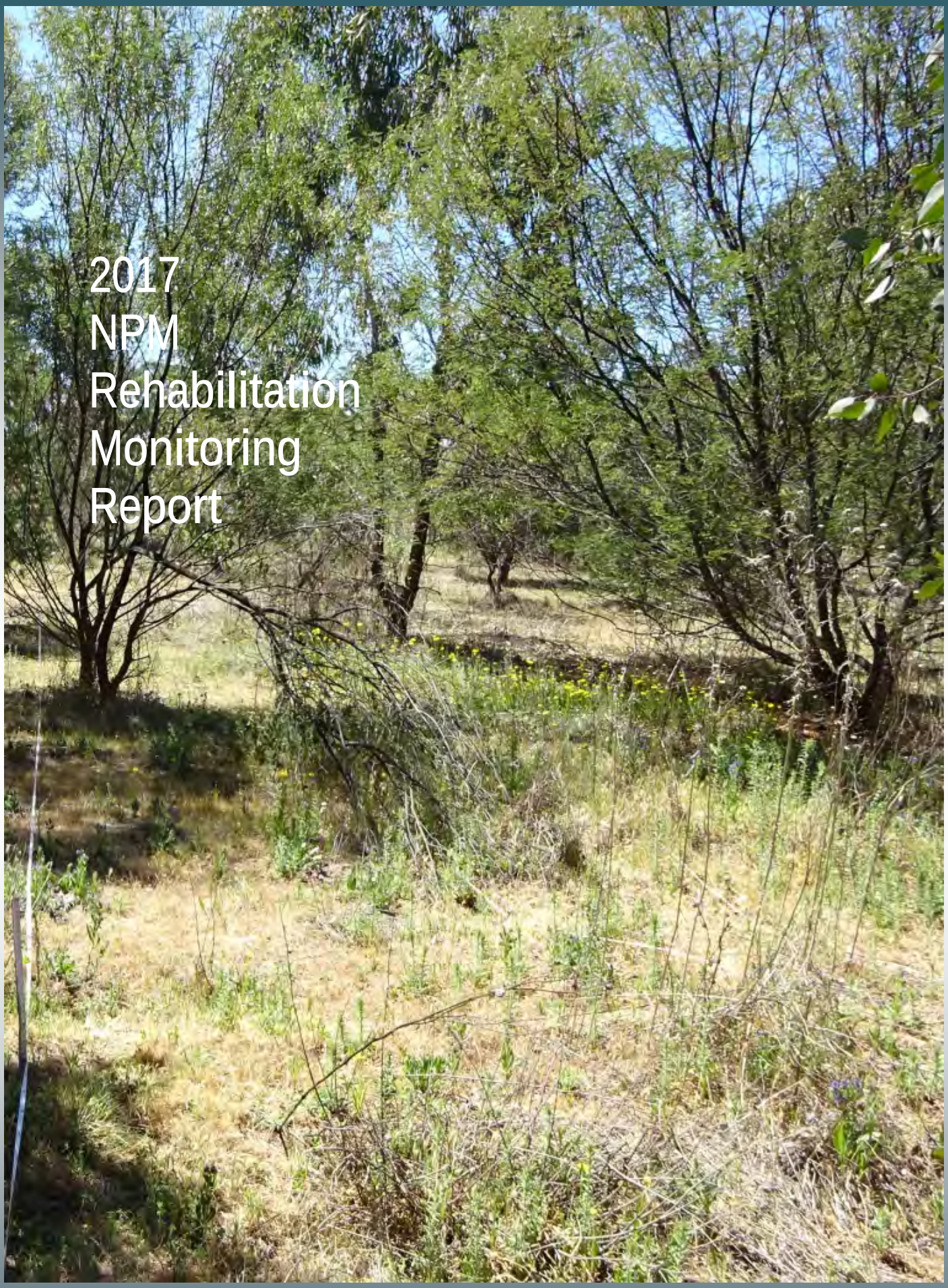

2017 NPM Rehabilitation Monitoring Report

January 2018
for
Northparkes Mines

Prepared by
DnA Environmental

Disclaimer

This is a report of work carried out by DnA Environmental, under contract and on behalf of China Molybdenum Co. Ltd (CMOC) Pty Ltd as agent severally for and on behalf of the Northparkes Joint Venture 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: 

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Executive summary

The 2017 rehabilitation monitoring report is a result of work carried out by DnA Environmental on behalf of China Molybdenum Co. Ltd (CMOC) Pty Ltd as agent severally for and on behalf of the Northparkes Joint Venture at Northparkes Mines (NPM). The primary objective of the rehabilitation monitoring program is to compare the progress of rehabilitated landforms and Biodiversity Offset Areas towards fulfilling long-term landuse objectives by comparing a selection of ecological targets or completion criteria against unmined areas of remnant vegetation (reference sites) that are representative of the final landuse and vegetation assemblage The monitoring program aims to comply and be consistent with a range of conditions specified within approval documents, management systems and associated Management Plans, Mining Operation Plans and government regulations and best practice guidelines.

Specifically this rehabilitation monitoring report aims to:

- Describes the annual rehabilitation monitoring program first established in 2009;
- Present the 2017 monitoring results of two woodland and six pasture rehabilitation sites and compare their ecological progress against relevant reference sites, also established as part of the rehabilitation monitoring program;
- Compare the performance of the rehabilitation sites against the selection of proposed primary completion targets; and
- Provide a range of management recommendations which will assist in achieving rehabilitation objectives and associated completion criteria targets.

NSW Trade & Investment released the revised ESG3 MOP guidelines in September 2013 which detail a process for monitoring and managing progression towards successful rehabilitation outcomes quantified by completion criteria. The Guideline requires industry to identify and provide measurable data and demonstrate that proposed rehabilitation outcomes are achievable and realistic within a given timeframe. Completion criteria are objective target levels or values that can be measured to quantitatively demonstrate the progress and ultimate success of a biophysical process. The requirement for more targeted information strengthens the capacity of the Department to regulate rehabilitation and environmental performance and more accurately determine rehabilitation security liabilities.

As part of the ESG guidelines rehabilitation of a mine site are conceptually described in terms of logical steps or phases and these should be made applicable to each of the similar land management units or domains within the mine site. The monitoring procedure as described in the MOP guidelines has been broken down into five main rehabilitation phases including:

1. Decommissioning;
2. Landform Establishment and Stability;
3. Growth medium development;
4. Ecosystem and Landuse Establishment;
5. Ecosystem and Land Use sustainability; and
6. Relinquished Lands.

NPM biodiversity monitoring program

The NPM Mine is located in the central west region of NSW and has had a long history of rural land use. The majority of the region consists of cleared land used for agricultural pursuits with patches of remnant vegetation largely associated with State Forests. At Northparkes Mines, rehabilitation is not

just limited to areas within the mining lease but has been undertaken across the entire NPM landholdings. Primary objectives include integrating rehabilitation areas into the surrounding landscape and maximising biodiversity and conservation outcomes across the farming properties which are managed to enhance the regional landscape and native habitat values. The future land uses for the Mining lease are therefore divided into three main categories:

1. Native vegetation areas including woodlands and native grasslands;
2. Agricultural land, primarily for cropping; and
3. Restricted access areas, associated with subsidence and open cut voids.

Biodiversity Offset areas situated within the Limestone Forest and Estcourt Offset Area are also included within the biodiversity monitoring program.

The native vegetation (eucalypt woodlands and native grasslands) situated within and surrounding the NPM form part of the *Eucalyptus microcarpa* (Inland Grey Box) - *E. populnea* (Bimble Box) - *Callitris glaucophylla* (White Cypress Pine) tall woodland which is consistent with Grey Box (*Eucalyptus microcarpa*) Grassy Woodlands and Derived Native Grasslands of South-Eastern Australia. These Inland Grey Box Woodlands are Endangered Ecological Communities (EEC) listed under the EPBC Act.

In 2009 DnA Environmental established a total of 21 monitoring sites which included four mixed woodland and three native grassland reference sites. All reference sites have been subjected to some prior form of disturbance, in particular clearing, logging and grazing and some sites were likely to be older regrowth. Exotic annual grasses and a range of other agricultural weeds such were also common.

The 14 rehabilitation monitoring sites were a combination of mixed native woodland and grasslands communities which occurred on various waste emplacements (E22, E26, E27) and on the sides of the Northern and Southern Tailings Storage Facilities (TSF1, TSF2). Some sites were also established in revegetation areas located around the farming properties (Kundibah, Beechmore, Altona and Estcourt) as well in the Limestone Forest Offset (LFO) areas. Separate monitoring reports have been prepared to record ecological changes occurring in the Estcourt and Kokoda Offset Areas. The monitoring sites were chosen based on their final landuse/vegetation community type and year of establishment and were considered to be representative of the rehabilitation area as a whole.

The monitoring methodology included a combination of Landscape Function Analyses, accredited soil analyses and various measurements of ecosystem diversity and habitat values based on and adapted from the Biometric methodology. Data obtained from within replicated reference sites were used to provide upper and lower ecological performance indicator limits. As not all performance indicators are considered to be fundamental to completion, or in some cases achievable (e.g. average trunk diameter), key performance indicators have been further separated into "*Primary Performance Indicators*" and "*Secondary Performance Indicators"*.

Primary performance indicators are those chosen as completion criteria targets and rehabilitation sites should equal, exceed or show positive trends towards those attributes of the reference sites. When these primary performance indicators have been met, or are trending in the right direction, the sites should therefore theoretically be eligible for closure sign off. The range values of each performance indicator are adapted annually to reflect seasonal conditions and local disturbance events.

This year there were several amendments to the monitoring program. This included the establishment of a new grassland reference site as the original RGrass01 had significantly deteriorated and was now not a suitable representative of the grasslands surrounding NPM. The farmland woodland plantings

were not included in this year's monitoring program but will be monitored on five year rotation, with the next monitoring due in 2019. Two grassland rehabilitation sites on TSF1 (TSF1-01, TSF1-02) and one grassland rehabilitation site on TSF2 (TSF2-01) had been affected by earthworks as a result of the upgrade of the Tailings Storage Facilities. No new sites were established on TSF1 however a new site, TSF2-03 was established on the western wall of the TSF2 which is not expected to be subjected to future disturbance. In addition, the site of the old E26 subsidence zone was longer readily accessible for monitoring. Subsequently a new site, E26-02 was established on the adjacent and similar topsoil stockpile situated to the west of the E26 subsidence zone. This year there were a total of 15 monitoring sites.

Rehabilitation monitoring has been undertaken during spring in all monitoring years and this year occurred from the 12th – 17th October.

The average annual rainfall at Parkes Airport is 615 mm, however there have been extreme seasonal conditions with below average rainfall being recorded in 2015 and 2017, while in 2016, widespread flooding was experienced around Parkes with a total annual rainfall of 833 mm being recorded. In 2017, very low rainfall activity occurred except in March where 195mm of rainfall was recorded. Rainfall remained well below the expected monthly averages for most of the year, with a total of 561mm being recorded for the year. The extreme seasonal conditions experienced over the past few years has had a significant impact on the composition and diversity of the vegetation at the NPM, and combined with simultaneous changes in total grazing pressure, have been reflected in the ecological monitoring data.

Summary of results

Woodland rehabilitation sites

The four woodland reference sites were characterised by having a mature tree canopy, scattered shrubs and a well developed grassy ground cover layer with moderate to high levels of decomposing litter and/or cryptogam cover and collectively provided highly functional 100% patch areas. The younger rehabilitation sites in the Limestone Forest Offset (LFO) which were planted in 2009 had demonstrated the most significant changes within the first three years of monitoring with both sites reaching 100% patch area in 2011. In 2009 there were significant areas of bare ground due to ground preparation techniques prior to planting but these rapidly became colonised by a variety of annual weeds and cryptogams. While perennial vegetation cover remained low, the annual plants, cryptogams and dead leaf litter created important and functional patch areas. In 2014, prolonged dry conditions combined with some patchy disturbance by macropods, resulted in a small reduction in patch area in LFO-02. This year both sites had improved ground covers and had 100% functional patch area.

In 2017, three years since last monitored, there was an increase in stability recorded in three of the four reference sites. Despite less live perennial and annual plant cover, there tended to be high levels of litter cover and cryptogams were well established in otherwise bare areas. Recent heavy grazing by travelling livestock however had decreased the stability at RWood01. The youngest and previously most disturbed revegetation sites LFO-01 and LFO-02 have shown an increased stability, infiltration and nutrient recycling capacity and this year were comparable to the local woodlands, except in LFO-01 infiltration was negligibly lower the minimum recorded in RWood01. The improved ecological function in these sites were largely due to an improvement in litter cover and rates of decomposition which were starting to develop a rich organic layer which was more coherent with less capacity for slaking.

The sum of the LFA stability, infiltration and nutrient recycling components provide an indication of the most functional to least functional monitoring site recorded in 2017. The maximum score possible is 300 with RWood02, a woodland reference site, being the most ecologically functional site with a total score of 200. This site contained high patch area, a mature tree canopy, shrub understorey and well developed grassy ground cover layer, with high levels of decomposing litter and cryptogam cover.

Most other sites did not tend to have such high levels of these attributes. The Limestone Forest revegetation site LFO-02 had very similar ecological function to RWood03 and RWood04 with a sum of scores of 163 compared to the woodland reference sites 162 and 161 respectively. In LFO-01, there was total ecological function 157 which was higher than the total function recorded in the woodland reference site RWood01 which scored a total of 146 this year.

In the woodland reference sites trees and mature shrubs with a trunk diameter > 5cm ranged from 5 – 22, equating to a density of 50 – 220 individuals per hectare. Tree densities recorded in the Limestone Forest rehabilitation sites have continued to increase as young trees and shrubs have continued to grow. This year there were tree densities of 24 and 22 individuals recorded in LFA-01 and LFO-02 this year, with these densities being comparable to the local woodlands. In the Limestone Forest rehabilitation sites the most common mature tree species were local endemic species, *Callitris glaucophylla, E. microcarpa, E. populnea* and mature *Acacia deanei* (Deane's Wattle).

Since 2013 the shrub and juvenile tree populations in the woodland reference sites have typically increased as new seedlings become established with 65 – 138 individuals being recorded this year, equating to a shrubs density of 650 – 1380 stems per hectare. In LFO-02 in 2013, a high number of very small (~3cm) *A. deanei* seedlings had recently germinated around a mature *A. deanei*, however most of these failed to become established by 2014. This year, the shrubs and juvenile tree population in both LFO-01 and LFO-02 were declining, as tubestock have grown with an increasing number having > 5cm dbh. Thus both Limestone Forest sites have low shrub densities compared to the local woodlands.

In the woodland reference sites there were 2 - 6 species of shrubs and juvenile trees and both Limestone Forest sites had this diversity of species. In three of the reference sites the most common shrubs included *Allocasuarina luehmannii* (Bulloak)*, Eucalyptus microcarpa* (Grey Box)*, Dodonaea viscosa* subsp*. cuneata* (Wedge-leaf Hopbush) and *Acacia hakeoides* (Hakea Wattle). Additionally there were some *Senna artemisioides* subsp*. zygophylla* (Senna), *Acacia deanei* (Green Wattle)*, Alectryon oleifolius* (Rosewood), *Geijera parviflora* (Wilga) and *Eucalyptus albens* (White Box) recorded in at least one of the reference sites. In RWood04, *Callitris glaucophylla* was the most dominant species. The most common species in the Limestone Forest rehabilitation areas included *Callitris glaucophylla* and *Acacia deanei,* however there were also individuals of *Allocasuarina luehmannii*, *Dodonaea viscosa* subsp. *cuneata, Eucalyptus microcarpa, Acacia hakeoides* and *Senna artemisioides* subsp. *zygophylla*.

Total ground cover, which is a combination of leaf litter, annual plants, cryptogams, rocks, logs and live perennial plants (<0.5m in height) continued to be relatively high in the woodland reference sites and had slightly improved since 2014. This year travelling livestock and heavy macropod browsing may have impacted RWood01 and RWood03 and total ground cover ranged from 87.5 – 100%. Improved ground cover was also recorded in the Limestone Forest revegetation sites and both LFO-01 and LFO-02 had 100% total ground cover this year.

This year the Limestone Forest sites were dominated by dead leaf litter and annual plants, and there was a sparse cover of perennial plants that continued to remain lower than the local woodlands. There

was an absence of cryptogams this year due to increasing levels of plant and litter cover and no rocks or branches were present. The woodland reference sites contain various level of vertical height cover, with all sites having a mature canopy > 6.0m in height. This year, vertical heights up to 4.0m high were recorded in LFO-1 and LFO-02 and a small amount of canopy cover > 6.0m was recorded in LFO-02.

Floristic diversity in the reference sites has tended to fluctuate with changes in seasonal conditions with the highest diversity being recorded in 2010 due to favourable seasonal conditions and the break of the drought. This year there tended to be a decline in native and exotic species diversity in most sites, except in RWood02 and RWood04, where exotic species diversity had increased. In LFO-01 and LFO-02 total and native species diversity was low and exotic species diversity was higher than the reference sites. In addition, exotic plants continued to provide the most live ground cover within the LFO sites and they were weedier than desired.

The woodland revegetation sites LFO-01 and LFO-02 had an appropriate diversity of tree, shrubs, reeds and ferns compared to the reference sites. There was however a low diversity of herbs and grasses and no sub-shrubs were recorded.

Native species common to both Limestone Forest revegetation sites included *Callitris glaucophylla*, *Dichondra repens* (Kidney Weed), *Einadia nutans* subsp. *nutans* (Climbing Saltbush), *Eucalyptus microcarpa* (Grey Box), *E. populnea* (Bimble Box), *Senecio quadridentatus* (Cotton Fireweed), *Vittadinia cuneata* var. *hirsuta* (Fuzzweed), *Vittadinia gracilis* (A Fuzzweed) and *Xerochrysum bracteatum* (Golden Everlasting). Common exotic species were *Avena fatua* (Wild Oats), *Carthamus lanatus* (Saffron Thistle), *Echium plantagineum* (Paterson's Curse), Hordeum leporinum (Barley Grass), *Medicago polymorpha* (Burr Medic) and *Rumex crispus* (Curled Dock). All species except *Rumex crispus* were also recorded in the woodland reference sites.

This year no particular species was sufficiently abundant to meet the abundance criteria in RWood02 or RWood04. In RWood01 the native grass *Austrostipa scabra* subsp. *scabra* (Rough Speargrass) was the most abundant species, while in RWood03 the native perennials *Austrostipa nitida* and *Vittadinia cuneata* provided the most ground cover. In LFO-01 the exotic annuals *Carthamus lanatus* (Saffron Thistle), *Echium plantagineum* (Paterson's Curse) and *Trifolium glomeratum* (Clustered Clover) were the most abundant species. In LFO-02 *Avena fatua* (Wild Oats) was dominant.

The soils were characteristically similar to the local woodlands but had low organic matter (OM) and cation exchange capacity (CEC) and in LFO-01 there were high concentrations of phosphorous (P).

Performance of the woodland rehabilitation monitoring sites against “proposed” Primary Completion Performance Indicators

The table below indicates the performance of the woodland rehabilitation monitoring sites against a selection of proposed Primary Performance Indicators during the 2017 monitoring period. The selection of criteria has been presented in order of rehabilitation phases according to the new ESG3 MOP guidelines *excluding Phase 1: Decommissioning.* The ecological targets begin at Phase 2: Landform establishment (orange) and end with indicators in Phase 5: Ecosystem Sustainability (dark blue). The range values of the ecological targets are amended annually. Rehabilitation sites meeting or exceeding the range values of their representative community type have been identified with a coloured box and have therefore been deemed to meet these primary completion criteria targets this year. Hashed coloured boxes indicate they may be outside of the reference target ranges, but within acceptable agricultural limits.

Performance of the woodland rehabilitation sites against Primary Completion Performance Indicators in 2017.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Unit of measurement	Woodland ecosystem range 2017		LFO-01	LFO-02
Performance indicators are quantified by the range of values obtained from replicated reference sites					Lower	Upper	2017	2017
Phase 2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope	< Degrees (18°)	0	5	4	1
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	No.	0	0	0	0
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 (5.6 - 7.3)	6.3	6.7	5.9	6.0
			Organic Matter	% (>4.5)	3.7	5.2	2.7	2.7
			Phosphorous	ppm (50)	22.0	36.1	73.1	32.1
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	%	60.6	79.3	67.5	68.5
			LFA Landscape organisation	%	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	species/area	2	6	4	5
				% population	100	100	100	100
			Exotic species richness	<No./area	5	19	17	10
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees	No./area	65	138	11	13
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees	No./area	3	4	4	3
			Shrubs	No./area	0	3	1	4
			Herbs	No./area	21	33	19	18
Phase 5: Ecosystem & Landuse Sustainability	Landscape Function Analysis (LFA): Landform function and ecological performance	Landform is ecologically functional and performing as it was designed to do	LFA Infiltration	%	44.3	61.2	44	48.5
			LFA Nutrient recycling	%	39.9	59.7	45	45.5
	Protective ground cover	Ground layer contains protective ground cover and habitat structure comparable with the local remnant vegetation	Perennial plant cover (< 0.5m)	%	11	20	4	6.5
			Total Ground Cover	%	88	100	100	100
	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	%	45	98	25.4	24.2

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Unit of measurement	Woodland ecosystem range 2017		LFO-01	LFO-02
	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	No./area	11	31	1	0
			shrubs and juvenile trees 1.5 - 2m in height	No./area	2	17	2	1
	Ecosystem structure	The vegetation is developing in structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5 - 2 m	% cover	4	6	11	11
			Foliage cover >6m	% cover	19	43	0	5
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity	%	100	100	100	100
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density	No./area	6	22	24	22
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees	% population	83	100	100	100
			Healthy trees	% population	36	83	87.5	77.3
			Flowers/fruit: Trees	% population	14	92	54.2	63.6

Grassland rehabilitation sites

The three grassland reference sites were dominated by a moderately dense sward of annual grasses and dead leaf litter and contained a sparse to moderate density of native perennial grass tussocks and scattered forbs. The three grassland reference sites had high functional patch area and had Landscape Organisation Indices (LOI) of 100%. The six grassland rehabilitation sites typically had high functional patch areas and all sites except TSF2-03 had an LOI of 100%.

The grassland reference sites have typically shown an improvement in stability from 2009 – 2012 due to the improved seasonal conditions after the extended drought and the absence of grazing pressure. Dry seasonal conditions since then have typically resulted in a decline in perennial plant cover but this has largely been compensated for by an increase in cryptogam cover and/or increased litter and higher levels of decomposition. There has also tended to be similar trends recorded in the grassland rehabilitation sites and most rehabilitation sites had a stability comparable to the local grasslands, with the exception of TSF2-02 and E26-02 which had slightly lower stability.

This year, marginal increases in infiltration capacity were recorded in the reference sites. In rehabilitation sites E22-01, E26-02 and E27-01 ecological infiltration was comparable to the local grasslands. In the remaining rehabilitation sites the litter layers were not as well developed, small bare patches may have persisted and the soils continued to be prone to some slaking. Similar trends in

nutrient recycling indices were also recorded this year with the grassland reference sites providing a slightly higher target range. Most rehabilitation sites continued to fall within the target range except E22-02 and TSF2-03.

The grassland reference sites RGrass03 and RGrass02 were the most ecologically functional sites scoring 173 and 168 out of a possible 300 this year. Site E27-01, a rehabilitated pasture site, also scored 168. Sites E22-01, TSF2-02 and E26-02 had similar total ecological function to each other and were more functional than RGrass01 which had a sum of scores of 152. Site E22-02 was similar to RGrass01 with a total score of 152. The new rehabilitation site TSF2-03 was the least functional of the rehabilitated grassland communities with a sum of scores of 139.

One mature *Acacia brachystachya* (Umbrella Mulga) was recorded at E27-01, thought to be the result of an old seeding program. This mature acacia had a dbh of 12 cm and was bearing immature pods. There were no trees and shrubs in the remaining grassland sites.

Shrubs have been recorded in low numbers in numerous rehabilitation sites with the shrubs typically being volunteer species establishing from the soil seed bank. This year low densities were recorded in both sites on the TSF2 and in E22-01. In site E27-01, 173 shrubs and shrub seedlings were recorded this year, with these numbers having significantly increased due to natural regeneration. All shrubs recorded on the TSF2 rehabilitation areas were young chenopod *Maireana brevifolia* (Yanga Bush). *Maireana brevifolia* individuals were also recorded at E27-01 however most shrubs were *Senna artemisioides,* thought to be the result of an old seeding program.

In most of the grassland rehabilitation sites total ground cover continued to be high and all sites had 100% ground cover, with the exception of E27-01. In E27-01, high disturbance by macropods has continued to leave areas of bare ground especially beneath the larger shady shrubs. This year total ground cover had improved but presently it was slightly lower than the reference sites.

The grassland reference sites were dominated by dead leaf litter which provided 50 – 68% of the total ground cover. Perennial plants provided 20.5 – 36.5% while annual plants provided the remaining 10.5 – 15% of the total cover values. There were no cryptogam covers despite some small bare patches, and there were no rocks or logs. Total ground cover in the grassland rehabilitation sites was also comprised of dead leaf litter and annual and perennial plants. Sites TSF2-02 and TSF2-03 were the only sites to have a perennial plant component similar to the reference sites. Annual plants were in much higher abundance in E22-01, E26-02 and E27-01 and other habitat features such as rocks or logs were limited to a small quantity of scattered rocks in E22-02. Most of the grasses had been grazed quite low and projected foliage cover >0.5m in height was limited to tall scattered weeds or large grass tussocks in E22-01 and E27-01 or occasional shrub in RGrass01.

Floristic diversity was particularly low in 2009 due to the prolonged drought conditions however in 2010 above average rainfall was received and floristic diversity significantly increased. Since then however extended dry periods combined with grazing pressure and/or rainfall preceding the monitoring events have resulted in highly variable diversity of species in the reference sites.

This year there were 33 – 41 different plants in the local grasslands and of these 17 – 22 were native species. The rehabilitation site E27-01 had a comparable diversity of total and native species however the remaining rehabilitation sites had lower total and native species diversity. All grassland rehabilitation sites had less exotic species diversity than the local grasslands. 2017 was a particularly dry year and there was less cover of annual and perennial ground covers and sites most affected by grazing were observed to be E22-02 and E27-01. In the reference sites native plants provided 43 - 48% of the live

plant cover with 53% measured in TSF2-02. In the remaining rehabilitation sites, native plant covers were lower than the reference sites and were therefore weedier than desired.

The rehabilitation sites contained an acceptable representation of all growth forms however the diversity of grasses was slightly low in E22-02 and there were no sub-shrubs in E22-01 and E26-02. While no shrubs were present in the reference sites, at least one species of shrub was recorded in all rehabilitation sites except E26-02.

Four species were common to all rehabilitation sites and these were exotic annuals *Avena fatua* (Wild Oats), *Lolium rigidum* (Wimmera Ryegrass) and Sonchus oleraceus (Milk Thistle) and the native perennial grass *Walwhalleya proluta* (Rigid Panic). All of these species were recorded in all grassland reference sites.

The most abundant species in the grassland reference sites were the native grasses *Walwhalleya proluta* (Rigid Panic), *Rytidosperma setaceum* (Small-flowered Wallaby Grass) and *Austrostipa nodosa* (Speargrass). Exotic annuals including *Avena fatua* (Wild Oats), *Salvia verbenaca* (Wild Sage) and *Lolium rigidum* (Wimmera Ryegrass) were also relatively abundant in one or more of the grassland sites. The rehabilitation areas on the TSF2 tended to be dominated by a similar composition of species to the grassland reference sites and were dominated by *Walwhalleya proluta,* with lower abundances of *Lolium rigidum.* In TSF2-03, *Medicago polymorpha* (Burr Medic) was also a dominant species, however cover values were relatively low. E22-01 and E26-02 were dominated by *Avena fatua,* while *E22-02* was dominated by *Carthamus lanatus* (Saffron Thistle) and low abundances of *Walwhalleya proluta.* E27-01 was dominated by *Avena fatua* and *Lolium rigidum.*

One rill had previously been recorded in E22-02 however by 2014 the rill had become sufficiently established with vegetation and was considered to be stable. No other rills were recorded in the grassland rehabilitation monitoring sites.

In most rehabilitation sites the soils were comparable to the local grasslands but in numerous sites they were deficient in organic matter and had elevated levels of silicon. In TSF2-03 and E22-02 the soil pH was elevated with the soils being moderately alkaline. In TSF2-02 and TSF2-03 the soils were sodic and there were elevated levels of sulfur. The soils in TSF2-03 were also deficient in phosphorous and nitrate and were slightly saline. In sites E22-01, E22-02 and E27-01 there were significantly high levels of copper.

Performance of the grassland rehabilitation monitoring sites against "proposed" Primary Completion Performance Indicators

The tables below indicates the performance of the rehabilitation monitoring sites against a selection of proposed Primary Performance Indicators during the 2017 monitoring period. The selection of criteria has been presented in order of rehabilitation phases according to the new ESG3 MOP guidelines *excluding Phase 1: Decommissioning.* The ecological targets begin at Phase 2: Landform establishment (orange) and end with indicators in Phase 5: Ecosystem Sustainability (dark blue). The range values of the ecological targets are amended annually. Rehabilitation sites meeting or exceeding the range values of their representative community type have been identified with a coloured box and have therefore been deemed to meet these primary completion criteria targets this year. Hashed coloured boxes indicate they may be outside of the reference target ranges, but within acceptable agricultural limits.

Performance of the grassland rehabilitation sites against Primary Completion Performance Indicators in 2017.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Unit of measurement	Grassland ecosystem range 2017		TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27-01
Performance indicators are quantified by the range of values obtained from replicated reference sites					Lower	Upper	2017	2017	2017	2017	2017	2017
Phase 2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope	< Degrees (18°)	2	3	13	13	14	12	15	15
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	No.	0	0	0	0	0	0	0	0
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 (5.6 - 7.3)	6.5	7.7	7.5	8.2	6.9	7.8	6.8	7.2
			Organic Matter	% (>4.5)	3.0	5.4	1.7	0.6	4.7	2.3	2.8	3.1
			Phosphorous	ppm (50)	19.7	23.6	21.3	16.1	30.8	22.3	46.6	26.2
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	%	67.5	78.0	75.5	67.4	68.5	70.0	67.0	71.9
			LFA Landscape organisation	%	100	100	100	83	100	100	100	100
	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Exotic species richness	<No./area	15	19	14	12	12	11	14	17
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Herbs	No./area	21	23	16	12	11	19	12	19
			Grasses	No./area	7	18	11	9	6	7	7	11
Phase 5: Ecosystem & Landuse Sustainability	Landscape Function Analysis (LFA): Landform function and ecological performance	Landform is ecologically functional and performing as it was designed to do	LFA Infiltration	%	43.0	51.3	38.5	36	48.9	40.9	46.3	48.4
			LFA Nutrient recycling	%	41.8	50.6	46.4	36	45.9	41.3	44.1	47.5

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Unit of measurement	Grassland ecosystem range 2017		TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27-01
	Protective ground cover	Ground layer contains protective ground cover and habitat structure comparable with the local remnant vegetation	Perennial plant cover (< 0.5m)	%	21	37	32	22	4.5	14.5	1.5	14.0
			Total Ground Cover	%	97	100	100	83.5	100	100	100	95
	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	%	43	48	52.8	35.9	15.8	22.2	17.9	12.5

Conclusion

Despite the prolonged dry conditions, the Limestone Forest revegetation sites have continued to improve and this year had ecological characteristics comparable to the local woodlands, except that LFO-01 had a negligible lower infiltration capacity. Both revegetation sites had a tree and mature shrub diversity and density also comparable to the local woodlands. However shrub and juvenile tree densities were too low and declining, as the young sapling continue to grow. This may have implications in meeting future completion targets in the absence of successful natural recruitment events. There was also low perennial plant cover and total and native species diversity was low, and as these sites were dominated by exotic annuals and were presently weedier than desired.

Most of the grassland rehabilitation sites were also ecologically comparable to the local grasslands with the exception of TSF2-03 which may have some implication with adverse soil chemistry. There tended to be low species diversity in all grassland rehabilitation sites and often native species richness and the diversity of herbs was low. All sites except TSF2-02 were dominated by exotic annual plants and were weedier than the local grasslands.

Many rehabilitated grassland sites lacked the diversity of native ground cover species and while these may improve naturally over time, enhanced diversity and other ecological targets could have been achieved via active rehabilitation methods such as seeding and/or planting when the sites were first rehabilitated. While some sites contained an abundance of exotic annual weeds, these species are part of the successional process and have made a significant contribution in providing protective ground cover and assisting with the development of microbial and nutrient recycling processes and topsoil improvement. In the absence of disturbance, many exotics annuals are likely to decline in diversity and abundance over time, as the perennial plants become more established. Some species however are now naturalised components of the local grasslands and agricultural lands and are likely to persist in the longer-term but these will also be reflected in the range of reference sites.

Some of the rehabilitation sites contained elevated concentrations silicon, sulfur and copper. While some elements were also elevated in the reference sites and are a reflection of the historic mining associated with these sites, high concentrations of some elements in the rehabilitation areas may provide adverse conditions for plant establishment and growth depending on bioavailability. These soils may require additional amelioration. Testing of waste rock materials and soils prior to application on

rehabilitation areas would ensure appropriate substrate materials are used and should be undertaken prior to spreading onto rehabilitation areas. Alternatively soil contaminants may be capable of leaching upward via capillary processes suggesting that this process may need intervention, particularly on TSF2.

Exotic perennial grasses may be useful for erosion control and livestock fodder however many species can readily invade native plant communities, with invasion by exotic perennial grasses being listed as a key threatening process that can have significant adverse impacts on biodiversity. In addition exotic perennial grasses often become tall rank tussocks and are not preferentially grazed thus becoming significant fire risks. At NPM *Chloris gayana* (Rhodes Grass) was recorded in TSF2-2, TSF2-03, E26-02 and E27-01. Long-term sustainability of the rehabilitation areas is more likely to be achieved by the replicating the function, composition and diversity of the local native grasslands. In future rehabilitation, the use of exotic perennial grasses should be avoided particularly when more suitable alternatives are available. At NPM, many grassland rehabilitation sites nonetheless are beginning to develop into grassland communities which are characteristically similar to and with comparable with the local native grasslands.

Other potential management issues may be related to high density *Callitris endlicheri* regeneration which was observed to be occurring in the Limestone Forest and within the reference site RWood04. Increasing levels of competition from high density stands is likely to suppress the herbaceous understorey as they become more established, thereby adversely affecting floristic and biodiversity targets in the medium to longer term. Selective thinning in these areas may be required.

Herbivory by macropods may also become an increasingly important management issue which should be regularly monitored, with overgrazing and high disturbance being observed in the Limestone Forest and adjacent conservation areas. High macropod activity was also observed at E27-01. A control program may need to be implemented with the most beneficial outcomes being obtained by seeking advice from the relevant authorities combined with a cooperative approach with neighbouring landholders.

