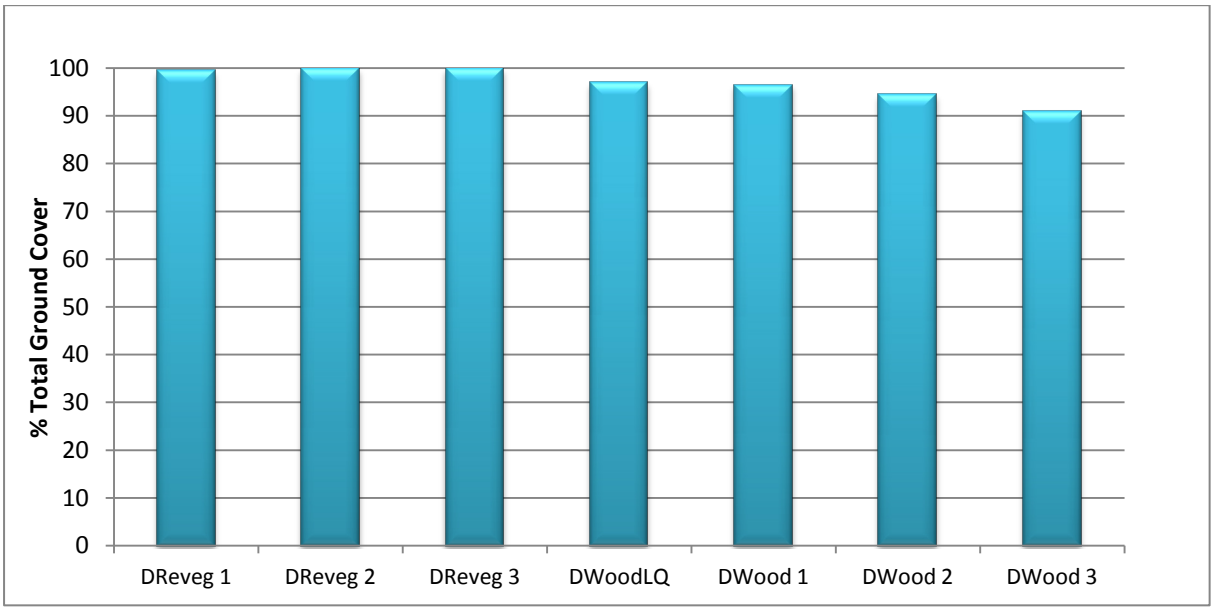


Figure 9-8. Total ground cover recorded in the Dwyer's Red Gum woodland monitoring sites.

9.5 Structural composition

The various combinations of the ground covers and structural compositions of the woodland sites are provided in Figure 9-9. In the Dwyer's Red Gum woodland reference sites and the low quality woodland the most dominant form of ground cover was dead leaf litter with these providing 41 – 78.5% of the total ground cover in the reference sites.

There was a small contribution of cover provided by scattered perennial (4 – 28%) and annual (1.3 – 14%) plants and cryptogams provided 1 – 6% ground cover. There was some cover provided by fallen branches, and there may have been an occasional rock. The low quality woodland had similar features in similar proportions but did not tend to have fallen branches. The reference sites and the low quality woodland were also characterised by having a mature canopy cover which exceeded 6.0m in height with low hanging braches (and scattered shrubs) also providing occasional projected cover in the lower height classes.

In comparison the revegetation sites were presently dominated by various proportions of annual plants and dead leaf litter but had similar proportions of perennial ground covers and cryptogam cover. Some taller grass tussock may have provided a small amount of vertical structure but they did not yet have a shrub or mature tree layer.

Examples of the various structural compositions of the individual sites have been provided in Table 9-4.

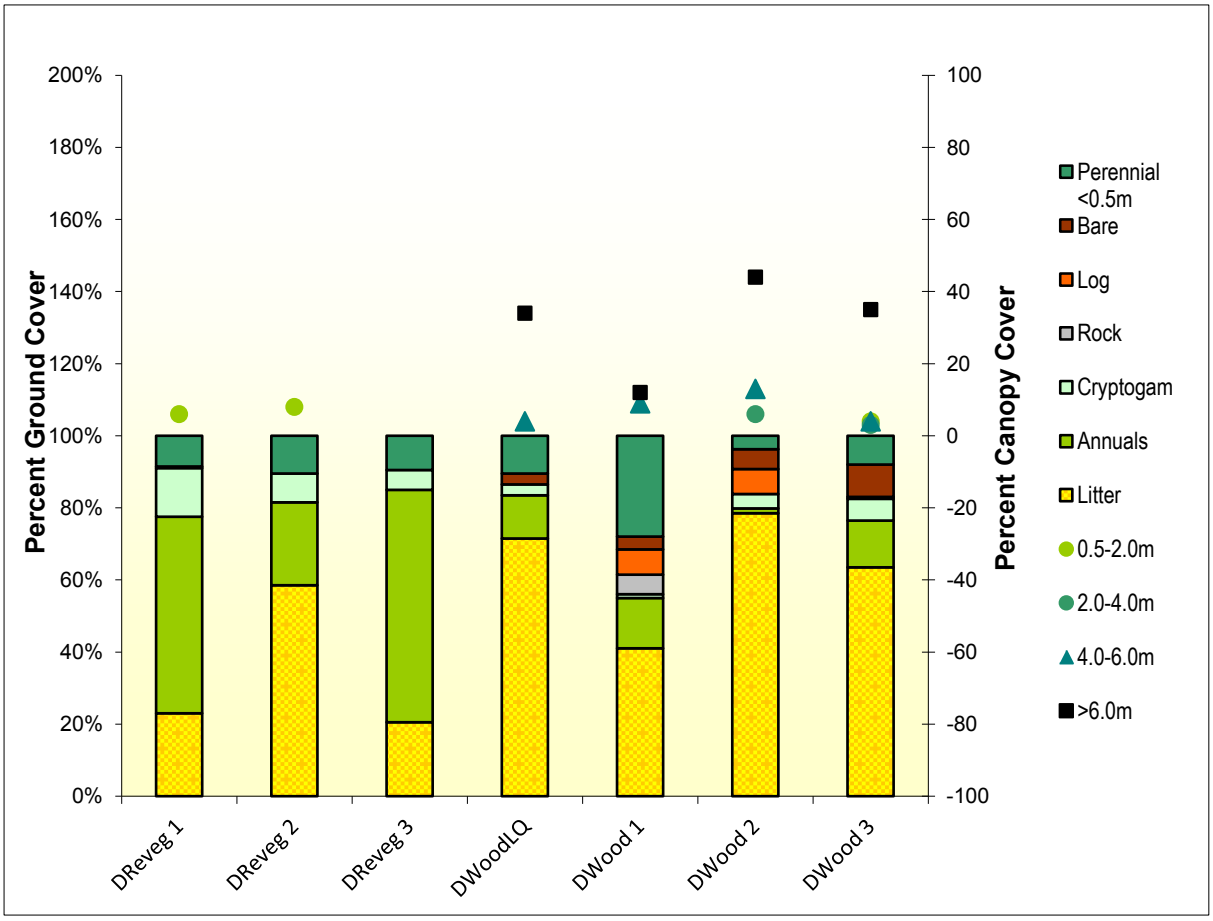
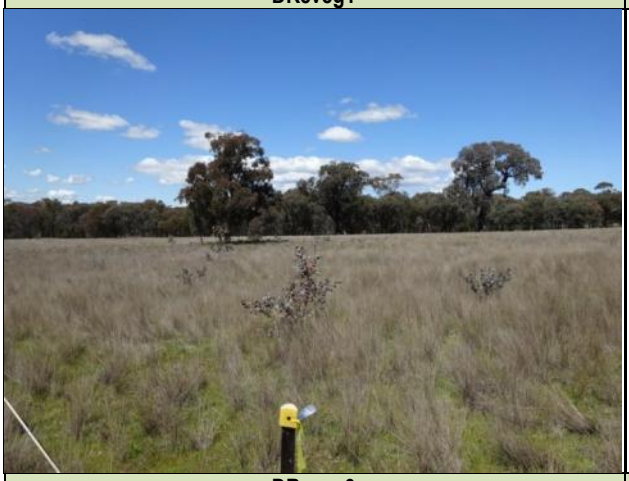


Figure 9-9. Average percent ground cover and projected foliage cover recorded in the Dwyer's Red Gum monitoring sites.

Table 9-4. Structural compositions of the Dwyer's Red Gum monitoring sites.

DReveg1	DReveg2
	
DReveg3	**DWoodLQ**
	
DWood1	**DWood2**
	
DWood3	
	

9.6 Floristic Diversity

Total floristic diversity recorded within the 20 x 20m Dwyer's Red Gum monitoring sites was highly variable with 31 – 49 species recorded in the reference sites (Figure 9-10). The low quality woodland contained the highest total species diversity with 50 species. Floristic diversity in the derived grassland sites was also variable and ranged from a low diversity of 27 species in DReveg2 to a high of 40 species in GBReveg3.

In the woodland reference sites, native species were far more diverse than exotic species with 29 – 44 native species being recorded and there were 33 native species in the low quality woodland (Figure 9-11). In the derived grasslands, native species were slightly more diverse than exotic species in DReveg1 and DReveg2 which had 19 native species each. Site DReveg3 had the lowest diversity of native species with only 18 species.

In the reference sites there were 2 – 8 exotic species with only eight exotics species also being recorded in DReveg2. The remaining sites had more exotic species than desired with 17 exotics in both DReveg1 and DWoodLQ, while there was 22 exotic species in DReveg2 (Figure 9-12).

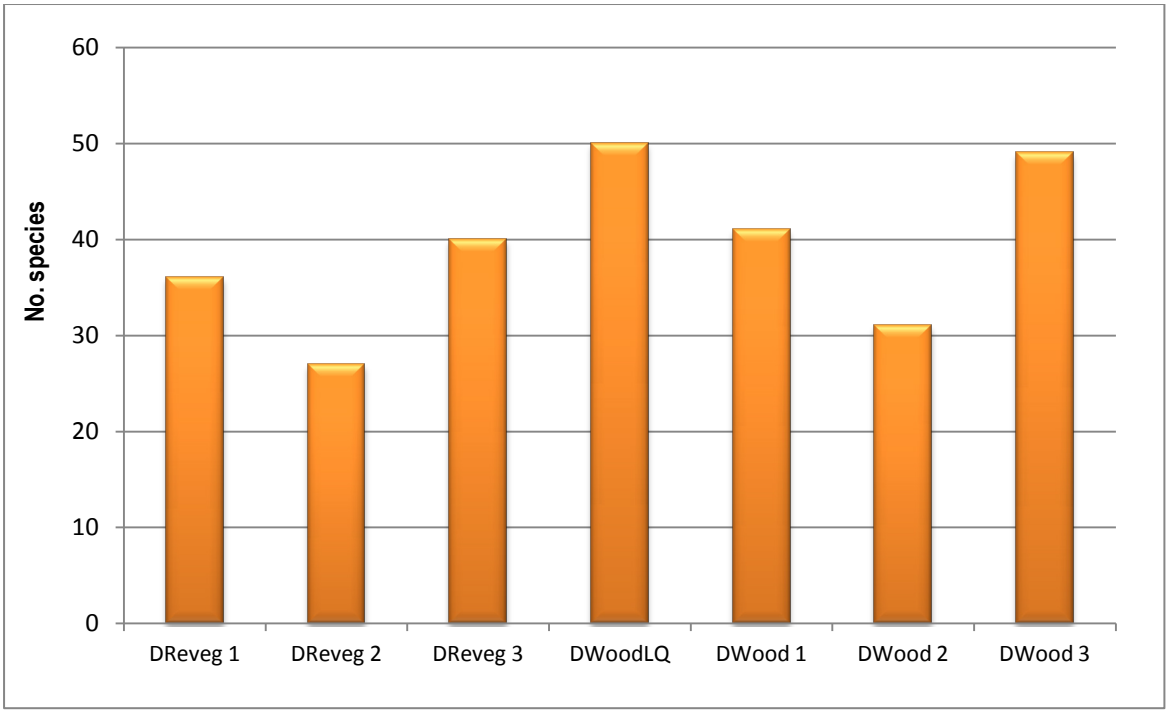


Figure 9-10. Total species diversity recorded in the Dwyer's Red Gum monitoring sites.

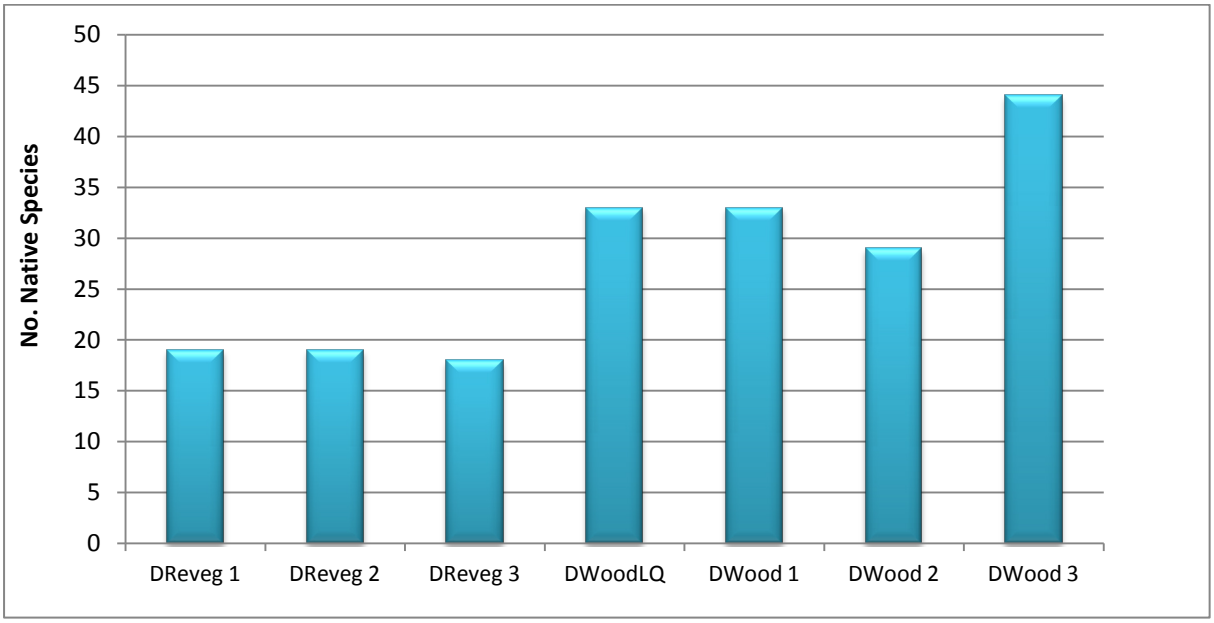


Figure 9-11. Total native species recorded in the Dwyer's Red Gum monitoring sites.