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1 2017 NPM Rehabilitation Monitoring Report: Introduction

1.1 Aims

The 2017 rehabilitation monitoring report is a result of work carried out by DnA Environmental on behalf of China Molybdenum Co. Ltd (CMOC) Pty Ltd as agent severally for and on behalf of the Northparkes Joint Venture at Northparkes Mines (NPM). The primary objective of the rehabilitation monitoring program is to compare the progress of rehabilitated landforms and Biodiversity Offset Areas towards fulfilling long-term landuse objectives by comparing a selection of ecological targets or completion criteria against unmined areas of remnant vegetation (reference sites) that are representative of the final landuse and vegetation assemblage. The monitoring program aims to comply and be consistent with a range of conditions specified within approval documents, management systems and associated Management Plans, Mining Operations Plan (MOP) and government regulations and best practice guidelines (NSW I&I 2010, NSW T&I 2012, 2013).

Specifically this rehabilitation monitoring report aims to:

- Describes the annual rehabilitation monitoring program first established in 2009;
- Present the 2017 monitoring results of two woodland and six pasture rehabilitation sites and compare their ecological progress since 2010 against relevant reference sites, also established as part of the rehabilitation monitoring program;
- Compare the performance of the rehabilitation sites against the selection of proposed primary completion targets; and
- Provide a range of management recommendations which will assist in achieving rehabilitation objectives and associated completion criteria targets.

1.2 Northparkes Mine

1.2.1 Background

Northparkes is a copper and gold mine located 27 kilometres north-west of Parkes in the Central West of New South Wales, Australia (Figure 1-1). The NPM was established in 1994 and was owned and operated by RioTinto up until 2013 where it was taken over by the joint venture between China Molybdenum Co., Ltd (CMOC) (80%) and the Sumitomo Groups (20%).

North Mining Limited originally received development consent for NPM in 1992, 15 years after the first onsite resource discovery. This approval was based on open cut mining of E22 and E27 and underground mining of E26 within the 'Mining Reserve' of 64.1 million tonnes (Mt). Underground block cave mining commenced at NPM in October 1993 with the construction of the E26 underground block cave mine (NPM 2014).

Open cut mining commenced with the E27 pit in December 1993 and the E22 pit in January 1994. The gold-enriched oxide ore was processed through a separate carbon-in-pulp (CIP) gold circuit, including the use of cyanide for gold extraction, prior to the construction of the copper-gold sulphide processing circuits in 1995. Ore was then stockpiled for blending with E26 underground material. Open cut mining at NPM operated on a campaign basis determined by economic and environmental viability. Previous open cut mining at NPM ceased in October 2010 with the completion of the E22 open cut campaign. The CIP processing plant has been decommissioned from site, with cyanide no longer used in process circuits on site (NPM 2014).

In February 2007, the NSW Minister for Planning granted approval provided for the ongoing operation of the previously approved mining operations and facilities and the extension of underground block cave mining into the E48 ore body. This project was known as the E48 Project. After approval in 2007, NPM commenced construction of E48 Lift 1, its third major block cave mine. Initial production of E48 Lift 1 began in 2010 and forms part of the approved underground mining operations in conjunction with E26 Lift 2 and E26 Lift 2N.

In October 2009, approval was granted for the construction of the Estcourt Tailings Storage Facility (TSF), a mine and mill upgrade to increase processing up to 8.5Mtpa and extension of mine life until 2025. Section 75W modification two (Mod 2) provided for the development of a 1200m^2 warehouse within the approved mine infrastructure area. In 2012 NPM was granted approval for development of a block cave knowledge centre.

The Mine Life Extension approval encompasses the continuation of underground block cave mining in two existing ore bodies, the development of underground block cave mining in the E22 resource, additional campaign open cut mining, augmentation to the approved TSFs and a seven year extension to the mine life to 2032 (NPM 2014).

Northparkes' ore is processed on site to produce a high-grade copper concentrate which is then transported by road train to the Goonumbla rail siding approximately 13 kilometres from the mine. The containers are then placed on to a train and transported to Port Kembla, south of Wollongong, where the concentrate is then shipped to customers primarily in China, Japan and India.

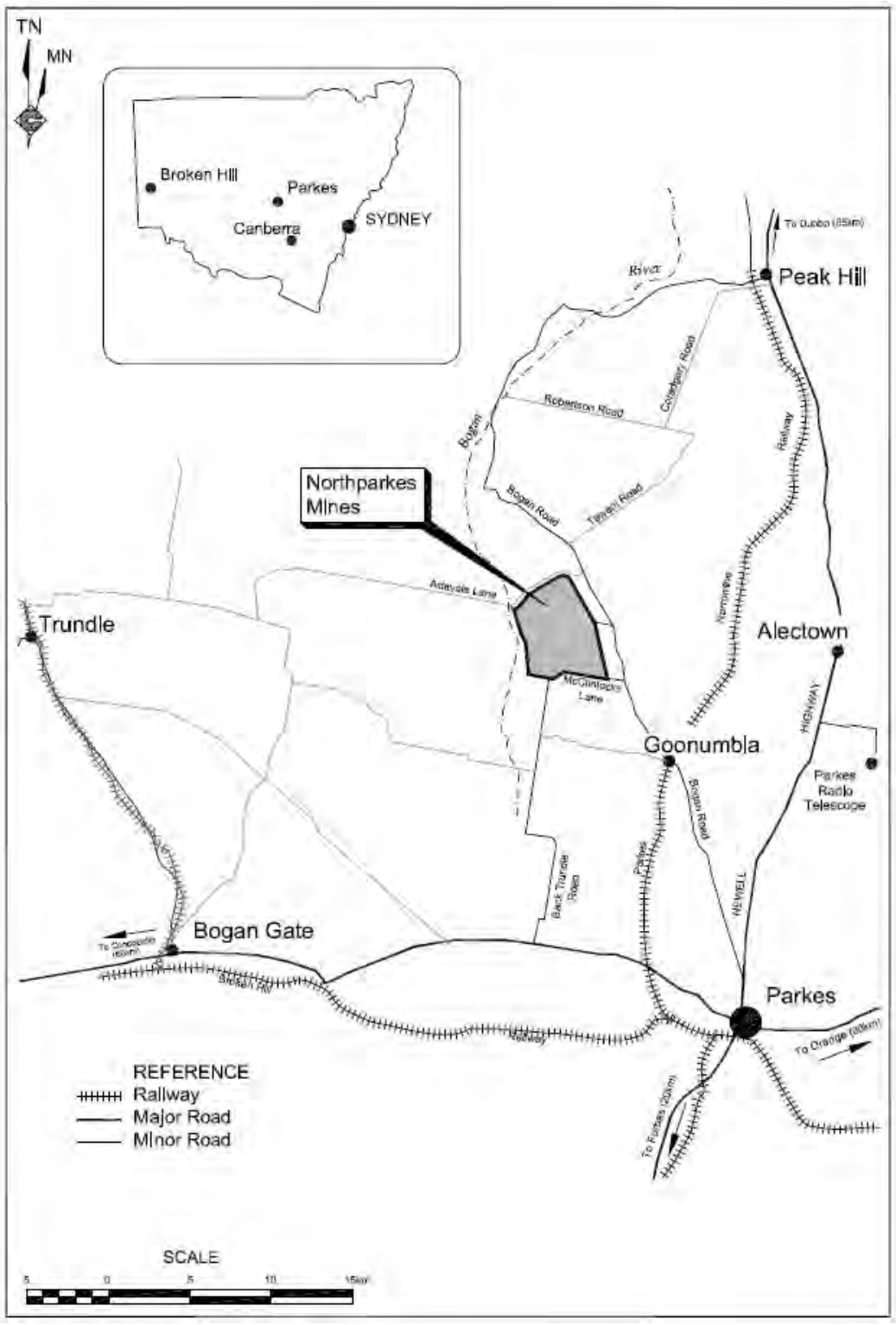


Figure 1-1. Location of the Northparkes Mine (NPM 2008).

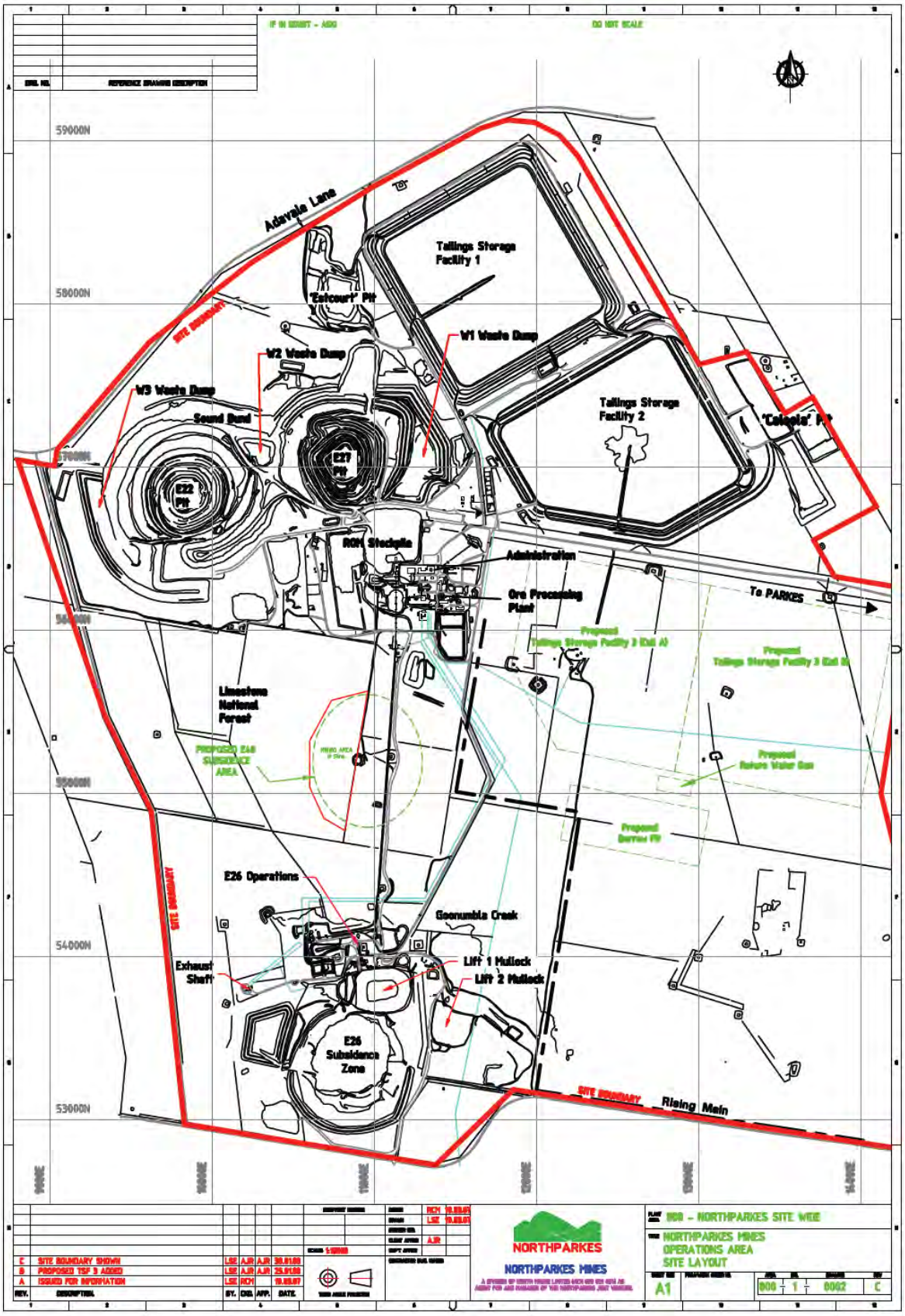


Figure 1-2. NPM Site Plan (NPM 2008).

1.3 Land ownership

The Mine is located in the central west region of NSW and has had a long history of rural land use. The majority of the region consists of cleared land used for agricultural pursuits with patches of remnant vegetation typically associated with State Forests. The existing Limestone State Forest is the only land not owned by NPM. The 24.4 ha portion of the Limestone State Forest required for on-going operations has been acquired through a land swap agreement with Department of Primary Industry – Forests (NPM 2014).

Historic aerial photography indicates the area around NPM has been extensively cleared. The known historical context of the area suggests the NPM site and surrounds has been subject to intensive agricultural practices since the 1800's. As well as mining, the Mining Lease is also used for commercial crop production. The future land uses for the Mining lease are divided into three main categories:

1. Native woodland with areas of native grasses;
2. Agricultural land, primarily for cropping; and
3. Restricted access areas, associated with subsidence and open cut voids.

As part of the site decommissioning, NPM will ensure all these areas are geotechnically stable, with appropriate buffer areas maintained and access appropriately restricted.

1.4 Environmental context

NPM is located on the edge of the inland slopes to the west of the Great Dividing Range. The surrounding landscape is generally flat with low undulations ranging from 280m to 300m AHD, with some higher peaks. The most significant topographical feature in the region is Goonumbla Hill (386m AHD) which is located to the south (NPM 2014).

Mining activities have created topographic highs in the form of TSFs and waste rock stockpiles and topographic lows formed by the two open cut mines (E22 and E27) and the E26 subsidence zone. There are limited intervening landforms between the mine site and the surrounding residences.

Although the Mine site is located near the low ridge line which delineates the boundary separating the regional Bogan River and the Lachlan River catchments, it is entirely encompassed by the Bogan River catchment.

The site, which is located in the catchment of the Bogan River, is also located in the tributary catchments of Goonumbla Creek, Tenandra Creek and Cookapie Creek. The majority of the site is located within the catchments of Goonumbla and Cookapie Creeks with Goonumbla Creek traversing the southern part of the site. The predominant water use surrounding NPM is for agriculture (cropping and some grazing) and is provided through capture of surface water runoff in numerous farm dams (NPM 2014).

1.4.1 Flora

Four vegetation communities were identified across the site and surrounding properties (NPM 2008) (Figure 1-3) and included:

1. Tall *Eucalyptus moluccana* (Grey Box) Open Woodlands;
2. Mid – High/Tall *Callitris glaucophylla* (White Cypress Pine) – *Eucalyptus populnea* (Poplar Box) open woodland to savannah grassland;

3. Mid – High/Tall *Eucalyptus populnea* (Poplar Box) open woodland to woodland; and
4. Mid – High/Tall *Eucalyptus albens* (White Box) – *Callitris glaucophylla* (White Cypress Pine) woodland.

Since that time, these communities can be more adequately described as forming part of the *Eucalyptus microcarpa* (Inland Grey Box) - *E. populnea* (Bimble Box) - *Callitris glaucophylla* (White Cypress Pine) tall woodland and can be considered to be consistent with Grey Box (*Eucalyptus microcarpa*) Grassy Woodlands and Derived Native Grasslands of South-Eastern Australia (TSCC 2014). These Inland Grey Box Woodlands are Endangered Ecological Communities (EEC) listed under the EPBC Act (TSCC 2014).

Community 4 (above) is likely to be consistent with Benson 267, White Box – White Cypress Pine – Inland Grey Box shrub/grass/forb woodland in the NSW South Western Slopes Bioregion. This is a mixed ecological community that represents an intergradation between the Grey Box woodlands of the western plain (IDs 76 and 80) and the White Box woodlands of the eastern hillslopes (ID 266). However where White Box is dominant, these communities are included as part of the "White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland" ecological community, that are listed as Critically Endangered Ecological Communities (CEEC) under the EPBC Act. This listing covers woodlands dominated by *Eucalyptus albens* (White Box), *E. melliodora* (Yellow Box) or *E. blakelyi* (Blakely's Red Gum) over a temperate grassy understorey. *Eucalyptus microcarpa* may be present in this ecological community but is not dominant except where this is the case in the Nandewar Bioregion (TSCC 2014).

The four threatened flora species with potential to occur in the locality as identified by the *Environment Protection and Biodiversity Conservation* (EPBC) Act 1999 database search have not been recorded onsite. Due to the disturbed nature of the habitats, these species are considered unlikely to occur onsite (NPM 2014).

1.4.2 Fauna

Detailed fauna surveys were conducted across site as part of the E48 Environmental Assessment. A total of 78 vertebrate fauna species within the study area, comprising 47 bird species, 11 mammal species, 11 microchiropteran bat species, three amphibian species and six reptile species were identified.

One Threatened species was recorded on the site during the surveys, namely the Yellow-bellied Sheathtail-bat (*Saccolaimous flaviventris*) which is listed as Vulnerable pursuant to the Threatened Species Conservation (TSC) Act 1995. Two additional Threatened species, the Grey-crowned Babbler (*Pomatostomus temporalis*) and the Superb Parrot (*Polytelis swainsonii*), were detected approximately 3km from the site. Both of these species are listed as Vulnerable under the TSC Act. The Superb Parrot is also listed as Vulnerable under the EPBC Act.

All other species identified during the surveys are considered to be common to the locality and broader region. Of the 11 mammal species identified, six were introduced species, including foxes, feral cats and house mice.

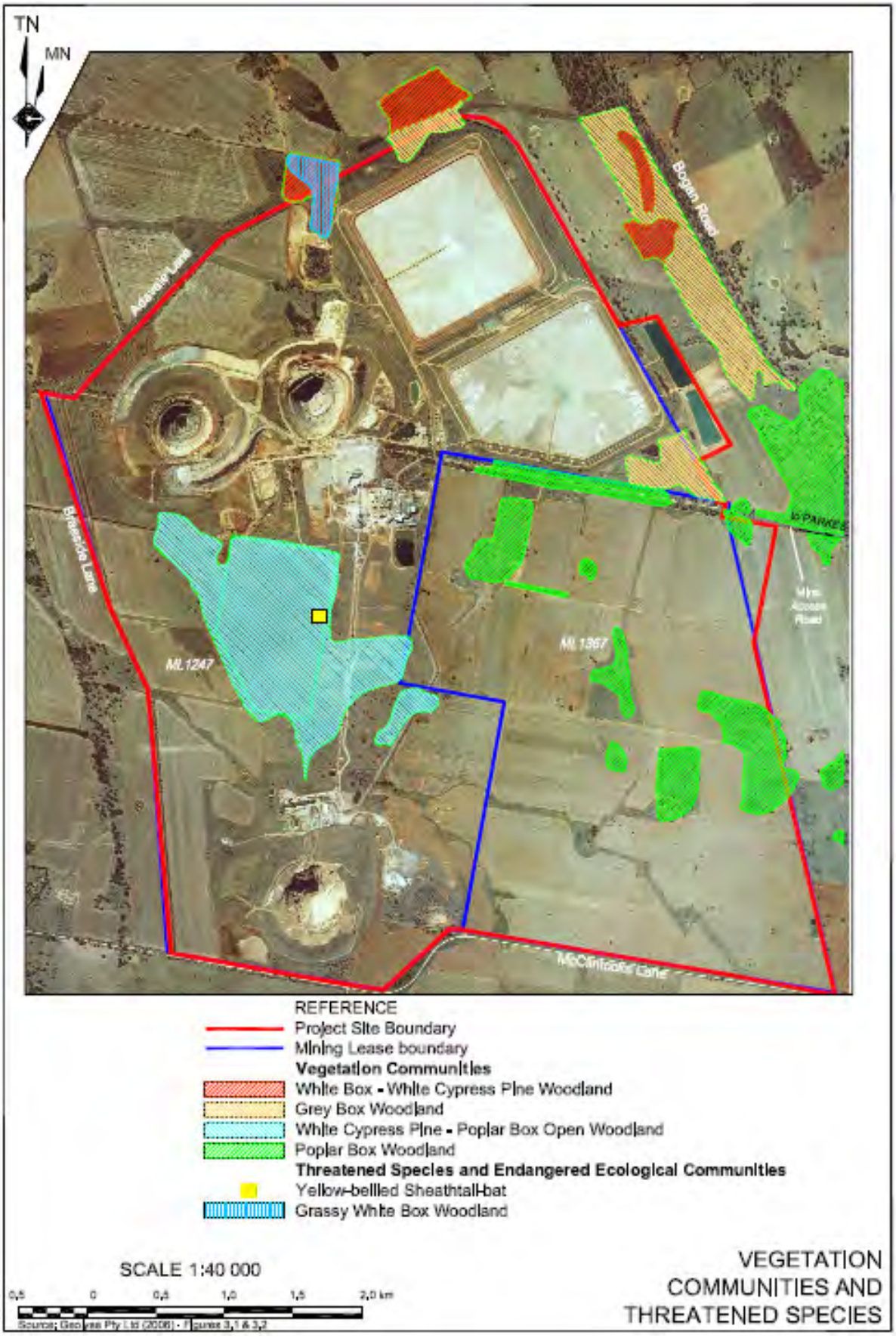


Figure 1-3. Vegetation Communities and Threatened Species identified at NPM (NPM 2008).

1.5 Post Mining Land Use Goal

NPM is committed to developing stable landforms that are capable of supporting sustainable ecosystems and enables sustainable land use after the completion of mining operations at the NPM.
The agreed final landscape as stated in Umwelt (2013) and the project approval includes the following:

- Agricultural land use;
- Native vegetation;
- Restricted land use,
- Limestone National Forest; and
- Offset Areas – Estcourt (and Kokoda).

1.6 Rehabilitation Objectives

NPM rehabilitation objectives as outlined in the project approval and captured within the Rehabilitation Management Plan (Umwelt 2013) have been provided in Table 1-1.

Table 1-1. Rehabilitation Objectives (Umwelt 2013).

Feature	Objective
Mine site (as a whole)	• safe, stable and non-polluting • constructed landforms drain to the natural environment (excluding final voids and subsidence areas) • minimise visual impact of final landforms as far as is reasonable and feasible
Agricultural Areas	Land is returned to a condition that sustains agricultural land use to at least the original rural land capability and agricultural productivity and requires a level of management that is comparable to adjacent agricultural areas
Final Voids and Subsidence Zones	• minimise the size and depth of the final voids and subsidence zones so far as is reasonable and feasible • minimise the drainage catchment of the final voids and subsidence zones so far as is reasonable and feasible • negligible high wall instability risk • restrict access • re-vegetate areas surrounding final voids and subsidence zones to minimise erosion • minimise risk of flood interaction for all flood events up to and including the Probable Maximum Flood level
Tailings Storage Facilities	• any seepage from TSFs to be contained and treated on the site • filled and shaped to final landform levels (as provided in Plan 4 MOP) • final landforms to be capped and re-vegetated to be stable, self-sustaining, free draining and consistent with surrounding rehabilitated areas
Waste Rock Dumps	Any seepage from waste rock dumps to be contained and treated on the site
Surface infrastructure	To be decommissioned and removed, unless the Executive Director, Mineral Resources agrees otherwise
Native Vegetation	Re-vegetation is to be sustainable for the long term, contains native vegetation communities, second generation trees and habitat for native fauna species

Feature	Objective
Community	• ensure public safety • minimise adverse socio-economic effects associated with mine closure

1.7 Rehabilitation Planning and Management

NPM will undertake rehabilitation as soon as practicable following the completion of mining activities. However, due to the ongoing operations of the site, closure is not anticipated during the MOP term and the opportunities for rehabilitation will be focussed on the capping of TSF1. The Rehabilitation and Closure Strategy outlined in Umwelt 2013 provides detail on the conceptual final land use for the site, and the rehabilitation objectives for the mining lease area (NPM 2014).

1.8 Domains

Domains for the site have been selected based on the operational areas of the site and proposed final land use post closure of the operation. The proposed final land use has been obtained from the conceptual information provided in Umwelt (2013) and further described in NPM (2014). Table 1-2 provides a summary of the domains of the NPM Project Area encompassed by the NPM MOP.

Table 1-2. Primary and Secondary Domains for Northparkes Mines

Primary Domain	Proposed Post mining Landuse
1 – Infrastructure	A-Infrastructure D-Pasture Land
2 – Tailings Storage Facilities	C-Grassland
3 – Water Management Area	B Water Management Area D-Pasture Land
4– Overburden Emplacement Area	C-Grassland
5 – Stockpiled Material	D-Pasture Land
6 - Voids	I-Final Void
7 – Buffer lands	D-Pasture Land G-Rural Land Capability Classification i-viii
9 - Limestone Forest	J-Conservation and Biodiversity Offset Land

1.9 Rehabilitation Objectives

Rehabilitation opportunities during the MOP term will concentrate on capping trial activities at the TSF's. There are a number of final land use options available to NPM and these will be refined as closure approaches, as part of the closure planning process. Based on site constraints and opportunities for consistency with adjacent land uses, it is considered that the most sustainable final land use option for the majority of disturbed areas across the Project Area will be the establishment of

native vegetation, with areas of native grassland. The final land use will also involve the maintenance of agricultural land, primarily for cropping use.

The proposed final land use will also include a number of restricted areas which are associated with the subsidence and open cut mining voids. As part of site decommissioning, NPM will ensure that that these areas are geotechnically stable, with appropriate buffer areas maintained and access appropriately restricted. The proposed final land use at NPM will be implemented to meet the following rehabilitation objectives:

- provide a safe and sustainable final landform and use that can co-exist with surrounding land uses;
- provide suitable conditions for establishment of a vegetation cover where practical;
- maintain sustainable agricultural lands;
- produce a diverse mosaic of sustainable native ecosystems within the agricultural landscape with the aim of conserving biodiversity and maintaining evolutionary potential;
- provide for the safety of employees and the public during and following the closure of the mining operations;
- control erosion and develop self-sustaining water management infrastructure;
- mitigate any exposure hazard from residual chemicals or mining wastes; and
- minimise the potential for exclusion of other potential post mining land use options should they be determined to be viable and preferable as part of the detailed mine closure planning process that commences at least five years prior to the planned cessation of mining.

In achieving these objectives, NPM will also aim to:

- minimise the potential environmental impacts from closure activities;
- comply with relevant regulatory requirements and attain regulatory consensus on the successful closure and rehabilitation of the site; and
- reduce the need for long term monitoring and maintenance by achieving effective rehabilitation.

As part of the refinement of criteria and performance indicators for the site over time, the productivity of the land will be considered in accordance with the results of future rehabilitation and environmental monitoring. Table 1-3 provides a summary of each of the domains and their rehabilitation outcomes (NPM 2014).

Table 1-3. Summary of Rehabilitation Objectives for Closure Domains (NMP 2014)

Domain	Rehabilitation Objective
Infrastructure - 1D	• Soil quality meets required soil quality requirements as required by the completion criteria for the site. • Area can be used for grazing or cropping activities based on the requirements of a final closure plan for the site. • Runoff to meet post mining water quality guidelines.
Tailings Storage Facility - 2C	• Provide a self sustaining land form post mine closure. • Design of capping to prevent soil erosion and exposure of tailings material. • Runoff to meet post mining water quality guidelines.
Water Management Area - 3D	• Maintain water quality requirements in accordance with post mining water quality guidelines. • Prevent adverse impacts on agricultural activity as a result of

Domain	Rehabilitation Objective
	poor water quality in runoff from the site.
Overburden Emplacement Area - 4C	• Runoff to meet post mining water quality guidelines. • Provide a self sustaining landform post mine closure. • dust deposition levels meet the EPL and Project Approval criteria for the site. • Final landforms blend with surrounding landscape where possible.
Stockpiled Material – 5D	• Provide stable landforms which are not susceptible to erosion and pose a risk to water quality or agricultural productivity on adjacent lands.
Voids - 6I	• Final voids will be managed in accordance with a Final Void Management Plan for the site. This management plan is yet to be developed. • Access to voids would be prevented to avoid injury to people or animals.
Pasture - 7D	• Develop a sustainable grassland community post mine closure. Provide the opportunity to conducting grazing or cropping activities in this domain.
Limestone Forest - 9J	• Complete maintenance, rehabilitation and remediation activities in accordance with the Occupation Permit, in particular the requirements outlined in Sections 3.14 to 3.19 and 4.10 of the permit. These sections outline the environmental and maintenance requirements and post termination environmental reporting requirements for the Offset Area.

2 ESG3 MOP Guidelines

2.1 Introduction

In NSW, mining operations must be carried out in accordance with a Mining Operations Plan (MOP) that has been approved by NSW Planning and Environment - Resources and Energy (the Department). The Mining Operations Plan (MOP) is a tool used by the Department to monitor the progress of mining and rehabilitation activities across the life of a mine (NSW T&I 2013). The MOP is intended to fulfil the function of both a rehabilitation plan and a mine closure plan. It should document the long-term mine closure principles and outcomes whilst outlining the proposed rehabilitation activities during the MOP term (NSW T&I 2013).

ESG3: Mining Operations Plan (MOP) Guidelines, September 2013 (ESG3) details a new process for monitoring and managing progression towards successful rehabilitation outcomes (NSW T&I 2013). The Guideline requires industry to identify and provide measurable data and demonstrate that proposed rehabilitation outcomes are achievable and realistic within a given timeframe. The requirement for more targeted information strengthens the capacity of the Department to regulate rehabilitation and environmental performance and more accurately determine rehabilitation security liabilities (NSW T&I 2013).

2.2 Rehabilitation phases

Successful rehabilitation of a mine site can be conceptually described in terms of logical steps or phases and these should be made applicable to each of the similar land management units or domains. It is likely that most domains will require a different rehabilitation methodology to achieve the intended post-mining land use (NSW T&I 2013). Rehabilitation Phases where the post mining land use is a native plant ecosystem according to the new MOP guidelines include:

1. Decommissioning;
2. Landform Establishment;
3. Growth Medium Development;
4. Ecosystem and Land Use Establishment;
5. Ecosystem and Land Use Sustainability; and
6. Relinquished Lands.

2.3 Performance Indicators

To satisfy regulatory conditions, performance measures, indicators and associated performance/completion criteria that are appropriate to the location and relevant to the stated rehabilitation goals and objectives must be presented for each land management unit or domain (NSW T&I 2013).

Completion criteria are objective target levels or values that can be measured to quantitatively demonstrate the progress and ultimate success of a biophysical process. These are the standards that are to be met by successful rehabilitation (NSW T&I 2013). They will generally be in the form of a numerical value that can be verified by measurement of the indicators selected for the rehabilitation objectives.

As part of the rehabilitation monitoring program at NPM some performance indicators relevant to the rehabilitation of native ecosystems have been identified in Table 2-1 and these directly relate to primary ecosystem components identified by Nichols (2005). These performance indicators have been grouped to align with natural ecosystem succession and primary rehabilitation phases as described in new MOP guidelines (NSW T&I 2013).

The application of the ecological performance data during the Decommissioning phase (Phase 1) are not considered applicable within the presentation of the ecological data obtained within the NPM rehabilitation monitoring program. Subsequently the ecological performance criteria which are consolidated into Key Performance Indicator (KPI) tables are only represented within Rehabilitation Phases 2 (Landform establishment) to Phase 5 (Ecosystem and Land Use Sustainability).

Table 2-1. Performance indicators relevant to the rehabilitation of native ecosystems

Rehabilitation Phase	Performance Indicator
Phase 1: Decommissioning	No applicable ecological data obtained
Phase 2: Landform Establishment and Stability	Landform slope/gradient
	Active erosion
Phase 3: Growth medium development	Soil chemical/physical properties
Phase 4: Ecosystem and Landuse Establishment	Landform stability and organisation
	Vegetation diversity
	Vegetation density
	Ecosystem composition
Phase 5: Ecosystem and Land Use Sustainability	Landform function and ecological performance
	Protective ground cover
	Ground cover diversity
	Native ground cover abundance
	Ecosystem growth and natural recruitment
	Tree diversity
	Floristic diversity
	Ecosystem health

2.4 Reference sites

Analogue or reference sites are effective in establishing completion criteria against which rehabilitation progress can be measured, assuming that the analogue sites are themselves sustainable. Data from reference sites provide suitable target values of key biophysical parameters, vegetation structures and diversity, and habitat complexity. It provides the ability to monitor both success against true values of an existing ecosystem and the effects of climatic variations and disturbance events (such as fire, flooding etc.). The reference site can be used as the target outcome of the final rehabilitated landscape and a time series record of ecosystem change or development can be obtained. By comparing data with reference sites, it is possible to see if the rehabilitation or disturbed site is developing adequately. All completion criteria at a given site should be within critical threshold values if ecosystem rehabilitation is to be judged successful (NSW T&I 2013).

2.5 Completion criteria and key performance indicators

At NPM, a range of Key Performance Indicators (KPI's) have been determined and are quantified by data obtained from replicated reference sites which are representative of the agreed final landuse. All ecological performance indicators are quantified by range values measured annually from these reference sites which form both an *upper* and *lower* KPI targets. The same ecological performance indicators are measured in the rehabilitation sites and these should equal or exceed these values, or demonstrate an increasing trend.

These Key Performance Indicators are then 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 specifically identified within the EIS, MOP and relevant Management Plans, and in particular the final landuse and any relevant conditions of consent relating to vegetation type, specific use of species and condition for example.

Secondary performance indicators are those that would be desirable to achieve but will not necessarily have an influence on relinquishment requirements. Therefore, please note that not all Performance Indicators are set as primary completion criteria targets.

3 NPM Rehabilitation monitoring program

3.1 Reference sites

Despite the variety of vegetation communities identified within and surrounding the NPM and associated properties, the long-term rehabilitation objectives at NPM are generally consistent with the establishment of "native vegetation" (NPM 2008) with no current specifications to the particular type of vegetation community or dominant species required (with the exceptions of the newly acquired offsets).

Subsequently two vegetation community types were identified for use as reference sites including:

- Mixed native woodland; and
- Native grassland.

These two main vegetation community types formed the foundation of the monitoring methodology used for establishing the proposed completion criteria.

Vegetation communities are seldom uniform and are comprised of a different suite of species according to variations in climate, geology, soils, topography, aspect as well as other influences such as seasonal conditions, disturbance events and management conditions. This makes it difficult to determine what exactly a "woodland community" or "native grassland" is, what features it should have, how to establish one and at what point is it considered to be one. Therefore we selected four woodland sites and three native grassland sites as replicated examples of each community type to allow for these inherent variations, range of local conditions and ecological transition.

3.1.1 Woodland reference sites

Variations of the Inland Grey Box EEC community are typical of the Parkes-Goonumbla area and occur within the majority of agricultural properties, roadside corridors and in the local Travelling Stock Routes of the area. The communities are generally confined to scattered remnants within agricultural areas while the forested areas in the bioregion include conservation reserves containing, larger, less disturbed remnants, some of which are floristically similar to the vegetation communities' onsite (NPM 2008).

The remnant vegetation on NPM property is generally in a poor condition and is considered to have a low conservation value (NPM 2008). In areas onsite where a native overstorey remains, the understorey is primarily dominated by introduced species. A few small areas have more than 50% native understorey however these are isolated and patchy within the general landscape of a highly modified and weed infested assemblage (NPM 2008). Remnants located on the adjacent Travelling Stock Routes are generally in better condition due to the different management practices and reduced grazing pressure.

These major vegetation communities have a patchy distribution across the local area and vary according to soil type and topography and often form ecotones. Species commonly associated with these communities include *Alectryon oleifolius* (Rosewood), *Allocasuarina luehmannii* (Bulloak), *Brachychiton populneus* (Kurrajong) and *Geijera parviflora* (Wilga). On the heavier soils, subjected to occasional inundation, *Acacia pendula* (Weeping Myall) and *Casuarina cristata* (Belah) can also be common. There are also areas dominated by *Eucalyptus melliodora* (Yellow Box) woodland and native grasslands (or derived native grasslands).

The composition and structure of the shrubby understorey is also variable but native shrubs including *Acacia decora* (Western Golden Wattle), *A. hakeoides* (Hakea Wattle), *Dodonaea viscosa* subsp. *cuneata* (Wedge-leaf Hopbush) and *Senna artemisioides* (Silver Cassia) are commonly encountered. The ground cover was often dominated by *Austrostipa* (Speargrasses) and *Rytidosperma* species (Wallaby Grasses) with a scattering of native herbs such as *Vittadinia* (Fuzzweeds) and *Calotis* (Burr Daisies) and chenopod sub-shrubs including *Sclerolaena diacantha* (Grey Copperburr), *Atriplex spinibractea* (Spiny-fruit saltbush) and *Enchylaena tomentosa* (Ruby Saltbush). There were numerous patches of bare ground but leaf litter was a dominant form of ground cover in most sites.

All reference sites have been subjected to some form of disturbance, in particular clearing, logging and grazing and some sites were likely to be older regrowth. Exotic annual grasses and a range of other agricultural weeds such as *Carthamus lanatus* (Saffron Thistle), *Echium plantagineum* (Paterson's Curse) and *Sisymbrium irio* (London Rocket) were also common. These sites however are typical of the local area and will help set realistic rehabilitation targets and set a benchmark of the transitional processes that can be expected or that are presently occurring in the rehabilitation areas.

3.1.2 Grassland reference sites

Derived native grasslands were also commonly encountered particularly on the Travelling Stock Routes. Common species include *Austrostipa* (Speargrasses), *Rytidosperma* species (Wallaby Grasses), *Chloris truncata* (Windmill Grass), *Enteropogon acicularis* (Curly Windmill Grass) and *Walwhalleya proluta* (Rigid Panic).

Previous surveys (Windsor 2000a, b) have shown these areas of native grasslands are significantly diverse in good seasonal conditions and *Bothriochloa macra* (Red-leg Grass) and *Dichanthium sericeum* (Queensland Bluegrass) are also particularly abundant in good rainfall years. In Windsor's (2000a, b) survey, there were also small infrequent populations of *Themeda avenacea* (Native oats) and *Themeda triandra* (Kangaroo Grass).

In 2009, exotic annuals such as *Avena fatua* (Wild Oats), *Lolium* and *Medicago* species were frequently encountered but were dead due to the hot, dry seasonal conditions. Agricultural weeds such as *Carthamus lanatus* (Saffron Thistle), *Echium plantagineum* (Paterson's Curse) and *Sisymbrium irio* (London Rocket) were also common. In better seasonal conditions they may contain a diverse range of other native grasses and forbs as well as agricultural weeds and introduced annual species.

3.2 Rehabilitation monitoring sites

The rehabilitation sites are a combination of mixed native woodland and pasture communities which occurred on various waste emplacements and on the sides of the Northern and Southern Tailings Storage Facilities (TSF). Some sites were also established in revegetation areas located around the farming properties as well in the Limestone Forest Biodiversity Offset areas. A separate monitoring report has been prepared to record changes occurring within the large Estcourt Offset Area (EOA; DnA Environmental 2018).

Rehabilitation monitoring sites were considered to be representative of the rehabilitation/revegetation project as a whole or were similar to and representative of other areas of rehabilitation. This year two woodland and six pastures monitoring sites were assessed.

4 Rehabilitation monitoring methodology

A range of ecological data and completion performance indicators were collected annually from the various reference and rehabilitation monitoring sites. The rehabilitation monitoring has been undertaken during Spring in all monitoring years and this year the field work was undertaken from 12th – 17th October by Dr Donna Johnston and Andrew Johnston (DnA Environmental).

Data were obtained using several key monitoring methodologies including a combination Landscape Function Analyses (LFA), accredited soil analyses and an assessment of ecosystem characteristics using an adaptation of methodologies derived by CSIRO Grassy woodland Benchmarking project (Gibbons 2002, Gibbons *et al* 2008a, 2008b). The methodology used has been consistent over the past four years A detailed description of the rehabilitation monitoring methodology can be found in the "Rehabilitation monitoring methodology and determination of completion criteria" (DnA Environmental 2010a), however a summarised description is provided below.

4.1 Landscape Function Analyses

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.

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 1m scale, with rapidly assessed indicators on the patches and interpatches identified at the 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;
- Percent litter cover, origin of the litter and 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 as demonstrated in Figure 4-1:

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).

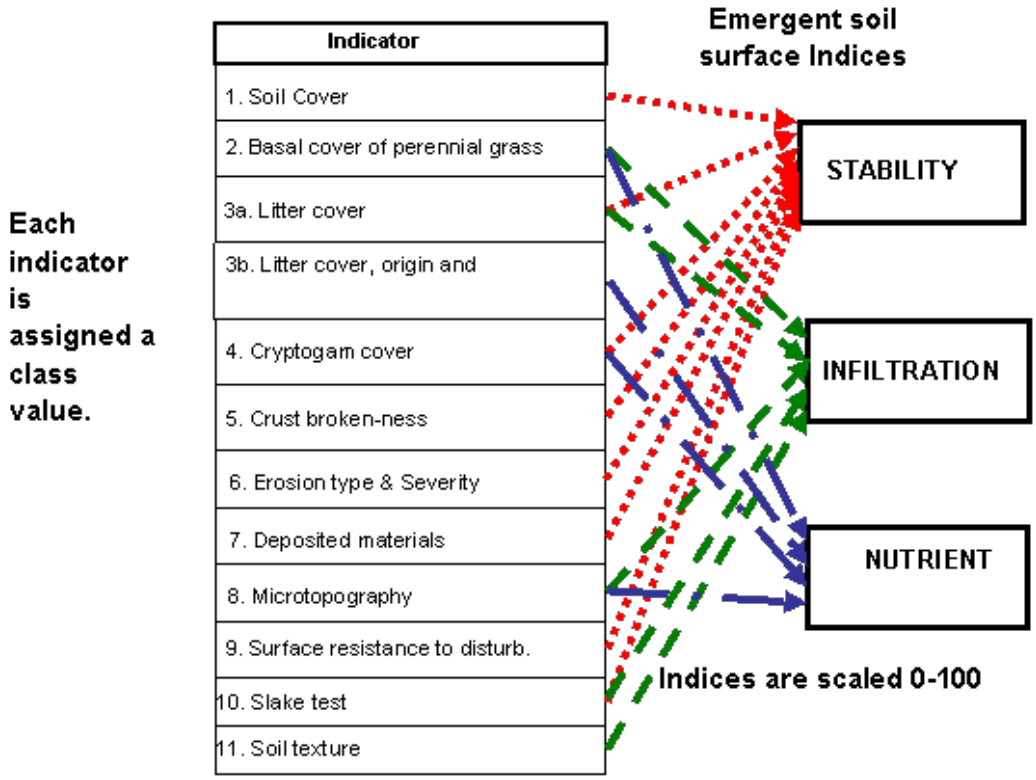


Figure 4-1. How the 11 soil surface indicators are calculated to produce the three indices of soil quality.

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 consists of assessing the following parameters:

- pH;
- Electrical Conductivity (EC);
- Organic Matter (OM);
- Cation Exchange Capacity (CEC;
- Exchangeable Sodium Percentage (ESP);
- Available calcium (Ca), magnesium (Mg), potassium (K), nitrate nitrogen (N), sulphur (S);
- Exchangeable sodium (Na), Ca, Mg, K, hydrogen (H);
- 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;

- Heavy metals including cadmium (Cd), lead (Pb), arsenic (As), chromium (Cr), nickel (Ni), mercury (Hg) and silver (Ag).

A report with analysis and desirable levels recommended in the agricultural industry is provided by the laboratory. Exchangeable Sodium Percentages are 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). They were developed for assessing habitat quality across a range of vegetation types in the southern NSW Murray-Darling Basin which formed the basis of the Biometric Model used in the Property Vegetation Planning Process (OEH 2012). 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.

4.4 Limitations

4.4.1 Plant identification

Due to the dry seasonal conditions and heavy grazing, there was often a lack of reproductive structures of low ground cover species that are required for the positive identification of numerous plant genera. Therefore some species were only able to be identified to the genera level.

4.5 Amendments

4.5.1 Changes to completion targets

On review of the proposed completion targets, a few changes were considered and these were:

- Inclusion of Landform slope as a primary completion criteria;
- Inclusion of Phosphorous (P) as a primary completion criteria;
- Omission of Nitrate (N) as a primary completion criteria; and
- Inclusion of Tree and mature shrubs (>5cm dbh) density as a primary completion criteria.

These changes have been reflected in the relevant KPI tables throughout the document.

4.5.2 Farmland plantings

The farmland woodland plantings (Kundibah, Beechmore, Altona and Estcourt) were not included in this year's monitoring program. Rather, these sites will be monitored on five year rotation and will next be monitored in 2019.

4.5.3 New grassland rehabilitation sites

Due to the upgrade works of the Tailings Facilities TSF1 and TSF2, two grassland rehabilitation sites on TSF1 (TSF1-01, TSF1-02) and one grassland rehabilitation site on TSF2 (TSF2-01) had been affected by earthworks. No new sites were established on TSF1 as it is likely to be affected by further disturbance. A new site, TSF2-03 was established on the western wall of TSF2.

The site of the old E26 subsidence zone was longer readily accessible for monitoring. Subsequently a new site, E26-02 was established on the adjacent and similar topsoil stockpile situated to the west of the E26 subsidence zone.

4.5.4 New grassland reference site

In 2017, the original grassland reference site RGrass01 had significantly deteriorated and was not representative of pastures more typical of the NPM. Therefore, a new grassland reference sites that was considered to be a more appropriate alternative grassland reference sites was established. This new replacement site is now named RGrass01.

5 Monitoring site locations

The location of the four woodland and three grassland reference sites in relation to the NPM rehabilitation monitoring sites is shown in Figure 5-1. GPS coordinates and other site specific information is provided in Table 5-1.

The rehabilitation monitoring sites were chosen based on their final landuse/vegetation community type and year of establishment and were considered to be representative of the rehabilitation area as a whole. In large rehabilitation areas multiple sites were established. In total, there were six "woodland" and eight "grassland" monitoring sites established in 2009 and these same sites have been monitored annually up until 2014. This year the farmland woodland plantings were not monitored.

The location of the rehabilitation monitoring sites is provided in Figure 5-2. GPS coordinates and other site specific information is provided in Table 5-2.

Table 5-1. GPS co-ordinates, aspects and slopes of the woodland and grassland reference monitoring sites.

Site Ref	LFA Start	LFA Finish	LFA slope°	LFA bearing°	Veg transect start	Veg transect finish	Veg transect bearing °
RWood01	55599368 E 6361978 N	55599386 E 6361982 N	0	52 NE	55599378 E 6361978 N	55599399 E 6361934 N	142 SE
RWood02	55604368 E 6350055N	55604386 E 6350060 N	5	56 NE	55604378 E 6350058 N	55604394 E 6350012 N	158 SE
RWood03	55600792 E 6359342 N	55600772 E 6359350 N	1	269 W	55600781 E 6359348 N	55600794 E 6359393 N	0 N
RWood04	55597396 E 6356649 N	55597398 E 6356626 N	4	159 S	55597398 E 6356637 N	55597350 E 6356628 N	240 SW
*RGrass01	55603351 E 6350839 N	55603344 E 6350859 N	2	322 NW	55603346 E 6350850 N	55603394 E 6350869 N	52 NE
RGrass02	55601382 E 6358380 N	55601379 E 6358397 N	2	350 N	55601378 E 6358389 N	55601431 E 6358387 N	80 E
RGrass03	55603432 E 6350661 N	55603425 E 6350682 N	3	325 NW	55603428 E 6350673 N	55603477 E 6350688 N	55 NE

*=New site established in 2017

Table 5-2. GPS co-ordinates and other site specific information related to the woodland and grassland rehabilitation monitoring sites.

Site Reference	LFA Start	LFA Finish	LFA slope°	LFA bearing °	Veg transect start	Veg transect finish	Veg transect bearing °
LFO-01	55597197E 6356500 N	55597178E 6356491 N	4	230 SW	55597197 E 6356500 N	55597153E 6356479 N	230 SW
LFO-02	55597032E 6356936N	55597013E 6356929N	1	241 SW	55597032 E 6356936N	55596985E 6356921N	241 SW
#Estcourt 1997	55600759E 6357771N	55600763E 6357785N	2	340 NE	55600764E 6357776N	55600807E 6357783N	70 NE
#Beechmore 1999	55595911E 6354638N	55595930E 6354635N	2	85 E	55595921E 6354636N	55595913E 6354590N	174 S
#Altona 1999	55598827E 6354733N	55598836E 6354753N	3	9 N	55598833E 6354742N	55598879E 6354726N	99 E
#Kundibah 2001	55597059E 6359558N	55597055E 6359580N	0	338 NW	55597057E 6359568N	55597106E 6359580N	68 NE
~~TSF1-01~~	~~55599592E 6369478N~~	~~55599609E 6359484E~~	~~14~~	~~50 NE~~	~~55599599E 6359481N~~	~~55599625E 6359439N~~	~~141 SE~~
~~TSF1-02~~	~~55598848E 6360055N~~	~~55598837E 6360073N~~	~~10~~	~~31 NW~~	~~55598844E 6360062N~~	~~55598886E 6360088N~~	~~45 NE~~
~~TSF2-01~~	~~55599339E 6358043N~~	~~55599335E 6358026N~~	~~11~~	~~178 S~~	~~55599338E 6358036N~~	~~55599285E 6358034N~~	~~268 W~~
TSF2-02	55600293E 6358536N	55600309E 6358946N	13	48 NE	55600301E 6358541N	55600330E 6358502N	135 SE

Site Reference	LFA Start	LFA Finish	LFA slope°	LFA bearing °	Veg transect start	Veg transect finish	Veg transect bearing °
*TSF2-03	55599015 E 6358395 N	55597997 E 6358387 N	12	230 SW	55599003 E 6358391 N	55598981 E 6358434 N	318 NW
E22-01	55596444E 6358102N	55596425E 55596413N	14	244 SE	55596434E 6358101N	55596421E 6358150N	332 NW
E22-02	55597201E 6358694N	55597204E 6358713N	12	358 N	55597204E 6358704N	55597252E 6358694N	87 E
~~E26-01~~	~~55598279E 6355148N~~	~~55598297E 6355150N~~	~~15~~	~~70 NE~~	~~55598286E 6355149N~~	~~55598302E 6355103N~~	~~162 SSE~~
*E26-02	55597349 E 6354794 N	55597329 E 6354797 N	15	265 W	55597339 E 6354794 N	55597347 E 6354841 N	265 W
E27-01	55598601E 6358343N	55598619E 6358341N	15	83 E	55598609E 6358343N	55598618E 6358295N	171 S

*=New site established in 2017

#= Sites to be monitored on a five year rotation and not monitored in 2017. To be next monitored in 2019.

Figure 5-1. Map showing the locations of the woodland and grassland reference sites in relation to NPM.

Figure 5-2. Map showing the locations of the rehabilitation monitoring sites.

6 Rainfall

The average annual rainfall at Parkes Airport is 614.6mm (BoM 2018), however there have been extreme seasonal conditions with below average rainfall being recorded in 2013, 2015 and 2017 (Figure 6-1). In 2014, there was above average annual rainfall of 716.6mm and in 2016 widespread flooding was recorded in the Parkes district with a total annual rainfall of 833mm being recorded.

Despite these extremes in rainfall activity, the monthly averages indicate there has also been high seasonal variability and erratic rainfall activity over the past few years (Figure 6-2).

There was an unusually dry period in 2013 where monthly rainfall was below average except in March, June and July. In 2014, monthly rainfall was also highly erratic, but above average rainfall was experiences more frequently, with significant rainfall events recorded in January, March, June and December. This was again followed by a dry rainfall year with limited rainfall occurring February and March 2015. Above average rainfall was then experienced in April, July and August.

April 2016, marked the beginning of a long period of above average monthly rainfall, with record breaking rains falling from April through to October causing widespread flooding. In this seven month period, 605 mm was recorded, with expected averages also being recorded in November and December. In 2017, very low rainfall activity occurred except in March where 195mm of rainfall was recorded. Rainfall remained well below the expected monthly averages for most of the year, with only 561mm being recorded for the year.

The extreme seasonal conditions experienced over the past few years has had a significant influence the diversity, abundance and composition of the monitoring sites, and these have been compounded by the increased levels of browsing and disturbances created by resident macropod populations, especially under the shelter of the tree canopies, particularly during extended periods of dry conditions.

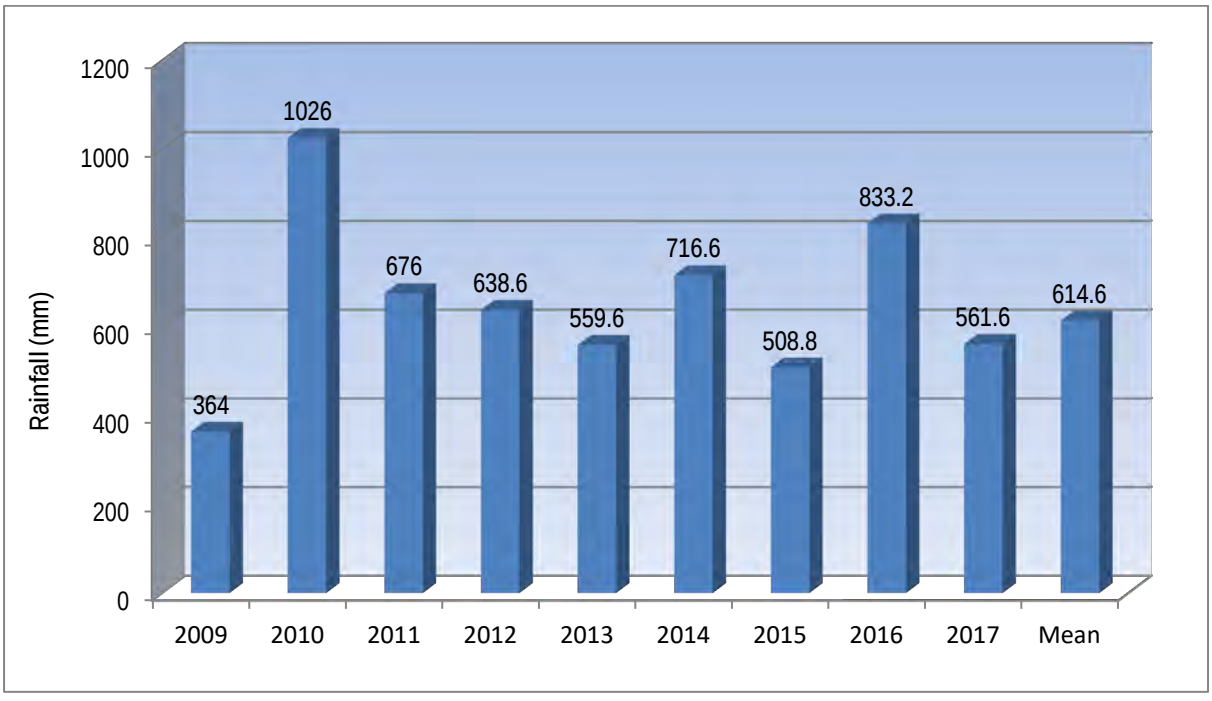


Figure 6-1. Annual rainfall recorded at NPM Jan 2009 - December 2017 compared to long-term mean annual rainfall for Parkes Airport AWS. (NB: All rainfall data from 2012 onwards from Parkes Airport AWS).

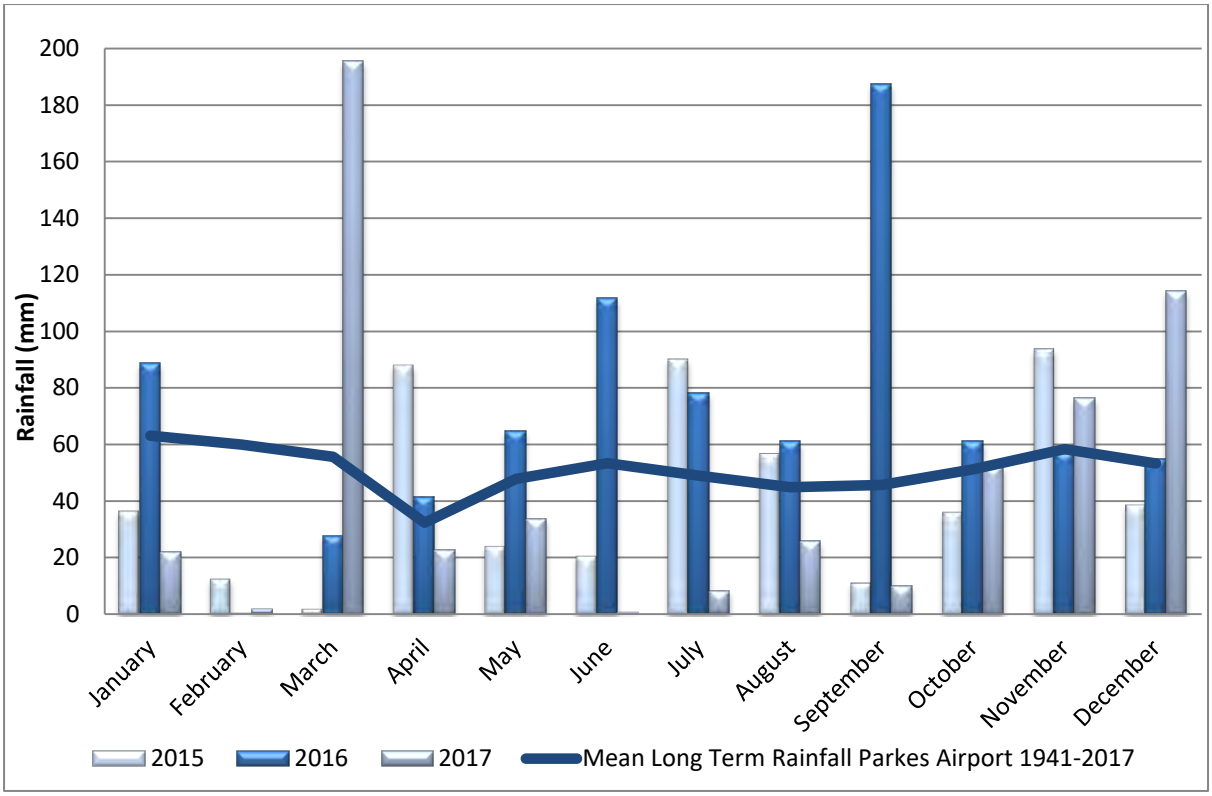


Figure 6-2. Monthly rainfall recorded at the Parkes Airport AWS from January 2015 to December 2017 compared to the long term monthly averages recorded at Parkes Airport AWS.

7 Ecological monitoring results: Woodlands

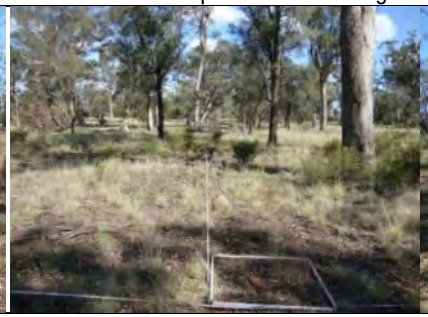
This section provides the results of the monitoring within the rehabilitated woodland sites and demonstrates ecological trends and performance of these sites against a selection of ecological performance indicators obtained from the woodland reference sites.

7.1 Photo-points of the woodland reference sites

General descriptions of the reference sites, including photographs taken in the permanent monitoring quadrats along the vegetation transect in 2009 – 2017 have been provided in Table 7-1. Please note that 2010 and 2012 photographs have been omitted for ease of presentation of data and that no monitoring was undertaken in 2015 or 2016.

Table 7-1. General site descriptions and permanent photo-points of the reference monitoring sites.

Site	Photo 2009	Photo 2011	Photo 2013	Photo 2014	Photo 2017
RWood01	Open grassy woodland dominated *by E. microcarpa* with some *Allocasuarina luehmannii* and *Alectryon oleifolius* sub dominants. There were some large old regrowth trees, scattered regrowth and some limited regeneration of the overstorey species. The site had small scattered patches of *Dodonaea viscosa* subsp*. cuneata, Acacia hakeoides* and *Maireana microphylla*. The ground cover included scattered tussocks of *Austrostipa* and *Rytidosperma* species as well as a variety of small chenopod sub-shrubs. There were some fallen branches. Leaf litter was abundant beneath tree canopies but there were numerous patches of bare ground particularly in the more open areas, which were commonly covered with cryptogams. In 2009 the wildflowers were flowering. In 2010, the area had been recently grazed by travelling stock with some shrubs damaged and some grass tussocks had been pulled out. In 2011, there was no evidence of recent livestock grazing however there was less plant diversity due to the drier conditions. In 2011 the *Rytidosperma* were flowering and one large *E. microcarpa* had fallen down. In 2012 and 2013 the site continued to be very dry. In 2014 the site continued to be very dry with hoof-print depression and damaged soil crusts and cryptogam cover persisted throughout the site with sparsely scattered *Austrostipa* flowering and seeding. In 2017, travelling stock has recently passed through and was heavily grazed with pockets of bare soil throughout and the scattered Austrostipa tussocks were grazed low. There was a low diversity of grass and forbs and the site was very dry. The small patch of Hopbush had grown.				
RWood02	Open regrowth woodland dominated *by E. albens, E. populnea and Callitris glaucophylla* with some older *Callitris* and eucalypt regeneration. The site had small scattered patches of *Acacia deanei* with some limited regeneration of the overstorey species. The ground cover included sparsely scattered tussocks of *Bothriochloa macra*, *Austrostipa* and *Rytidosperma* species as well as a diverse range of herbs and forbs. Leaf litter was abundant beneath tree canopies but there were numerous patches of bare ground particularly in the more open areas, which were commonly covered in cryptogams. There were some fallen branches and an active presence of ants and ant nests. In 2010, the area had been recently grazed by travelling stock with numerous deep hoof print depressions scattered across the site, but there was little grazing damage. In 2011, there was no evidence of recent livestock grazing however there was less plant diversity due to increased grass cover and drier conditions. In 2012 and 2013 the site continued to be very dry. In 2014 the site continued to be very dry but annual were abundant in the old stockcamp areas and there were patches of *Trifolium*. There was a noticeable decline in native wildflowers. In 2017, exotic annuals were abundant in the old stockcamps and the scattered native grasses and forbs were very stressed, but had some green growth as a result of the recent rain. The trees appeared healthy and mosses were abundant. The shrubs had grown and there continued to be a lot of Callitris and *A. deanei* regeneration.				


Site	Photo 2009	Photo 2011	Photo 2013	Photo 2014	Photo 2017
RWood03					
	Open grassy woodland dominated *by E. microcarpa* with an individual *Allocasuarina luehmannii*. There were some large old growth trees with hollows, scattered regrowth and some limited regeneration of the overstorey species. The site had small scattered patches of *Dodonaea viscosa* subsp. *cuneata, Acacia hakeoides* and *Senna artemisioides*. The ground cover included sparsely scattered tussocks of *Austrostipa* and *Rytidosperma* species as well as a variety of small chenopod sub-shrubs. Leaf litter was abundant beneath tree canopies but there were numerous patches of bare ground particularly in the more open areas, which were commonly covered in cryptogams. There were some fallen branches. Grey Crowned Babblers were present at this site. In 2010, the area had been recently grazed by travelling stock with numerous deep hoof print depressions scattered across the site, but there was little grazing damage. In 2011, there was no evidence of recent livestock grazing however there was less plant diversity due to increased grass cover and drier conditions. In 2012 and 2013 the site continued to be very dry. In 2014 the site continued to be very dry but annual weeds were abundant in the old stockcamp areas and there were patches of *Trifolium*. The grass was sparse but retained a green tinge and there were some scattered wildflowers. Several skinks were observed. In 2017, travelling stock has recently passed through and was lightly grazed. The scattered native grass tussocks were stressed but retained a green tinge as a result of recent rainfall and cryptogams were abundant. The shrubs have grown and the trees appeared to be healthy. there was good grass and ground cover retained.				
					
RWood04	Open woodland dominated *by E. populnea, E. melliodora* and *Callitris glaucophylla* which has some large old growth trees and numerous stumps but in 2009 there was no shrub or tree regeneration. The ground cover was patchy and contained sparsely scattered tussocks of *Austrostipa* and *Rytidosperma* species. In 2009 there was a limited diversity of herbs and forbs, but generally total ground cover was good with large patches of *Xerochrysum bracteatum* (Golden everlasting) scattered across the forest area. In 2010, there was a high diversity of native understorey species, including significant patches of *Dichopogon* (Chocolate lily). There were also old stock camps beneath the trees which were dominated by weeds. The area is not subjected to livestock grazing but maintains a healthy macropod population. In 2011, there had been a significant increase in grass cover resulting in lower plant diversity and fewer weeds, especially beneath the tree canopies in the old stockcamps. The patch of *Dichopogon* was reduced to about one dozen individuals due to increased competition and drier conditions. In 2012 the site continued to be exceptionally dry but there was some *Callitris regeneration*. In 2013, it continued to be very dry, but significant regeneration of Callitris was evident across the larger Limestone Forest area, with seedlings having grown over the year. In 2014 the site was particularly dry and the Austrostipa tussocks small and very stressed with macropod grazing also adversely impacting the area. Annual weeds persisted in the old stockcamp area beneath the eucalypt. There were small stunted pockets of Xerochrysum but other wildflower were scarce. Persisting Callitris seedlings have grown. In 2017 the site was very dry and stressed and scattered forbs were small and stunted. Heavy macropod grazing was evident. The stockcamps remained weedy. The Callitris regeneration has grown and the trees appeared healthy.				

Site	Photo 2009	Photo 2011	Photo 2013	Photo 2014	Photo 2017
					

7.2 Photo-points of the woodland rehabilitation monitoring sites

General descriptions of the rehabilitation sites, including photographs taken in the permanent monitoring quadrats in 2009 – 2014, and 2017 have been provided in Table 7-2. Please note that 2010 and 2012 photographs have been omitted for ease of presentation of data. General site description and photo of the farmland woodland planting monitoring sites that were not monitored this year are provided in Table 7-3.

Table 7-2. General site description and photo of the woodland rehabilitation monitoring sites.

Site	Photo 2009	Photo 2011	Photo 2013	Photo 2014	Photo 2017
LFO-01	LFO-01: Mixed native woodland planted 2009. Limestone Forest Offset (LFO) planting situated at the southern end of the offset area. Variation: The vegetation transect aligned with the LFA transect to accommodate the row and inter-row sequence. This site has had a long cropping history and was graded several years in preparation for planting. Tubestock were planted in July 2009. In 2009 the site was predominantly bare within the inter-rows but weeds have begun to colonise the rip line and in some of the area spraying around the tubestock was recently undertaken. There appears to have been moderate wind erosion within the bare inter-rows but due to the flat topography the site is generally stable. In 2010, this site had been sprayed and dead tubestock had recently been replaced. In 2011 the site had become very weedy with weeds colonising the bare areas and the tubestock had grown considerably. Parts of the area had been slashed. The troughs and banks had become redundant with the entire are now described as a "weak" woodland rehab patch. In 2012, the tubestock has further grown and the plants had become better established. *Xerochrysum bracteatum* has become well colonised within the site but the site continued to be weedy. In 2013 the tubestock had grown and *Xerochrysum* were prolific but the site remained weedy. In 2014 the site was similar in terms of ground cover composition but the plants were smaller and less dense with *Hypochaeris glabra* (Smooth Cats-ear), *Trifolium glomeratum* (Clustered clover and *Carthamus lanatus* (Saffron Thistle) continuing to be very abundant. The trees and shrubs had significantly grown and were very healthy, with some Callitris already bearing cones. In 2017, the area was dominated by Saffron Thistle and Echium plantagineum (Paterson's Curse). The persisting exotic annual grasses were very short and grazed low by macropods. There were numerous trees and shrubs with >5cm dbh, with most individuals appearing healthy except for the Callitris glaucophylla saplings which were very stressed. Thornbills were using the revegetation area.				
					
LFO-02	LFO-02: Mixed native woodland planted 2009. Limestone Forest Offset (LFO) planting situated at the northern end of the offset area. This site has had a long agricultural history but has not been cropped. It has been a native grassland area which was direct drilled with Lucerne several years ago. Tubestock were planted in July 2009. The site contained adequate ground cover and leaf litter. There were relatively few weeds within the rip lines. In 2010, this site had been sprayed and dead tubestock had recently been replaced. In 2011 the site was weedy with weeds colonising the bare areas and the tubestock had grown considerably and was similar to LF0-01. Termites were abundant. The entire are now described as a "weak" woodland rehab patch. In 2012 and 2013, the tubestock has further grown and the plants had become better established but the site remained weedy. In 2014 The trees and shrubs had significantly grown and were very healthy, with some Callitris and Acacia deanei bearing cones/pods. Some low branches had been damaged by macropods with some macropod camps occurring beneath the saplings. The site remained weedy but they appeared to have decline with Avena fatua and patches of Salvia verbenaca and Carthamus lanatus common. Xerochrysum remained scattered throughout but macropod grazing and drier weather has kept the ground cover comparatively low. In 2017, the area was dominated by Saffron Thistle and *Echium plantagineum* (Paterson's Curse). The persisting exotic annual grasses were very short and grazed low by macropods. There were numerous trees and shrubs with >5cm dbh, with most individuals appearing healthy except for the *Callitris glaucophylla* saplings which were very stressed. There were trees and shrubs that were now bearing fruit and/or bud.				

Site	Photo 2009	Photo 2011	Photo 2013	Photo 2014	Photo 2017
					

Table 7-3. General site description and photo of the farmland woodland planting monitoring sites.