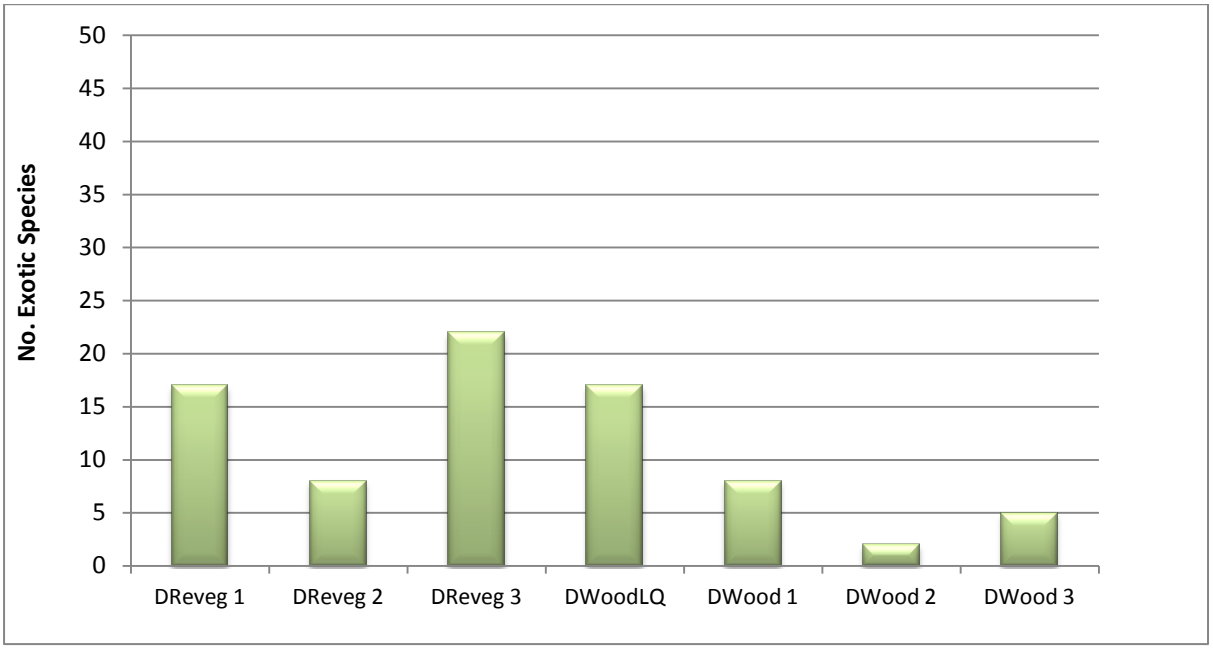


Figure 9-12. Total exotic species recorded in the Dwyer's Red Gum monitoring sites.

9.6.1 Percent endemic ground cover

The percent endemic ground cover is an ecological indicator used to provide some measure of the cover abundance of the live native vegetation along the vegetation transect and therefore indicates the level of weediness at the monitoring sites. While it is only estimation the percent cover of endemic ground cover species has been derived by the following equation.

Percent cover endemic species = sum of the five Braun- blanquet scores for native species / (sum of the five Braun- blanquet scores of exotic species + native species) x 100

In the Dwyer's Red Gum woodland reference sites most of the live plant cover was provided by native species with endemic plants providing 73.6 – 90.1% of the total plant cover (Figure 9-13). There was a slightly lower abundance of native species in DWoodLQ with 65.8% and was slightly weedier than desired. In the derived grasslands the highest cover of native plants was recorded in DReveg2 with

62.5% endemic cover. In DReveg1 and DReveg3 exotic species dominated the sites with only 33.0% and 32.1% endemic plant covers respectively. Therefore all grassland sites were presently dominated by exotic species and were weedier than desired.

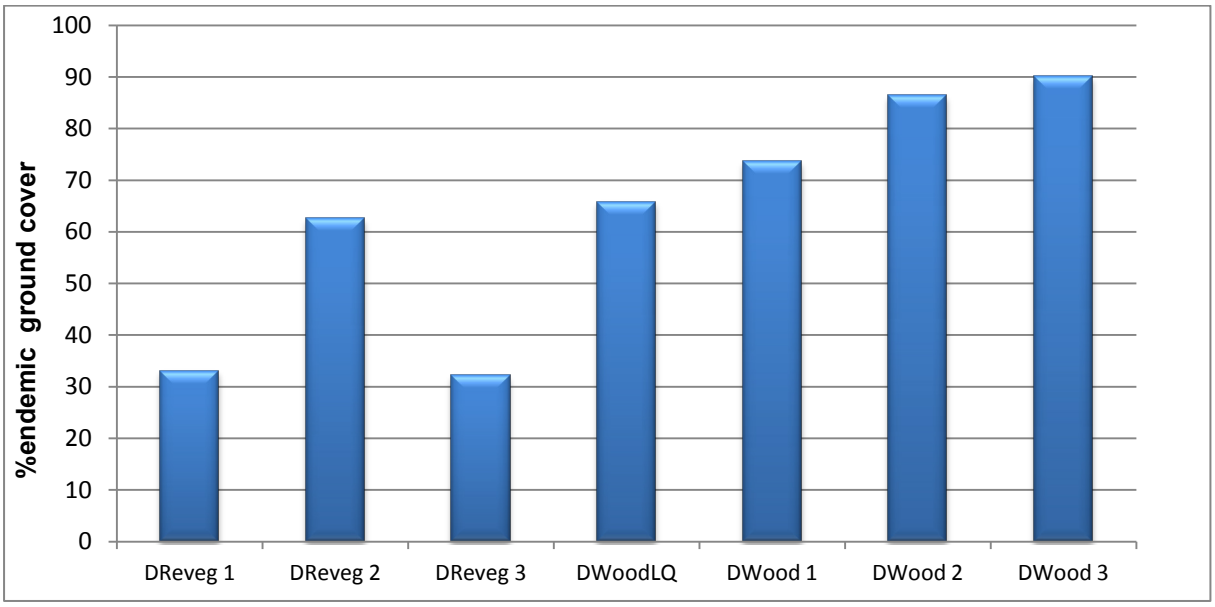


Figure 9-13. Percent endemic ground cover recorded in the Dwyer's Red Gum monitoring sites.

9.7 Vegetation composition

The composition of the vegetation as categorised by seven different growth forms is given in Figure 9-14. In the Dwyer's Red Gum woodland reference sites herbs were the most diverse plant group with 16 - 28 different species followed by grasses with 5 – 8 species. There were four tree species, 2 – 6 shrub species and one sub-shrub was recorded in all three sites. There were up to 2 reed species and all sites had one species of fern.

The low quality woodland site had similar composition of the herbaceous ground covers, but it had a low diversity of tree species and no sub – shrubs were recorded. In the grassland revegetation areas there was also an adequate representation of most growth forms in the herbaceous ground covers but there was presently a low diversity of trees and shrubs and no sub-shrubs were recorded.

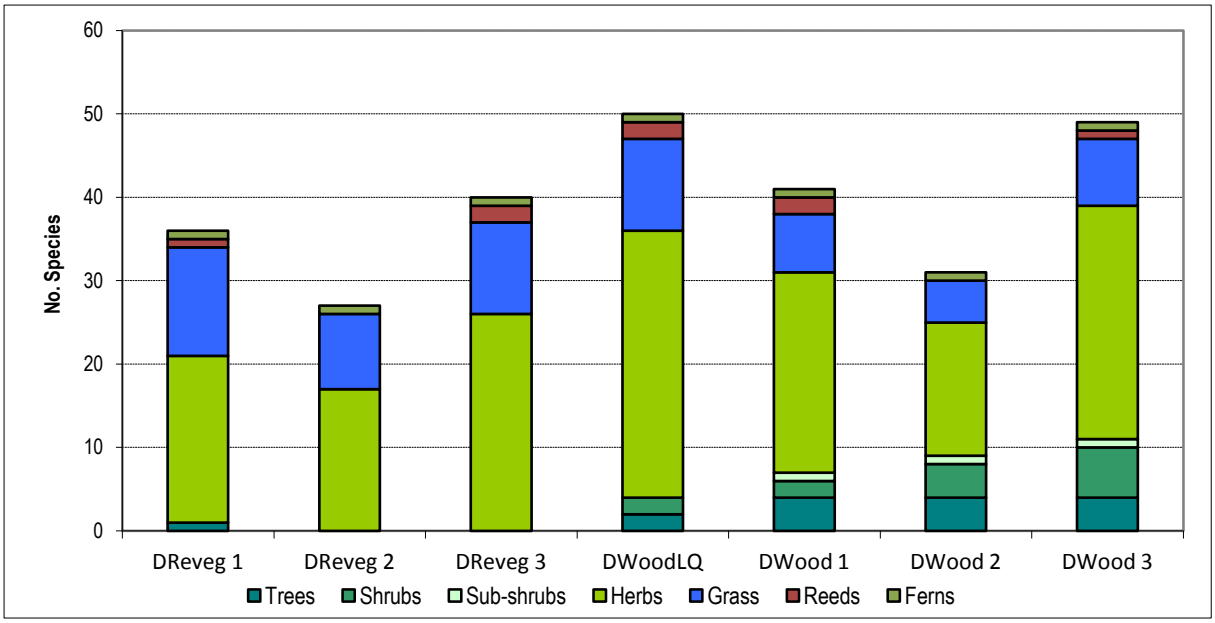


Figure 9-14. Composition of the vegetation recorded in the Dwyer's Red Gum monitoring sites.

9.8 Most common species

There were 126 species recorded across the Dwyer's Red Gum monitoring sites with 41 (33%) of these being exotic species (Appendix 1). The exotic annual *Hypochaeris glabra* (Smooth Catsear) and *Vulpia muralis* (Rats-tail Fescue) were recorded in all sites including the three reference sites and so was the native fern *Cheilanthes sieberi subsp. sieberi* (Rock Fern).Other common exotic annuals were *Aira cupaniana* (Silvery Hairgrass), *Arctotheca calendula* (Capeweed) and *Briza minor* (Shivery Grass) (Table 9-5).

Some common native species included the native perennial grasses *Aristida ramosa* (Threeawn Grass) and *Bothriochloa macra* (Red-leg Grass). Native herbs *Bulbine bulbosa* (Bulbine Lily), *Drosera peltata* (Pale Sundew), *Stuartina muelleri* (Spoon Cudweed) and *Triptilodiscus pygmaeus* (Austral Sunray) were also relatively common. A comprehensive list of species recorded in all monitoring sites has been included in Appendix 1.

Table 9-5. The most common species recorded in the Dwyer's Red Gum monitoring sites.

Family	exotic	Scientific Name	Common Name	Habit	DReveg1	DReveg2	DReveg3	DWoodLQ	DWood1	DWood2	DWood3	Total
Adiantaceae		*Cheilanthes sieberi subsp. sieberi*	Rock Fern	f	1	1	1	1	1	1	1	**7**
Asteraceae	*	*Hypochaeris glabra*	Smooth Catsear	h	1	1	1	1	1	1	1	**7**
Poaceae	*	*Vulpia muralis*	Rats-tail Fescue	g	1	1	1	1	1	1	1	**7**
Poaceae	*	*Aira cupaniana*	Silvery Hairgrass	g	1	1	1	1	1		1	**6**
Droseraceae		*Drosera peltata*	Pale Sundew	h	1	1	1	1		1	1	**6**
Asteraceae	*	*Arctotheca calendula*	Capeweed	h	1	1	1	1			1	**5**
Poaceae		*Aristida ramosa*	Threeawn Grass	g	1	1	1		1		1	**5**
Anthericaceae		*Arthropodium minus*	Small Vanilla Lily	h	1	1		1	1	1		**5**
Poaceae		*Bothriochloa macra*	Red-leg Grass	g	1	1	1	1			1	**5**
Poaceae	*	*Briza minor*	Shivery Grass	g	1	1	1	1	1			**5**
Asphodelaceae		*Bulbine bulbosa*	Bulbine Lily	h	1	1	1	1			1	**5**
Asteraceae		*Stuartina muelleri*	Spoon Cudweed	h		1	1	1	1		1	**5**
Asteraceae		*Triptilodiscus pygmaeus*	Austral Sunray	h	1	1	1	1			1	**5**

9.9 Most abundant species

The most abundant species recorded in each of the Dwyer's Red Gum monitoring sites this year are provided in Table 9-6. The most abundant species were those that collectively summed to a Braun-blanquet total of 10 or more from the five replicated sub-plots along the vegetation transect. The maximum score that can be obtained by an individual species is 30.

No species was particularly abundant in the understorey in the Dwyer's Red Gum woodland reference sites DWood2 and DWood3. However in DWood1 the native perennial ground covers *Cheilanthes sieberi subsp. sieberi* and *Gonocarpus elatus* (Hill Raspwort) were relatively abundant but so was the exotic annual *Hypochaeris glabra.* The derived grasslands also tended to have a high abundance of *Hypochaeris glabra,* with other annual species including *Vulpia muralis* and *Aira cupaniana* also being abundant in some sites. The native grasses *Aristida ramosa, Bothriochloa macra* and *Rytidosperma fulvum* were relatively abundant in DReveg1 and/or DReveg2.

Table 9-6. The most abundant species recorded in the Dwyer's Red Gum monitoring sites.

Scientific Name	Common Name	DReveg1	DReveg2	DReveg3	DWoodLQ	DWood1	DWood2	DWood3
**Hypochaeris glabra*	Smooth Catsear	17	14	15		13		
**Vulpia muralis*	Rats-tail Fescue	12		19				
Aristida ramosa	Threeawn Grass	18	19					
Bothriochloa macra	Red-leg Grass	10						
Rytidosperma fulvum	Wallaby Grass		10					
**Aira cupaniana*	Silvery Hairgrass			15				
Rytidosperma racemosum	Wallaby Grass				11			
Cheilanthes sieberi subsp. sieberi	Rock Fern					14		
Gonocarpus elatus	Hill Raspwort					18		

9.10 Soil analyses

9.10.1 pH

Figure 9-15 shows the pH recorded in the Dwyer's Red Gum monitoring sites compared to the "desirable" range in medium or clay loam soils as prescribed by the agricultural industry for growing introduced pastures and crops. The pH range recorded in the woodland reference sites was somewhat lower than desirable agricultural ranges and with a soil pH ranging from 5.2 – 5.4 the soils were strongly acidic (Bruce & Rayment 1982), and this was also the case the low quality woodland site. In the derived grasslands, the soil pH tended to be slightly higher than the reference sites, however the soils ranged from 5.3 – 5.9 indicating the soils were moderately to strongly acidic. Soil pH in DReveg3 was just within the desirable range.

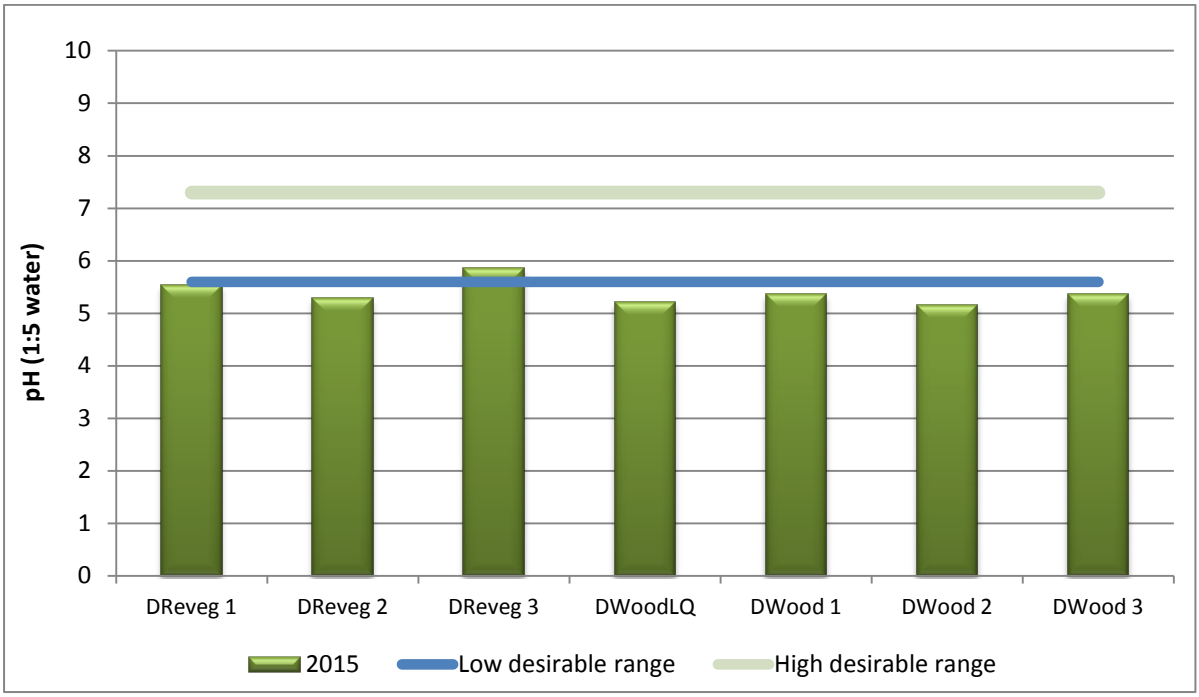


Figure 9-15. Soil pH recorded in the Dwyer's Red Gum monitoring sites compared to the desirable agricultural range.