Photo 2009	Photo 2011	Photo 2013	Photo 2014
Estcourt 1997: Mixed native woodland planted 1997. Situated at the south-east corner of TSF 2 adjacent to the main NPM access Road. This site was one of the oldest rehabilitation areas planted with mixed native tubestock in 1997. The site maintains an open woodland structure, scattered shrubs and a mosaic of grassy clearings and bare patches. Vegetation cover was limited beneath the tree canopies but there was generally good leaf litter cover. In 2009, ground cover species were particularly stressed with little active green growth. The site contains kangaroo camps and would be subjected to kangaroo grazing. There has been excellent establishment and growth with some trees exceeding 6m in height, generally healthy and setting seed. In 2011, the site had reduced plant diversity due to the dry seasonal conditions. In 2012 and 2013 the site continued to be very dry. In 2014 leaf litter continues to accumulate beneath the maturing trees, with most trees and shrubs very healthy and bearing reproductive structures but there continued to be few to no seedlings. Patches of very hard clay pans devoid of ground cover persist, but there was less noticeable disturbance by macropods this year.			
			
Beechmore 1999: Mixed native woodland planted 1999. Within a fenced off area around a drainage line on "Beechmore" situated SW of the NPM. Due to patchiness of the site, the vegetation transect fell within a particularly bare area and may under represent certain characteristics of the site. This site was planted in 1999 and maintains an open woodland structure, scattered shrubs and a mosaic of grassy clearings and bare patches. Vegetation cover was limited beneath the tree canopies but there was generally good leaf litter cover. In 2009, ground cover species were particularly stressed with little active green growth. There has been excellent establishment and growth with some trees exceeded 6m in height, were generally healthy and setting seed. Grey Crowned Babblers were observed within the site in 2009, 2010. In 2011, there was a slight improvement in ground cover and the site retains its patchiness. In 2012 and 2013 the site continued to be very dry. In 2014 leaf litter continues to accumulate beneath the maturing trees, with most trees and shrubs very healthy and bearing reproductive structures but there continued to be few to no seedlings. Patches of very hard clay pans devoid of ground cover persist but there was overall little apparent change.			




Altona 1999: Mixed native woodland 1999. An old quarry area on a property named "Altona" south of the NPM. This site was planted in 1999 and maintains an open woodland structure, scattered shrubs and a mosaic of grassy clearings and bare patches. Heavy grazing pressure by Kangaroos was particularly evident at this site as ground cover vegetation cover was limited across the site but there was generally good leaf litter cover beneath tree canopies. In 2009, the ground cover species were particularly stressed with little active green growth. There has been excellent establishment and growth with some trees exceeded 6m in height, were generally healthy and setting seed. In 2010, there were large patches of weeds (*Echium* and *Lolium*), but was relatively bare beneath the shrubs due to Macropod camps. In 2009, Grey Crowned Babbler nests were observed within the tree planting areas. In 2011, there was a significant reduction in cover provided by exotic annual species and macropods continue to be evident. In 2012 and 2013 the site continued to be very dry. In 2012 the site continued to be very dry. In 2014 there were large patches of dying annual weeds and large patches of bare stony slope. The trees and shrubs were typically healthy and bearing reproductive structures but overall there were seedlings. There continued to be evidence of high macropod disturbance and rabbits/hares.




Kundibah 2001: Mixed native woodland 2001. A small tree planting area north of TSF 1 and north of Adavale Lane. The site was planted in 2001 and maintains an open woodland structure, scattered shrubs and a mosaic of grassy clearings and bare patches. Vegetation cover was limited beneath the tree canopies but there was generally good leaf litter cover. In 2009, ground cover species were particularly stressed with little active green growth. There has been good establishment and growth with some trees exceeded 6m in height, were mostly healthy and setting seed. Some trees however were showing signs of stress and some insect attack by lerps. Some species (e.g. *E. melliodora*) appeared to be stunted. In 2009, Grey Crowned Babblers were observed within the site. In 2011 there was a significant reduction in cover provided by exotic annual species. In 2012 and 2013 the site continued to be very dry. In 2014 leaf litter continues to accumulate beneath the maturing trees, with most trees and shrubs very healthy and bearing reproductive structures but there continued to be few to no seedlings. Patches of very hard clay pans devoid of ground cover persist. The native grasses were very stressed and there were few wildflowers.




7.3 Landscape Function Analyses

7.3.1 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 four reference sites were characterised by having a mature tree canopy, scattered shrubs and a well developed grassy ground cover layer with moderate to high levels of decomposing litter and/or cryptogam cover and collectively provided a highly functional patch area and subsequently scored Landscape Organisation Indices (LOI) of 100% (Figure 7-1).

The younger rehabilitation sites in the Limestone Forest Offset (LFO) which were planted in 2009 had demonstrated the most significant changes within the first three years of monitoring. In 2009 there were significant areas of bare ground due to ground preparation techniques prior to planting but these rapidly became colonised by a variety of weeds and cryptogams. While perennial vegetation cover remained low, the annual plants, cryptogams and dead leaf litter created important and functional patch areas. In 2014, prolonged dry conditions combined with some patchy disturbance by macropods, resulted in a small reduction in patch area in LFO-02 to provide an LOI of 84%. This year both sites had improved ground covers and had 100% functional patch area and 100% LOI.

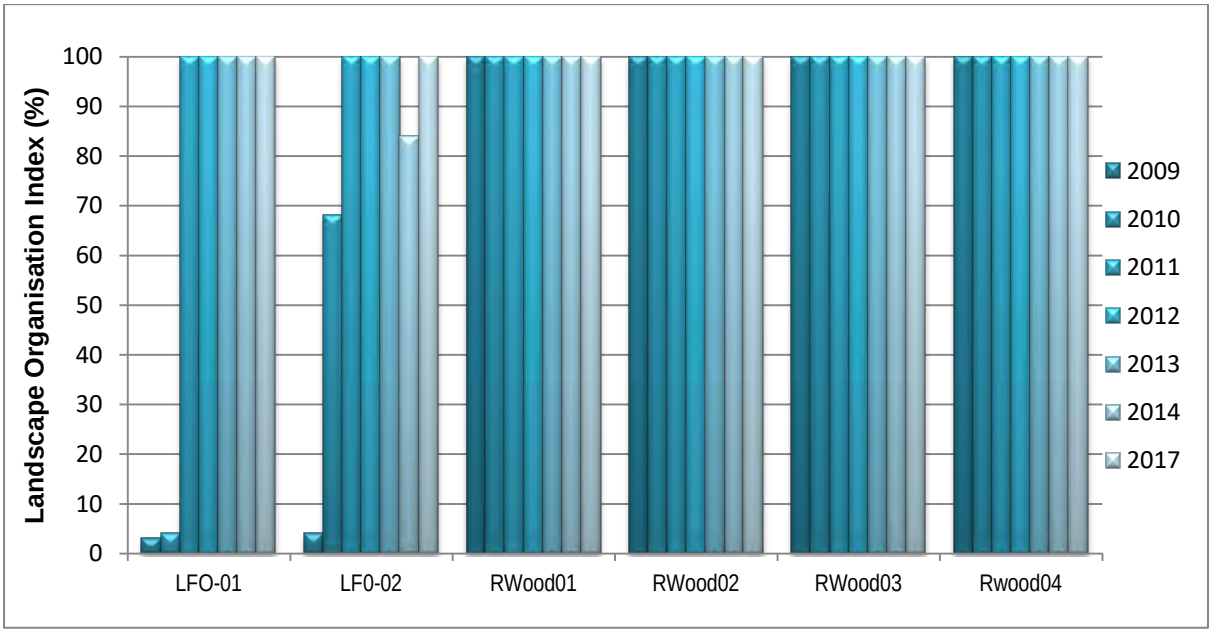


Figure 7-1. Landscape Organisation indices recorded in the woodland rehabilitation sites compared to the woodland reference sites.

7.3.2 Soil surface assessments

7.3.2.1 Stability

Up until 2012 there had been an increasing trend in stability in most monitoring sites largely due to improved seasonal conditions since the peak of the drought which stimulated active perennial ground cover and provided an abundance of live annual vegetation. Since then a minor but declining trend was observed as the extended dry periods resulted in a reduction in active growth of the perennial ground cover plants. Often these were also compounded with the existing high competition levels from the mature trees and shrubs and the development of bare clay pans which are common on the heavier soils or floodplain sites. Low rainfall conditions into 2013 and 2014 may also have also increased macropod predation and disturbance levels across the range of monitoring sites, including three of the woodland reference sites.

In 2017, some three years later an increase was recorded in three of the four reference sites. Despite less live perennial and annual plant cover, there tended to be high levels of litter cover and cryptogams were well established in otherwise bare areas. Recent heavy grazing by travelling livestock however had decreased the stability at RWood01. The LFA stability for the woodland reference sites this year ranged from 60.6 – 79.3.

The youngest and previously most disturbed sites LFO-01 and LFO-02 have shown an increased stability and this year and were more stable than RWood01 and had a stability similar to RWood03 with stability indices of 67.5 and 68.5 respectively. In these sites most stability was attributed to the high levels of litter cover, limited evidence of erosion or deposition and the very hard setting soils were moderately to very stable.

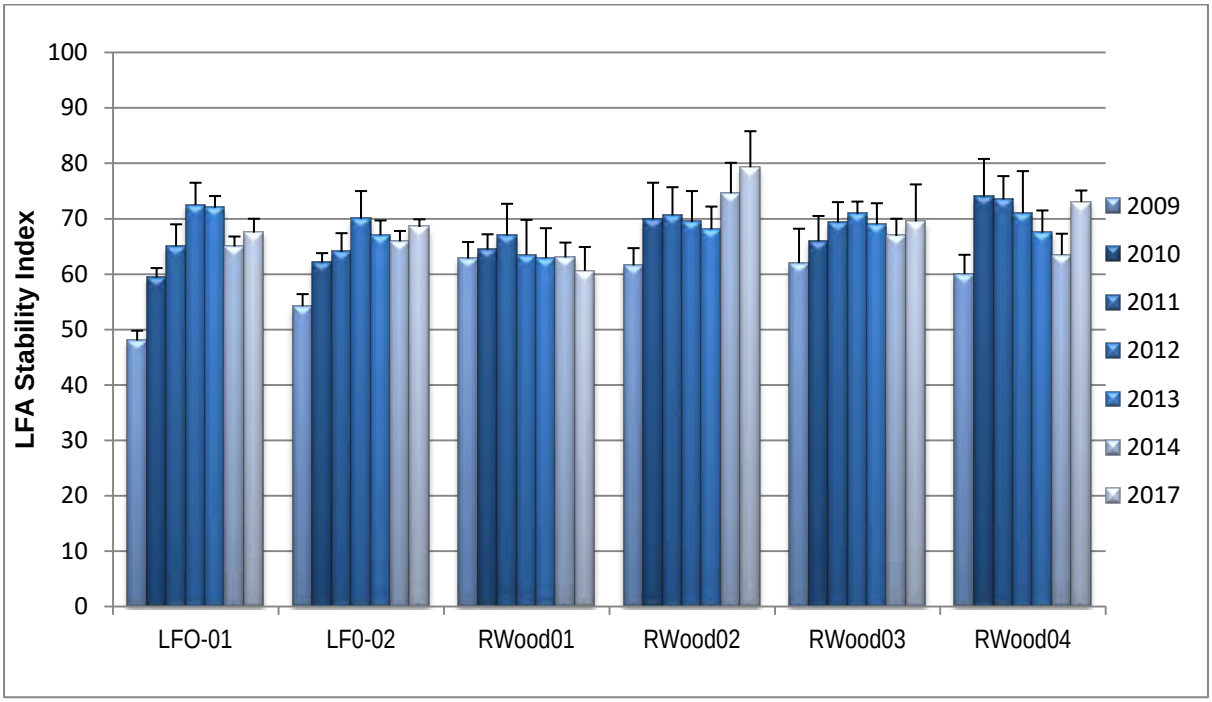


Figure 7-2. LFA stability indices recorded in the woodland rehabilitation sites compared to the woodland reference sites.

7.3.2.2 Infiltration

There has been no consistent change in infiltration indices across the range of woodland reference sites however this year there was increased infiltration in RWood02 and RWood04 probably due to increased litter cover and moderate to high decomposition rates. There was essentially no change in RWood01 and RWood03 with less cover of litter in these sites and the hard setting soils that continue to limit moisture infiltration. The infiltration capacity recorded in the woodland reference sites this year ranged from 44.3 – 61.2 (Figure 7-3).

Revegetation sites LFO-01 and LFO-02 continued to demonstrate increasing infiltration capacity largely due to an improvement in litter cover and rates of decomposition, with the soils also being more coherent with less capacity for slaking. This year LFO-01 had an infiltration index of 44.0 which was negligibly lower the required minimum, however in LFO-02 an index of 48.5 was measured which was comparable to the local woodlands.

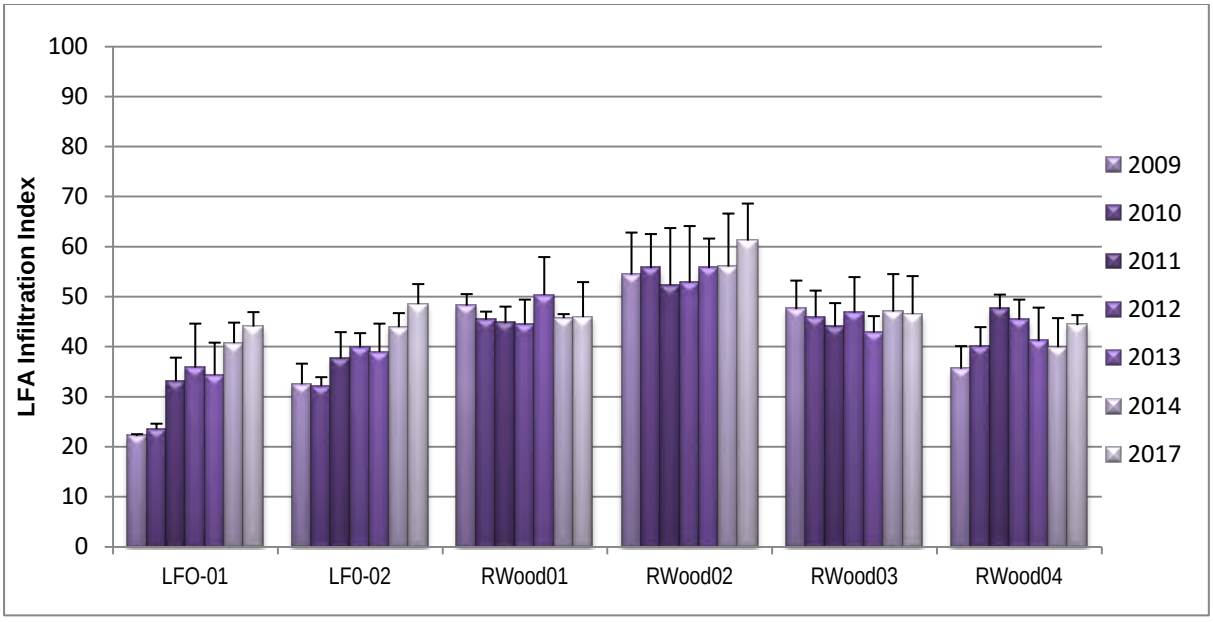


Figure 7-3. LFA infiltration indices recorded in the woodland rehabilitation sites compared to the woodland reference sites.

7.3.2.3 Nutrient recycling

Similar trends in LFA nutrient recycling indices were also observed across the range of woodland monitoring sites and these area also influenced by the level of active plant growth, litter cover and development and extent of cryptogam covers. The extent of these varied significantly between sites as well as within sites. This year the reference sites provided a range of 39.9 – 59.7 (Figure 7-4).

Revegetation sites LFO-01 and LFO-02 continued to demonstrate increasing nutrient recycling capacity, largely due to an improvement in litter cover and rates of decomposition. They were starting to develop a rich organic soil that was more coherent with less capacity for slaking. This year sites LFO-01 and LFO-02 had infiltration indices of 45.0 and 45.5 respectively and these were comparable to the local woodlands.

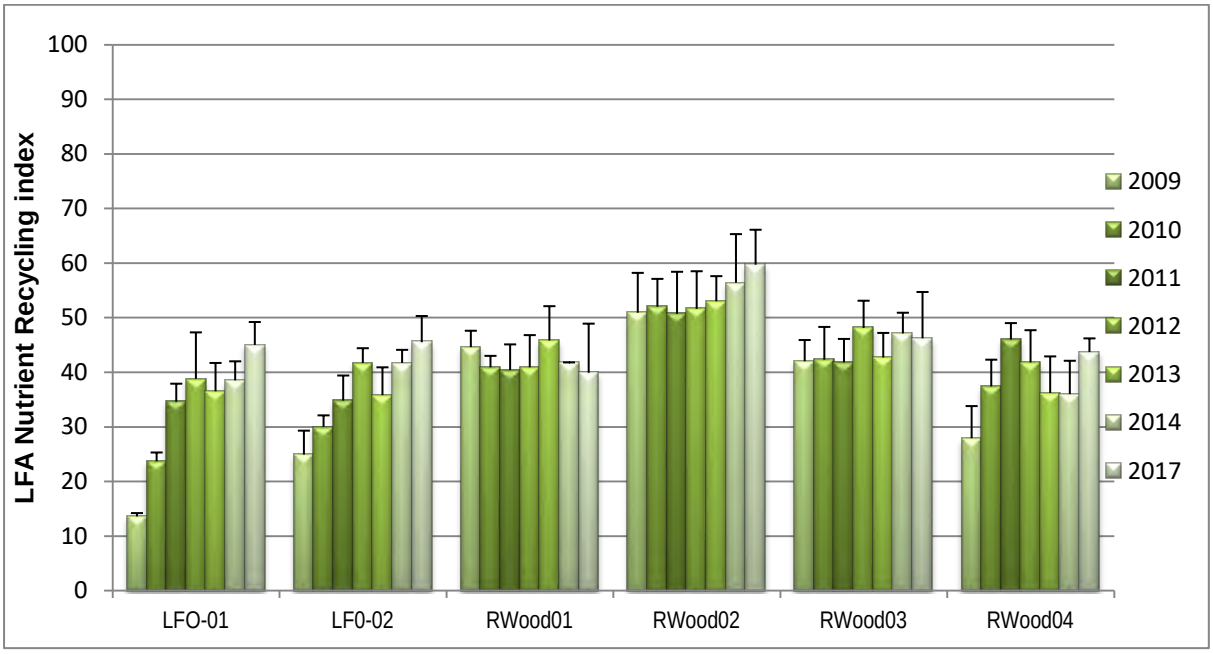


Figure 7-4. LFA nutrient recycling indices recorded in the woodland rehabilitation sites compared to the woodland reference sites.

7.3.3 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 site recorded in 2017 and is provided in Figure 7-5. The maximum score possible is 300 with RWood02 being the most ecologically functional site with a total score of 200.2. This site contained high patch area, a mature tree canopy, shrub understorey and well developed grassy ground cover layer, with high levels of decomposing litter and cryptogam cover.

Most other sites did not tend to have such high levels of these attributes or if they did they were patchy. The Limestone Forest revegetation site LFO-02 had very similar ecological function to RWood03 and RWood04 with a sum of scores of 163 compared to the woodland reference sites 162 and 161. In LFO-01, there was total ecological function 157 which was higher than the total function of 146 recorded in the woodland reference site RWood01 this year.

Examples of the substrates and vegetation covers in the woodland monitoring sites have been illustrated in Table 7-4.

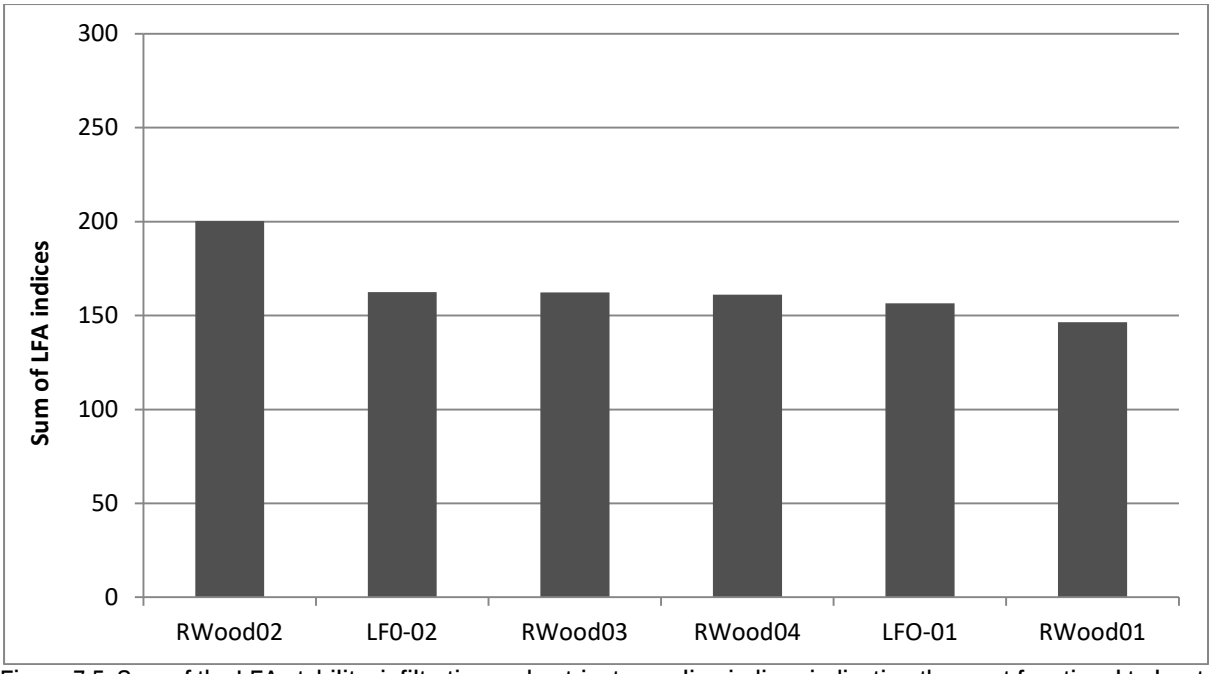


Figure 7-5. Sum of the LFA stability, infiltration and nutrient recycling indices indicating the most functional to least functional monitoring site recorded in 2017.

Table 7-4. Examples of the substrates and ground cover in the woodland monitoring sites in 2017.

LFO-01	LFO-02
	
RWood01	RWood02
	

RWood03	RWood04
	

7.4 Trees and mature shrub populations

7.4.1 Density

In 2013, trees and mature shrubs with a trunk diameter which was 5cm or greater were recorded in Limestone Forest rehabilitation sites for the first time. Since then the density of trees has continued to increase in RWood02 and RWood03 as young saplings continue to grow. In RWood01 and RWood04, no net change was recorded with densities this year ranging from 5 – 22, equating to a density of 50 – 220 individuals per hectare (Figure 7-6).

Tree densities recorded in Limestone Forest rehabilitation sites have continued to increase as young trees and shrubs have continued to grow. This year there were tree densities of 24 and 22 individuals recorded in LFA-01 and LF-02 this year, with these densities being comparable to the local woodlands tree population densities.

7.4.2 Diameter at breast height

The average dbh recorded in the woodland reference sites ranged from 18 – 55cm with the minimum being 5cm and the largest 86cm. The average trunk diameters in the rehabilitation sites were much lower with an average of 8 cm this year. The maximum dbh of 14cm recorded within the rehabilitation sites was a *Eucalyptus microcarpa* growing in LFO-01 (Table 7-5).

7.4.3 Condition

Trees and mature shrubs in the woodland reference sites were predominantly in good to medium health. One individual was dead in RWood04. Mistletoe was recorded in low densities in RWood01. In all four sites 14 – 92% of the populations were bearing flowers of fruits and all sites contained suitable nesting hollows (Table 7-5). In LFO-01 and LFO-02 the majority of individuals were healthy and 54 – 64% were bearing fruits.

7.4.4 Species composition

The reference sites were comprised of various proportions of overstorey species including *Eucalyptus microcarpa* (Grey Box), *E. albens* (White Box), *E. populnea* (Bimble Box) and *E. melliodora* (Yellow Box) and mid-storey species such as *Callitris glaucophylla* (White Cypress Pine), *Allocasuarina luehmannii* (Bulloak) and *Acacia hakeoides* (Hakea Wattle).

In the rehabilitation sites in the Limestone Forest the most common species were *Callitris glaucophylla, E. microcarpa, E. populnea* and mature *Acacia deanei* (Deane's Wattle).

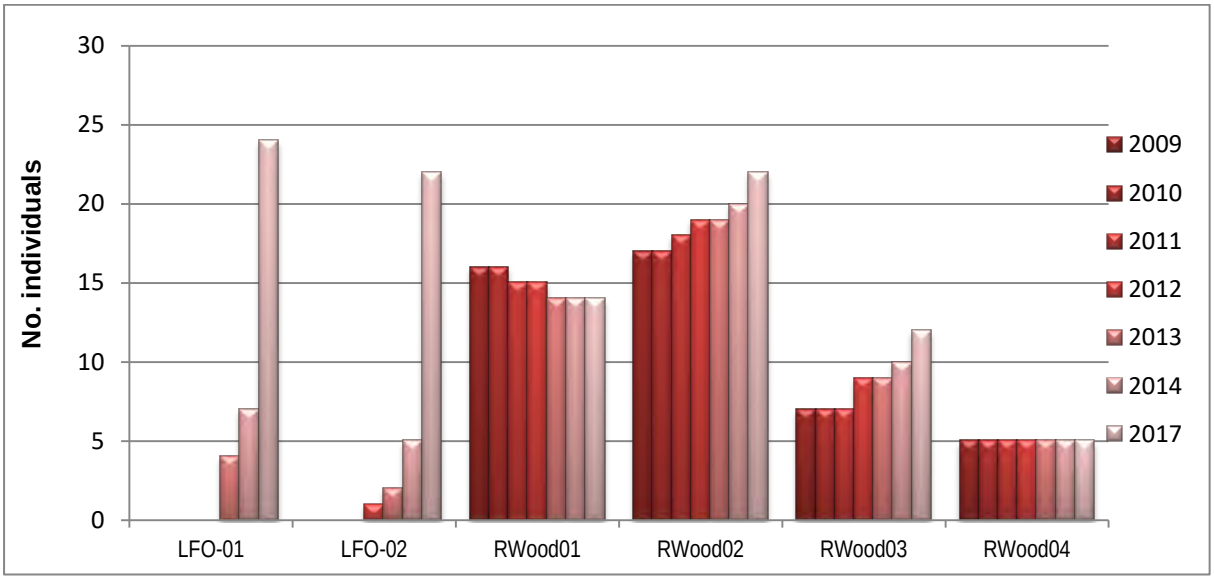


Figure 7-6. Tree densities (>5cm dbh) in the rehabilitation sites compared to the woodland reference sites.

Table 7-5. Trunk diameters and condition of the trees and mature shrubs in the woodland monitoring sites in 2017.

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
LFO-01	3	8	14	1	24	12	100	88	13	0	0	0	54	0
LFO-02	4	8	13	5	22	17	100	77	23	0	0	0	64	0
RWood01	3	35	76	6	14	2	100	36	64	0	0	7	43	21
RWood02	3	18	50	5	22	2	100	36	59	5	0	0	14	14
RWood03	3	29	67	6	12	2	100	50	50	0	0	0	92	42
RWood04	3	55	86	36	6	0	83	83	0	0	17	0	83	17

7.5 Shrubs and juvenile trees

7.5.1 Population density

In 2009, when monitoring first began, no shrubs or juvenile trees were recorded in RWood04, a reference site situated in the Limestone Forest, due to a long agricultural history and continuous grazing by livestock and local macropod populations. In 2012 a recruitment event was initiated with 48 *Callitris glaucophylla* seedlings being recorded in this site which subsequently increased the minimum shrub and juvenile tree density target (Figure 7-7).

Since 2013 the shrub and juvenile tree populations in the woodland reference sites have typically increased as new seedlings become established and this year 65 – 138 individuals were recorded, equating to a shrubs density of 650 – 1380 stems per hectare.

In 2013 LFO-02 had a high number of very small (~3cm) *A. deanei* seedlings that had germinated around a mature *A. deanei*, however most of these failed to become established by 2014. This year, the shrubs and juvenile tree population in both LFO-01 and LFO-02 were declining, as individuals have grown with an increasing number having > 5cm dbh. Thus both Limestone Forest sites have low shrub densities compared to the local woodlands.

7.5.2 Height class

In the woodland reference sites, the majority of shrubs and juvenile trees were 0.5 – 1.5m in height, however all sites, except RWood04, had individuals exceeding 2.0m, and all sites had young seedlings <0.5m tall. In LFO-01, all height classes were represented but most individuals were > 2.0m in height. Small individuals were usually browsed and stunted. In LFO-02, all individuals were >1.0m tall but most were > 2.0m in height (Table 7-6).

7.5.3 Species diversity

In the woodland reference sites there were 2 - 6 species of shrubs and juvenile trees and both Limestone Forest sites had this diversity of species (Table 7-6).

7.5.4 Common species

In three of the reference sites the most common shrubs included *Allocasuarina luehmannii* (Bulloak), *Eucalyptus microcarpa* (Grey Box), *Dodonaea viscosa* subsp. *cuneata* (Wedge-leaf Hopbush) and *Acacia hakeoides* (Hakea Wattle). Additionally there were some *Senna artemisioides* subsp. *zygophylla* (Senna), *Acacia deanei* (Green Wattle), *Alectryon oleifolius* (Rosewood), *Geijera parviflora* (Wilga) and *Eucalyptus albens* (White Box) recorded in at least one of the reference sites. In RWood04, *Callitris glaucophylla* was the most dominant species.

The most common species in the Limestone Forest rehabilitation areas included *Callitris glaucophylla* and *Acacia deanei.* There were also individuals of *Allocasuarina luehmannii*, *Dodonaea viscosa* subsp. *cuneata, Eucalyptus microcarpa, Acacia hakeoides* and *Senna artemisioides* subsp. *zygophylla*.

Table 7-6. Number of individuals represented in each height class across the range of monitoring sites in 2017.

Site Name	0-0.5m	0.5-1.0m	1.0-1.5m	1.5-2.0m	>2.0m	Total	No. species	% endemic
LFO-01	1	1	2	2	5	11	4	100
LFO-02	0	0	1	1	11	13	5	100
RWood01	15	27	15	2	10	69	6	100
RWood02	31	15	2	6	11	65	4	100
RWood03	11	24	21	12	58	126	6	100
RWood04	11	41	69	17	0	138	2	100

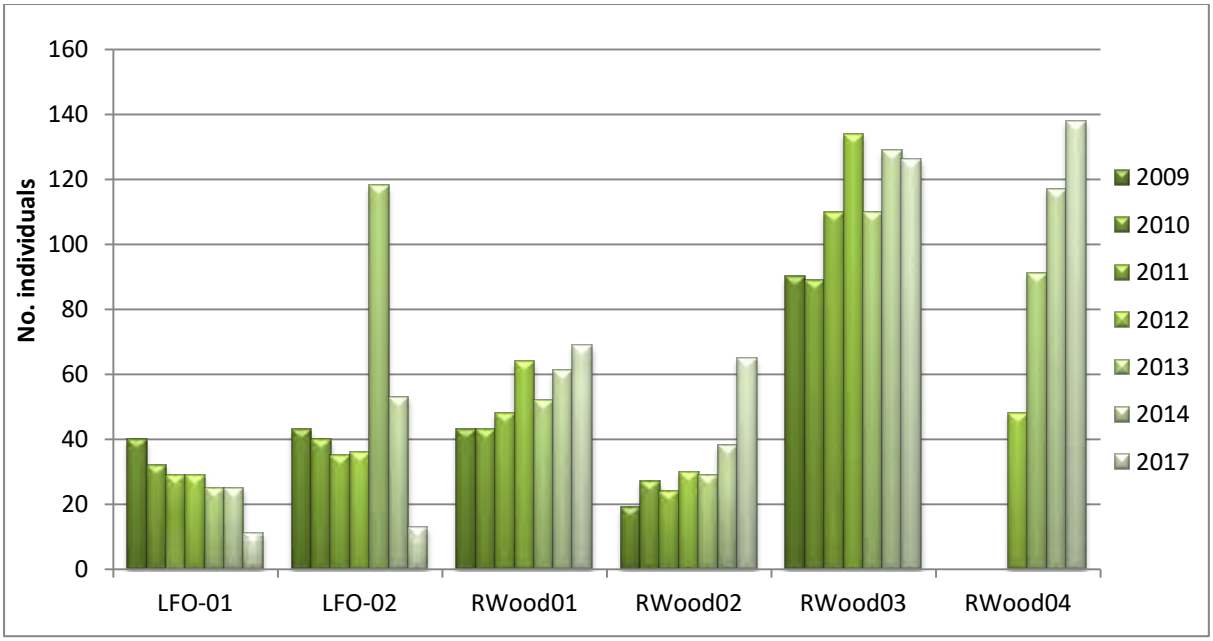


Figure 7-7. Total shrubs and juvenile trees recorded in the rehabilitation sites compared to the woodland reference sites.

7.6 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) continued to be relatively high in the woodland reference sites and had slightly improved since 2014. This year travelling livestock and heavy macropod browsing may have impacted RWood01 and RWood03 and total ground cover ranged from 87.5 – 100% (Figure 7-8).

Improved ground cover was also recorded in the Limestone Forest revegetation sites and both LFO-01 and LFO-02 had 100% total ground cover this year.

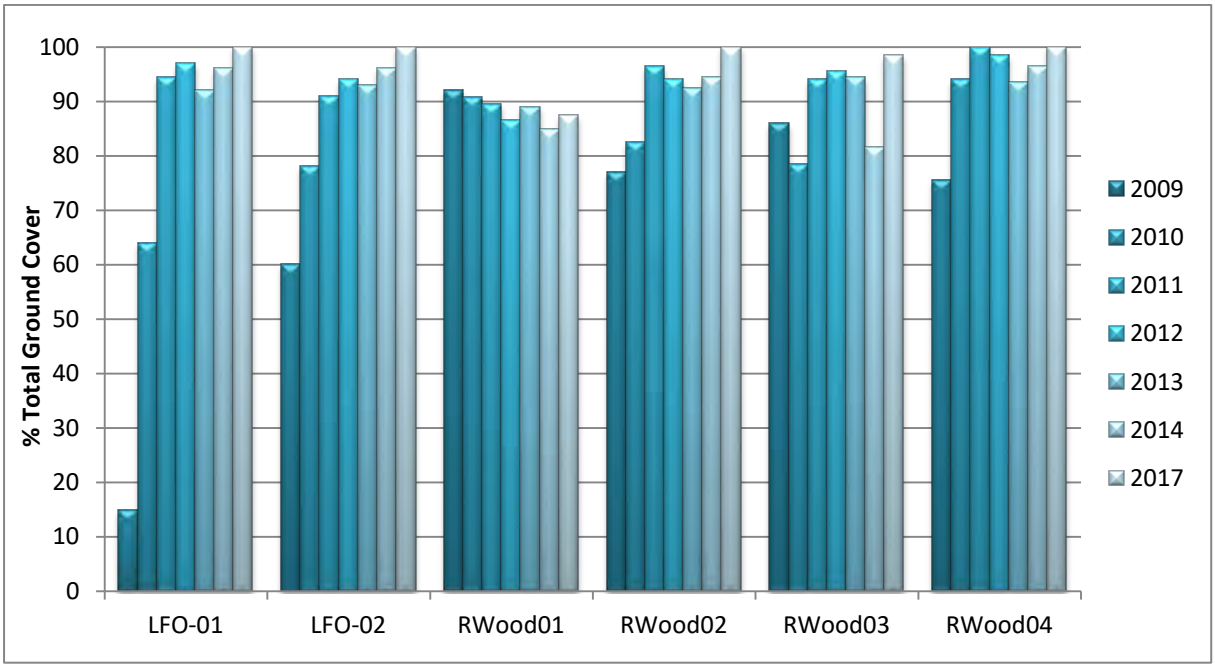


Figure 7-8. Total ground cover recorded in the LFO rehabilitation sites compared to the woodland reference sites.