9.10.2 Conductivity

Figure 9-16 shows the Electrical Conductivity (EC) recorded in the Dwyer's Red Gum monitoring sites compared to the "desirable" range in medium or clay loam soils as prescribed by the agricultural industry for growing introduced pastures and crops. The EC recorded across the range of sites was well below the agricultural threshold indicating there are very low levels of soluble salts in the soil profile and that they are non saline. The EC readings in the reference sites ranged from 0.021 – 0.24 dS/m. In the remaining sites EC ranged from a low of 0.022 dS/m in DReveg3 to a high of 0.027 dS/m in DReveg2 and DWoodLQ.

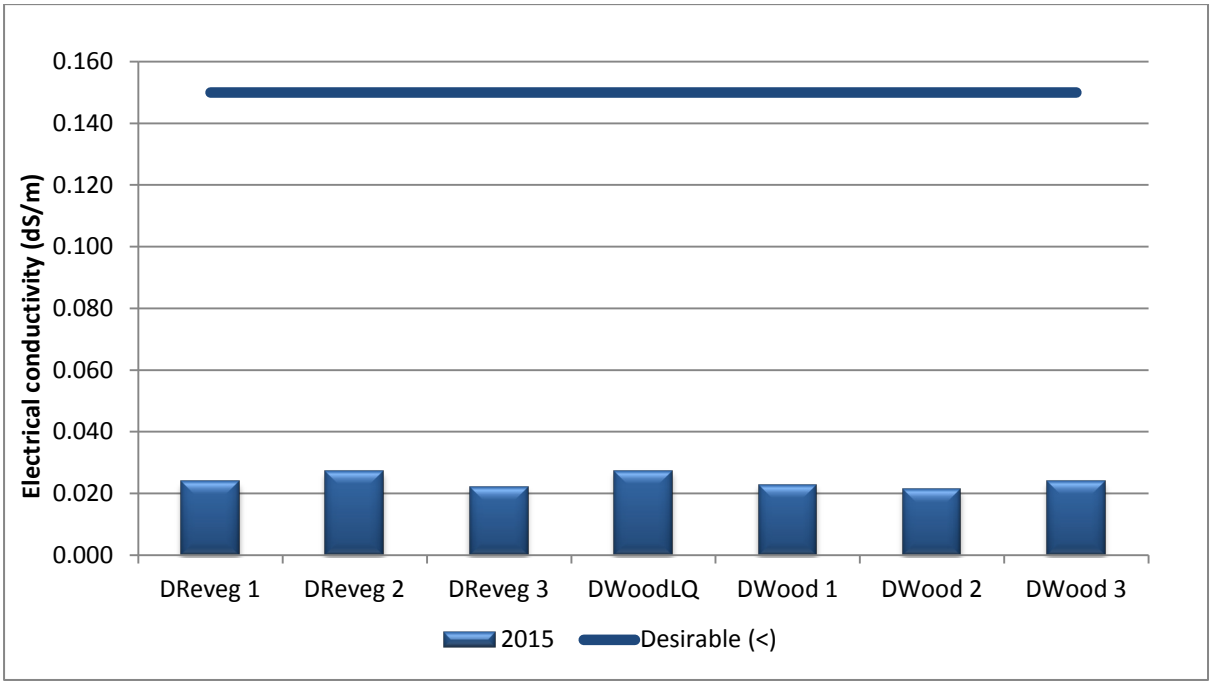


Figure 9-16. Electrical Conductivity recorded in the Dwyer's Red Gum monitoring sites compared to the desirable agricultural levels.

9.10.3 Organic Matter

In the Dwyer's Red Gum woodland reference sites OM levels ranged from 2.3 – 3.5% and were well below the desirable agricultural threshold of 4.5% (Figure 9-17). OM in the derived grassland sites fell within the local OM ranges, and so did the low quality woodland which had 2.3% OM.

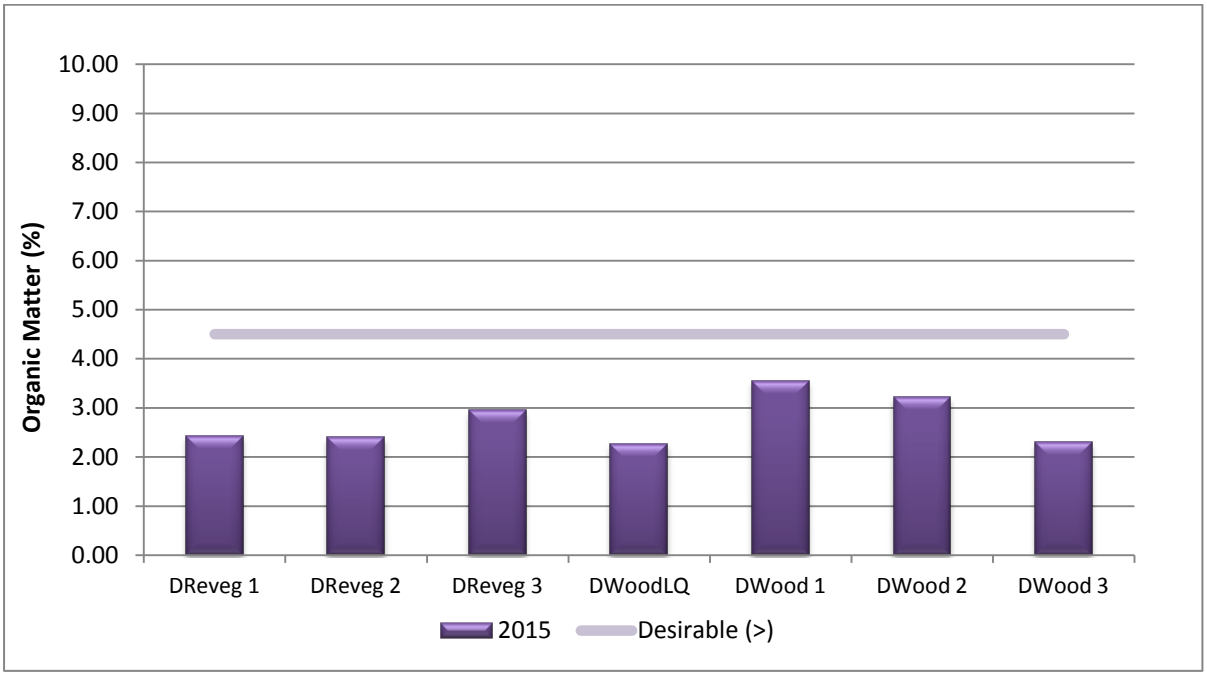


Figure 9-17. Organic Matter concentrations recorded in the Dwyer's Red Gum monitoring sites compared to desirable agricultural levels.

9.10.4 Phosphorous

Phosphorous levels were lower than the agricultural standards across all Dwyer's Red Gum monitoring sites. In the woodland reference sites P concentrations were 17mg/kg. There were minor differences in P across the other Dwyer's Red Gum monitoring sites which ranged from a low of 17 mg/kg in DReveg3 to a high of 21 mg/kg in DWoodLQ (Figure 9-18).

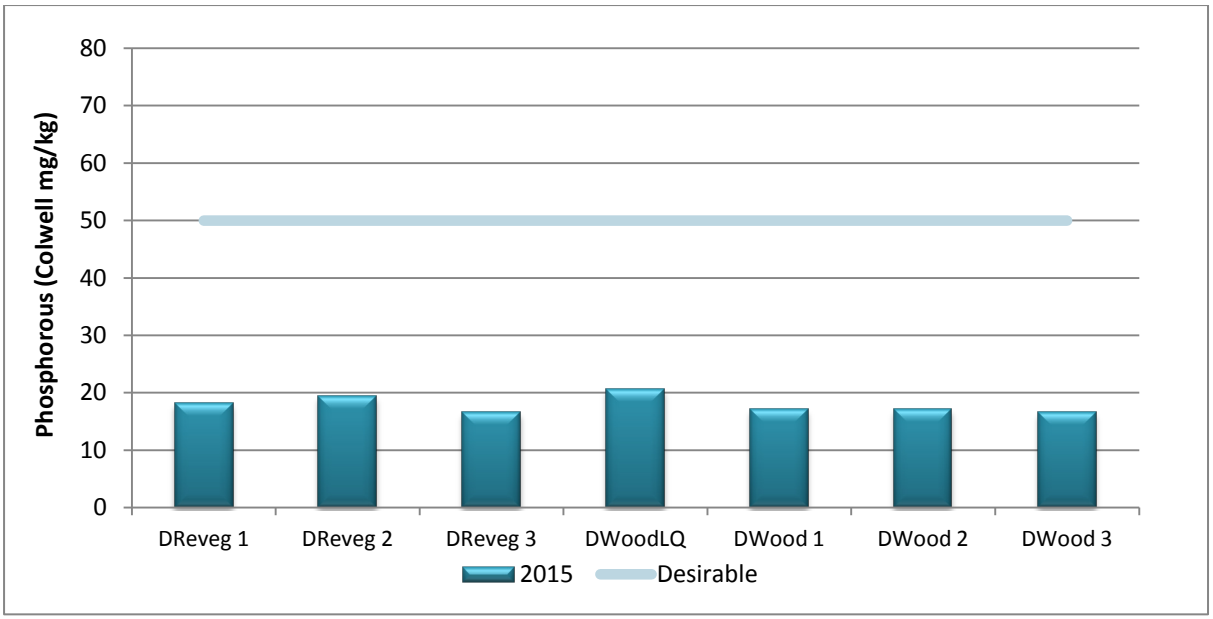


Figure 9-18. Phosphorous concentrations recorded in the Dwyer's Red Gum monitoring sites compared to desirable agricultural levels.

9.10.5 Nitrate

Nitrate levels were lower than the agricultural standards across all Dwyer's Red Gum monitoring sites and there were little differences between the sites. In the reference sites N ranged from 1.0 – 2.0 mg/kg and most of the other sites were similar (Figure 9-19).

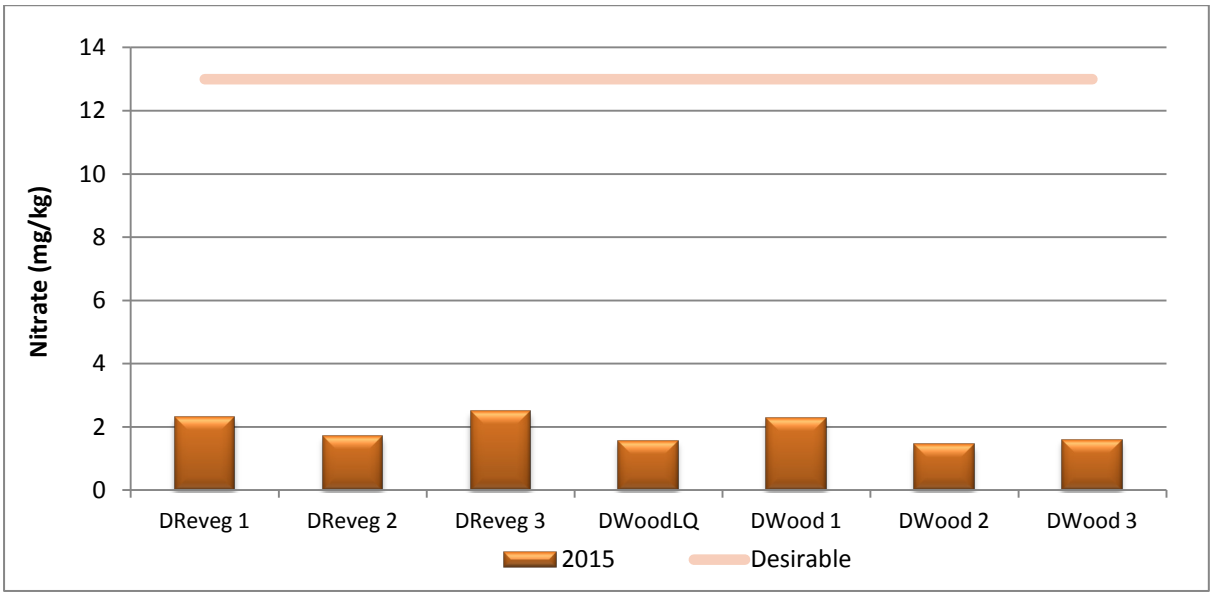


Figure 9-19. Nitrate concentrations recorded in the Dwyer's Red Gum monitoring sites compared to desirable agricultural levels.

9.10.6 Cation Exchange Capacity

Cation Exchange Capacity (CEC) is the capacity of the soil to hold the major cations (calcium, magnesium, sodium and potassium) and is also a measure of the potential fertility of the soil. All of the Dwyer's Red Gum monitoring sites had a low CEC and in the reference CEC ranged from 2.8 – 4.7 cmol/kg. In the remaining sites CEC ranged from a low of 2.6 cmol/kg in DWoodLQ to a high of 4.1 cmol/kg in DReveg3 (Figure 9-20).

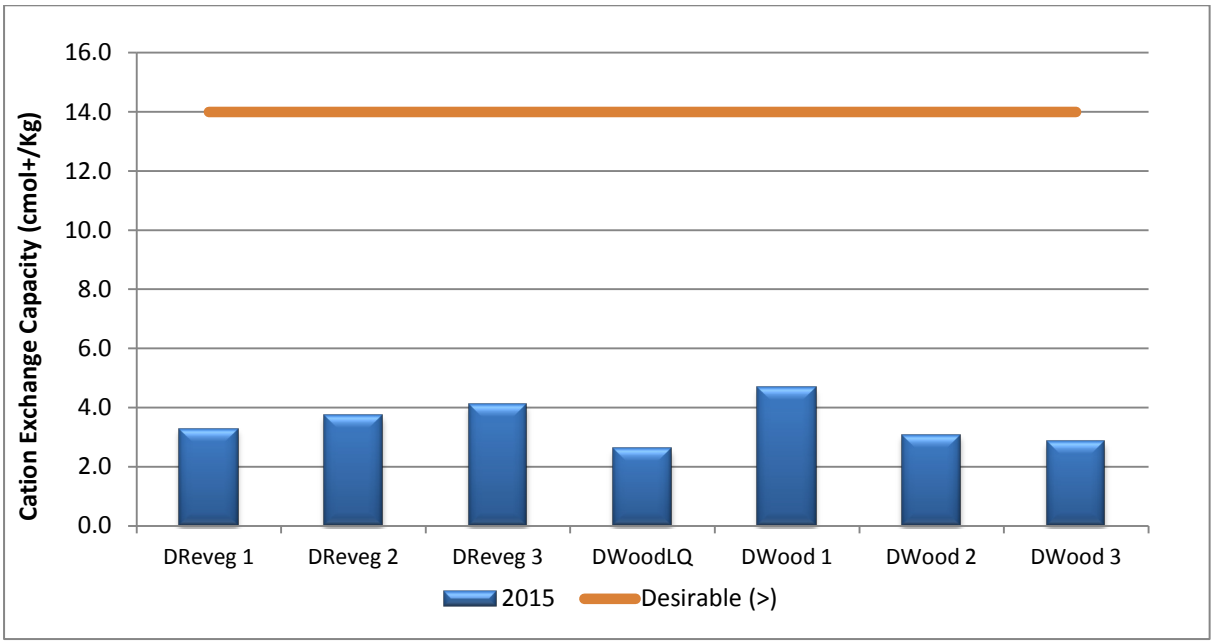


Figure 9-20. Cation Exchange Capacity recorded in the Dwyer's Red Gum monitoring sites compared to desirable agricultural levels.

9.10.7 Exchangeable Sodium Percentage

Sodicity refers to a significant proportion of sodium in the soil compared to other cations with soil considered to be sodic when there is sufficient sodium to interfere with its structural stability which often interferes with plant growth. Sodic soils tend to suffer from poor soil structure including hard soil, hardpans, surface crusting and rain pooling on the surface, which can affect water infiltration, drainage, plant growth, cultivation and site accessibility.

ESP recorded in the woodland reference sites was highly variable and ranged from 1.7 – 4.3% (Figure 9-21). In DReveg1 and the low quality woodland, ESP was elevated indicating the soils are likely to be sodic (Isbell 1996). In the remaining sites, ESP was similar to the woodland reference sites and are non sodic.

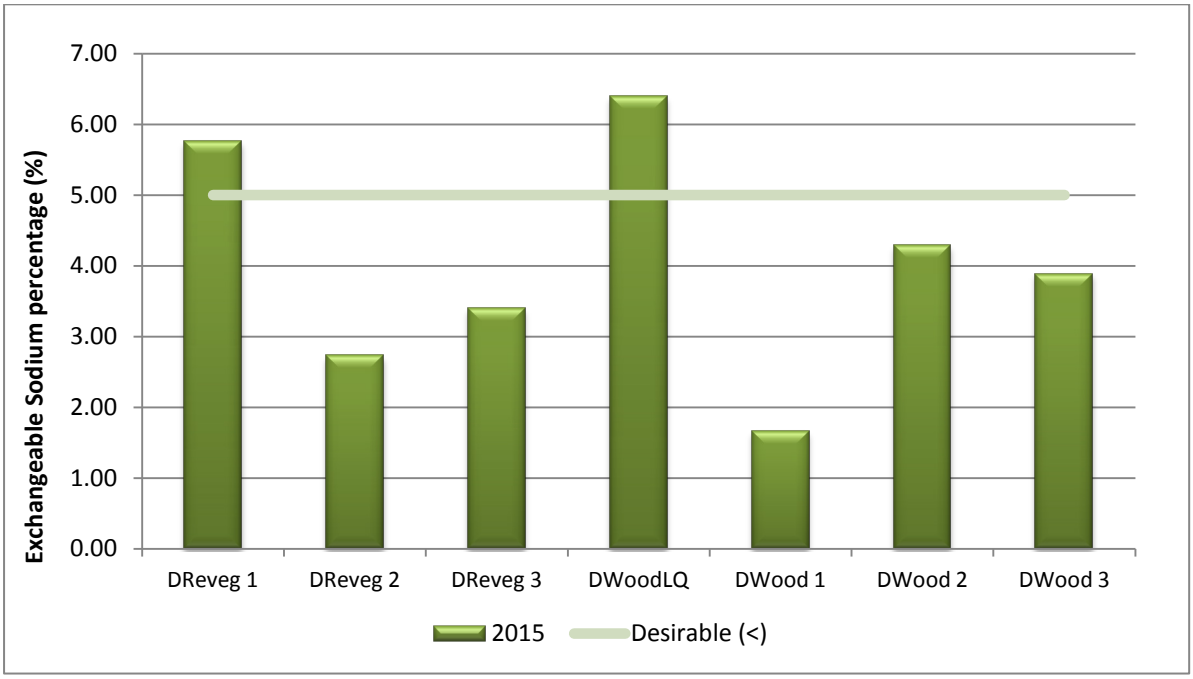


Figure 9-21. ESP recorded in the Dwyer's Red Gum monitoring sites compared to desirable agricultural levels.

9.10.8 Other soil tests

The full results of the soil analysis are provided in Appendix 3 but a summarised version highlighting elevated test results is provided in Table 9-7. The results indicate there are significantly high concentrations of Iron in all of the Dwyer's Red Gum sites, including the three reference sites. These data indicate that the soils at Kokoda are likely to be naturally high Iron and/or implicated with the long agricultural history.

Table 9-7. Summarised soil analyses highlighting elevated test results.

Method	*Nutrient*		*Units*	DReveg1	DReveg2	DReveg3	DWoodLQ	DWood1	DWood2	DWood3	***Indicative guidelines only- refer Note 6***
DTPA	Iron	Fe	mg/kg	291	189	170	345	103	216	180	22

Purple = Excessively high; Brown =significantly high; Red = very high; Yellow = moderately high; Green = slightly high

9.11 Dwyer's Red Gum: Site performance towards meeting woodland completion criteria targets

Table 9-8 indicates the performance of the Kokoda Dwyer's Red Gum monitoring sites against a selection of proposed Completion Performance Indicators during the 2015 monitoring period. The selection of criteria has been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) and ending with indicators of ecosystem and landuse development (blue). The range values are amended annually.

Monitoring sites meeting or exceeding the range values of the Dwyer's Red Gum woodland reference sites have been identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2015. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 9-8. Performance of the Dwyer's Red Gum revegetation monitoring sites against the Primary and Secondary Performance Indicators obtained from the Dwyer's Red Gum woodlands.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	DWood1	DWood2	DWood3	Dwyer's Red Gum Woodland ecosystem range 2015		DReveg1	DReveg2	DReveg3	DWoodLQ
Performance indicators are quantified by the range of values obtained from replicated reference sites							2015	2015	2015	Lower	Upper	2015	2015	2015	2015
Phase 2: Landform establishment and stability	**Landform slope, gradient**	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	4	3	3	**3**	**4**	4	3	4	3
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Number of gullies or rills >0.3m in width or depth in a 50m transect are limited and stabilising		No.	**0**	**0**	**0**	**0**	**0**	0	0	0	0
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	**0**	**0**	**0**	**0**	**0**	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	DWood1	DWood2	DWood3	Dwyer's Red Gum Woodland ecosystem range 2015		DReveg1	DReveg2	DReveg3	DWoodLQ
Phase 3: Growth medium development	**Soil chemical, physical properties and amelioration**	Soil properties are suitable for the establishment and maintenance of selected vegetation species	pH	pH is typical of that of the surrounding landscape or falls within desirable ranges provided by the agricultural industry		pH (5.6 - 7.3)	**5.4**	**5.2**	**5.4**	**5.2**	**5.4**	**5.5**	**5.3**	**5.9**	**5.2**
			EC		Electrical Conductivity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	< dS/m (<0.150)	**0.023**	**0.021**	**0.024**	**0.021**	**0.024**	**0.024**	**0.027**	**0.022**	**0.027**
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	**3.5**	**3.2**	**2.3**	**2.3**	**3.5**	**2.4**	**2.4**	**2.9**	**2.3**
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	**17.1**	**17.1**	**16.5**	**16.5**	**17.1**	**18.1**	**19.3**	**16.5**	**20.6**
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	**2.3**	**1.4**	**1.6**	**1.4**	**2.3**	**2.3**	**1.7**	**2.5**	**1.6**
			CEC		Cation Exchange Capacity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	Cmol+/kg (>14)	**4.7**	**3.1**	**2.8**	**2.8**	**4.7**	**3.3**	**3.7**	**4.1**	**2.6**
			ESP		Exchangeable Sodium Percentage (a measure of sodicity) is typical of the surrounding landscape or is less than the 5% threshold for sodicity	% (<5)	**1.7**	**4.3**	**3.9**	**1.7**	**4.3**	**5.8**	**2.7**	**3.4**	**6.4**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	DWood1	DWood2	DWood3	Dwyer's Red Gum Woodland ecosystem range 2015		DReveg1	DReveg2	DReveg3	DWoodLQ
Phase 4: Ecosystem & Landuse Establishment	**Landscape Function Analysis (LFA): Landform stability and organisation**	Landform is stable and performing as it was designed to do	LFA Stability	The LFA stability index provides an indication of the sites stability and is comparable to or trending towards that of the local remnant vegetation		%	**70.0**	**63.1**	**63.8**	**63.1**	**70.0**	**75.0**	**71.3**	**69.2**	**66.5**
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and is comparable to that of the local remnant vegetation		%	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees	The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.		species/area	**4**	**4**	**7**	**4**	**7**	**1**	**0**	**0**	**3**
				The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		% population	**100**	**100**	**100**	**100**	**100**	**100**	**0**	**0**	**100**
			Total species richness		The total number of live plant species provides an indication of the floristic diversity of the site and is comparable to the local remnant vegetation	No./area	**41**	**31**	**49**	**31**	**49**	**36**	**27**	**40**	**50**
			Native species richness		The total number of live native plant species provides an indication of the native plant diversity of the site and that it is greater than or comparable to the local remnant vegetation	>No./area	**33**	**29**	**44**	**29**	**44**	**19**	**19**	**18**	**33**
			Exotic species richness	The total number of live exotic plant species provides an indication of the exotic plant diversity of the site and that it is less than or comparable to the		<No./area	**8**	**2**	**5**	**2**	**8**	**17**	**8**	**22**	**17**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	DWood1	DWood2	DWood3	Dwyer's Red Gum Woodland ecosystem range 2015		DReveg1	DReveg2	DReveg3	DWoodLQ
				local remnant vegetation											
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees	The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation		No./area	**32**	**194**	**598**	**32**	**598**	**9**	**0**	**0**	**8**
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees	The number of tree species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	**4**	**4**	**4**	**4**	**4**	**1**	**0**	**0**	**2**
			Shrubs	The number of shrub species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	**2**	**4**	**6**	**2**	**6**	**0**	**0**	**0**	**2**
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**0**	**0**
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	**24**	**16**	**28**	**16**	**28**	**20**	**17**	**26**	**32**
			Grasses		The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	**7**	**5**	**8**	**5**	**8**	**13**	**9**	**11**	**11**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	DWood1	DWood2	DWood3	Dwyer's Red Gum Woodland ecosystem range 2015		DReveg1	DReveg2	DReveg3	DWoodLQ
			Reeds		The number of reed, sedge or rush species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	2	0	1	0	2	1	0	2	2
			Ferns		The number of ferns comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	1	1	1	1	1	1	1	1	1
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0	0	0
Phase 5: Ecosystem & Landuse Development	**Landscape Function Analysis (LFA): Landform function and ecological performance**	Landform is ecologically functional and performing as it was designed to do	LFA Infiltration	LFA infiltration index provides an indication of the sites infiltration capacity and is comparable to or trending towards that of the local remnant vegetation		%	54.6	49.8	43.6	43.6	54.6	47.1	46	40.1	49.9
			LFA Nutrient recycling	LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and is comparable to or trending towards that of the local remnant vegetation		%	51.7	46.7	44.5	44.5	51.7	43.4	46.4	40.9	46.9
	Protective ground cover	Ground layer contains protective ground cover and habitat structure comparable with the local remnant vegetation	Litter cover		Percent ground cover provided by dead plant material is comparable to that of the local remnant vegetation	%	41	78.5	64	41	79	23	58.5	21	71.5
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	14	1.3	13	1	14	55	23	65	12
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	1	4.0	6	1	6	13.5	8	5.5	3

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	DWood1	DWood2	DWood3	Dwyer's Red Gum Woodland ecosystem range 2015		DReveg1	DReveg2	DReveg3	DWoodLQ
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	6	0.0	0	0	6	0	0	0	0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	7	7.0	1	1	7	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	4	5.5	9	4	9	0.5	0	0	3
			Perennial plant cover (< 0.5m)	Percent ground cover provided by live perennial vegetation (< 0.5m in height) is comparable to that of the local remnant vegetation		%	28	3.7	8	4	28	8.5	10.5	9.5	10.5
			Total Ground Cover	Total groundcover is the sum of protective ground cover components (as described above) and that it is comparable to that of the local remnant vegetation		%	97	94.5	91	91	97	99.5	100	100	97
	Ground cover diversity	Vegetation contains a diversity of species per square meter comparable to that of the local remnant vegetation	Native understorey abundance		The abundance of native species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has more than or an equal number of native species as the local remnant vegetation	> species/m^2	5.2	4.8	9.2	4.8	9.2	3.6	6.4	6.6	7.2
			Exotic understorey abundance		The abundance of exotic species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has less than or an equal number of exotic species as the local remnant	< species/m^2	2.0	0.8	1.2	0.8	2.0	7.4	3.8	10.8	3.6

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	DWood1	DWood2	DWood3	Dwyer's Red Gum Woodland ecosystem range 2015		DReveg1	DReveg2	DReveg3	DWoodLQ
					vegetation										
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation		%	**73.6**	**86.5**	**90.1**	**73.6**	**90.1**	**33.0**	**62.5**	**32.1**	**65.8**
	Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	shrubs and juvenile trees 0 - 0.5m in height	The number of shrubs or juvenile trees < 0.5m in height provides an indication of establishment success and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation		No./area	**31**	**180**	**502**	**31**	**502**	**2**	**0**	**0**	**8**
			shrubs and juvenile trees 0.5 - 1m in height		The number of shrubs or juvenile trees 0.5-1m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	**1**	**14**	**68**	**1**	**68**	**4**	**0**	**0**	**0**
			shrubs and juvenile trees 1 - 1.5m in height		The number of shrubs or juvenile trees 1-1.5m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	**0**	**0**	**26**	**0**	**26**	**2**	**0**	**0**	**0**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	DWood1	DWood2	DWood3	Dwyer's Red Gum Woodland ecosystem range 2015		DReveg1	DReveg2	DReveg3	DWoodLQ
			shrubs and juvenile trees 1.5 - 2m in height	The number of shrubs or juvenile trees 1.5-2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation		No./area	0	0	0	0	0	0	0	0	0
			shrubs and juvenile trees >2m in height		The number of shrubs or juvenile trees > 2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	2	0	2	1	0	0	0
	Ecosystem structure	The vegetation is developing in structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5 - 2 m	Projected foliage cover provided by perennial plants in the 0.5 - 2m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover	0	0	4	0	4	6	8	0	0
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	6	3	0	6	0	0	0	0
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 -6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	9	13	4	4	13	0	0	0	4
			Foliage cover >6m	Projected foliage cover provided by perennial plants > 6m vertical height stratum indicates the community		% cover	12	44	35	12	44	0	0	0	34

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	DWood1	DWood2	DWood3	Dwyer's Red Gum Woodland ecosystem range 2015		DReveg1	DReveg2	DReveg3	DWoodLQ
				structure is comparable to that of the local remnant vegetation											
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	**4**	**3**	**3**	**3**	**4**	**0**	**0**	**0**	**2**
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	**100**	**100**	**100**	**100**	**100**	**0**	**0**	**0**	**100**
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	**70**	**32**	**11**	**11**	**70**	**0**	**0**	**0**	**9**
			Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	**11**	**18**	**23**	**11**	**23**	**0**	**0**	**0**	**22**
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees	The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation		% population	**30**	**78**	**82**	**30**	**82**	**0**	**0**	**0**	**100**
			Healthy trees	The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation		% population	**1**	**6**	**27**	**1**	**27**	**0**	**0**	**0**	**0**
			Medium health		The percentage of the tree population which are in a medium health condition and that the percentage is	% population	**24**	**53**	**27**	**24**	**53**	**0**	**0**	**0**	**100**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	DWood1	DWood2	DWood3	Dwyer's Red Gum Woodland ecosystem range 2015		DReveg1	DReveg2	DReveg3	DWoodLQ
					comparable to the local remnant vegetation										
			Advanced dieback		The percentage of the tree population which are in a state of advanced dieback and that the percentage is comparable to the local remnant vegetation	<% population	4	19	27	4	27	0	0	0	0
			Dead Trees		The percentage of the tree population which are dead (stags) and that the percentage is comparable to the local remnant vegetation	% population	70	22	18	18	70	0	0	0	0
			Mistletoe		The percentage of the tree population which have mistletoe provides an indication of community health and habitat value and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0	0	0
			Flowers/fruit: Trees	The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation		% population	10	28	82	10	82	0	0	0	44
			Hollows: Trees		The percentage of the tree population which have hollows provides an indication of the habitat value and that the percentage is comparable to the local remnant vegetation	% population	9	3	9	3	9	0	0	0	0

10 Noxious weeds

No noxious species were recorded in the range of monitoring sites.