7.7 Structural composition

The structural composition of the woodland sites is provided in Figure 7-9. It indicates the most dominant form of ground cover continues to be provided by dead leaf litter. Low growing scattered perennial grasses and forbs are also an important component in the woodland reference sites, this year providing 11 – 19.5% of the total ground cover. Annual plants were relatively abundant in RWood04 and provided 22.5% cover, while none were recorded in RWood01. Cryptogams also provided 9 – 10% cover in RWood02 and RWood03 and up to 9% cover was provided by fallen branches.

The Limestone Forest sites were also dominated by dead leaf litter and while they contain a small cover (4.0 – 6.0%) of perennial plants they also contained a high cover of annual plants which provided 14.5 – 35.5% of the total ground covers. There was an absence of cryptogams this year due to increasing levels of plant and litter cover and no rocks or branches were present.

The woodland reference sites contain various level of vertical height cover, with all sites having a mature canopy > 6.0m in height. This year, vertical heights up to 4.0m high were recorded in LFO-1 and LFO-02 and a small amount of canopy cover > 6.0m was recorded in LFO-02. The structural compositions of the different woodland monitoring sites are provided in Table 7-7.

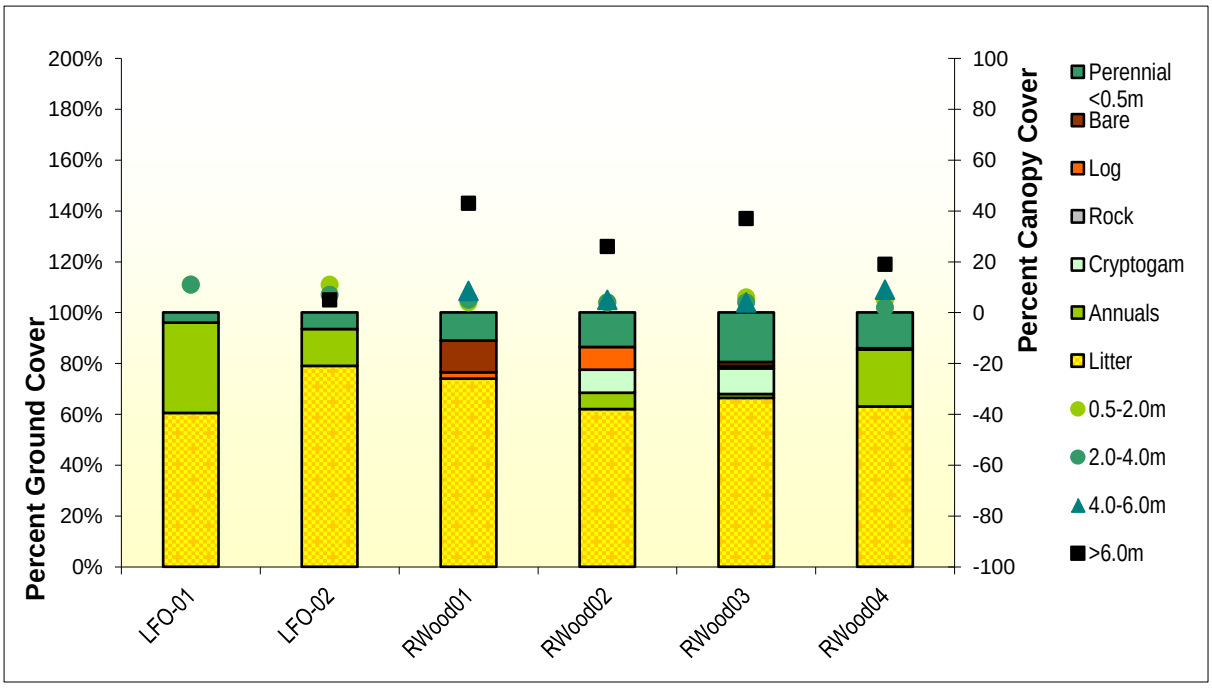


Figure 7-9. Average percent ground cover and projected foliage cover recorded in the woodland monitoring sites in 2017.

Table 7-7. Structure and composition of the woodland monitoring sites.

LFO-01	LFO-02
	
RWood01	RWood02
	
RWood03	RWood04
	

7.8 Species Diversity

7.8.1 Total species diversity

Floristic diversity in the reference sites has tended to fluctuate with changes in seasonal conditions. The highest diversity was recorded in 2010 with favourable seasonal conditions and the break of the drought. 2011 and 2012 were relatively dry, thus diversity had declined. In 2013 a small increase in

diversity was recorded in most sites and this was followed by a decline in diversity in 2014 as dry conditions continued.

While 2016 had above average rainfall, most of 2017 was particularly dry, resulting in only the hardiest of the native perennial ground covers to persist in most sites. Recent rainfall preceding the monitoring event however had resulted in a small flush of exotic species in some sites.

This year there was a reduction in total diversity being recorded in RWood01 and RWood03, while increased diversity was recorded in RWood02 and RWood04 and these provided a total floristic diversity of 43 – 60 species (Figure 7-10).

In the disturbed Limestone Forest revegetation sites, species diversity tended to increase up until 2012, but this was then followed a declining trend due to a combination of the dry conditions and the sites having become more established (and less weedy). This year there was a total of 32 and 30 species recorded in LFO-01 and LFO-02 respectively.

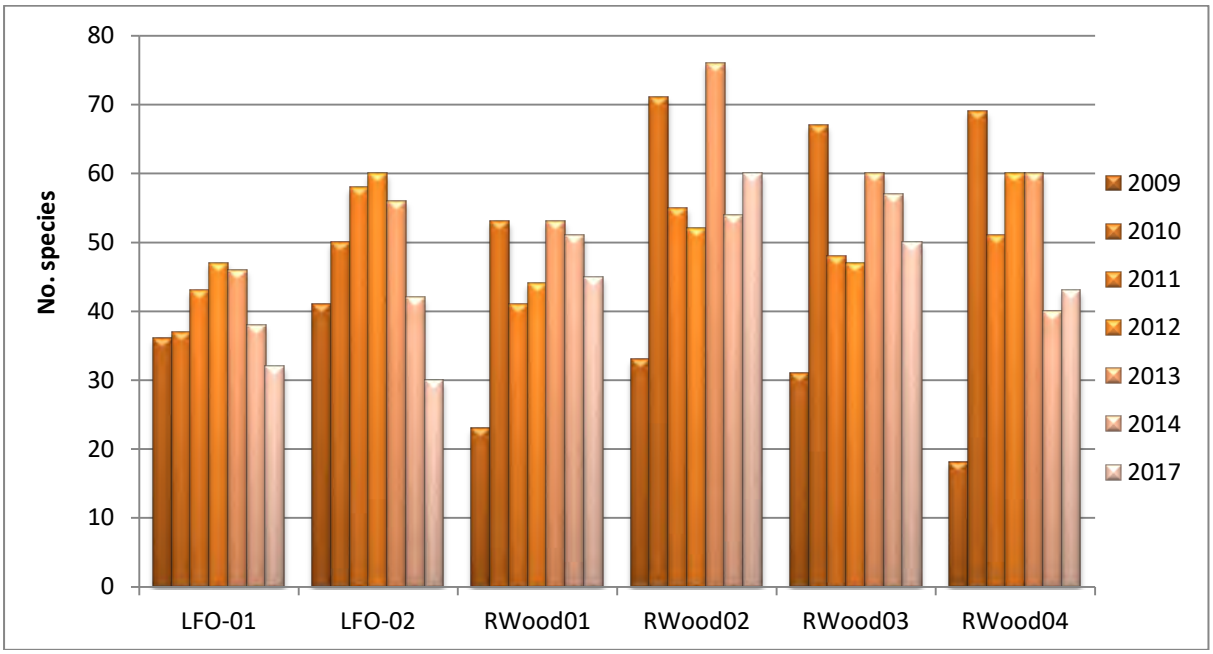


Figure 7-10. Total species recorded in the rehabilitation sites compared to the woodland reference sites.

7.8.2 Native species diversity

In the woodland reference sites native species were far more diverse than exotic species and this year there were 24 – 45 native species. In LFO-01 and LFO-02 there were almost similar diversities of native and exotic species with 15 and 20 native species recorded respectively and thus had less native diversity than the local woodlands.

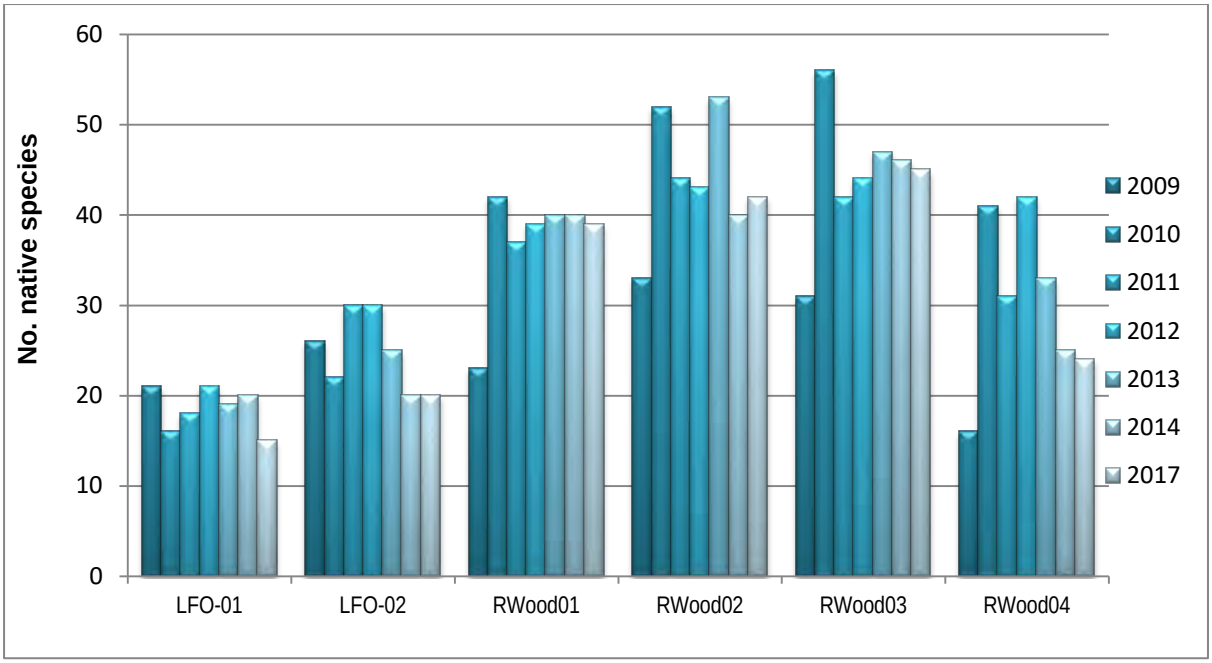


Figure 7-11. Native species recorded in the rehabilitation sites compared to the woodland reference sites.

7.8.3 Exotic species diversity

This year there were 11 – 15 exotic species recorded in the woodland reference sites with an increased exotic species diversity being recorded in RWood02 and RWood04 (Figure 7-12). In LFO-01 and LFO-02 there was a decline in exotic diversity but with 18 and 22 exotic species respectively, had a higher exotic diversity compared to the local woodlands.

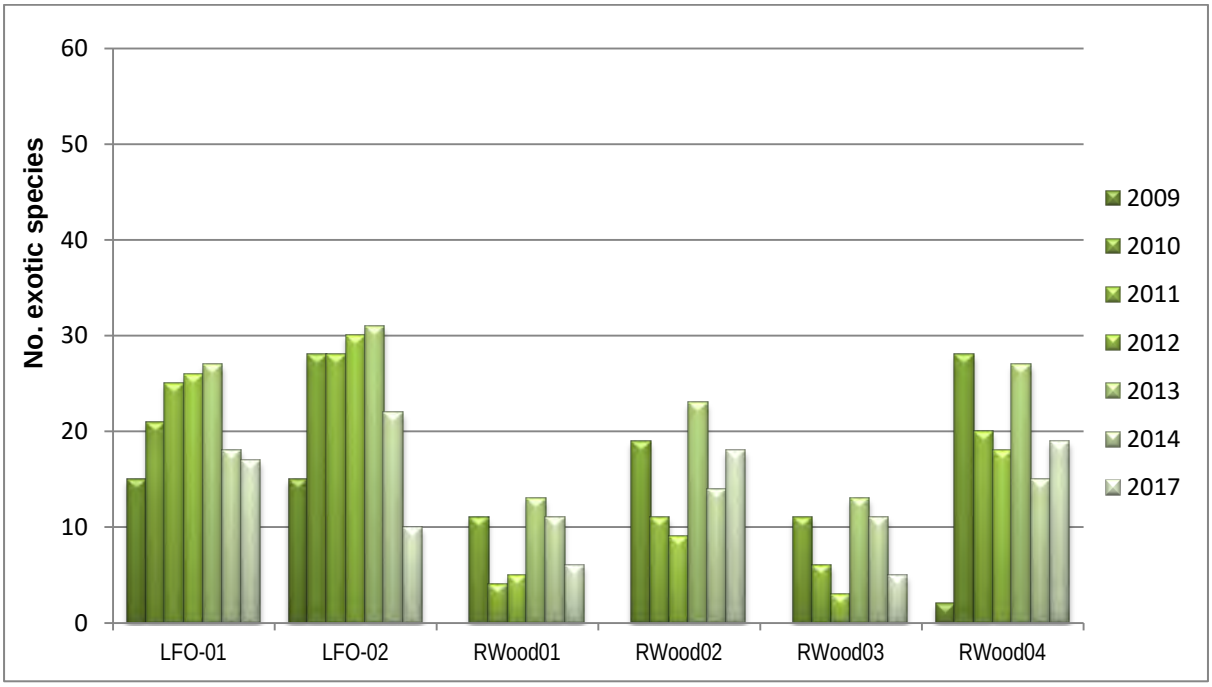


Figure 7-12. Exotic species recorded in the rehabilitation sites compared to the woodland reference sites.

7.9 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 woodland reference sites the percent cover provided by native species dramatically declined in 2010 as the improved rainfall conditions promoted a flush of annual exotics which tended to mask many native plants. The drier conditions over the next two years resulted in the lower abundance of exotic annual plants and subsequently the percent cover of native species demonstrated an increasing trend. In 2013 and 2014 however, the prolonged dry conditions appear to have taken its toll on persisting native plants, especially over the summer period, with rainfall events over the winter – spring period enough to support the establishment of the annual plants. Most of 2017 was particularly dry however recent rainfall prior to monitoring promoted a small flush of exotic species in some sites, including RWood04. This year most of the live plant cover in RWood04 was provided by exotic species.

In the woodland reference sites native plants provided was 45 – 98% of the live plant covers this year (Figure 7-13). In LFO-01 and LFO-02 native plants provided 25 and 24% of the total plant covers.

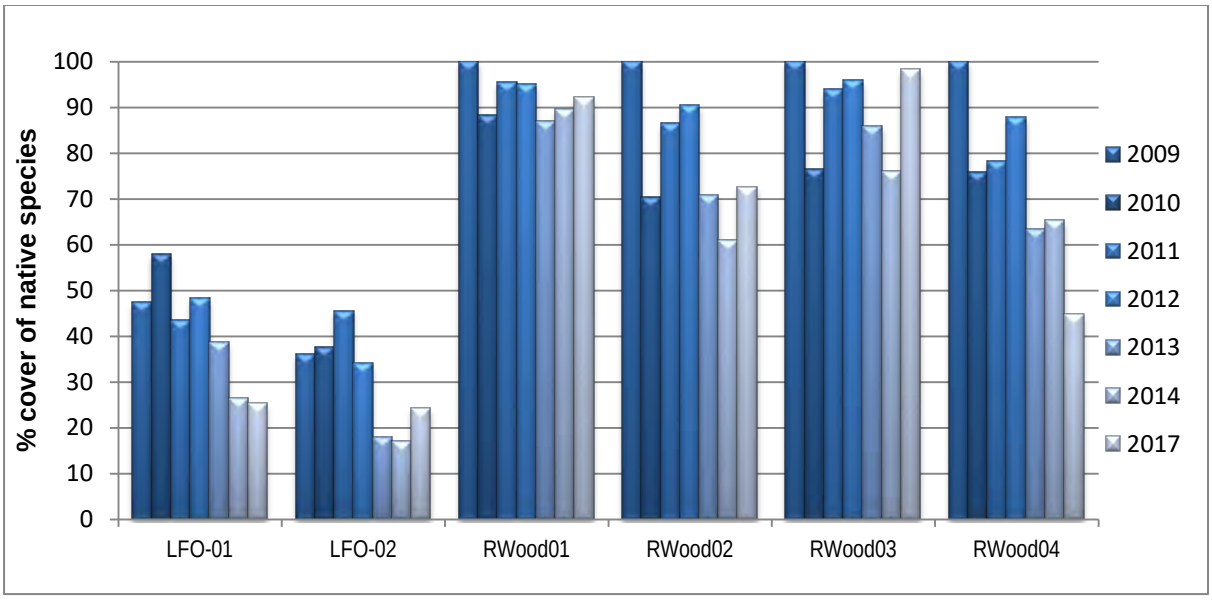


Figure 7-13. Percent endemic ground cover recorded in the woodland monitoring sites.

7.10 Vegetation composition

The composition of the vegetation as categorised by eight different growth forms is given in Figure 7-14. In the reference sites herbs were the most dominant growth form with 21 - 33 different species followed by grasses which had 8 – 18 species. There were 3 - 4 tree species, 0 - 3 shrub species and 1 - 6 different sub-shrubs. There may have been up to one reed, one fern and one parasite species.

The woodland revegetation sites LFO-01 and LFO-02 had an appropriate diversity of tree, shrubs, reeds and ferns compared to the reference sites. There was however a low diversity of herbs and grasses and no sub-shrubs or parasite species were recorded.

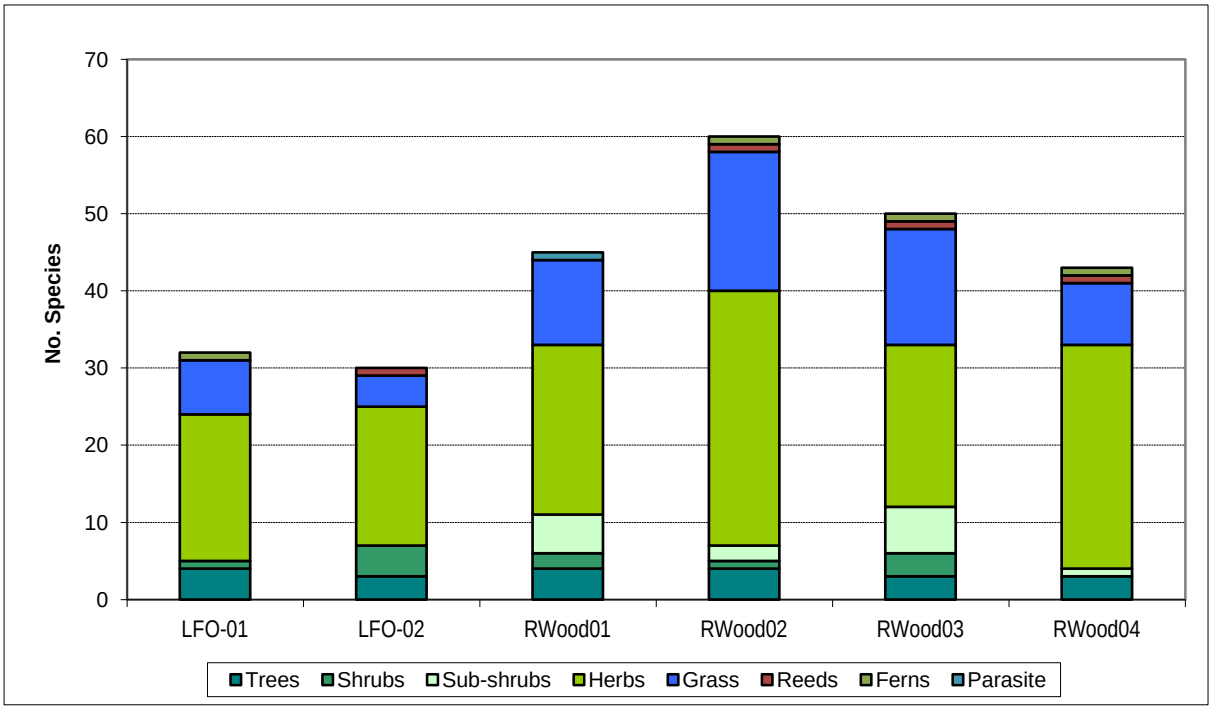


Figure 7-14. Composition of the vegetation recorded in the woodland rehabilitation sites compared to the woodland reference sites in 2017.

7.11 Most common species

In 2017, 15 species were recorded in both Limestone Forest revegetation sites (Table 7-8). Common native species included Callitris glaucophylla, *Dichondra repens* (Kidney Weed) *Einadia nutans* subsp. *nutans* (Climbing Saltbush), *Eucalyptus microcarpa* (Grey Box), *E. populnea* (Bimble Box), Senecio quadridentatus (Cotton Fireweed), Vittadinia cuneata var. hirsuta (Fuzzweed), Vittadinia gracilis (A Fuzzweed) and Xerochrysum bracteatum (Golden Everlasting).

Common exotic species included *Avena fatua* (Wild Oats), Carthamus lanatus (Saffron Thistle), Echium plantagineum (Paterson's Curse), Hordeum leporinum (Barley Grass), Medicago polymorpha (Burr Medic) and *Rumex crispus* (Curled Dock).

All species except *Rumex crispus* were also recorded in the woodland reference sites. A comprehensive list of species recorded in all monitoring sites in 2017 has been included in Appendix 1.

Table 7-8. Species that were recorded in at least four of the six woodland rehabilitation monitoring sites in 2017.

exotic	Scientific Name	Common Name	Habit	LFO-01	LFO-02	Total	RWood01	RWood02	RWood03	RWood04
*	*Avena fatua*	Wild Oats	g	1	1	2		1		1
	Callitris glaucophylla	White Cypress Pine	t	1	1	2	1	1		1
*	*Carthamus lanatus*	Saffron Thistle	h	1	1	2		1		1
	Dichondra repens	Kidney Weed	h	1	1	2	1	1	1	1
*	*Echium plantagineum*	Paterson's Curse	h	1	1	2	1			1
	Einadia nutans	Climbing Saltbush	h	1	1	2	1			
	Eucalyptus microcarpa	Grey Box	t	1	1	2	1		1	
	Eucalyptus populnea	Bimble Box	t	1	1	2		1		1
*	*Hordeum leporinum*	Barley Grass	g	1	1	2	1			1
*	*Medicago polymorpha*	Burr Medic	h	1	1	2		1	1	1
*	*Rumex crispus*	Curled Dock	h	1	1	2				
	Senecio quadridentatus	Cotton Fireweed	h	1	1	2		1		1
	Vittadinia cuneata var. hirsuta	Fuzzweed	h	1	1	2		1	1	1
	Vittadinia gracilis	A Fuzzweed	h	1	1	2	1	1		1
	Xerochrysum bracteatum	Golden Everlasting	h	1	1	2		1		1

7.12 Most abundant species

The most abundant species recorded in each of the woodland monitoring sites this year are provided in Table 7-9. The most abundant species were those that collectively summed to a Braun-blanquet total of 7 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.

This year no particular species was sufficiently abundant to meet the criteria in RWood02 or RWood04. In RWood01, the native grass *Austrostipa scabra* subsp. *scabra* (Rough Speargrass) was the most abundant species, while in RWood03 the native perennials *Austrostipa nitida* and *Vittadinia cuneata* provided the most ground cover.

In LFO-01 the exotic annuals *Carthamus lanatus* (Saffron Thistle), *Echium plantagineum* (Paterson's Curse) and *Trifolium glomeratum* (Clustered Clover) were the most abundant species. In LFO-02 *Avena fatua* (Wild Oats) was dominant.

Table 7-9. The most abundant species recorded in the woodland monitoring sites in 2017.

Scientific Name	Common Name	LFO-01	LFO-02	RWood01	RWood02	RWood03	RWood04
**Carthamus lanatus*	Saffron Thistle	13					
**Echium plantagineum*	Paterson's Curse	10					
**Trifolium glomeratum*	Clustered Clover	7					
**Avena fatua*	Wild Oats		7				
Austrostipa scabra subsp. scabra	Rough Speargrass			10			
Austrostipa nitida	Speargrass					9	
Vittadinia cuneata	Fuzzweed					7	

7.13 Rill assessment

No rills were recorded in any woodland revegetation site.

7.14 Soil analyses

7.14.1 pH

Figure 7-15 shows the pH recorded in the woodland rehabilitation sites compared to the woodland reference sites and "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 remnant woodlands was slightly lower this year to provide a target range of 6.3 – 6.7, with these soils being slightly acidic to neutral (Bruce & Rayment 1982).

In the Limestone Forest revegetation sites the soil pH recorded in LFO-01 and LFO-02 were slightly lower than the woodland reference sites. With soil pH of 5.9 and 6.0 however, they were moderately acidic but within desirable agricultural ranges (Bruce & Rayment 1982).

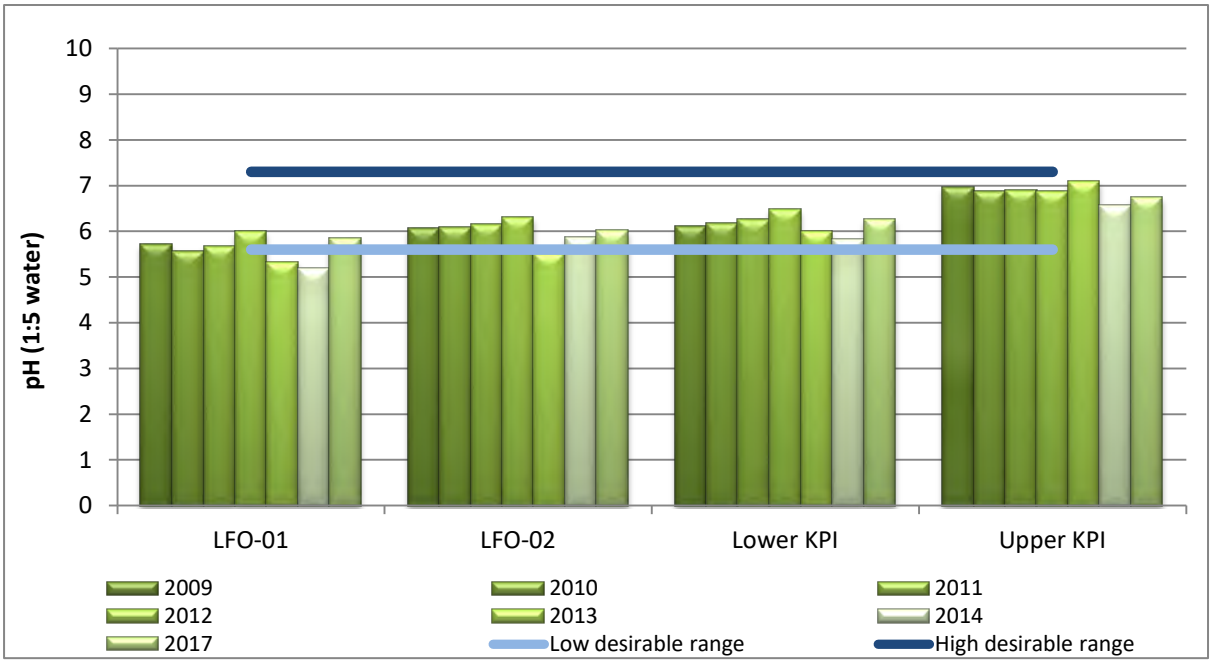


Figure 7-15. Soil pH recorded in the rehabilitation sites compared to the woodland reference sites and desirable agricultural range.

7.14.2 Conductivity

Figure 7-16 shows the Electrical Conductivity (EC) recorded in the rehabilitation sites compared to the woodland reference sites and "desirable" range in medium or clay loam soils as prescribed by the agricultural industry for growing introduced pastures and crops. Since 2009 EC recorded across the range of monitoring sites has tended to demonstrate a declining trend in most cases. This year EC in the woodland reference sites ranged from 0.043 - 0.061 dS/m and these remained within non saline levels (Slavich & Petterson 1993).

EC in the Limestone Forest rehabilitation sites LFO-01 and LFO-02 were similar to or slightly lower than the local woodlands this year. With EC concentrations of 0.034 dS/m and 0.045 dS/m the soils were non saline.

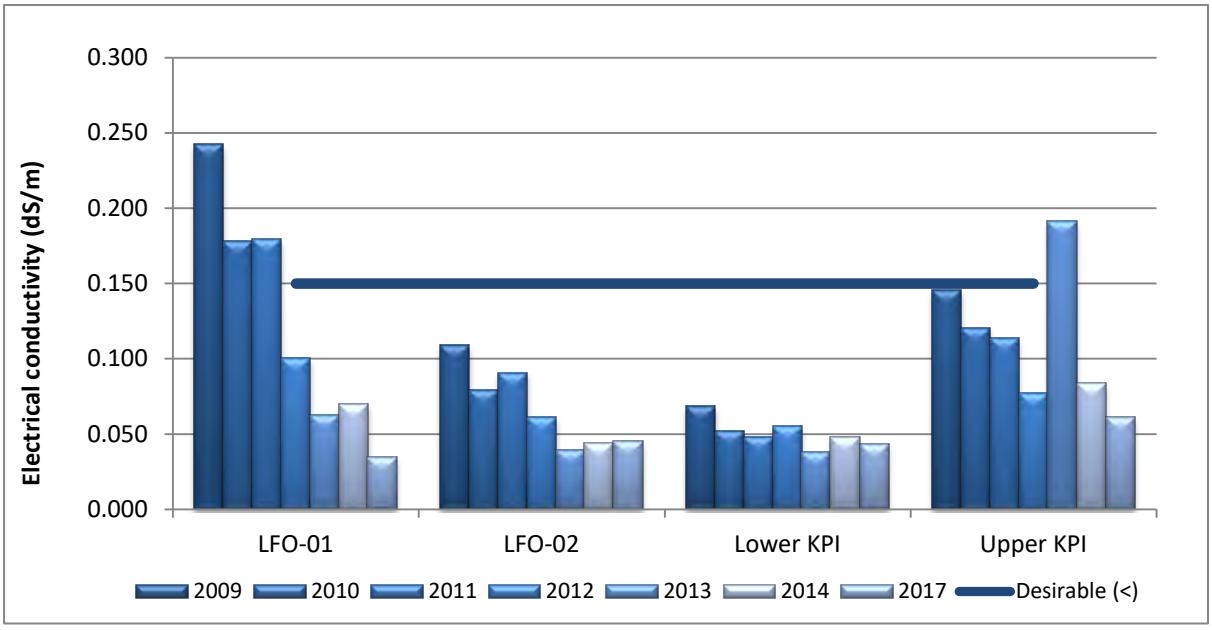


Figure 7-16. Electrical Conductivity recorded in the rehabilitation sites compared to the woodland reference sites and desirable agricultural levels.

7.14.3 Organic Matter

There has been no consistent trend in the changes in the percentage Organic Matter (OM) recorded in the rehabilitation sites but the data suggests that OM levels continue to fluctuate and this may be related to the inherent site and sampling variability within and across sites. This year OM recorded in the reference sites this year ranged from 3.7 – 5.2% (Figure 7-17) and were close to or slightly higher than desirable.

Marginal increases were recorded in the Limestone Forest Offset sites with both sites having an OM of 2.7%. OM therefore continued to be lower than the local woodlands and desirable levels, but these appear to be slowly improving.

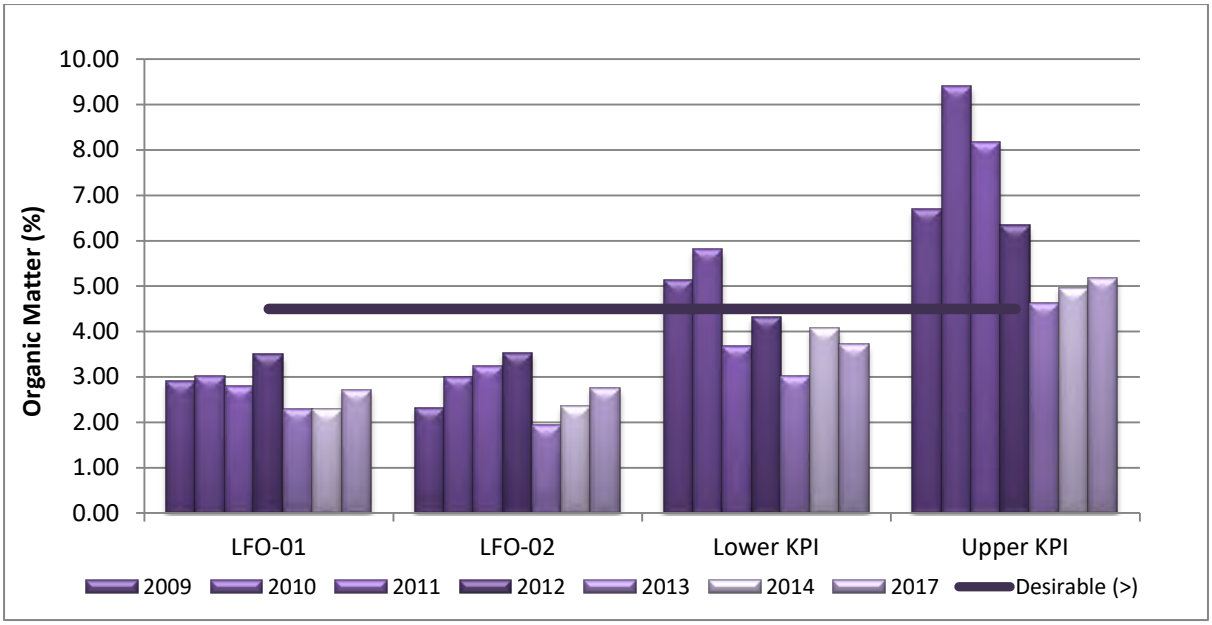


Figure 7-17. Organic Matter concentrations recorded in the rehabilitation sites compared to the woodland reference sites and desirable agricultural levels.

7.14.4 Phosphorous

Phosphorous levels continued to be lower than the desirable level in the woodland reference sites reflecting the naturally low soil fertility in the local area but these have slightly increased this year to provide a target range of 22 – 36 mg/kg (Figure 7-18). Phosphorous levels in the LFO-01 continued to far exceed the local range and remained above the desirable agricultural thresholds with concentrations of 73 mg/kg. In LFO-02, P concentrations were comparable to the local woodland with concentrations of 32 mg/kg.

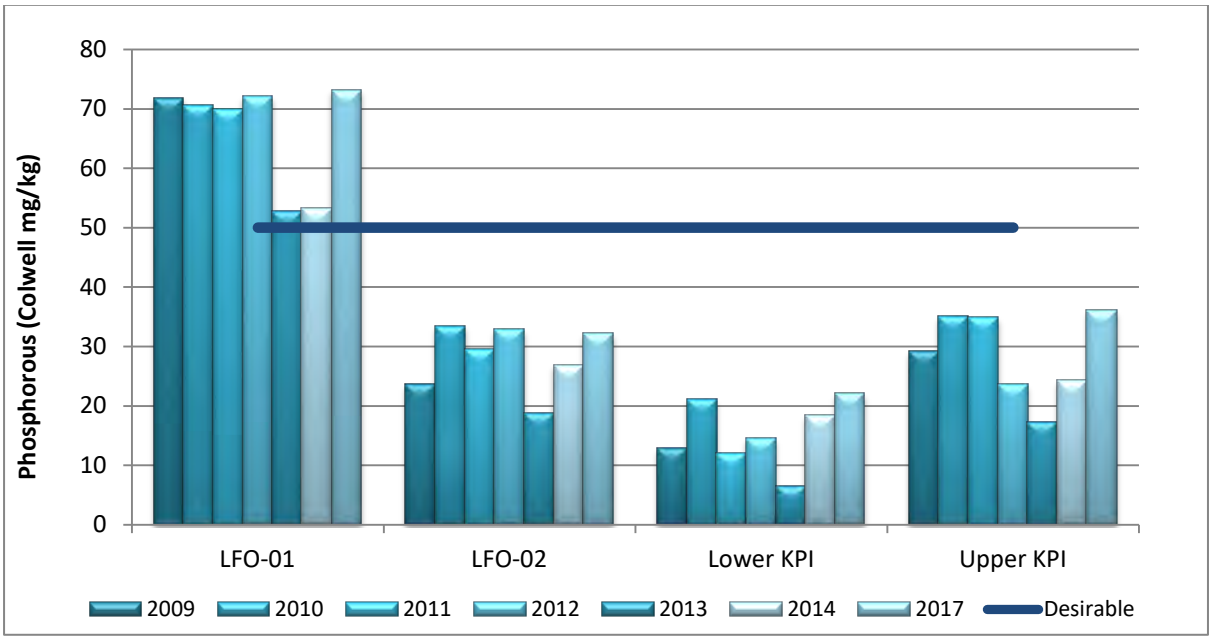


Figure 7-18. Phosphorous concentrations recorded in the rehabilitation sites compared to the woodland reference sites and desirable agricultural levels.

7.14.5 Nitrate

The concentration of nitrates recorded in the woodland reference sites continued to provide a very low target of 1.3 – 7.2 mg/kg (Figure 7-19). These concentrations are significantly lower than that prescribed by the agricultural industry which is also a reflection of the naturally low soil fertility around NPM. Marginal increases were also recorded in the Limestone Forest revegetation areas and these remained comparable to those recorded in the local woodlands, with N concentrations of 1.9 mg/kg and 3.8 mg/kg in LFO-01 and LFO-02 respectively.

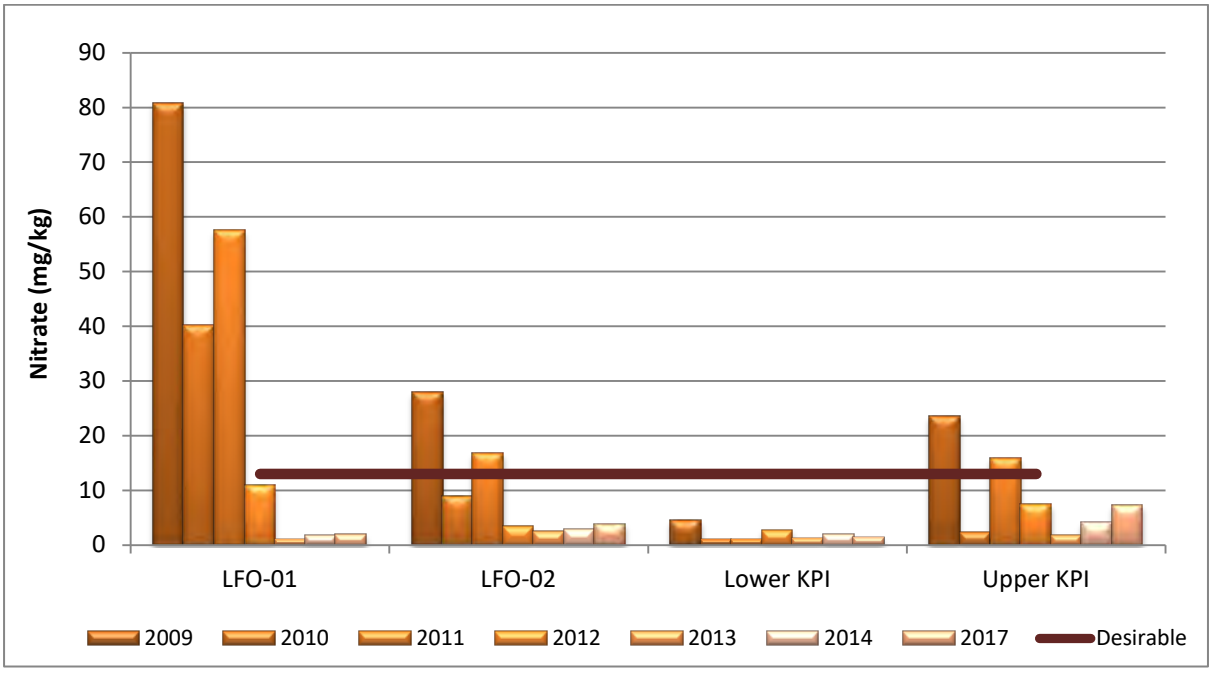


Figure 7-19. Nitrate concentrations recorded in the rehabilitation sites compared to the woodland reference sites and desirable agricultural levels.

7.14.6 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. This year the CEC target had slightly increased to provide a range of 13.4 – 17.8 cmol/kg and these were close to or slightly higher than the desirable level of 14.0 cmol/kg (Figure 7-20). In the Limestone revegetation sites, CEC in LFP-01 and LFO-02 were slightly low with CECs of 9.0 cmol/kg and 9.2 cmol/kg respectively.

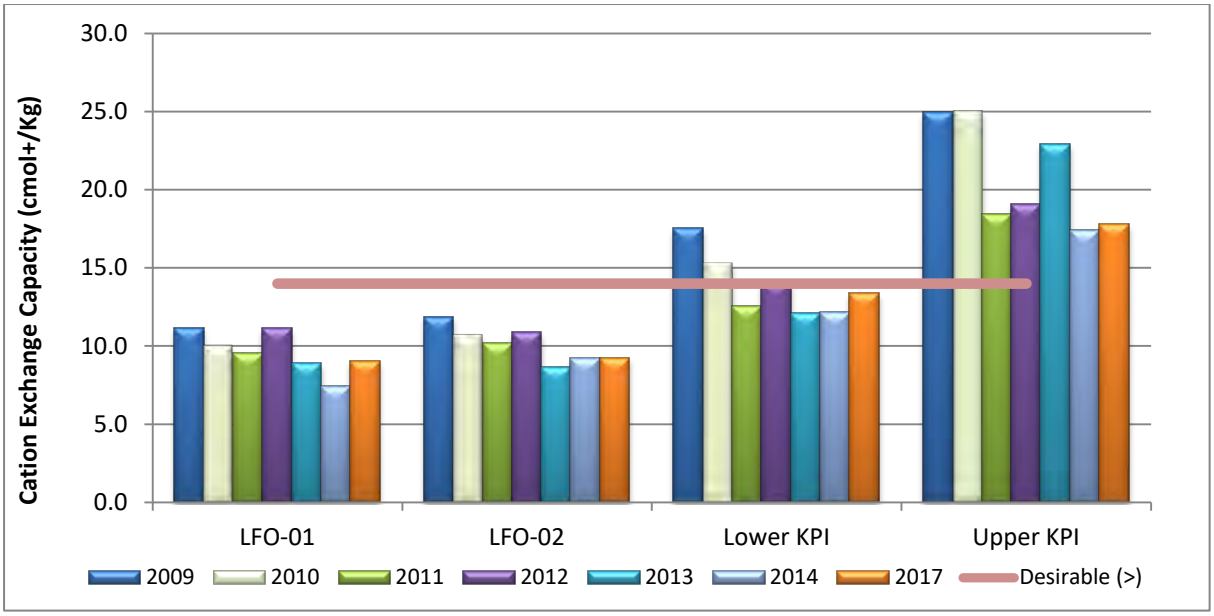


Figure 7-20. Cation Exchange Capacity recorded in the woodland rehabilitation sites compared to the upper and lower values from the woodland reference sites and desirable agricultural levels.

7.14.7 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 demonstrated a slight decline this year and provided a target range of 0.31 – 3.1% and these remained below the 5% threshold for sodicity. Both Limestone Forest revegetation sites LFO-01 and LFO-02 had an ESP comparable to the local woodlands with ESPs of 0.5% and 0.3% respectively and were non sodic (Isbell 1996).

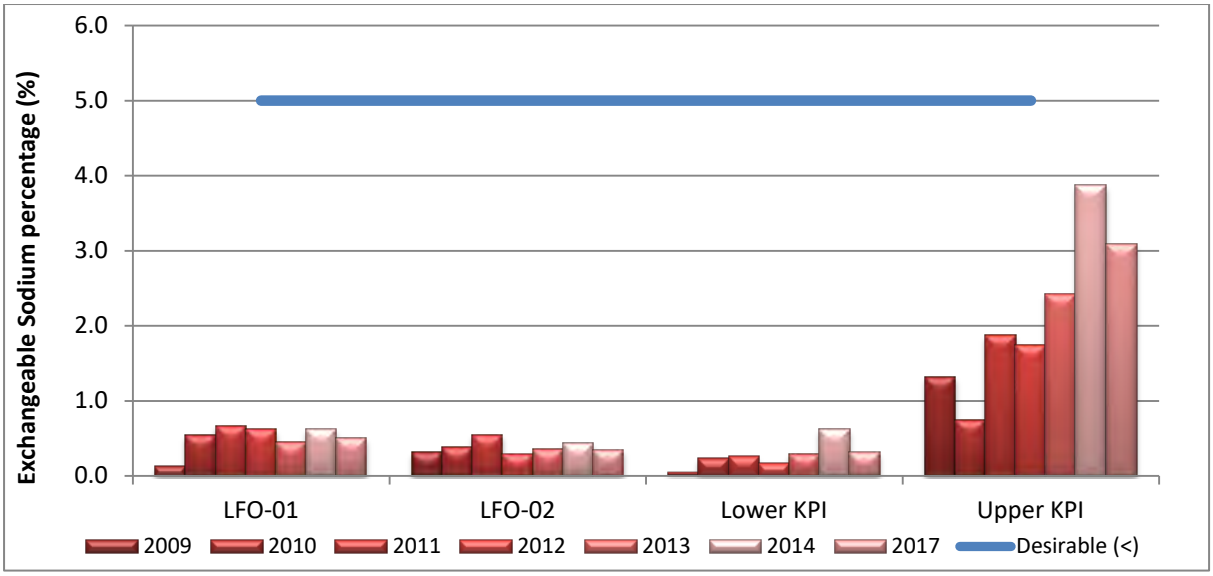


Figure 7-21. ESP recorded in the rehabilitation sites compared to the woodland reference sites and desirable agricultural levels.

7.14.8 Other soil test results

The full results of the soil analysis are provided in Appendix 3 however a summarised version highlighting abnormal results is provided below in Table 7-10. In 2017 there were elevated levels of potassium, manganese, iron, copper and silicon in all sites including all four reference sites.

As these woodland rehabilitation areas are essentially tree planting enhancement projects rather than rehabilitation of mine disturbed areas, the results tend to indicate that various elements may occur at naturally high levels within soils surrounding the Northparkes Mines which may be implicated with landscape clearing, as well as historical agricultural and mining practices.

Table 7-10. Summarised soil analyses highlighting abnormal test results in the woodland monitoring sites in 2017.

Method	*Nutrient*		*Units*	LFO-01	LFO-02	RWood01	RWood02	RWood03	RWood04	*Indicative guidelines only- refer Note 6*
Morgan 1	Calcium	Ca	mg/kg	461	463	539	986	694	858	*750*
	Magnesium	Mg		111	124	294	314	437	199	*105*
	Potassium	K		243	327	188	231	132	213	*75*
KCl	Sulfur	S	mg/kg	5.8	5.0	4.1	5.7	4.5	9.4	*8.0*
DTPA	Manganese	Mn	mg/kg	78	68	165	46	49	98	*22*
	Iron	Fe		44	45	48	31	34	41	*22*
	Copper	Cu		10.5	14.7	4.4	7.0	3.4	18.4	*2.0*
$CaCl_2$	Silicon	Si	mg/kg	70	65	61	59	77	71	*45*
Total Acid Extractable	Zinc	Zn	mg/kg	53	72	32	45	22	178	*20 - 50 Zn*
	Manganese	Mn		1,427	1,332	3,856	982	712	2,581	*200 - 2,000 Mn*
	Iron	Fe		40,951	38,549	22,431	51,359	21,717	44,532	*1,000 - 50,000 Fe*
	Copper	Cu		98.1	110.5	39.1	77.9	31.2	154.8	*20 - 50 Cu*
	Silicon	Si		3,222	2,477	4,069	2,289	3,083	2,539	*1,000 - 3,000 Si*
Total Acid Extractable	Chromium	Cr	mg/kg	30	24	25	96	20	24	*<25 Cr*

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

7.15 Woodland rehabilitation site performance towards meeting completion criteria targets

Table 7-11 indicates the performance of the rehabilitation monitoring sites against a selection of proposed Primary and Secondary Performance Indicators developed for woodland communities during the 2017 monitoring period. The selection of indicators has been presented in order of ecosystem successional processes, beginning with landform establishment (orange) and ending with indicators of ecosystem stability (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have been identified with a shaded colour box and have therefore been deemed to have met the respective ecological target. 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 2017. 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 targets using the adopted methodology.

Table 7-11. Performance of the woodland rehabilitation monitoring sites against a selection of proposed Primary and Secondary Performance Indicators in 2017.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2017		LFO-01	LFO-02
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2017	2017
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°)	**0**	**5**	**4**	**1**
	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**
			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**
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)	**6.3**	**6.7**	**5.9**	**6.0**
			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)	**0.043**	**0.061**	**0.034**	**0.045**
			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)	**3.7**	**5.2**	**2.7**	**2.7**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2017		LFO-01	LFO-02
			Phosphorous	Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (50)	22.0	36.1	73.1	32.1
			Nitrate		Nitrate levels are typical of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (>12.5)	1.3	7.2	1.9	3.8
			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)	13.4	17.8	9.0	9.2
			ESP		Exchangeable Sodium Percentage (a measure of sodicity) is typical of the surrounding landscape or is less than the 5% threshold for sodicity	% (<5)	0.3	3.1	0.5	0.3
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		%	60.6	79.3	67.5	68.5
			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
	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	2	6	4	5
				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
			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	43	60	32	30
			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	24	45	15	20

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2017		LFO-01	LFO-02
			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	5	19	17	10
	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	65	138	11	13
	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	3	4	4	3
			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	4
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	1	6	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	21	33	19	18
			Grasses		The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	8	18	7	4
			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	0	1
			Ferns		The number of ferns comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	1	1	0
			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
			Parasite		The number of parasite species comprising the vegetation community is comparable to that of the local remnant vegetation		0	1	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2017		LFO-01	LFO-02
Phase 5: Ecosystem & Landuse Sustainability	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		%	44.3	61.2	44	48.5
			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		%	39.9	59.7	45	45.5
	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	%	62	74	60.5	79
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	0	23	35.5	14.5
			Cryptogam cover		Percent ground cover provided by cryptogams (e.g mosses, lichens) is comparable to that of the local remnant vegetation	%	0	10	0	0
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	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	9	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	0	13	0	0
			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		%	11	20	4	6.5
			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		%	88	100	100	100
	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	3.2	7.6	3	1.2

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2017		LFO-01	LFO-02
			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	3.4	4.8	3
	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		%	45	98	25.4	24.2
	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	11	31	1	0
			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	15	41	1	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	2	69	2	1
			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	2	17	2	1
			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	58	5	11
	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	4	6	11	11

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2017		LFO-01	LFO-02
			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	2	5	11	7
			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	4	9	0	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	19	43	0	5
	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	3	3	3	4
				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
	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	6	22	24	22
			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	18	55	8	8
	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	83	100	100	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	36	83	87.5	77.3
			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	0	64	12.5	22.7

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2017		LFO-01	LFO-02
			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	**0**	**5**	**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	**0**	**17**	**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**	**7**	**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	**14**	**92**	**54.2**	**63.6**
			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		**14**	**42**	0	0

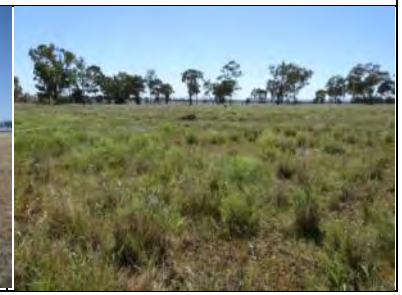
8 Ecological monitoring results: Grasslands

This section provides the results of the monitoring within the rehabilitated grassland sites and demonstrates ecological trends and performance of these sites against a selection of ecological performance indicators obtained from the grassland reference sites. This year a new grassland reference and two new grassland rehabilitation sites were established to replace sites that had become disturbed.

8.1 Photo-points of the grassland reference sites

General descriptions of the reference sites, including photographs taken in the permanent monitoring quadrats 2009 – 2014, and 2017 have been provided in Table 8-1. Please note that 2010 and 2012 photographs have been omitted for ease of presentation of data.

Table 8-1. General site descriptions and permanent photo-points of the grassland reference monitoring sites.

Site	Photo 2009	Photo 2011	Photo 2013	Photo 2014	Photo 2017
RGrass01	Large open natural grassland area on the TSR adjacent to the Wombin State Forest, on the Bogan Rd. In 2009, the site contained sparsely scattered tussocks of native grass tussocks, with *Austrostipa* and *Rytidosperma* species being the most dominant. In 2014 the grassland appears to have been grazed very low with the grasses being short and stressed, with cattle hoof prints providing abundance indents. The soils remained very hard and were often bare but cryptogams remained abundant. In 2017 a new reference sites was established which was dominated by *Walwhalleya proluta* (Rigid Panic) with low grazed exotic annual grasses and forbs in between stressed tussocks.				
					
	Old grassland reference site that had significantly deteriorated and was no longer considered acceptable.				

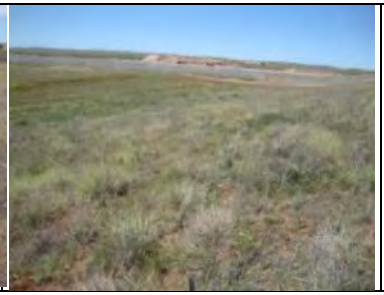
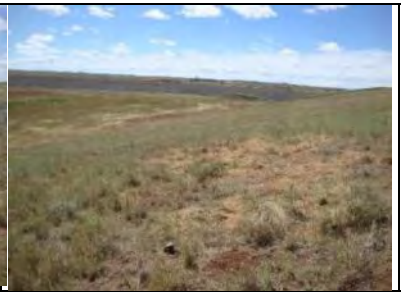
Site	Photo 2009	Photo 2011	Photo 2013	Photo 2014	Photo 2017
RGrass02	A derived grassland area on the TSR on the Bogan Rd east of TSF 2. It was a relatively dense sward of mixed native grasses dominated by *Austrostipa bigeniculata, Bothriochloa macra* and *Rytidosperma* species. There were few areas of bare soil as cryptogams were in significant abundance across the area. In 2009, the grasses were particularly stressed due to the extreme hot and dry conditions and introduced annuals and weeds were dead. In 2010, the site contained an abundance of exotic annuals. Recent grazing and trampling by a large herd of cattle during/after heavy rainfall has caused extensive soil damage and large deep hoof-prints across the site. In 2011 the area remained ungrazed and there was an increased cover of grasses. In 2012 and 2013 the site continued to be very dry. In 2014 the site had not been grazed recently but may have been grazed in March? Annuals were again very dominant especially Trifolium, Medicago, Lolium and Avena, but the Avena was more sparse and short. Old hoof prints have persisted but most were now covered with litter. In 2017 the grassland continued to be dominated by native grasses and had low grazed exotic annual grasses and forbs in between stressed tussocks. The hoof indentations continued to exist but most had grown over. There has been some light grazing by travelling stock but the impact appeared minor.				
					
RGrass03	A large derived grassland area opposite “Berra Lee” on the TSR adjacent to the Bogan Rd. It was a relatively dense sward of mixed native grasses dominated by *Austrostipa bigeniculata* and *Rytidosperma erianthum* and in suitable conditions, *Avena fatua* (Wild Oats) The history of the site is largely unknown but there were a series of old contour banks transversing the slope which were usually low in ground cover, therefore creating patchiness. Apart from some of these contours, there were few areas of bare soil with the presence of some cryptogams. In 2009, the grasses were particularly stressed due to the extreme hot and dry conditions and overall plant diversity was low and introduced annuals and weeds were dead. In 2010, the site contained an abundance of exotic annuals, but ground cover was very good and appeared unaffected by livestock. In 2011 the area remained ungrazed and there was an increased cover of grasses and a reduction in annual exotics. In 2012 and 2013 the site continued to be very dry. In 2014 the site had not been grazed recently but may have been grazed in March? Annuals were again very dominant especially Trifolium, Medicago, Lolium and Avena, but the Avena was more sparse and short. Old hoof prints have persisted but had been covered with litter. In 2017 the grassland continued to be dominated by native grasses and had low grazed exotic annual grasses and forbs in between stressed tussocks, with some active green growth after recent rainfall.				
					

8.2 Photo-points of the grassland rehabilitation monitoring sites

General descriptions of the rehabilitation sites, including photographs taken in the permanent monitoring quadrats in 2009 – 2014, and 2017 have been provided in Table 7-2. Please note that 2010 and 2012 photographs have been omitted for ease of presentation of data.

Table 8-2. General site description and photo of the grassland rehabilitation monitoring sites.

Site	Photo 2009	Photo 2011	Photo 2013	Photo 2014	Photo 2017
TSF2-02	Native grassland. Rehabilitation area on the northeast wall of TSF 2. A grassy slope similar to TSF2-01 with scattered tussocks of native perennial grasses (*Walwhalleya proluta)* and a heavy cover of *Medicago polymorpha*. A *single Acacia hakeoides* and *M. brevifolia* were noted further along the slope. In 2009, the grasses and annual plants were particularly stressed with little active green growth or were dead. In 2010, there was evidence of extensive soil erosion from the bare upper slope which contained numerous rills, but the eroded materials were captured within the plant patches down slope. The bare areas had a light cover of annual plants. In 2011, there was a significant increase in perennial plant cover largely due to the native grasses and there were fewer weeds. The top of the slope continued to be bare and eroding. In 2012 and 2013 the site continued to be very dry. In 2014 *Walwhalleya* tussocks were actively growing and setting seed and *Avena* and patches of *Vicia* and *Carthamus lanatus* were abundant throughout, but most had died off. The upper slope remained bare, cracked and crusted. In 2017 there was an increased abundance of *Walwhalleya* and the exotic annual were grazed low by macropods. There was now good ground cover throughout.				
					
TSF2-03	Native grassland. Rehabilitation area on the western wall of TSF 2. A grassy slope similar to TSF2-02 with scattered tussocks of native perennial grasses (*Walwhalleya proluta)* and patches of *Lolium* and *Avena.* The site was grazed low between the large tussocks and there were occasional *Maireana brevifolia.* There were large patches of *Trifolium angustifolium* and *Vicia sativa* at the end of the transect. The bare upper slope contained numerous rills, but the eroded materials were captured within the plant patches down slope.				
	N/A	N/A	N/A	N/A	

Site	Photo 2009	Photo 2011	Photo 2013	Photo 2014	Photo 2017
E22-01	Native grassland. Rehabilitation area the western batters of the waste emplacement surrounding the E22 open cut. An open grassy area on the upper slope of the waste emplacement batter. The upper half of the monitoring plot contains less vegetation cover with scattered tussocks of *Walwhalleya proluta* and exotic annuals. The lower part of the slope is more densely vegetated and in 2010 it was dominated by *Vicia, Rapistrum rugosum* and various other weeds. Spiny Orb weavers were abundant. Below the site there are some small planted tree lots with little to no ground cover with severe tunnel erosion observed nearby. Some Grey Crowned Babblers were observed in these trees during the monitoring. In 2011, there was a significant increase in perennial plant cover largely due to the native grasses and there were fewer weeds. In 2012 and 2013 the site continued to be very dry. In 2014 there were large patches of *Vicia* and Avena fatua which had mostly died back. There appeared to have been a decline in other weeds. The ground cover was low due to grazing by macropods and drier conditions but the site retained good ground cover. In 2017 the site had become dominated by Wild Oats and had large patches of Vicia but there were few other weeds. The Oats were small and stunted but good ground cover was retained. There were occasional native grass tussock and the site only appeared to be slightly grazed. There were fresh echidna scratchings. There also continued to be tunnel erosion near the adjacent tree plantings which require amelioration along with scattered *Acacia baileyana* (Cootamundra Wattle), an environmental weed.				
					
E22-02	Native grassland. Rehabilitation area located on the northern face of the waste rock emplacement that surrounds E22 open cut. A rocky north facing slope that appears to have been deep ripped after shaping. There are sparse tussocks of *Walwhalleya proluta* scattered over the site and in 2010 there was a significant increase in ground cover dominated by *Medicago polymorpha, Echium plantagineum* and *Rapistrum rugosum.* In 2009 active sheet erosion was observed across the site with one active rill of concern. In 2010 the rills had become vegetated and appeared to have stabilised. In 2011, there has been a significant increase in perennial plant cover largely due to the native grasses and there were fewer weeds but there were still patches of weeds including *Carthamus lanatus* (Saffron thistle). *Vittadinia* (Fuzzweed) was becoming very abundant. There were echidna scratching at the end of the veg transect. In 2012 and 2013 the site continued to be very dry. In 2014 there were large patches of *Carthamus lanatus* and native grasses appeared to be more abundant. The large patch of *Vicia* had mostly died back. The ground cover was low due to grazing by macropods and drier conditions but the site retained good ground cover, however there were numerous small bare patches throughout. In 2017, the site was heavily grazed by macropods but good ground cover was retained. There were scattered native grass tussocks and large stones. Saffron Thistles had become more abundant.				
					

Site	Photo 2009	Photo 2011	Photo 2013	Photo 2014	Photo 2017
E26-02	Native grassland. Western facing slope of a topsoil stockpile. The site contained a mixture of pasture species but was dominated by Oats. Paterson's Curse was dominant in the upper part of the slope. There were pockets of Rumex crispus (Curled Dock) and Cirsium vulgare (Spear Thistle) which were stunted. The site was expose to some macropod grazing but there was a good build up of litter with the site having good ground cover and was stable.				
					
	Original grassland rehabilitation site at E26 that was no longer readily accessible.				
E27-01	E27-01: Native grassland. Rehabilitation area located on the western side of the E27 open cut waste rock emplacement. The site had generally good ground cover with scattered native perennial grasses and scattered establishment of *Maireana brevifolia* (Yanga Bush), *Senna artemisioides* (Silver Cassia) and *Acacia brachystachya* (Umbrella Mulga). In 2009, there was little green growth with all the annual species being dead. In 2010, there was a significant increase in cover provided a range of annual plants especially *Vicia villosa* and *Medicago polymorpha* which may have compromised the floristic diversity of the site (it was particularly difficult to detect plants beneath the dense cover of *Vicia* and *Medicago*). Well used Kangaroo camps exist under the larger shrubs within the site. In 2011 there was significant reduction in the abundance of exotic annuals (especially Vicia and Medicago) and there has been an increase in native perennial plant cover. Kangaroo camps continue to exist under the larger shrubs within the site. In 2012 and 2013 the site continued to be very dry. In 2014 Vicia had become significantly abundant with most of the plants dead. Macropods kept the ground covers short and the bare camps were maintained beneath the larger shrubs. In 2017 the site was dominated by Oats and *Bromus diandrus* (Giant Brome) with macropods keeping the grasses short and stunted. The Senna's were healthy with many bearing pods, but some of the larger individuals had died or had broken branches. Macropod camps persist under the mature acacia.				
					

8.3 Landscape Function Analyses

8.3.1 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 grassland reference sites were dominated by a moderately dense sward of annual grasses and dead leaf litter and contained a sparse to moderate density of native perennial grass tussocks and scattered forbs. The three grassland reference sites were very stable communities and continued to be characterised as functional "grassland" patches which subsequently resulted in a Landscape Organisation Index (LOI) of 100% (Figure 8-1).

The rehabilitation sites typically had high functional patch area and all sites had 100% LOI except TSF2-03 which had 83% LOI this year.

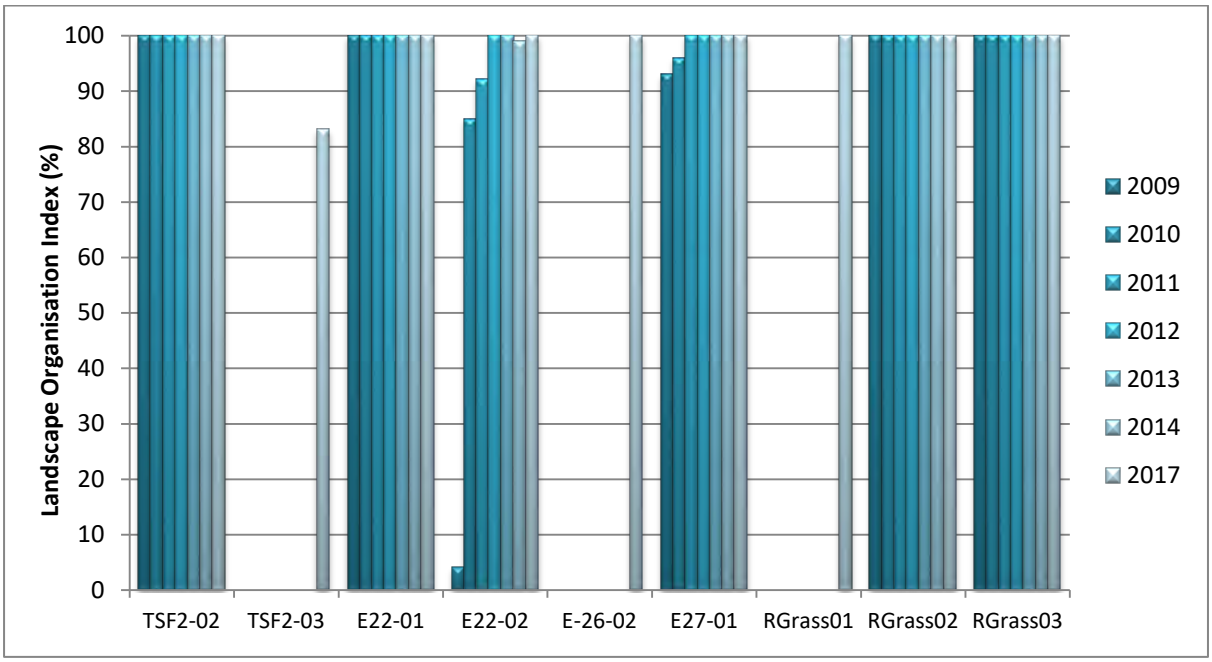


Figure 8-1. Landscape Organisation Indices recorded in the grassland rehabilitation sites compared to the grassland reference sites.

8.3.2 Soil surface assessments

8.3.2.1 Stability

The LFA stability indices in the grassland reference sites typically showed an improvement between 2009 – 2012 due to the improved seasonal conditions after the extended drought and absence of grazing pressure. Dry seasonal conditions since then have typically resulted in a decline in perennial plant cover but this has largely been compensated for by an increase in cryptogam cover and/or increased litter and higher levels of decomposition. This year the grassland reference sites provided a stability range of 67.5 – 78.0 (Figure 8-2).

There has also tended to be similar trends recorded in the grassland rehabilitation sites which have generally continued to show an improvement in stability due to increased litter and cryptogam cover and decomposition, a decline in deposition of sediments and in some sites there appeared to be increased soil coherency. After 2012 the drier conditions usually resulted in a decline in perennial plant covers and a reduction in site stability. This year lower stability was recorded in TSF2-02 and E22-02.

The remaining rehabilitation sites appeared to have improved site stability which was often related to increased litter cover and rates of decomposition as well as a reduction in slaking potential. The reduction in slaking however in TSF2-01 and TSF2-02 was due in part to the exposure of a more stable but very hard setting clay soil which also provided large cracks and increased soil surface roughness. Despite these changes most rehabilitation sites fell within the target range, with the exception of TSF2-03 and E26-02 which had slightly lower stability indices of 67.4 and 67.0 respectively.