11 Orchid observations

A map showing the locations of orchid species sighted around the property is provided in Figure 11-2. Several species of orchid were recorded at WBWood1/location 8 and included *Prasophyllum campestre* (Inland Leek Orchid), *Caladenia carnea* (Pink Fingers), *Diuris goonooensis* (Western Donkey Orchid) and *Pterostylis nana* (Dwarf Greenhood). A moderately sized population of *Microseris lanceolata* (Yam Daisy) were also recorded upslope from the monitoring quadrat.

Caladenia aff. *tentaculata* (Greencomb Spider Orchid) is an undescribed inland Greencomb Spider Orchid related to *Caladenia tentaculata*. It has a different specific pollinator from related species including *C. phaeoclavia*, *C. tentaculata* and *C. atrovespa* [a species described for the ACT, but occurring more widely]) according to local orchid specialist Dr Col Bower. This species was recorded in several areas including locations 2, 3 and 7.

Glossodia major (Wax-lip Orchid) was recorded in locations 2 and 4, with approximately 10 individuals occurring in a single patch at location 5.

Diuris goonooensis (Western Donkey Orchid) was observed at locations 2, 3 and 8. Two species of *Pterostylis*, *Pterostylis bicolour* (Bicolor Greenhood) and *Pterostylis nana* (Dwarf Greenhood) were common throughout the grassland sites, with *Pterostylis nana* also recorded within some of the woodland areas.

Other species of interest include *Lobelia gibbosa* (Tall Lobelia) which was found in DReveg3. *Stackhousia monogyna* (Creamy Candles) was also quite common and often occurred in quite large patches in the grassland an open woodland areas and was recorded in monitoring sites WBWood1 and GBReveg5.

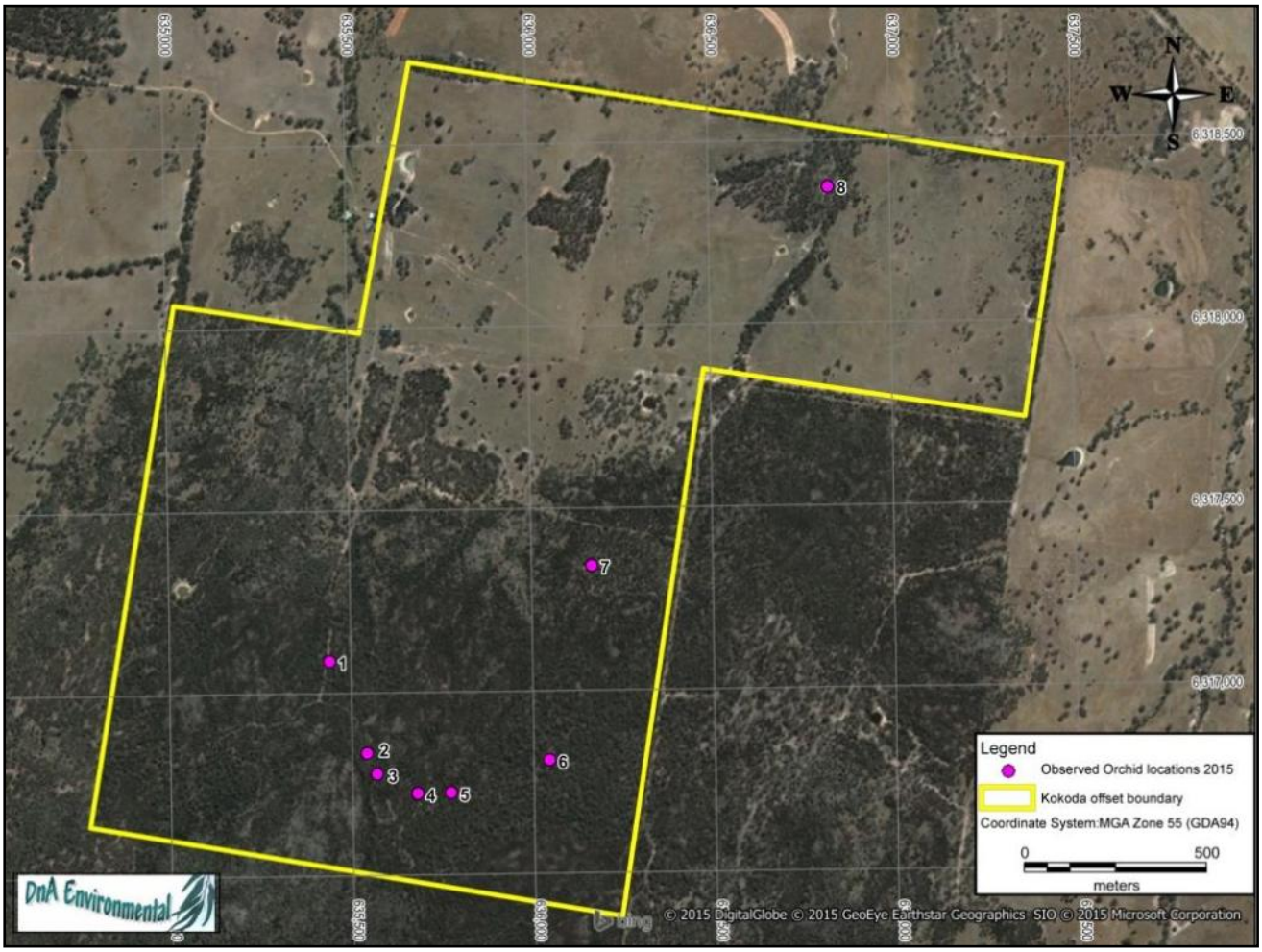


Figure 11-1. A map showing the locations of orchid species sighted around the Kokoda property.

Prasophyllum campestre (Inland Leek Orchid)

Prasophyllum campestre (Inland Leek Orchid)

Caladenia aff. tentaculata **(Greencomb Spider Orchid)**

Diuris goonooensis **(Western Donkey Orchid)**

	
***Glossodia major* (Wax-lip Orchid)**	***Pterostylis bicolour* (Bicolor Greenhood)**

12 Summary of results

The three Grey Box woodland reference sites were characterised by having a mature tree canopy and a well developed decomposing leaf litter layer with a sparse cover of native perennial forbs and grasses which collectively provided a highly functional patch area. The White Box and Ironbark woodlands also had a mature tree canopy and while both sites had a well developed leaf litter layer, native grasses and forbs were more abundant in the White Box woodland while in the Ironbark woodland there was an understorey of low and scattered shrubs with both sites having high functional patch areas. While the Grey Box revegetation sites presently existed as degraded pastures and were structurally different to the woodland reference sites, they typically had good ground cover comprised of a combination of annual and perennial plants and cryptogams and also had a high functional patch areas.

Despite the lack of a mature tree canopy, the Grey Box revegetation sites tended to be more stable than the reference sites due to the higher abundance of perennial ground covers, very hard soil crusts which were usually contained a significant abundance of cryptogam cover and subsequently there tended to be less evidence of erosion or deposition within these sites. The revegetation sites however had a lower infiltration and nutrient recycling capacity largely due to lack of a mature overstorey, undeveloped leaf litter layer and hard surface crusts.

The White Box grassy woodland was the most ecologically functional site with the sum of a total score of 170.3 out of a possible score of 300. This site contained high patch area, a mature tree canopy and well developed grassy ground cover layer, with high levels of decomposing litter and had very stable soils. The Grey Box woodland sites GBWood3 and GBWood2 were the next most functional communities but did not tend to have such high levels of these attributes and scored 168.4 and 164.3 respectively. The derived native grasslands GBReveg1, GBReveg4 and GBReveg3 that will be revegetated to Grey Box woodland were presently more functional than GBWood1 and the Ironbark woodland. These two woodland areas had also been severely degraded through overgrazing with the herbaceous understorey having been severely depleted and the soils being quite compacted with these sites scoring 159.7 and 159.5 respectively. The least functional communities were presently GBReveg5 which scored 155.6 and GBReveg2 with 151.8.

The Dwyer's Red Gum (DRG) woodland reference sites were also characterised by having a mature tree canopy and a well developed decomposing leaf litter layer and a sparse cover of native perennial forbs and grasses. The low quality Dwyer's Red Gum woodland site was characterised with having an open mature tree canopy, moderate cover of annual and perennial ground cover species and typically had a well developed leaf litter layer but this was patchy. The Dwyer's Red Gum revegetation sites presently existed as degraded pastures but they typically had good ground cover comprised of a combination of annual and perennial plants and cryptogams and also had a high functional patch areas.

DWood1, the Dwyer's Red Gum reference site was the most ecologically functional DRG site with a total score of 176.3. DReveg1, DReveg2 and the low quality woodland DWoodLQ were the next most functional sites and had a sum of scores which exceeded the reference sites DWood2 and DWood3 which scored relatively low scores of 159.6 and 151.9 respectively. The lowest ecological function was recorded in DReveg3 with a sum of indices of 150.2.

In GBWood1 no shrubs were recorded and therefore set a zero shrub and juvenile tree benchmark, while the Dwyer's Red Gum woodlands had relatively high shrub and juvenile tree densities. All derived grassland revegetation sites presently did not meet many completion targets related to the mature tree population and the structural complexity of the sites due to the lack of a well developed overstorey and in the DRG revegetation sites lack of a shrub understorey. In most of the revegetation sites there was an appropriate diversity of native herbs and grasses but the sites also tended to be dominated by exotic species and were weedier than desired. Other primary ecological attributes which fell short of meeting

completion performance target tended to be largely associated with low density and diversity of trees and shrubs.

13 Recommendations

The proposed revegetation activities within the derived grassland areas as described in the BOMP aim to increase biodiversity and habitat values through the removal of livestock grazing to allow natural regeneration, supplemented with tubestock planting. These activities are likely to result in the cleared grassland areas developing into woodland communities and therefore meeting most ecological performance indicators in the medium to longer term. The reference sites at Kokoda are typically degraded and of low quality which subsequently have provided low performance targets. In the Grey Box woodlands in particular, there was limited abundance and diversity of the grassy understorey and there were limited shrubs. Subsequently the revegetation activities proposed should include a range of species known to occur within these communities and not just restricted to those occurring within the existing reference sites. To ensure good establishment success revegetation practices should follow Best Practice Revegetation Guidelines (Sydes *et al* Greening Australia 2003). When undertaking revegetation it would be important to establish a mosaic of shrub thickets, open woodland and grassy clearings, to increase heterogeneity and patchiness which will be critical in the long term sustainability of the woodlands, whilst promoting and maintaining biodiversity and varying habitats.

While floristic diversity targets were often met, the revegetation sites tended to be dominated by exotic annual species, which are likely to decline in the medium to longer-term as perennial plants become more abundant. However, these natural successional processes could be enhanced with strategic grazing management. Strategic grazing is likely to be a critical management strategy which will be required to maintain biodiversity, encourage tree and shrub regeneration and to reduce fuel loads as part of the integrated and adaptive management strategy for the Kokoda Offset Area. As part of the BOMP it would be beneficial to implement strategic grazing management to manipulate the grassy understorey biomass in order to:

- Promote natural tree and shrub recruitment;
- Reduce cover abundance of exotic annual grasses, in favour of native perennial grasses (grazing late summer/early autumn and/or late winter early spring);
- Promote and maintain diversity in the herbaceous understorey cover;
- Reduce understory growth in preparation for direct seeding and/or tubestock planting;
- Reduce the incidence of bush-fire and bush-fire intensity;
- prevent invasion from weeds via the maintenance of strong native perennial pastures and high ground cover levels;
- Assist ongoing site maintenance and monitoring by providing better access around the property.

This year several species of orchids were observed at various locations around the property. As part of the management of the Kokoda property, the location of these populations should be considered when undertaking revegetation, weed control and strategic grazing, particularly as most orchids are only identifiable during a limited time period.

Other potential management issues may be related to high density *Callitris endlicheri* regeneration which was observed to be occurring within and adjacent to woodland areas where mature Callitris were present. The increase in competition from high density stands is likely to suppress the herbaceous understorey as they become more established, thereby adversely affecting floristic and biodiversity targets. Strategic grazing may reduce the density of existing seedlings and regulate the degree of Callitris regeneration through manipulation of the herbaceous understorey and germination niches.

Herbivory by feral and pests species may also become an increasingly important management issue which should be regularly monitored. A control program may need to be implemented with the most beneficial outcomes being obtained by a cooperative approach with neighbouring landholders.

Safe and easy access should always be maintained around main access tracks and boundary fences to facilitate monitoring, property maintenance and bushfire management. Regular inspections should be undertaken with slashing and/or strategic grazing management implemented on a needs basis. There were little other management issues that have not already been addressed in the BOMP.

14 References

Bruce, R.C. and Rayment, G.E. 1982. *Analytical Methods and Interpretations Used by the Agricultural Chemistry Branch for Soil and Land Use Surveys*, Bulletin No. QB2004, Dept of Primary Industries, Brisbane, Qld.

Bureau of Meteorology. 2015. *Parkes Airport AWS Monthly Rainfal,1941-2014..* http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=139&p_display_type=dataFile&p_startYear=&p_c=-846980701&p_stn_num=065068 Accessed 16th November 2015.

DnA Environmental (2010a). *Rehabilitation monitoring methodology and determination of completion criteria for Northparkes Mines*. North Mining Limited.

DnA Environmental (2010 - 2014). *2009 – 2014 Rehabilitation Monitoring Reports for Northparkes Mines.* CMOC (formerly North Mining Limited).

DnA Environmental (2010 - 2014). *2010 – 2014 Estcourt Offset Area Monitoring Reports for Northparkes Mines.* CMOC (formerly North Mining Limited).

Gibbons (2002). *Methodology for the Grassy Box Woodlands Benchmarking Project in southern NSW* Murray-Darling Basin. CSIRO, Canberra.

Gibbons, P., Briggs, S.V., Ayers, D.A., Doyle, S., Seddon, J., McElhinny, C., Jones, N. Simes, R. and Doody, J.S. (2008). *Rapidly quantifying reference conditions in modified landscapes*. *Journal of Biological Conservation*.

GHD (2010). *Northparkes Mines Vegetation Management Plan* [for the Kokoda VCA]. North Mining Limited.

Northparkes Mines. 2008. *Management Plan Sitewide Landscape*. Northparkes Mines.

NSW I&I: Department of Industry and Investment. 2010. *Rehabilitation and Environmental Management Plan (REMP) Guidelines*. Consultation Draft V2.0, June 2010. Minerals and Energy Division, Mineral Resources Branch. Maitland, NSW.

NSW T&I: Resources and Energy. 2012. ESG3: Mining Operations Plan (MOP) guidelines. December 2012. NSW Trade and Investment, Regional Infrastructure and Services – Division of Resources and Energy.

NSW T&I: Resources and Energy. 2013. ESG3: Mining Operations Plan (MOP) guidelines. September 2013. NSW Trade and Investment, Regional Infrastructure and Services – Division of Resources and Energy.