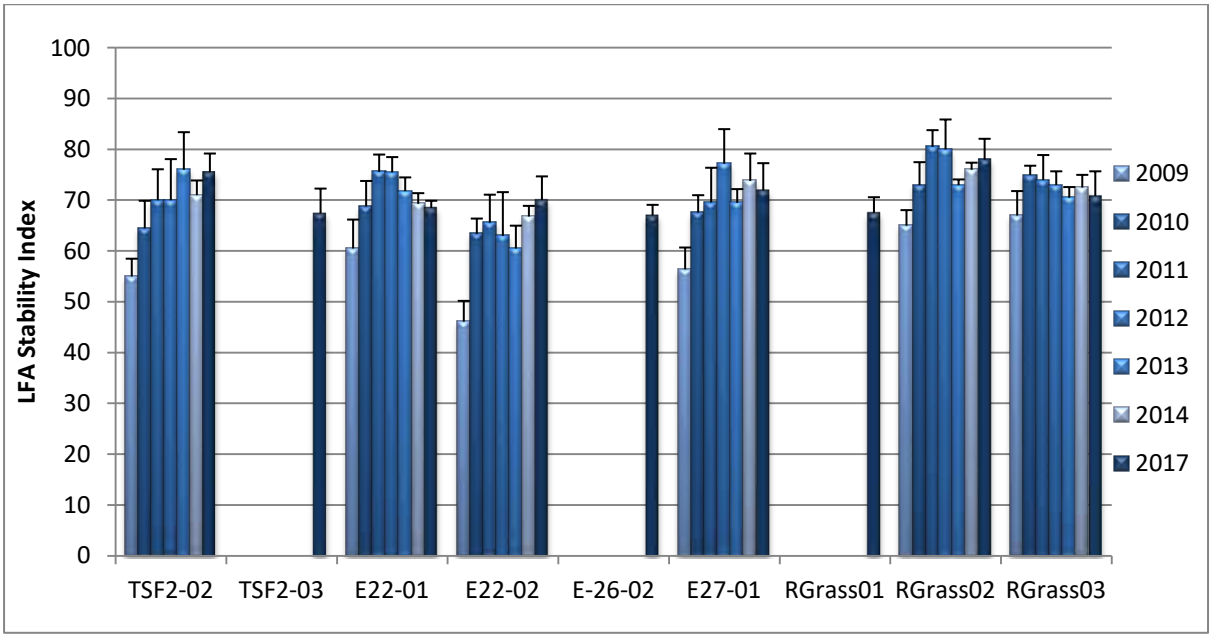


Figure 8-2. LFA stability indices recorded in the grassland rehabilitation monitoring site compared to the grassland reference sites.

8.3.2.2 Infiltration

This year, marginal increases in infiltration capacity were recorded in RGrass02 and RGrass03, largely as a result of increased litter cover and higher rates of decomposition. In the grassland reference sites infiltration capacity ranged from 43.0 – 51.3 (Figure 8-3).

In rehabilitation site E22-01 increased infiltration was also recorded and this site had many ecological attributes similar to those recorded in the reference sites with an infiltration index of 48.9. Sites E26-02 and E27-01 were also similar and with indices of 46.3 and 48.4 respectively also had an ecological infiltration comparable to the local grasslands.

In the remaining rehabilitation sites the litter layers were not as well developed, small bare patches may have persisted and the soils continued to be prone to some slaking. The stability indices in these sites ranged from a low of 36.0 in TSF2-03 to a high of 40.9 in E22-02.

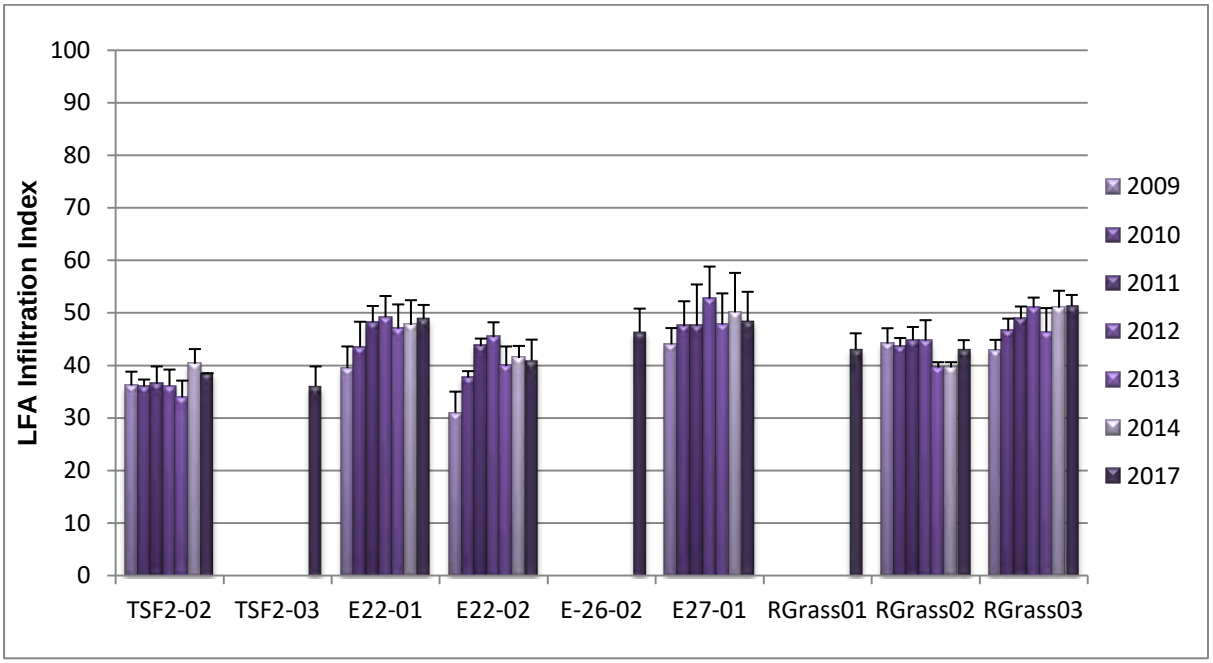


Figure 8-3. LFA infiltration indices recorded in the grassland rehabilitation monitoring site compared to the grassland reference sites.

8.3.2.3 Nutrient recycling

Similar trends in nutrient recycling indices were also recorded this year with the grassland reference sites providing a slightly higher target range of 41.8 – 50.6. Most rehabilitation sites continued to fall within the target range (Figure 8-4). Site E22-02 had a slightly low nutrient recycling capacity compared to the reference sites with an index of 41.3, while site TSF2-03 was presently much lower with and index of 36.0.

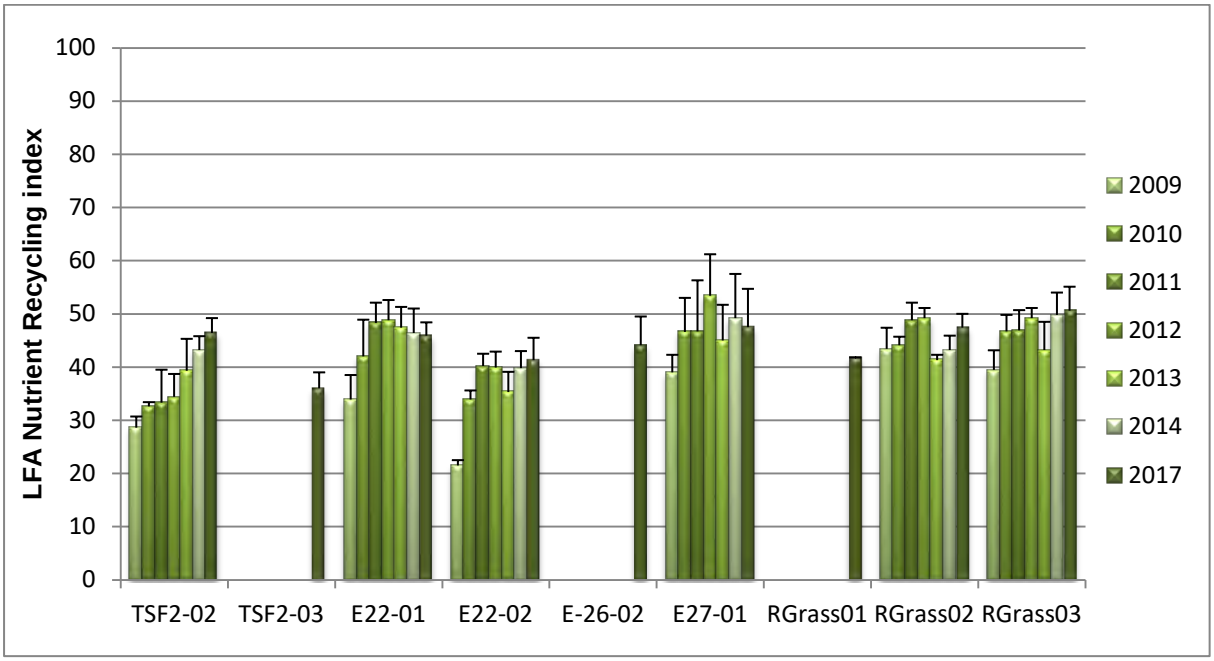


Figure 8-4. LFA nutrient indices recorded in the grassland rehabilitation monitoring site compared to the grassland reference sites.

8.3.3 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 site recorded in 2017 and is provided in Figure 8-5. The grassland reference sites RGrass03 and RGrass02 were the most ecologically functional sites and scored 173 and 168 out of a possible 300 this year. Site E27-01, a rehabilitated pasture site, was equivalent to RGrass02 with a sum of scores equating to 167.8.

Sites E22-01, TSF2-02 and E26-02 had similar total function to each and were more functional than RGrass01 which had a sum of scores of 152. Site E22-02 was equivalent to RGrass01 with a total score of 152. Site TSF2-03, the new rehabilitation sites was the least functional of the rehabilitated grassland communities with a sum of scores of 139.4.

Table 8-3 demonstrates the varying levels of ground covers within the grassland monitoring sites and that active perennial plant growth was minimal this year due to the dry conditions.

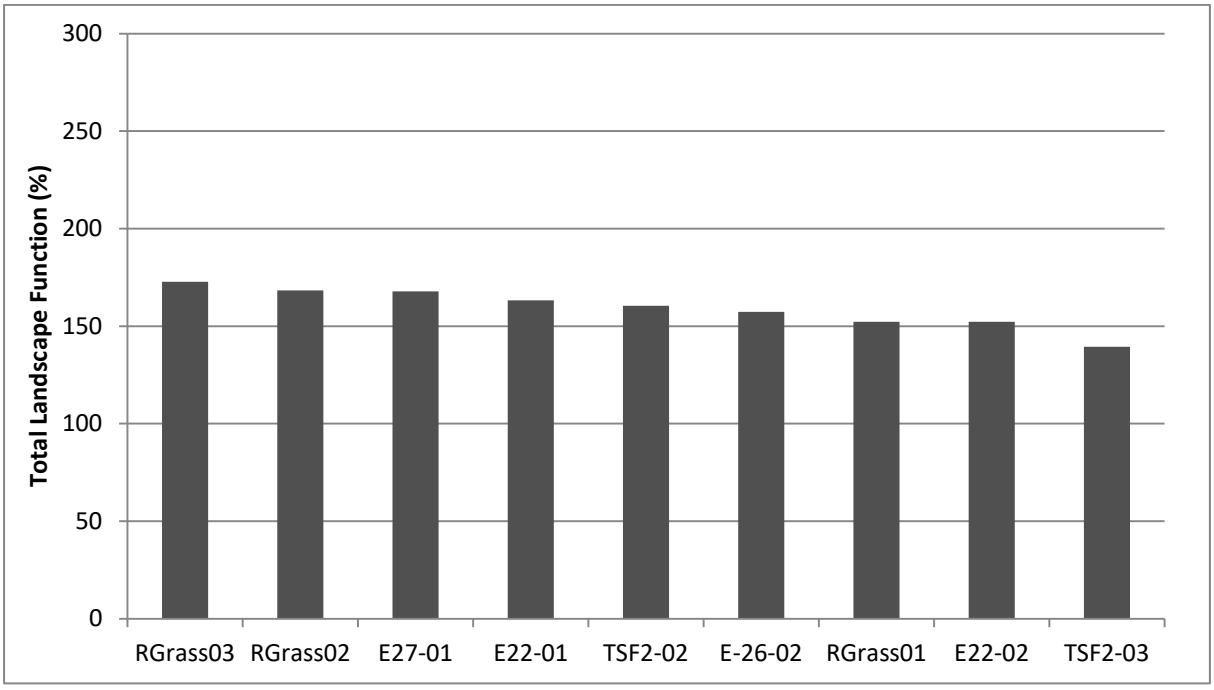


Figure 8-5. Sum of the LFA stability, infiltration and nutrient recycling components indicating the most functional to least functional monitoring site recorded in 2017.

Table 8-3. Ground cover in the grassland monitoring sites in 2017.

TSF2-02	TSF2-03
	

E22-01

E22-02

E26-02

E27-01

RGrass01

RGrass02

RGrass03

8.4 Tree density

One mature *Acacia brachystachya* (Umbrella Mulga) was recorded at E27-01, thought to be the result of an old seeding program. This mature acacia had a dbh of 12 cm and was bearing immature pods. There were no trees and shrubs in the remaining grassland sites.

8.5 Shrubs and juvenile trees

Native grasslands are usually devoid of shrubs and this was the case within the grassland reference sites and therefore all rehabilitation sites met or exceeded target ranges provided by the reference sites (Figure 8-6).

Shrubs have been recorded in low numbers in numerous rehabilitation sites with the shrubs typically being volunteer species establishing from the soil seed bank. This year low densities were recorded in both sites on the TSF2 and in E22-01. In sites E27-01, 173 shrubs and shrub seedlings were recorded this year, with these numbers having significantly increased due to natural regeneration.

All shrubs recorded on the TSF2 rehabilitation areas were young chenopod *Maireana brevifolia* (Yanga Bush). *Maireana brevifolia* individuals were also recorded at E27-01 however most shrubs were *Senna artemisioides,* thought to be the result of an old seeding program.

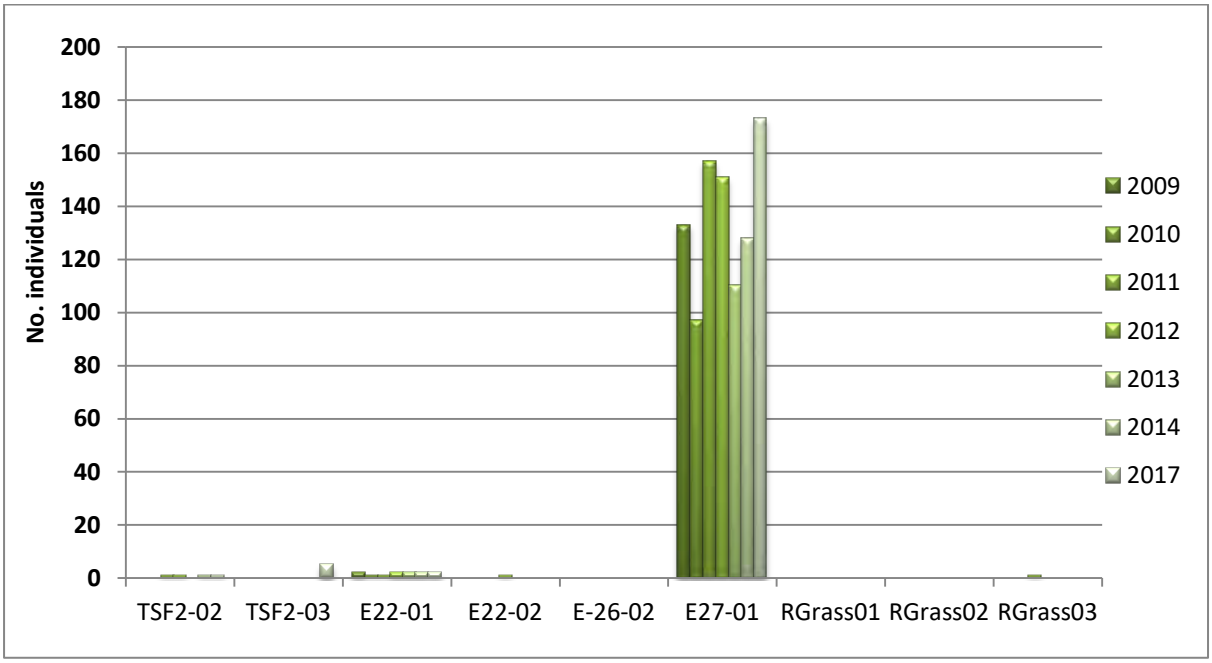


Figure 8-6. Total shrub densities recorded in the rehabilitation sites compared to the grassland reference sites.

8.6 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) continued to be high in the grassland reference sites and this year the resultant total ground cover targets were 97 – 99.50% (Figure 8-7).

In most of the grassland rehabilitation sites total ground cover also continued to be high and all sites had 100% ground cover, with the exception of E27-01. In E27-01, high disturbance by macropods has continued to leave areas of bare ground especially beneath the larger shady shrubs. This year total ground cover had improved but presently it was slightly lower than the reference sites with 95% cover.

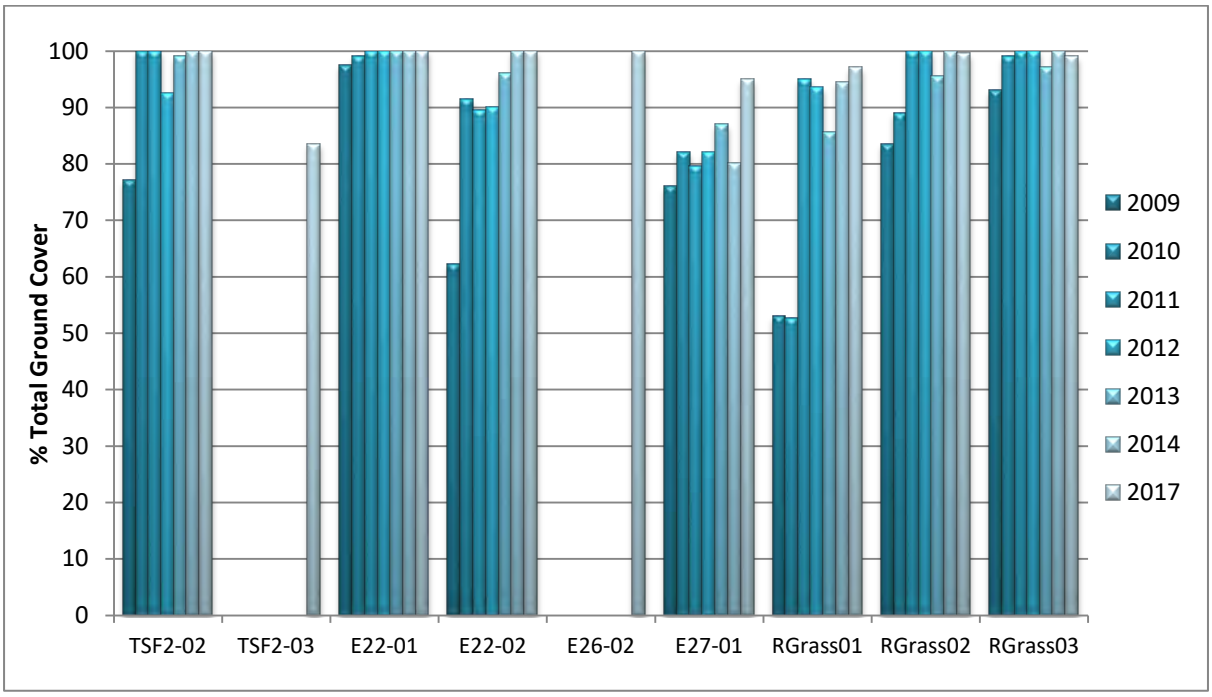


Figure 8-7.Total ground cover recorded in the rehabilitation sites compared to the grassland reference sites.

8.7 Structural composition

The structural composition of the grassland sites is provided in Figure 8-8. In the grassland reference sites, dead leaf litter provided 50 – 68% with this being the most dominant form of ground cover. Perennial plants provided 20.5 – 36.5% while annual plants provided the remaining 10.5 – 15% of the total cover values. There were no cryptogam covers despite some small bare patches, and there were no rocks or logs.

Total ground cover in the rehabilitation sites were also comprised of dead leaf litter and annual and perennial plants. Sites TSF2-02 and TSF2-03 were the only sites to have a perennial plant component similar to the reference with 32% and 22% perennial plant cover respectively. Annual plants were in much higher abundance in E22-01, E26-02 and E27-01 compared to the reference sites. Other habitat features such as rocks or logs were also limited to a small quantity of small scattered rocks in E22-02.

Most of the grasses had been grazed quite low and projected foliage cover >0.5m in height was limited to tall scattered weeds or large grass tussocks in E22-01 and E27-01 and RGrass01. Examples of the different structural composition within the grassland sites are provided in Table 8-4.

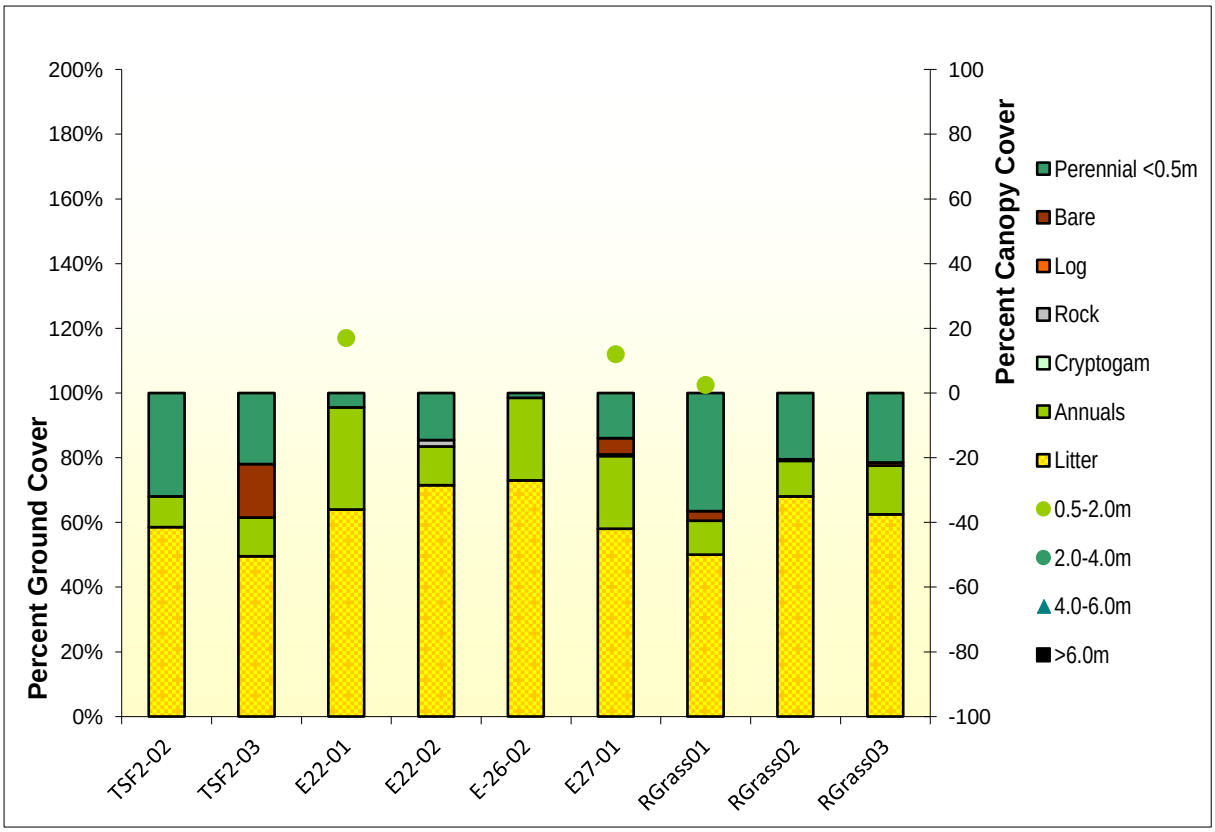


Figure 8-8. Average percent ground cover and projected foliage cover recorded in the grassland monitoring sites in 2017.

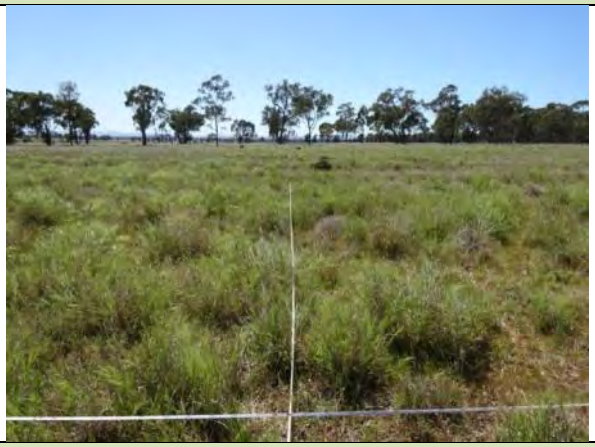
Table 8-4. Examples of the different structure and composition of the grassland monitoring sites.

TSF2-02	TSF2-03
	
E22-01	**E22-02**
	

E26-02

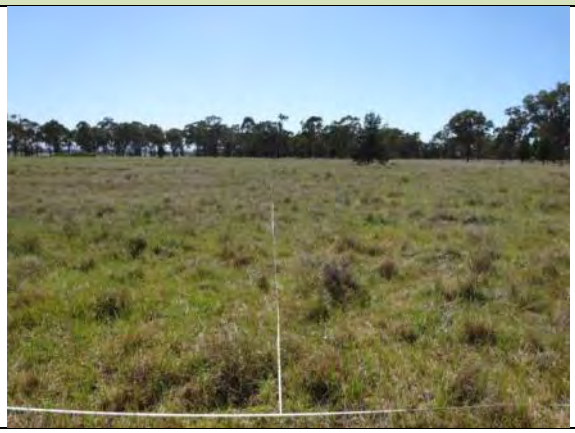
E27-01

RGrass01



RGrass02

RGrass03



8.8 Species Diversity

8.8.1 Total species diversity

Floristic diversity was particularly low in 2009 due to the prolonged drought conditions with a total of 20-29 species recorded in the derived grassland areas. 2010 marked the end of the drought and with above average rainfall, floristic diversity significantly increased. Since then however, extended dry periods have tended to precede the monitoring events and in the reference sites, the diversity of live plants has been somewhat variable (Figure 8-9).

Most rehabilitation sites had more plant diversity than was recorded in 2009 and it appears that total plant diversity is strongly influenced by the fluctuation with seasonal conditions rather than any other

single cause. In 2016 above average rainfall was experienced, however this year prolonged dry conditions have returned, typically resulted in a decline in floristic diversity. In the reference sites there were 33 – 41 different plants and this year site E27-01 had 36 species and therefore had a comparable diversity of species. Of the remaining rehabilitation sites, E26-02 contained the lowest diversity with 19 species, while the highest was recorded in TSF2-02 with 29 species.

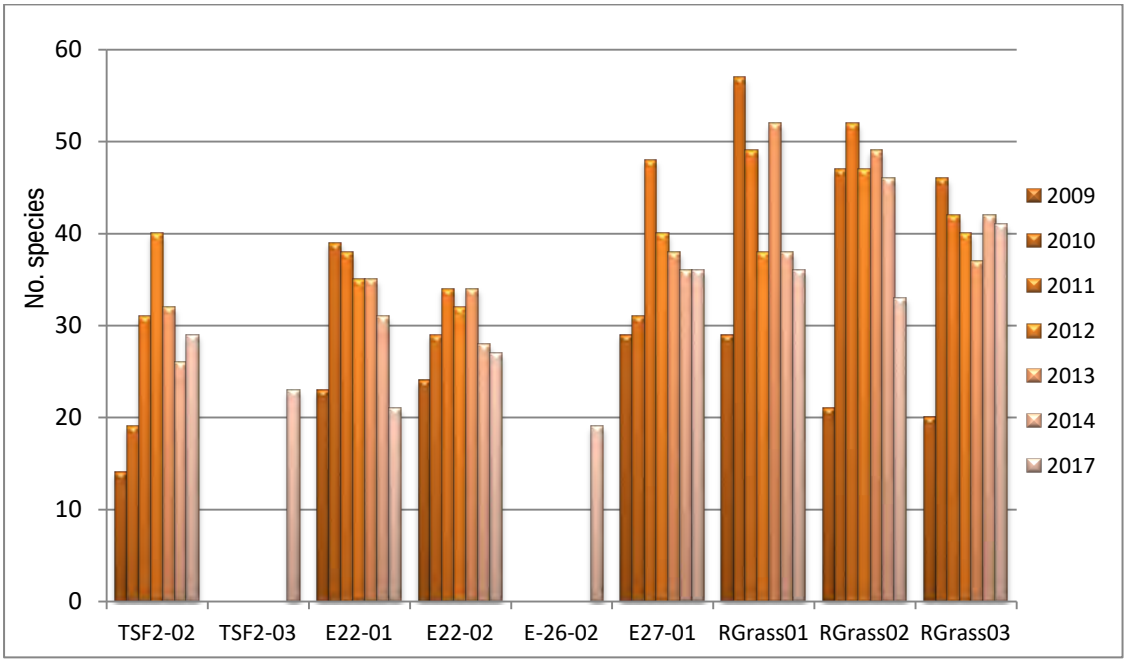


Figure 8-9.Total live plant species recorded the rehabilitation sites compared to the grassland reference sites.

8.8.2 Native species diversity

This year there were 17 – 22 native species recorded in the reference sites (Figure 8-10) with E27-01 having a comparable diversity of natives with 19 species. In the remaining rehabilitation the lowest number of native species was recorded in E26-02 which had five native species, while the highest was recorded in E22-02 with 16 species.

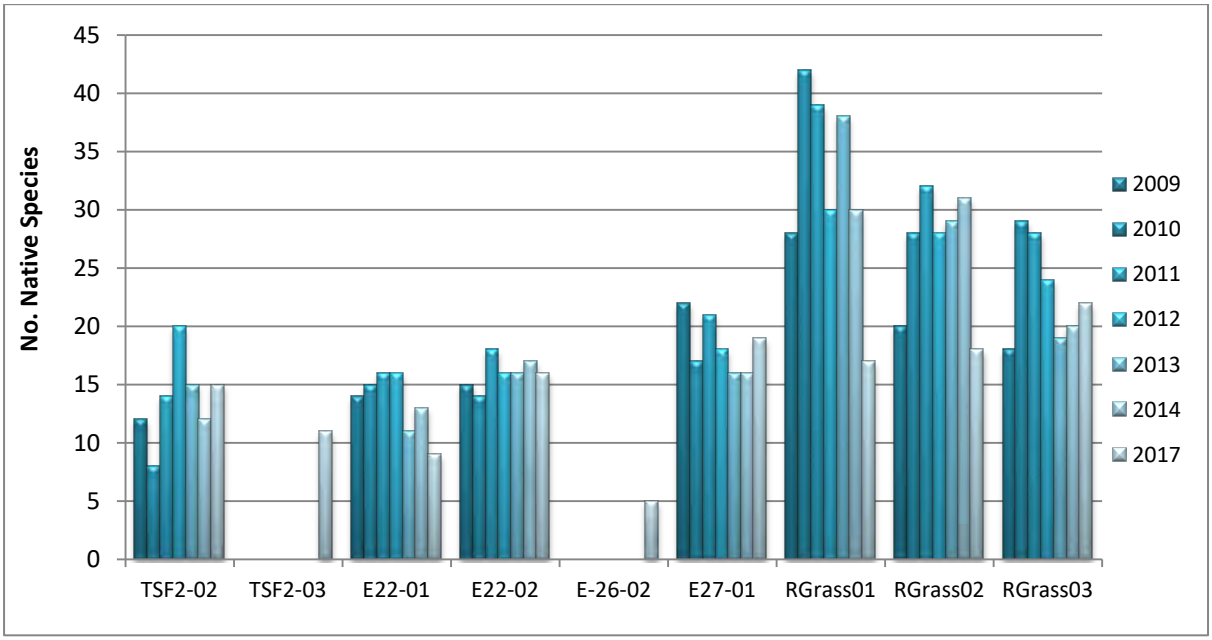


Figure 8-10. Native species recorded the rehabilitation sites compared to the grassland reference sites.

8.8.3 Exotic species diversity

This year there was typically a decreasing number of exotic species in all monitoring sites and in the reference sites there were 15 – 19 different exotic species. This year all rehabilitation sites had less than the maximum desirable level (Figure 8-11). The lowest number of exotic species was recorded in E22-02 which continued to have 11 species, while the highest was recorded in E27-01 with 17 species.

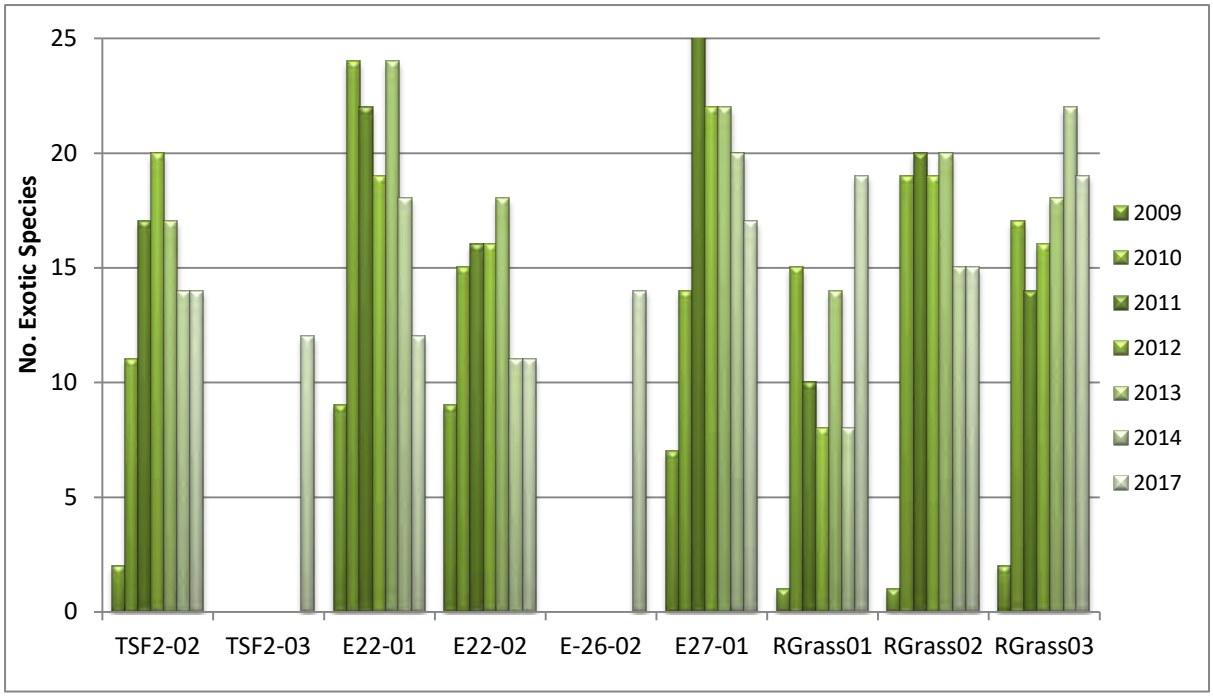


Figure 8-11. Exotic species recorded the rehabilitation sites compared to the grassland reference sites.

8.9 Percent endemic ground cover

The percent endemic ground cover provides some measure of the cover abundance of the native vegetation and a better indication of the extent of exotic plants (which are usually weeds) across the sites. In 2009, the prolonged drought ensured all but the hardiest of species were able to exist and in numerous sites the only live plants were native species thus providing 100% endemic plant cover. The break of the drought resulted in an increase in exotic species, and since then the percent of endemic ground cover has been variable. The percent endemic cover may also be implicated with the extent of grazing pressure especially during drier seasonal, which may have affected some sites more than others.