Peverill, K.I., Sparrow, L.A. and Reuter, D.J. 2005. *Soil analysis. An Interpretation Manual*. CSIRO Publishing, Collingwood Victoria.

Slavich, P.G. and Petterson, G.H. 1993. *Estimating the electrical conductivity of saturated paste extracts from 1:5 soil:water suspensions and texture.* Australian Journal of Soil Research **31**, 73-81.

Sydes M, Butterfield, L and Rutledge, S (2003). *A practical guide to revegetation in the Mid Lachlan region*. Greening Australia NSW (Central West).

Threatened Species Scientific Committee TSCC. 2014. Advice to the Minister for Environment Protection, Heritage and the Arts from the Threatened Species Scientific Committee (the Committee) on an Amendment to the List of Threatened Ecological Communities under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) http://www.environment.gov.au/biodiversity/threatened/communities/pubs/86-listing-advice.pdf (accessed 6/1/2015).

Tongway, D. & Hindley, N. 1996. *Landscape Function Analysis. Understanding more about your landscape. A method for monitoring landscape productivity.* CSIRO Sustainable Ecosystems. CD Version 3.1.

Tongway, D. & Hindley, N. 1996. *Landscape Function Analysis. Understanding more about your landscape. A method for monitoring landscape productivity.* CSIRO Sustainable Ecosystems. CD Version 3.1

Tongway, D. & Hindley, N. 2003. *Indicators of Ecosystem Rehabilitation Success. Stage Two – Verification of EFA Indicators.* Final Report for the Australian Centre for Mining Environmental Research. CSIRO Sustainable Ecosystems In association with Ben Seaborn CMLR, University of Queensland

Tongway, DJ and Hindley, NL 2004. *Landscape Function Analysis: Methods for monitoring and assessing landscapes, with special reference to minesites and rangelands*. CSIRO Sustainable Ecosystems, Canberra.

Umwelt (2014a). *Biodiversity Offset Management Plan: Kokoda Offset Area for Northparkes Mine*. Revised 22nd September 2015.

Umwelt (2014b). *Northparkes Mine Ecological Monitoring, Baseline Survey - Winter and Spring 2014*, December 2014.

Appendix 1. List of flora species recorded in the Kokoda monitoring sites in 2015

Group	Family	exotic	Scientific Name	Common Name	Habit	DWood1	DWood2	DWood3	DWoodLQ	GBWood1	GBWood2	GBWood3	IronWood1	WBWood1	DReveg1	DReveg2	DReveg3	GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5
Coniferopsida	Cupressaceae		*Callitris endlicheri*	Black Cypress Pine	t	1	1	1					1	1								
Dicotyledon	Apiaceae		*Daucus glochidiatus*	Australian Carrot	h	1	1	1	1		1	1	1	1				1				
Dicotyledon	Apiaceae		*Hydrocotyle laxiflora*	Stinking Pennywort	h	1		1	1		1	1	1	1			1		1			
Dicotyledon	Apiaceae		*Hydrocotyle trachycarpa*	Wild Parsley	h	1																
Dicotyledon	Asteraceae		*Actinobole uliginosum*	Flannel Cudweed	h														1			
Dicotyledon	Asteraceae	*	*Arctotheca calendula*	Capeweed	h			1	1	1	1	1			1	1	1	1	1	1	1	1
Dicotyledon	Asteraceae		*Brachyscome perpusilla*	Tiny Daisy	h				1										1			
Dicotyledon	Asteraceae		*Calotis lappulacea*	Yellow Burr Daisy	h					1	1								1			
Dicotyledon	Asteraceae	*	*Carthamus lanatus*	Saffron Thistle	h															1		
Dicotyledon	Asteraceae		*Cassinia laevis*	Cough Bush	s			1				1	1									
Dicotyledon	Asteraceae	*	*Chondrilla juncea*	Skeleton Weed	h						1			1	1			1				
Dicotyledon	Asteraceae	*	*Cirsium vulgare*	Spear Thistle	h							1		1								
Dicotyledon	Asteraceae		*Cotula australis*	Common Cotula	h				1	1	1	1										
Dicotyledon	Asteraceae		*Cymbonotus lawsonianus*	Bear's Ear	h									1								
Dicotyledon	Asteraceae		*Euchiton sphaericus*	Japanese Cudweed	h			1														
Dicotyledon	Asteraceae		*Euchiton spp.*		h											1						
Dicotyledon	Asteraceae		*Hyalosperma demissum*	Dwarf Sunray	h			1														
Dicotyledon	Asteraceae	*	*Hypochaeris glabra*	Smooth Catsear	h	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Dicotyledon	Asteraceae	*	*Hypochaeris radicata*	Flatweed	h	1			1	1										1	1	1
Dicotyledon	Asteraceae		*Isoetopsis graminifolia*	Grass Cushion	h														1			
Dicotyledon	Asteraceae		*Myriocephalus rhizocephalus*	Woolly Heads	h				1										1			
Dicotyledon	Asteraceae		*Rhodanthe laevis*	Smooth Sunray	h	1																
Dicotyledon	Asteraceae		*Solenogyne bellioides*		h									1					1			
Dicotyledon	Asteraceae	*	*Soliva sessilis*	Jo-jo	h												1		1			
Dicotyledon	Asteraceae	*	*Sonchus oleraceus*	Milk Thistle	h	1			1	1								1				
Dicotyledon	Asteraceae		*Stuartina muelleri*	Spoon Cudweed	h	1		1	1	1	1	1				1	1		1			
Dicotyledon	Asteraceae	*	*Tolpis umbellata*	Yellow Hawkweed	h				1								1		1	1	1	
Dicotyledon	Asteraceae		*Triptilodiscus pygmaeus*	Austral Sunray	h			1	1						1	1	1		1	1	1	1
Dicotyledon	Asteraceae		*Vittadinia cuneata*	Fuzzweed	h											1		1	1			
Dicotyledon	Asteraceae		*Vittadinia gracilis*	A Fuzzweed	h													1				

Group	Family	exotic	Scientific Name	Common Name	Habit	DWood1	DWood2	DWood3	DWoodLQ	GBWood1	GBWood2	GBWood3	IronWood1	WBWood1	DReveg1	DReveg2	DReveg3	GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5
Dicotyledon	Asteraceae		*Xerochrysum bracteatum*	Golden Everlasting	h	1		1			1		1									
Dicotyledon	Brassicaceae		*Geococcus pusillus*	Earth Cres	h					1												
Dicotyledon	Campanulaceae		*Wahlenbergia gracilenta*	Australian Bluebell	h			1	1							1			1			
Dicotyledon	Campanulaceae		*Wahlenbergia spp.*	Bluebell	h														1			
Dicotyledon	Campanulaceae		*Wahlenbergia stricta*	Tall Bluebell	h	1		1														
Dicotyledon	Campanulaceae		*Wahlenbergia stricta subsp. alterna*	Tall Bluebell	h		1															
Dicotyledon	Caryophyllaceae	*	*Cerastium glomeratum*	Mouse-ear Chickweed	h				1													
Dicotyledon	Caryophyllaceae	*	*Moenchia erecta*	Erect Chickweed	h				1					1	1		1			1	1	
Dicotyledon	Caryophyllaceae	*	*Paronychia brasiliana*	Chilean Whitlow Wort	h				1													
Dicotyledon	Caryophyllaceae	*	*Petrorhagia nanteuilii*	Proliferous Pink	h					1				1	1						1	1
Dicotyledon	Caryophyllaceae	*	*Stellaria media*	Chickweed	h				1	1		1										
Dicotyledon	Casuarinaceae		*Allocasuarina luehmannii*	Bulloak	t	1	1															
Dicotyledon	Casuarinaceae		*Allocasuarina verticillata*	Drooping Sheoak	t			1														
Dicotyledon	Chenopodiaceae		*Einadia nutans subsp. nutans*	Climbing Saltbush	h					1		1										
Dicotyledon	Clusiaceae		*Hypericum gramineum*	Small St. John's Wort	h									1						1		
Dicotyledon	Convolvulaceae		*Dichondra repens*	Kidney Weed	h					1	1											
Dicotyledon	Crassulaceae		*Crassula colorata*	Dense Stonecrop	h					1	1	1			1	1			1			
Dicotyledon	Crassulaceae		*Crassula peduncularis*	Purple Stonecrop	h			1	1						1				1			
Dicotyledon	Dilleniaceae		*Hibbertia obtusifolia*	Hoary Guinea Flower	ss								1	1								
Dicotyledon	Dilleniaceae		*Hibbertia riparia*	Silky Guinea Flower	ss						1		1	1								
Dicotyledon	Droseraceae		*Drosera glanduligera*	Scarlet Sundew	h																1	
Dicotyledon	Droseraceae		*Drosera peltata*	Pale Sundew	h		1	1	1					1	1	1	1			1	1	
Dicotyledon	Epacridaceae		*Astroloma humifusum*	Native Cranberry	ss	1	1	1					1									
Dicotyledon	Epacridaceae		*Brachyloma daphnoides*	Daphne Heath	s	1	1	1			1		1									
Dicotyledon	Epacridaceae		*Lissanthe strigosa*	Peach Heath	ss		1	1					1	1								
Dicotyledon	Euphorbiaceae		*Chamaesyce drummondii*	Caustic Weed	h											1			1			
Dicotyledon	Euphorbiaceae		*Poranthera microphylla*	Small Poranthera	h	1	1	1														
Dicotyledon	Fabaceae (Faboideae)		*Bossiaea buxifolia*	Box-leaved Bitter-pea	s								1									
Dicotyledon	Fabaceae (Faboideae)		*Dillwynia spp.*		s			1														
Dicotyledon	Fabaceae (Faboideae)		*Glycine clandestina*	Climbing Glycine	h									1								

Group	Family	exotic	Scientific Name	Common Name	Habit	DWood1	DWood2	DWood3	DWoodLQ	GBWood1	GBWood2	GBWood3	IronWood1	WBWood1	DReveg1	DReveg2	DReveg3	GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium angustifolium*	Narrow-leaf Clover	h										1	1	1	1				
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium arvense*	Haresfoot Clover	h									1						1		
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium campestre*	Hop Clover	h									1	1		1	1		1	1	1
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium glomeratum*	Clustered Clover	h													1				
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium spp.*	A Clover	h				1		1											
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium subterraneum*	Subterraneum Clover	h				1			1			1		1	1	1	1		1
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia doratoxylon*	Spearwood	s	1		1	1													
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia implexa*	Hickory	s						1		1	1								
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia lanigera*	Woolly Wattle	s				1													
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia paradoxa*	Kangaroo Thorn	s						1											
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia spp.*	A Wattle	s		1						1									
Dicotyledon	Gentaniaceae	*	*Centaurium erythraea*	Common Centaury	h												1		1			
Dicotyledon	Gentianaceae	*	*Cicendia quadrangularis*		h				1								1		1	1	1	1
Dicotyledon	Geraniaceae	*	*Erodium botrys*	Long Storksbill	h												1	1				
Dicotyledon	Geraniaceae	*	*Erodium cicutarium*	Common Crowsfoot	h												1					1
Dicotyledon	Geraniaceae		*Erodium crinitum*	Blue Storksbill	h																	1
Dicotyledon	Geraniaceae		*Geranium solanderi*	Native Geranium	h									1								
Dicotyledon	Goodeniaceae		*Goodenia hederacea*	Forest Goodenia	h	1	1						1			1						
Dicotyledon	Goodeniaceae		*Goodenia spp.*		h			1	1		1				1							
Dicotyledon	Haloragaceae		*Gonocarpus elatus*	Hill Raspwort	h	1		1					1									
Dicotyledon	Haloragaceae		*Gonocarpus tetragynus*	Raspwort	h		1		1		1			1		1			1			1
Dicotyledon	Haloragaceae		*Haloragis heterophylla*	Rough Raspwort	h			1	1		1			1	1		1		1	1		
Dicotyledon	Lamiaceae		*Ajuga australis*	Australian Bugle	h									1								
Dicotyledon	Lamiaceae	*	*Salvia verbenaca*	Wild Sage	h													1				
Dicotyledon	Lobeliaceae		*Lobelia gibbosa*	Tall Lobelia	h												1			1	1	

Group	Family	exotic	Scientific Name	Common Name	Habit	DWood1	DWood2	DWood3	DWoodLQ	GBWood1	GBWood2	GBWood3	IronWood1	WBWood1	DReveg1	DReveg2	DReveg3	GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5
Dicotyledon	Myrtaceae		*Calytrix tetragona*	Common Fringe Myrtle	s		1	1														
Dicotyledon	Myrtaceae		*Eucalyptus albens*	White Box	t				1				1	1								
Dicotyledon	Myrtaceae		*Eucalyptus blakelyi*	Blakely's Red Gum	t									1								
Dicotyledon	Myrtaceae		*Eucalyptus dealbata*	Tumbledown Gum	t	1	1						1									
Dicotyledon	Myrtaceae		*Eucalyptus dwyeri*	Dwyer's Red Gum	t	1		1	1						1							
Dicotyledon	Myrtaceae		*Eucalyptus microcarpa*	Grey Box	t			1		1	1	1	1									
Dicotyledon	Myrtaceae		*Eucalyptus sideroxylon*	Mugga Ironbark	t		1				1	1	1									
Dicotyledon	Orobanchaceae	*	*Parentucellia latifolia*	Red Bartsia	h	1									1	1	1	1	1	1	1	1
Dicotyledon	Oxalidaceae		*Oxalis perennans*	Yellow Wood-sorrel	h	1			1	1	1			1				1				1
Dicotyledon	Plantaginaceae	*	*Echium plantagineum*	Paterson's Curse	h										1		1	1			1	1
Dicotyledon	Plantaginaceae		*Plantago varia*	Variable Plantain	h	1																
Dicotyledon	Polygonaceae	*	*Acetosella vulgaris*	Sheep Sorrel	h												1					
Dicotyledon	Polygonaceae		*Rumex brownii*	Swamp Dock	h				1	1	1	1			1			1				1
Dicotyledon	Primulaceae	*	*Anagallis arvensis*	Scarlet Pimpernel	h	1		1			1	1		1			1	1	1	1		1
Dicotyledon	Ranunculaceae		*Ranunculus sessiliflorus var. sessiliflorus*	Small-flowered Buttercup	h			1	1	1				1								
Dicotyledon	Rubiaceae		*Asperula conferta*	Common Woodruff	h												1	1	1			
Dicotyledon	Rubiaceae		*Galium gaudichaudii*	Rough Bedstraw	h		1	1	1					1				1		1		
Dicotyledon	Scrophulariaceae	*	*Verbascum virgatum*	Twiggy Mullein	h																	1
Dicotyledon	Stackhousiaceae		*Stackhousia monogyna*	Creamy Candles	h									1								1
Dicotyledon	Sterculiaceae		*Brachychiton populneus*	Kurrajong	t								1									
Monocotyledon	Anthericaceae		*Arthropodium minus*	Small Vanilla Lily	h	1	1		1	1				1	1	1			1			1
Monocotyledon	Anthericaceae		*Caesia parviflora*	Pale Grass-Lilly	h	1					1	1	1									
Monocotyledon	Anthericaceae		*Dichopogon fimbriatus*	Nodding Chocolate Lily	h									1								
Monocotyledon	Anthericaceae		*Laxmannia gracilis*	Slender Wire Lily	h		1						1									
Monocotyledon	Anthericaceae		*Thysanotus patersonii*	Twining Fringe Lily	h	1	1	1					1	1								
Monocotyledon	Anthericaceae		*Tricoryne elatior*	Yellow Autumn-lily	h	1		1			1											
Monocotyledon	Asphodelaceae		*Bulbine bulbosa*	Bulbine Lily	h			1	1						1	1	1		1		1	1
Monocotyledon	Asphodelaceae		*Bulbine semibarbata*	Leek Lily	h													1				
Monocotyledon	Colchicaceae		*Wurmbea dioica*	Early Nancy	h	1	1	1	1					1			1		1		1	
Monocotyledon	Cyperaceae		*Carex inversa*	Knob Sedge	r																1	
Monocotyledon	Cyperaceae		*Lepidosperma laterale*	Broad Sword-sedge	r	1																
Monocotyledon	Cyperaceae		*Schoenus apogon*	Common Bog Rush	r	1		1	1								1		1	1		1

Group	Family	exotic	Scientific Name	Common Name	Habit	DWood1	DWood2	DWood3	DWoodLQ	GBWood1	GBWood2	GBWood3	IronWood1	WBWood1	DReveg1	DReveg2	DReveg3	GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5
Monocotyledon	Hypoxidaceae		*Hypoxis spp.*		h			1														
Monocotyledon	Iridaceae	*	*Romulea rosea*	Onion Grass	h												1					
Monocotyledon	Juncaceae		*Juncus bufonius*	Toad Rush	r										1		1	1	1			
Monocotyledon	Juncaceae		*Juncus usitatus*		r				1		1	1										
Monocotyledon	Ophioglossaceae		*Ophioglossum lusitanicum*	Adders Tongue	h										1				1		1	1
Monocotyledon	Orchidaceae		*Caladenia aff. tentaculata*	Greencomb Spider Orchid	h			1														
Monocotyledon	Orchidaceae		*Caladenia carnea*	Pink Fingers	h	1	1	1					1	1								
Monocotyledon	Orchidaceae		*Diuris goonooensis*	Western Donkey Orchid	h									1								
Monocotyledon	Orchidaceae		*Glossodia major*	Wax-lip Orchid	h	1	1						1									
Monocotyledon	Orchidaceae		*Prasophyllum campestre*	Inland Leek Orchid	h									1								
Monocotyledon	Orchidaceae		*Pterostylis bicolor*	Bicolor Greenhood	h									1		1			1			
Monocotyledon	Orchidaceae		*Pterostylis nana*	Dwarf Greenhood	h		1															
Monocotyledon	Orchidaceae		*Thelymitra spp.*	Sun Orchid	h		1	1					1									
Monocotyledon	Phormiaceae		*Dianella longifolia*	Blueberry Lily	h									1								
Monocotyledon	Poaceae	*	*Aira cupaniana*	Silvery Hairgrass	g	1		1	1						1	1	1	1	1	1	1	1
Monocotyledon	Poaceae		*Aristida ramosa*	Threeawn Grass	g	1		1			1		1	1	1	1	1	1	1	1	1	1
Monocotyledon	Poaceae		*Austrostipa scabra subsp. falcata*	Speargrass	g		1	1	1	1	1	1	1	1					1	1		1
Monocotyledon	Poaceae		*Austrostipa scabra subsp. scabra*	Rough Speargrass	g	1												1				
Monocotyledon	Poaceae		*Austrostipa spp.*	A Speargrass	g	1																
Monocotyledon	Poaceae		*Bothriochloa macra*	Red-leg Grass	g			1	1	1	1			1	1	1	1	1	1	1	1	1
Monocotyledon	Poaceae	*	*Briza minor*	Shivery Grass	g	1			1					1	1	1	1	1	1	1	1	1
Monocotyledon	Poaceae	*	*Bromus diandrus*	Great Brome	g										1					1	1	1
Monocotyledon	Poaceae	*	*Bromus hordeaceus*	Soft Brome	g													1				
Monocotyledon	Poaceae	*	*Bromus molliformis*	Soft Brome	g										1		1	1		1	1	1
Monocotyledon	Poaceae	*	*Bromus spp.*	A Brome	g									1								
Monocotyledon	Poaceae		*Chloris truncata*	Windmill Grass	g										1	1	1	1			1	
Monocotyledon	Poaceae		*Dichelachne micrantha?*	Shorthair Plumegrass	g			1														
Monocotyledon	Poaceae		*Dichelachne spp.*	A Plumegrass	g						1		1									
Monocotyledon	Poaceae		*Digitaria spp.*		g												1				1	
Monocotyledon	Poaceae		*Echinopogon ovatus*	Forest Hedgehog Grass	g						1		1									
Monocotyledon	Poaceae		*Elymus scaber*	Common Wheatgrass	g						1			1	1	1	1	1		1	1	1
Monocotyledon	Poaceae		*Eragrostis spp.*	Lovegrass	g				1		1				1		1		1			

Group	Family	exotic	Scientific Name	Common Name	Habit	DWood1	DWood2	DWood3	DWoodLQ	GBWood1	GBWood2	GBWood3	IronWood1	WBWood1	DReveg1	DReveg2	DReveg3	GBReveg1	GBReveg2	GBReveg3	GBReveg4	GBReveg5
Monocotyledon	Poaceae	*	*Lolium rigidum*	Wimmera Ryegrass	g				1	1				1	1						1	1
Monocotyledon	Poaceae		*Microlaena stipoides*	Weeping Rice-grass	g		1		1		1	1	1									
Monocotyledon	Poaceae		*Panicum spp.*		g													1				
Monocotyledon	Poaceae		*Paspalidium constrictum*	Knottybutt Grass	g						1			1							1	
Monocotyledon	Poaceae		*Paspalidium sp.*		g														1			
Monocotyledon	Poaceae	*	*Pentaschistis airoides*	False Hairgrass	g						1				1	1						
Monocotyledon	Poaceae	*	*Poa bulbosa*	Bulbous Poa	g				1					1			1		1			
Monocotyledon	Poaceae		*Rytidosperma caespitosum*	Wallaby Grass	g							1										
Monocotyledon	Poaceae		*Rytidosperma erianthum*	Hill Wallaby Grass	g													1			1	
Monocotyledon	Poaceae		*Rytidosperma fulvum*	Wallaby Grass	g		1	1	1			1	1			1						
Monocotyledon	Poaceae		*Rytidosperma racemosum*	Wallaby Grass	g			1	1				1	1					1	1		1
Monocotyledon	Poaceae		*Rytidosperma setaceum*	Small-flowered Wallaby Grass	g						1	1										
Monocotyledon	Poaceae		*Rytidosperma sp.*	Wallaby Grass	g	1	1			1					1			1			1	
Monocotyledon	Poaceae		*Sporobolus caroli*	Fairy Grass	g					1												
Monocotyledon	Poaceae		*Sporobolus creber*	Western Rat's-tail Grass	g																1	
Monocotyledon	Poaceae	*	*Vulpia muralis*	Rats-tail Fescue	g	1	1	1	1						1	1	1	1	1	1	1	1
Pteridophyta	Adiantaceae		*Cheilanthes sieberi subsp. sieberi*	Rock Fern	f	1	1	1	1		1		1	1	1	1	1		1	1	1	1

Appendix 2. ROUTINE AGRICULTURAL SOIL ANALYSIS REPORT– Grey Box Woodland Sites Kokoda Offset Area 2015

Soil samples supplied by DnA Environmental on 6th October, 2015 - Lab Job No. E4975

				Site	GBReveg 1	GBReveg 2	GBReveg 3	GBReveg 4	GBReveg 5	WBWood 1	IronWood 1	GBWood 1	GBWood 2	GBWood 3	***Heavy Soil*** *e.g Clay*	***Medium Soil*** *e.g Clay Loam*	***Light Soil*** *e.g Loam*	***Sandy Soil*** *e.g Loamy Sand*
Method		*Nutrient*		*Units*	*E4975/4*	*E4975/5*	*E4975/6*	*E4975/7*	*E4975/8*	*E4975/15*	*E4975/16*	*E4975/12*	*E4975/13*	*E4975/14*	***Indicative guidelines only- refer Note 6***			
Morgan 1		Calcium	Ca	mg/kg	436	292	247	167	304	269	90	202	124	278	*1150*	*750*	*375*	*175*
		Magnesium	Mg		65	97	71	56	66	73	42	161	101	155	*160*	*105*	*60*	*25*
		Potassium	K		79	73	58	77	112	77	66	145	87	115	*113*	*75*	*60*	*50*
		Phosphorus	P		1.3	1.0	0.8	0.6	1.2	1.0	0.6	1.5	1.0	1.6	*15*	*12*	*10*	*5.0*
Bray1		Phosphorus	P	mg/kg	2.0	2.0	1.3	1.7	1.7	1.7	1.7	10.5	2.7	5.8	*45 note 8*	*30 note 8*	*24 note 8*	*20 note 8*
Colwell					16	19	18	17	19	17	20	41	21	27	*80*	*50*	*45*	*35*
Bray2					3	4	2	2	3	2	3	17	4	8	*90 note 8*	*60 note 8*	*48 note 8*	*40 note 8*
KCl		Nitrate Nitrogen	N	mg/kg	2.6	2.1	2.3	2.5	2.2	1.8	1.5	1.8	1.5	1.8	*15*	*13*	*10*	*10*
		Ammonium Nitrogen			3.7	3.8	5.6	2.7	2.6	2.6	2.8	5.0	3.5	5.1	*20*	*18*	*15*	*12*
		Sulfur	S		3.4	3.6	4.2	3.9	3.2	3.8	4.4	8.4	9.2	12.4	*10.0*	*8.0*	*8.0*	*7.0*
1:5 Water		pH		units	6.45	5.80	6.12	5.88	6.02	5.84	5.00	5.01	4.94	5.16	*6.5*	*6.5*	*6.3*	*6.3*
		Conductivity		dS/m	0.026	0.029	0.022	0.019	0.024	0.026	0.038	0.074	0.069	0.077	*0.200*	*0.150*	*0.120*	*0.100*
Calculation		Organic Matter		% OM	2.6	4.6	1.9	1.7	2.2	1.5	4.2	7.8	4.7	6.3	*>5.5*	*>4.5*	*>3.5*	*>2.5*
Ammonium Acetate + Calculations		Calcium	Ca	cmol+/Kg	4.45	3.06	2.52	1.62	2.86	2.65	0.97	2.47	1.52	3.22				
				kg/ha	1998	1375	1131	728	1286	1189	437	1109	683	1445				
				mg/kg	892	614	505	325	574	531	195	495	305	645	*3125*	*2150*	*1000*	*375*
		Magnesium	Mg	cmol+/Kg	0.93	1.36	1.07	0.82	0.88	1.09	0.62	2.48	1.63	2.58				
				kg/ha	252	370	292	223	241	297	170	676	444	702				

				Site	GBReveg 1	GBReveg 2	GBReveg 3	GBReveg 4	GBReveg 5	WBWood 1	IronWood 1	GBWood 1	GBWood 2	GBWood 3	***Heavy Soil*** *e.g Clay*	***Medium Soil*** *e.g Clay Loam*	***Light Soil*** *e.g Loam*	***Sandy Soil*** *e.g Loamy Sand*
				mg/kg	112	165	130	99	108	133	76	302	198	313	*290*	*200*	*145*	*75*
		Potassium	K	cmol⁺/Kg	0.40	0.36	0.29	0.41	0.57	0.41	0.37	0.85	0.56	0.99				
				kg/ha	349	318	257	357	496	357	320	741	493	864				
				mg/kg	156	142	115	159	221	159	143	331	220	386	*235*	*190*	*150*	*100*
		Sodium	Na	cmol⁺/Kg	0.06	0.24	0.15	0.14	0.06	0.06	0.13	0.11	0.28	0.13				
				kg/ha	31	121	75	73	33	29	68	57	142	66				
				mg/kg	14	54	34	33	15	13	30	25	64	30	*69*	*60*	*51*	*25*
	KCl	Aluminium	Al	cmol⁺/Kg	0.05	0.36	0.10	0.44	0.06	0.16	1.88	1.43	1.97	1.13				
				kg/ha	10	72	19	88	13	31	379	289	396	227				
				mg/kg	4	32	9	39	6	14	169	129	177	101	*54*	*45*	*41*	*14*
	Acidity Titration	Hydrogen	H^+	cmol⁺/Kg	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00				
				kg/ha	0	0	0	0	0	0	0	0	0	0				
				mg/kg	0	0	0	0	0	0	0	0	0	0	*6*	*5*	*5*	*2*
	Calculation	Effective Cation Exchange Capacity (ECEC)		cmol⁺/Kg	5.88	5.38	4.13	3.43	4.46	4.36	3.97	7.34	5.96	8.04	*20*	*14*	*7*	*4*
	Base Saturation Calculations	Calcium	Ca	%	75.6	57.0	61.0	47.3	64.2	60.8	24.5	33.6	25.5	40.0	*77*	*76*	*69*	*60*
		Magnesium	Mg		15.7	25.3	26.0	23.9	19.8	25.0	15.7	33.8	27.4	32.1	*12*	*12*	*16*	*20*
		Potassium	K		6.8	6.8	7.1	11.9	12.7	9.3	9.2	11.5	9.5	12.3	*3*	*4*	*5*	*8*
		Sodium - ESP	Na		1.0	4.4	3.6	4.2	1.4	1.3	3.3	1.5	4.6	1.6	*2*	*2*	*3*	*3*
		Aluminium	Al		0.8	6.6	2.3	12.8	1.4	3.6	47.3	19.5	33.0	14.0	*7*	*7*	*7*	*9*
		Hydrogen	H^+		0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0				
	Calculation	Calcium/ Magnesium Ratio		ratio	4.8	2.3	2.3	2.0	3.2	2.4	1.6	1.0	0.9	1.2	*6.4*	*6.3*	*4.3*	*3.0*
	DTPA	Zinc	Zn	mg/kg	0.3	0.5	0.2	0.3	0.6	0.3	0.4	0.9	0.8	0.6	*6.0*	*5.0*	*4.0*	*3.0*
		Manganese	Mn		7	8	2	4	16	5	9	11	15	11	*25*	*22*	*18*	*15*

				Site	GBReveg 1	GBReveg 2	GBReveg 3	GBReveg 4	GBReveg 5	WBWood 1	IronWood 1	GBWood 1	GBWood 2	GBWood 3	***Heavy Soil*** *e.g Clay*	***Medium Soil*** *e.g Clay Loam*	***Light Soil*** *e.g Loam*	***Sandy Soil*** *e.g Loamy Sand*
		Iron	Fe		49	172	116	105	113	93	268	332	407	282	*25*	*22*	*18*	*15*
		Copper	Cu		0.1	0.1	0.1	0.1	0.3	0.1	0.1	0.3	0.2	0.2	*2.4*	*2.0*	*1.6*	*1.2*
	$CaCl_2$	Boron	B	mg/kg	0.32	0.26	0.28	0.22	0.23	0.36	0.32	0.72	0.42	0.71	*2.0*	*1.7*	*1.4*	*1.0*
		Silicon	Si		28	30	29	28	27	29	22	34	38	37	*50*	*45*	*40*	*35*
	LECO IR Analyser	Total Carbon	C	%	1.51	2.62	1.08	0.96	1.27	0.84	2.39	4.44	2.69	3.58	*>3.1*	*>2.6*	*>2.0*	*>1.4*
		Total Nitrogen	N	%	0.10	0.11	0.07	0.06	0.10	0.06	0.08	0.21	0.11	0.18	*>0.30*	*>0.25*	*>0.20*	*>0.15*
	Calculation	Carbon/ Nitrogen Ratio		ratio	15.8	23.9	16.2	14.8	13.2	15.2	28.7	21.4	24.2	20.1	*10-12*	*10-12*	*10-12*	*10-12*
		Basic Texture			Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam	Loam	..	..	..	..
		Basic Colour			Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	..	..	..	..
	Calculation	Chloride Estimate		equiv. ppm	17	19	14	12	16	16	25	47	44	49	..	..	..	..
	Total Acid Extractable	Calcium	Ca	mg/kg	815	918	562	418	679	635	293	787	457	1,094	*1,000 - 10,000 Ca*			
		Magnesium	Mg		218	325	264	451	339	268	219	545	347	516	*500 - 5,000 Mg*			
		Potassium	K		533	467	443	707	756	547	420	746	488	658	*200 - 2,000 K*			
		Sodium	Na		<50	74	<50	<50	<50	<50	<50	<50	69	<50	*100 - 500 Na*			
		Sulfur	S		65	83	57	53	75	<50	58	190	98	155	*100 - 1,000 S*			
	Total Acid Extractable	Phosphorus	P	mg/kg	62	88	82	115	99	77	64	203	95	173	*400 - 1,500 P*			
	Total Acid Extractable	Zinc	Zn	mg/kg	8	8	6	10	12	6	4	10	5	8	*20 - 50 Zn*			
		Manganese	Mn		144	96	83	104	249	78	69	83	112	154	*200 - 2,000 Mn*			
		Iron	Fe		8,159	7,640	11,134	17,595	11,287	10,473	7,628	8,700	7,918	9,872	*1,000 - 50,000 Fe*			
		Copper	Cu		2.2	2.8	2.2	3.6	4.0	2.6	1.8	4.4	2.7	4.2	*20 - 50 Cu*			
		Boron	B		<2	<2	<2	<2	<2	<2	<2	2	<2	<2	*2 - 50 B*			
		Silicon	Si		1,366	1,857	1,547	1,437	2,085	1,467	1,484	1,796	1,114	1,453	*1,000 - 3,000 Si*			
		Aluminium	Al		4,127	5,482	5,069	5,927	5,558	3,833	4,459	8,366	5,371	7,781	*2,000 - 50,000 Al*			

				Site	GBReveg 1	GBReveg 2	GBReveg 3	GBReveg 4	GBReveg 5	WBWood 1	IronWood 1	GBWood 1	GBWood 2	GBWood 3	***Heavy Soil*** *e.g Clay*	***Medium Soil*** *e.g Clay Loam*	***Light Soil*** *e.g Loam*	***Sandy Soil*** *e.g Loamy Sand*
	Total Acid Extractable	Molybdenum	Mo	mg/kg	0.4	0.4	0.4	0.5	0.3	0.3	0.4	0.6	0.4	0.4	*0.5 - 3 Mo*			
		Cobalt	Co		1	1	1	2	3	2	1	1	1	1	*5 - 50 Co*			
		Selenium	Se		<0.5	0.7	<0.5	0.6	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	*0.1 - 2.0 Se*			
	Total Acid Extractable	Cadmium	Cd	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	*< 5 Cd*			
		Lead	Pb		5	7	6	12	8	8	5	6	6	6	*< 75 Pb*			
		Arsenic	As		<2	<2	<2	2	<2	<2	<2	<2	<2	<2	*< 25 As*			
		Chromium	Cr		6	4	7	9	8	10	5	8	42	8	*<25 Cr*			
		Nickel	Ni		2	2	2	2	3	2	2	4	4	4	*<150 Ni*			
		Mercury	Hg		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*< 3.75 Hg*			
		Silver	Ag		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	*.. Ag*			

Appendix 3. ROUTINE AGRICULTURAL SOIL ANALYSIS REPORT– Dwyer's Red Gum Sites Kokoda Offset Area 2015

Soil samples supplied by DNA Environmental on 6th October, 2015 - Lab Job No. E4975

				Site	DReveg 1	DReveg 2	DReveg 3	DWoodLQ	DWood 1	DWood 2	DWood 3	***Heavy Soil*** *e.g Clay*	***Medium Soil*** *e.g Clay Loam*	***Light Soil*** *e.g Loam*	***Sandy Soil*** *e.g Loamy Sand*
Method	*Nutrient*			*Units*	*E4975/1*	*E4975/2*	*E4975/3*	*E4975/17*	*E4975/9*	*E4975/10*	*E4975/11*	***Indicative guidelines only- refer Note 6***			
Morgan 1	Calcium	Ca	mg/kg		132	151	218	35	200	37	104	*1150*	*750*	*375*	*175*
	Magnesium	Mg			50	37	66	55	44	47	51	*160*	*105*	*60*	*25*
	Potassium	K			48	54	68	55	68	59	68	*113*	*75*	*60*	*50*
	Phosphorus	P			0.5	0.5	0.6	0.2	0.5	0.3	0.4	*15*	*12*	*10*	*5.0*
Bray1	Phosphorus	P	mg/kg		1.7	4.5	1.5	1.7	1.7	1.4	1.4	*45note 8*	*30note 8*	*24note 8*	*20note 8*
Colwell					18	19	17	21	17	17	17	*80*	*50*	*45*	*35*
Bray2					3	7	3	3	2	2	2	*90note 8*	*60note 8*	*48note 8*	*40note 8*
KCl	Nitrate Nitrogen	N	mg/kg		2.3	1.7	2.5	1.6	2.3	1.4	1.6	*15*	*13*	*10*	*10*
	Ammonium Nitrogen				3.4	2.2	2.5	2.4	5.7	2.1	3.0	*20*	*18*	*15*	*12*
	Sulfur	S			5.1	6.0	5.1	2.2	3.0	2.9	3.6	*10.0*	*8.0*	*8.0*	*7.0*
1:5 Water	pH		units		5.53	5.28	5.86	5.21	5.36	5.16	5.35	*6.5*	*6.5*	*6.3*	*6.3*
	Conductivity		dS/m		0.024	0.027	0.022	0.027	0.023	0.021	0.024	*0.200*	*0.150*	*0.120*	*0.100*
Calculation	Organic Matter		% OM		2.4	2.4	2.9	2.3	3.5	3.2	2.3	*>5.5*	*>4.5*	*>3.5*	*>2.5*
Ammonium Acetate + Calculations	Calcium	Ca	$cmol^+/Kg$		1.13	1.42	2.30	0.27	2.15	0.37	1.01				
			kg/ha		506	638	1035	121	965	168	452				
			mg/kg		226	285	462	54	431	75	202	*3125*	*2150*	*1000*	*375*
	Magnesium	Mg	$cmol^+/Kg$		0.65	0.53	0.97	0.69	0.66	0.67	0.67				
			kg/ha		177	146	264	188	180	182	183				
			mg/kg		79	65	118	84	80	81	82	*290*	*200*	*145*	*75*

				Site	DReveg 1	DReveg 2	DReveg 3	DWoodLQ	DWood 1	DWood 2	DWood 3	***Heavy Soil** e.g Clay*	***Medium Soil** e.g Clay Loam*	***Light Soil** e.g Loam*	***Sandy Soil** e.g Loamy Sand*
		Potassium	K	cmol⁺/Kg	0.22	0.27	0.34	0.25	0.38	0.31	0.30				
				kg/ha	191	239	301	219	334	269	259				
				mg/kg	85	106	134	98	149	120	116	*235*	*190*	*150*	*100*
		Sodium	Na	cmol⁺/Kg	0.19	0.10	0.14	0.17	0.08	0.13	0.11				
				kg/ha	97	52	72	86	40	68	57				
				mg/kg	43	23	32	38	18	30	25	*69*	*60*	*51*	*25*
	KCl	Aluminium	Al	cmol⁺/Kg	1.09	1.40	0.35	1.08	1.41	1.59	0.75				
				kg/ha	221	282	70	218	284	320	151				
				mg/kg	98	126	31	97	127	143	68	*54*	*45*	*41*	*14*
	Acidity Titration	Hydrogen	H^+	cmol⁺/Kg	0.00	0.00	0.00	0.14	0.00	0.00	0.00				
				kg/ha	0	0	0	3	0	0	0				
				mg/kg	0	0	0	1	0	0	0	*6*	*5*	*5*	*2*
	Calculation	Effective Cation Exchange Capacity (ECEC)		cmol⁺/Kg	3.28	3.73	4.10	2.60	4.68	3.07	2.84	*20*	*14*	*7*	*4*
	Base Saturation Calculations	Calcium	Ca	%	34.4	38.1	56.2	10.4	46.0	12.2	35.5	*77*	*76*	*69*	*60*
		Magnesium	Mg		19.9	14.3	23.6	26.5	14.1	21.8	23.7	*12*	*12*	*16*	*20*
		Potassium	K		6.6	7.3	8.4	9.6	8.2	10.0	10.4	*3*	*4*	*5*	*8*
		Sodium - ESP	Na		5.8	2.7	3.4	6.4	1.7	4.3	3.9	*2*	*2*	*3*	*3*
		Aluminium	Al		33.4	37.5	8.5	41.6	30.1	51.7	26.5	*7*	*7*	*7*	*9*
		Hydrogen	H^+		0.0	0.0	0.0	5.5	0.0	0.0	0.0				
	Calculation	Calcium/ Magnesium Ratio		ratio	1.7	2.7	2.4	0.4	3.3	0.6	1.5	*6.4*	*6.3*	*4.3*	*3.0*
	DTPA	Zinc	Zn	mg/kg	0.3	0.2	0.4	0.5	0.4	0.3	0.3	*6.0*	*5.0*	*4.0*	*3.0*
		Manganese	Mn		2	1	5	2	13	3	8	*25*	*22*	*18*	*15*
		Iron	Fe		291	189	170	345	103	216	180	*25*	*22*	*18*	*15*
		Copper	Cu		0.2	0.1	0.1	0.1	0.2	0.1	0.1	*2.4*	*2.0*	*1.6*	*1.2*

				Site	DReveg 1	DReveg 2	DReveg 3	DWoodLQ	DWood 1	DWood 2	DWood 3	***Heavy Soil*** *e.g Clay*	***Medium Soil*** *e.g Clay Loam*	***Light Soil*** *e.g Loam*	***Sandy Soil*** *e.g Loamy Sand*
$CaCl_2$	Boron	B	mg/kg		0.31	0.21	0.25	0.31	0.42	0.35	0.24	*2.0*	*1.7*	*1.4*	*1.0*
	Silicon	Si			35	28	27	23	33	26	24	*50*	*45*	*40*	*35*
LECO IR Analyser	Total Carbon	C	%		1.39	1.37	1.68	1.30	2.03	1.84	1.31	*>3.1*	*>2.6*	*>2.0*	*>1.4*
	Total Nitrogen	N	%		0.08	0.06	0.08	0.07	0.09	0.07	0.06	*>0.30*	*>0.25*	*>0.20*	*>0.15*
Calculation	Carbon/ Nitrogen Ratio		ratio		17.4	22.0	21.1	17.4	23.0	27.8	23.7	*10-12*	*10-12*	*10-12*	*10-12*
	Basic Texture				Loam	Loam	Loam	Loam	Loam	Loam	Loam	..	..	..	..
	Basic Colour				Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	..	..	..	..
Calculation	Chloride Estimate		equiv. ppm		15	17	14	17	15	14	15	..	..	..	..
Total Acid Extractable	Calcium	Ca	mg/kg		308	381	642	110	578	129	269	*1,000 - 10,000 Ca*			
	Magnesium	Mg			249	200	263	226	345	228	177	*500 - 5,000 Mg*			
	Potassium	K			543	478	444	436	566	469	392	*200 - 2,000 K*			
	Sodium	Na			51	<50	56	54	<50	<50	<50	*100 - 500 Na*			
	Sulfur	S			98	50	70	66	62	<50	<50	*100 - 1,000 S*			
Total Acid Extractable	Phosphorus	P	mg/kg		92	75	88	80	62	60	48	*400 - 1,500 P*			
Total Acid Extractable	Zinc	Zn	mg/kg		6	4	9	7	15	4	5	*20 - 50 Zn*			
	Manganese	Mn			33	29	85	28	172	42	69	*200 - 2,000 Mn*			
	Iron	Fe			11,043	7,461	15,417	9,717	13,119	9,471	8,207	*1,000 - 50,000 Fe*			
	Copper	Cu			2.9	1.8	3.2	1.9	3.6	2.5	2.5	*20 - 50 Cu*			
	Boron	B			<2	<2	<2	<2	<2	<2	<2	*2 - 50 B*			
	Silicon	Si			2,216	1,796	1,521	1,773	2,475	1,468	1,542	*1,000 - 3,000 Si*			
	Aluminium	Al			6,423	5,041	5,276	4,975	7,974	5,359	3,655	*2,000 - 50,000 Al*			
Total Acid Extractable	Molybdenum	Mo	mg/kg		0.5	0.4	0.5	0.6	0.7	0.4	0.4	*0.5 - 3 Mo*			
	Cobalt	Co			1	1	1	1	2	1	1	*5 - 50 Co*			

				Site	DReveg 1	DReveg 2	DReveg 3	DWoodLQ	DWood 1	DWood 2	DWood 3	***Heavy Soil*** *e.g Clay*	***Medium Soil*** *e.g Clay Loam*	***Light Soil*** *e.g Loam*	***Sandy Soil*** *e.g Loamy Sand*
		Selenium	Se		0.8	<0.5	<0.5	0.7	0.5	0.7	<0.5	*0.1 - 2.0 Se*			
	Total Acid Extractable	Cadmium	Cd	mg/kg	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	*< 5 Cd*			
		Lead	Pb		8	5	10	8	9	6	6	*< 75 Pb*			
		Arsenic	As		2	<2	2	2	3	3	<2	*< 25 As*			
		Chromium	Cr		8	7	5	5	5	6	4	*<25 Cr*			
		Nickel	Ni		2	2	1	1	2	2	1	*<150 Ni*			
		Mercury	Hg		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*< 3.75 Hg*			
		Silver	Ag		<1	<1	<1	<1	<1	<1	<1	*.. Ag*			

Understanding your EAL soil results

Soil Acidity - Is the water pH >6.5 or $CaCl_2$ pH >5.5 – hence no major problem. >7pH indicates alkaline soil. Soil with pH below 4.5 often has high kg/ha exchangeable hydrogen and aluminium (and likely high % exchangeable H and Al).

Cation Exchange Capacity - Using the ECEC or CEC is the soil heavy, medium, light or sandy? In particular, compare the exchangeable Calcium and Potassium in kg/ha to suggested guidelines.

Soil Salinity - Is the electrical conductivity (EC) above texture guidelines (ie. > 0.2dS/m heavy soil) – hence indicates possible salinity issue. If the Exchangeable Sodium Percentage or % Exchangeable Sodium > 5% then possible salt issue. With high EC the chloride is also likely to be elevated.

Ca/Mg Ratio - Above 5 indicates good soil structure. Ratio 1 – 5 suggests addition of calcium to assist soil structure. Ratio <1 (ie. far higher magnesium) often indicates high clay soil and possibly a sub-soil. Compaction and poor water infiltration is a likely indication of the cation imbalance.

Organic Matter - Refer to guidelines - >5.5% indicates good organic carbon and organic matter in the soil. Total Carbon to Total Nitrogen ratio should be around 12:1 – If higher then suggests depletion of organic nitrogen.

Phosphorus - Are the levels of Bray I (plant available)/Bray II (exchangeable P) below or above the guidelines. At, above or near guidelines suggests no need for P addition.

Solubles - Nitrate, ammonium and sulfur – compare to guidelines for soil type. Leachable nutrients hence may be further down soil profile.

Micronutrients - Plant available Iron, Manganese, Copper and Zinc – compare to guidelines to assess if relatively low or high. Iron and manganese availability is significantly influenced by soil pH (acid soils often have very high soluble iron). Leaf testing is ideal for confirming potential issues with micronutrients.

Boron - A micronutrient extracted as plant available – compare to guidelines but be aware boron is very leachable and could be elevated down the soil profile.

Acid Extractable Nutrients - If total available nutrients were analysed then use numbers as a guide to compare to assess store of nutrients.