2017 has been a particularly dry year with less cover of annual and perennial ground covers. The sites most affected by grazing were observed to be E22-02 and E27-01. In the reference sites native plants provided 43 - 48% of the live plant cover and in TSF2-02 there was 53%. In the remaining rehabilitation sites, there was less native plant cover than the reference sites and this year they were weedier than desired.

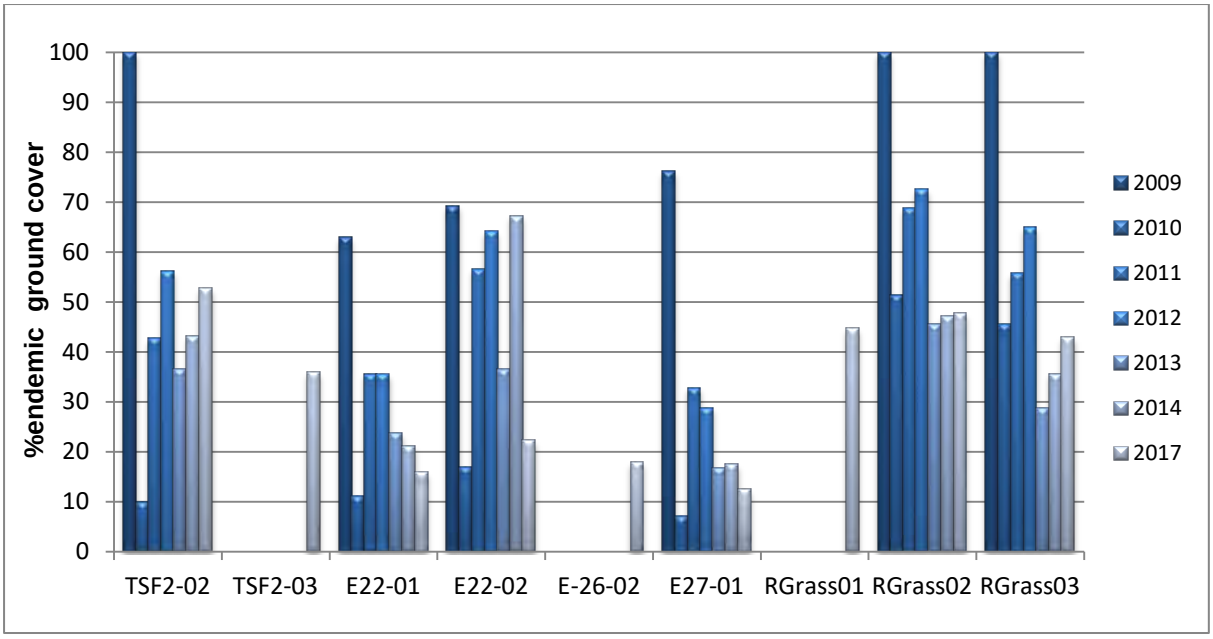


Figure 8-12. Percent endemic ground cover recorded in the grassland monitoring sites.

8.10 Vegetation composition

The composition of the vegetation as categorised by seven different growth forms is given in Figure 8-13. The grassland reference sites were comprised of 21 – 23 different herbs and 7 – 18 grasses. There were up to 2 sub-shrubs and one reed species may have been present. There were no trees, shrubs or ferns.

The rehabilitation sites were also dominated by herbs and grasses with there being an acceptable diversity of herbs and grasses in most cases, except the diversity of grasses was slightly low in E22-01 this year with 6 species. There was an adequate representation on tree, shrubs reeds and ferns compared to the reference but there were no sub-shrubs in E22-02 and E26-02. While no shrubs were present in the reference sites, at least one species of shrub was recorded in all rehabilitation sites except E26-02.

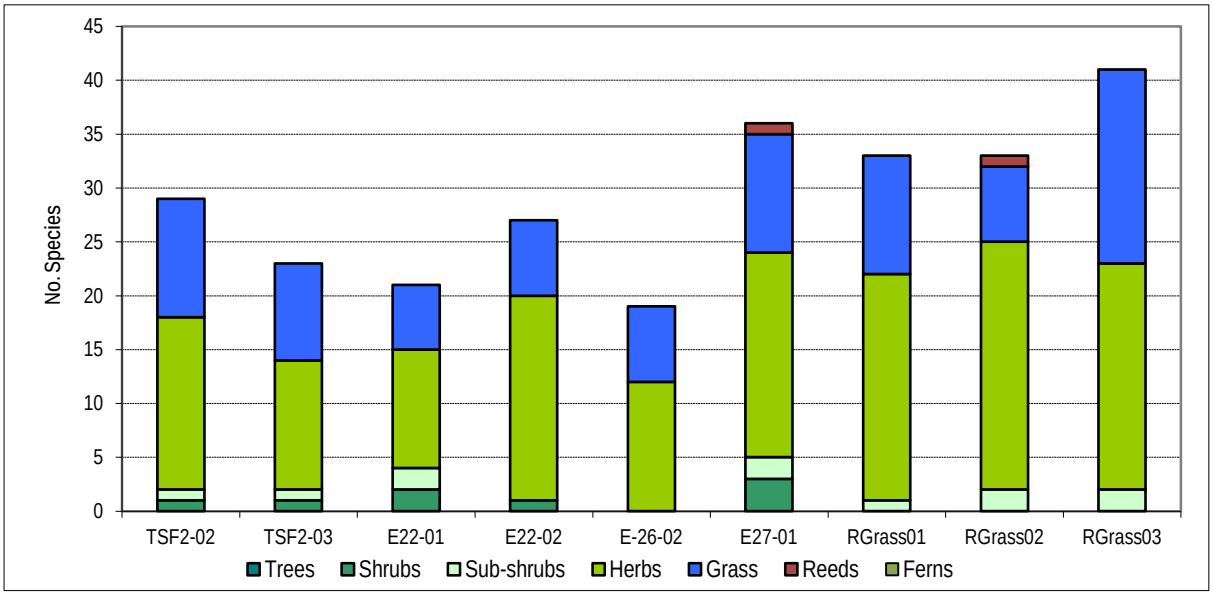


Figure 8-13. Composition of the vegetation recorded at the rehabilitation sites compared to the grassland reference sites in 2017.

8.11 Most common species

The most common species, those that were recorded in at least four of the six monitoring plots in 2017 is given in Table 8-5. Four species were common to all rehabilitation sites and these were exotic annuals *Avena fatua* (Wild Oats), *Lolium rigidum* (Wimmera Ryegrass) and *Sonchus oleraceus* (Milk Thistle) and the native perennial grass *Walwhalleya proluta* (Rigid Panic) and all of these species were recorded in all grassland reference sites.

Other common exotic species included *Echium plantagineum* (Paterson's Curse), *Medicago polymorpha* (Burr Medic), *Rapistrum rugosum* (Turnip Weed), *Vicia villosa* (Vetch), *Bromus diandrus* (Great Brome), *Chloris gayana* (Rhodes Grass), *Cirsium vulgare* (Spear Thistle) and *Rumex crispus* (Curled Dock). Other common native species were *Maireana brevifolia* (Yanga Bush), *Enteropogon acicularis* (Curly Windmill Grass), *Rytidosperma* spp. (Wallaby Grass) and *Vittadinia sulcata* (Fuzzweed). Most, but not all of these common species were also present in the local grasslands.

A comprehensive list of species recorded in all monitoring sites in 2017 has been provided in Appendix 1.

Table 8-5. Species that were recorded in at least four of the six grassland rehabilitation monitoring sites in 2017.

exotic	Scientific Name	Common Name	Habit	TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27-01	Total	RGrass01	RGrass02	RGrass03
*	*Avena fatua*	Wild Oats	g	1	1	1	1	1	1	6	1	1	1
*	*Lolium rigidum*	Wimmera Ryegrass	g	1	1	1	1	1	1	6	1	1	1
*	*Sonchus oleraceus*	Milk Thistle	h	1	1	1	1	1	1	6	1	1	1
	Walwhalleya proluta	Rigid Panic	g	1	1	1	1	1	1	6	1	1	1
*	*Echium plantagineum*	Paterson's Curse	h	1		1	1	1	1	5	1	1	1
	Maireana brevifolia	Yanga Bush	s	1	1	1	1		1	5			
*	*Medicago polymorpha*	Burr Medic	h	1		1	1	1	1	5	1		
*	*Rapistrum rugosum*	Turnip Weed	h	1	1	1	1		1	5			
*	*Vicia villosa*	Vetch	h	1	1	1		1	1	5			
*	*Bromus diandrus*	Great Brome	g	1		1		1	1	4			1
*	*Chloris gayana*	Rhodes Grass	g	1	1			1	1	4			
*	*Cirsium vulgare*	Spear Thistle	h	1	1			1	1	4	1		1
	Enteropogon acicularis	Curly Windmill Grass	g	1			1	1	1	4		1	
*	*Rumex crispus*	Curled Dock	h	1		1		1	1	4			
	Rytidosperma bipartitum	Wallaby Grass	g	1	1		1		1	4			1
	Rytidosperma setaceum	Small-flowered Wallaby Grass	g	1	1	1			1	4	1	1	1
	Vittadinia sulcata	A Fuzzweed	h		1		1	1	1	4			

8.12 Most abundant species

The most abundant species recorded in the grassland 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 7 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.

The most abundant species in the grassland reference sites were the native grasses *Walwhalleya proluta* (Rigid Panic), *Rytidosperma setaceum* (Small-flowered Wallaby Grass) and *Austrostipa nodosa* (Speargrass). Exotic annuals including *Avena fatua* (Wild Oats), *Salvia verbenaca* (Wild Sage) and

Lolium rigidum (Wimmera Ryegrass) were also relatively abundant in one or more of the grassland sites.

The rehabilitation areas on the TSF2 tended to be dominated by a similar composition of species to the grassland reference sites and were dominated by *Walwhalleya proluta,* with lower abundances of *Lolium rigidum.* In TSF2-02, *Medicago polymorpha* (Burr Medic) was also a dominant species, but cover values were relatively low. E22-01 and E26-02 were dominated by *Avena fatua,* while *E22-02* was dominated by *Carthamus lanatus* (Saffron Thistle) and low abundances of *Walwhalleya proluta.* E27-01 was dominated by *Avena fatua* and *Lolium rigidum.*

Table 8-6. The most abundant species recorded in the grassland monitoring sites in 2017.

exotic	Scientific Name	Common Name	Habit	TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27-01	RGrass01	RGrass02	RGrass03
*	*Lolium rigidum*	Wimmera Ryegrass	g	8	8				7		9	
*	*Medicago polymorpha*	Burr Medic	h	10								
	Walwhalleya proluta	Rigid Panic	g	19	17		7			17	7	
*	*Medicago minima*	Small Woolly Burr Medic	h		11							
*	*Trifolium angustifolium*	Narrow-leaf Clover	h		8							
*	*Avena fatua*	Wild Oats	g			20		15	8	7		11
*	*Carthamus lanatus*	Saffron Thistle	h				11					
*	*Salvia verbenaca*	Wild Sage	h							12		
	Rytidosperma setaceum	Small-flowered Wallaby Grass	g								13	
	Austrostipa nodosa	Speargrass	g									8

8.13 Rill assessment

A rill assessment was undertaken despite most rills being much smaller (< 30cm in width or depth) than warranted to be recorded as prescribed by Nichols (2005). To identify potential rills of concern we have selected the dimensions of 10cm x 30cm (0.03m^2) as the minimum value of concern.

One rill had previously been recorded in E22-02 however by 2014 the rill had become sufficiently established with vegetation and was considered to be stable. No other rills were recorded in the grassland rehabilitation monitoring sites.

8.14 Soil analyses

8.14.1 pH

Figure 8-14 shows the pH recorded in the grassland rehabilitation sites compared to the upper and lower pH values recorded in the grassland reference sites and prescribed “desirable” levels in medium soils. There have only been marginal changes in soil pH since monitoring began and this year pH in the grassland reference sites ranged from 6.5 – 7.7 ranging from slightly acidic to slightly alkaline (Bruce and Rayment 1982).

Soil pH recorded in the grassland rehabilitation sites TSF2-01, E22-01, E26-02 and E27-01 was comparable to the grassland reference sites. In sites TSF2-03 and E22-02 soil pH was slightly high and with pHs of 8.2 and 7.8 were slightly to moderately alkaline and exceeded desirable agricultural levels.

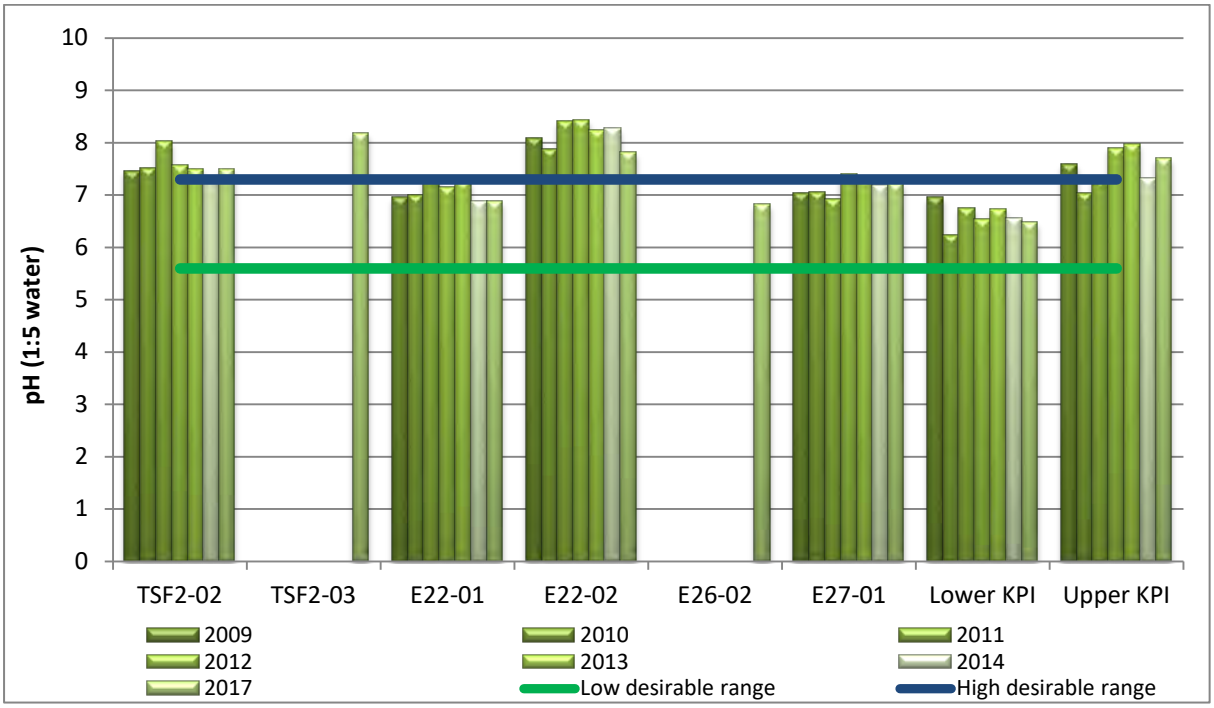


Figure 8-14. Soil pH recorded in the grassland rehabilitation sites compared to the grassland reference sites and desirable agricultural levels.

8.14.2 Conductivity

Figure 8-15 shows the Electrical Conductivity (EC) recorded in the grassland rehabilitation sites, the lower and upper levels recorded in the grassland reference sites as well as desirable agricultural level. This year EC levels in the grassland reference sites ranged from 0.050– 0.242 dS/m. The upper EC target continued to exceed the desirable agricultural levels and with an EC of 0.242 dS/m can be classed as slightly saline (Slavich and Petterson 1993).

In the grassland rehabilitation sites, EC has tended to demonstrate a declining trend in most cases. This year, EC in the grassland rehabilitation sites was comparable to the local grasslands in all sites. In TSF2-03 however EC slightly exceeded the desirable agricultural threshold with an EC of 0.173 dS/m but remained non saline (Slavich and Petterson 1993).

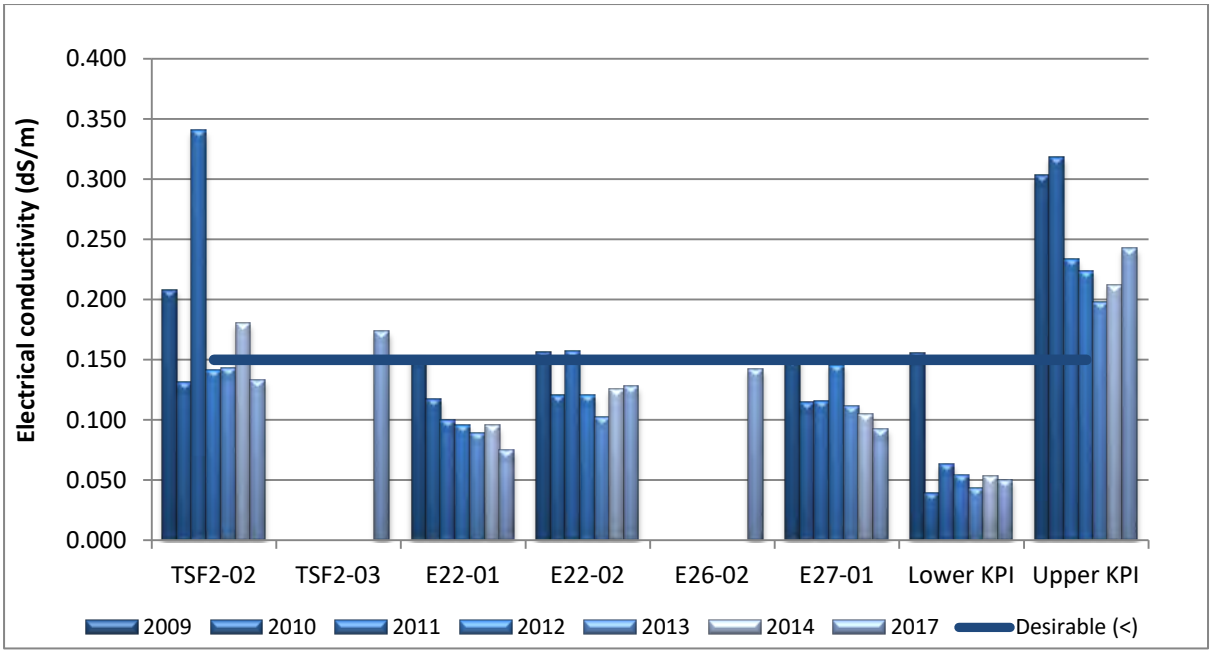


Figure 8-15. Electrical Conductivity recorded in the rehabilitation sites compared to the grassland reference sites and desirable levels.

8.14.3 Organic Matter

Organic Matter (%) recorded in the grassland monitoring sites demonstrated an increase in all sites this year, with 3.0 – 5.4% OM being recorded in the grassland reference sites and close to or slightly higher than desirable agricultural level (Figure 8-16). OM in rehabilitation sites E22-01 and E27-01 were comparable with the local grasslands with OM of 4.7% and 3.1%. OM was lower than the local grasslands in TSF2-02, TSF2-03, E22-02 and E26-02 with these ranging from 0.6 mg/kg (TSF2-03) to 2.8 mg/kg (E26-02).

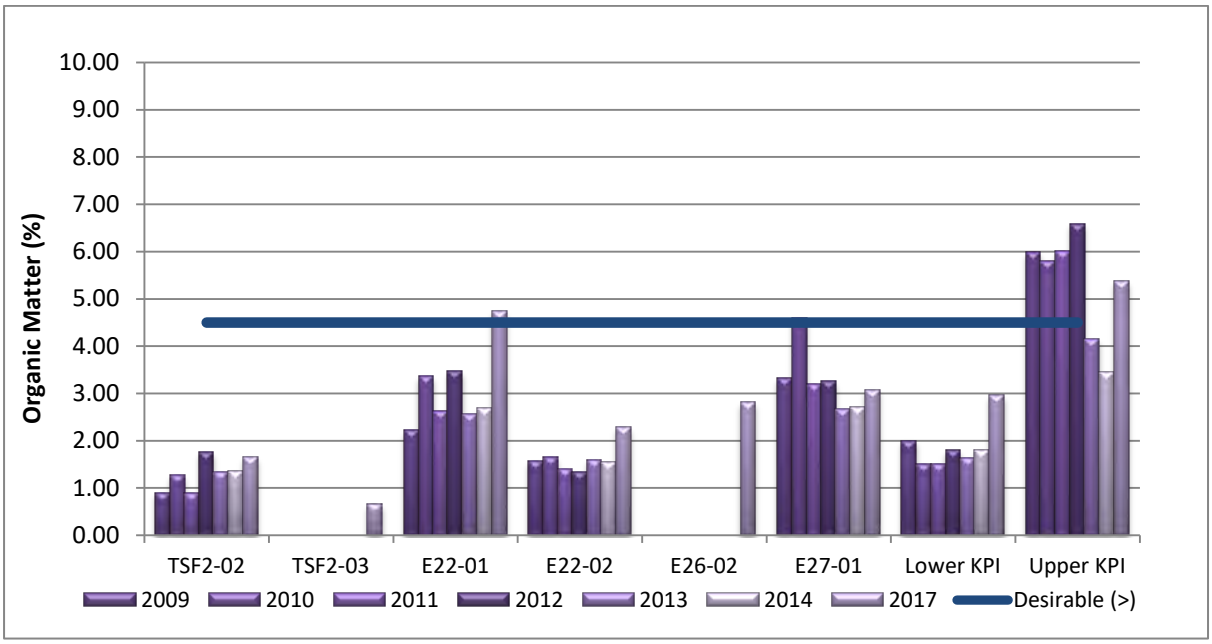


Figure 8-16. Organic Matter concentrations recorded in the rehabilitation sites compared to grassland reference sites and desirable agricultural levels.

8.14.4 Phosphorous

Phosphorous levels in the grassland reference sites continued to be significantly lower than the prescribed desirable level despite a slight increase this year, with the P target being 20 - 24 mg/kg (Figure 8-17). In the rehabilitation sites all sites also demonstrated an increase in P this year. In all rehabilitation sites P was comparable to the local grasslands or within desirable agricultural levels and ranged from 16 – 47 mg/kg.

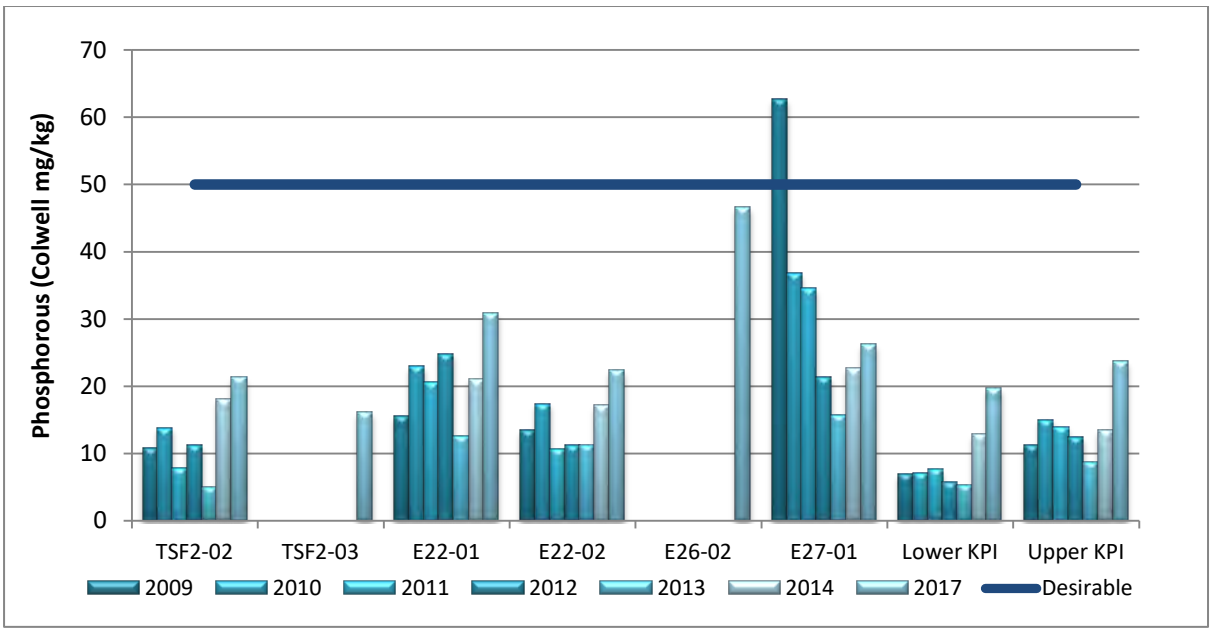


Figure 8-17. Phosphorous concentrations recorded in the rehabilitation sites compared to the grassland reference sites and desirable agricultural levels.

8.14.5 Nitrate

Nitrate levels in the reference sites have been highly variable, however over the last few years these have continued to be significantly lower than the prescribed desirable level. In the reference sites N ranged from 2.5 – 4.1 mg/kg and all rehabilitation sites fell within this range or within desirable levels, except in TSF2-03 which had low N of 0.7 mg/kg (Figure 8-18).

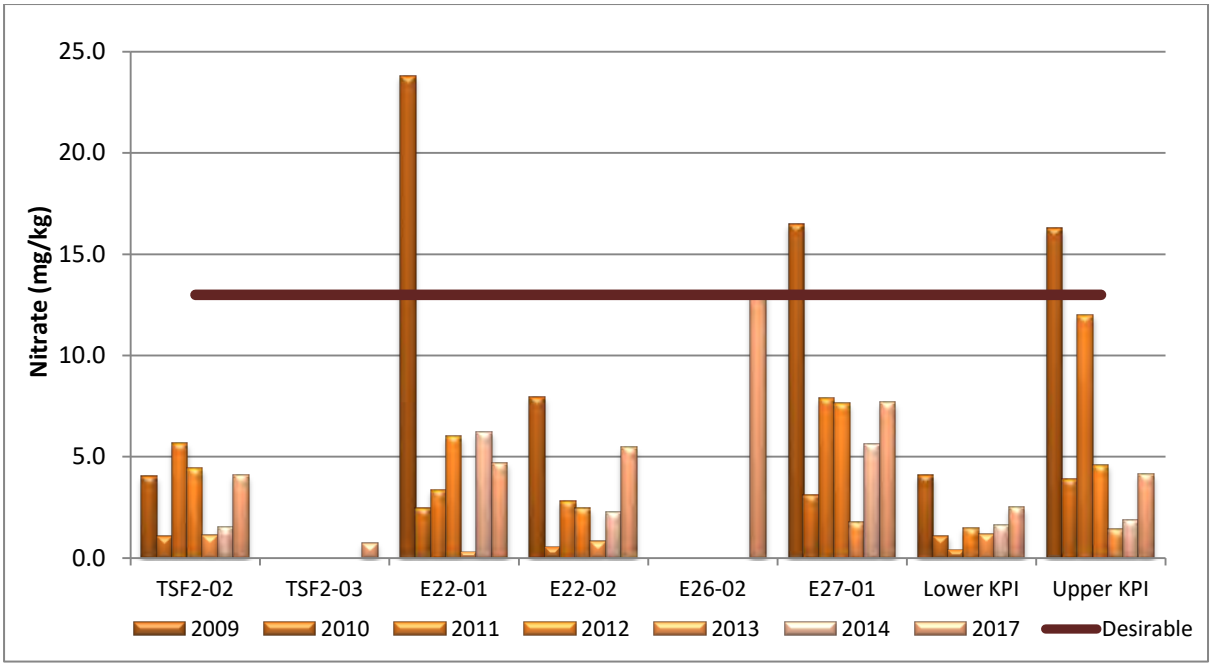


Figure 8-18. Nitrate concentrations recorded in the rehabilitation sites compared to the grassland reference sites and desirable agricultural levels.

8.14.6 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. The range of CEC recorded in the grassland reference sites has increased this year to provide a CEC target of 19.2 – 62.1 and these continued to be well above the desirable level indicating the soils are likely to have a high soil retention capacity (Figure 8-19). This year CEC also demonstrated a slight increase across the rehabilitation sites with all rehabilitation sites having high CEC and comparable to the local grassland communities.

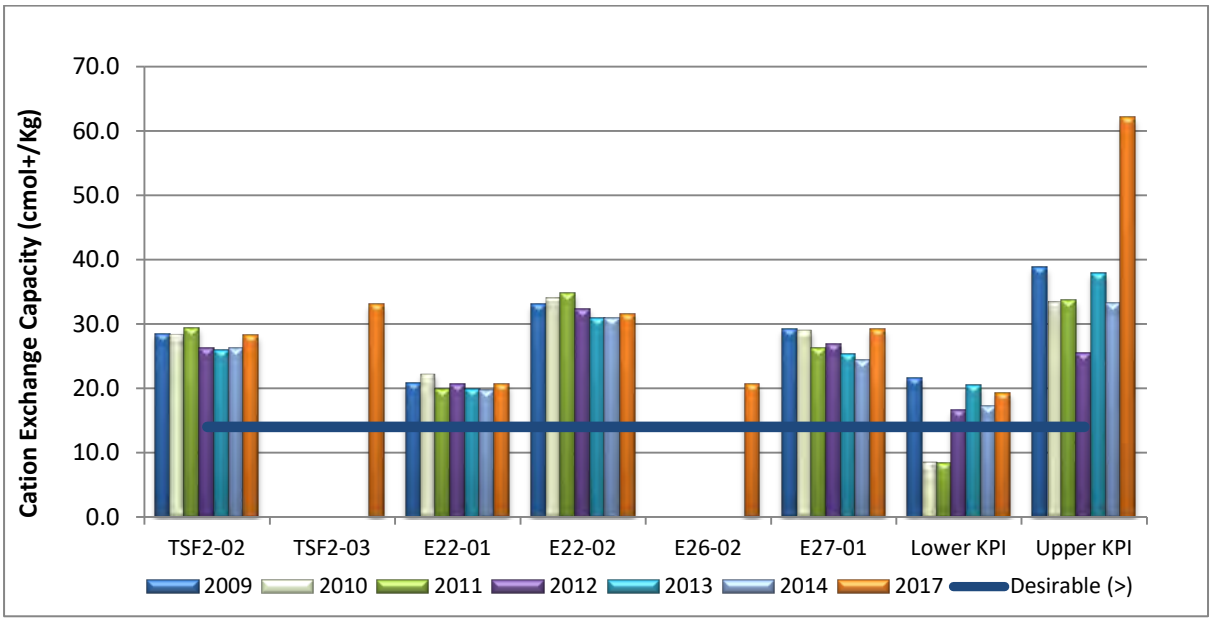


Figure 8-19. Cation Exchange Capacity recorded in the rehabilitation sites compared to the grassland reference sites and desirable agricultural levels.

8.14.7 Exchangeable Sodium Percentage

Sodicity refers to a significant proportion of sodium in 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 reference sites has been highly variable over the years and has fluctuated above and below the 5% threshold of sodicity as a result of the high sodium levels. This year the ESP range had decreased providing a target range of 0.3 – 3.5% (Figure 8-20) with these soils being classed as non sodic (Isbell 1996). ESP recorded in the grassland rehabilitation sites has also been variable but both sites on TSF2 have elevated ESP's of 6.6% and 5.7% and are sodic. In the remaining rehabilitation areas ESP ranged from 0.5% in E22-02 to a high of 2.7% in E26-02 with ESP being below the sodic threshold.

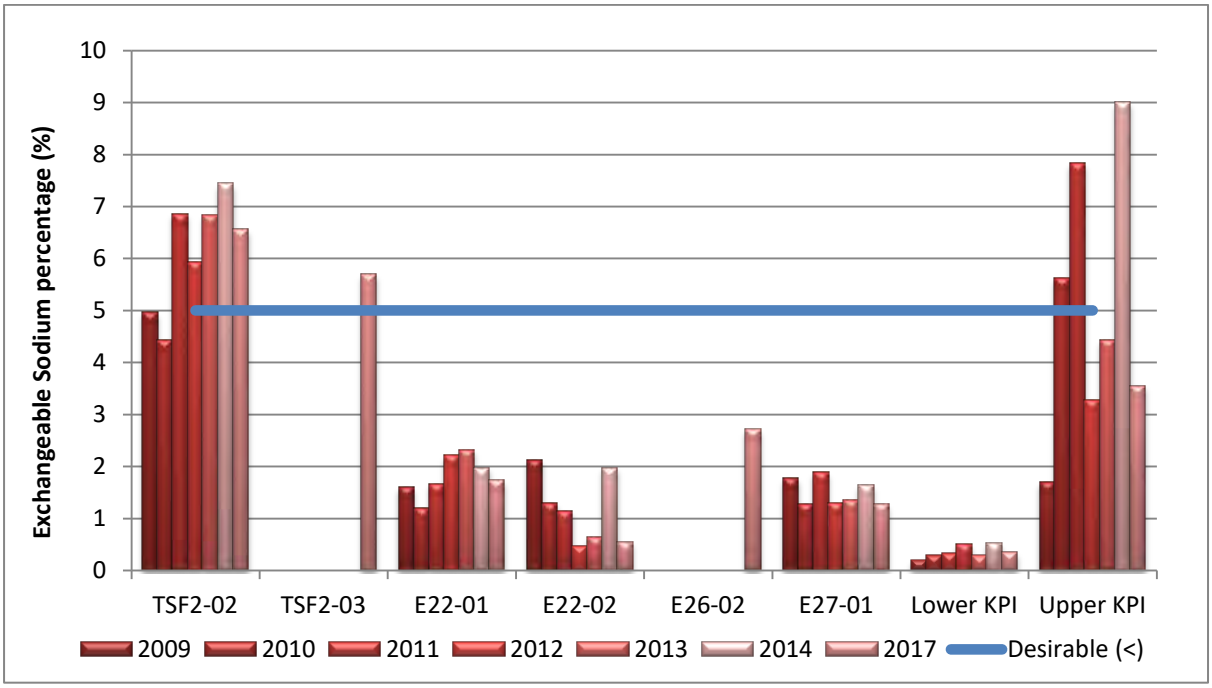


Figure 8-20. ESP recorded in the rehabilitation sites compared to the grassland reference sites and desirable agricultural levels.

8.14.8 Other soil test results

The full results of the soil analysis are provided in Appendix 4. A summarised version highlighting abnormal results in the grassland monitoring sites is provided below in Table 8-7. The results indicate there are numerous elements which occur at elevated levels in the rehabilitation sites, however some such as manganese, iron and copper were also found to be slightly elevated within the grassland reference sites, indicating that various elements occur at naturally higher levels within soils surrounding the Northparkes Mine which may be implicated with landscape clearing, as well as a long agricultural and mining history.

There were however elevated levels of sulfur in both rehabilitation sites on TSF2 and copper concentrations were significantly high in E22-01, E22-02 and E27-01.

Table 8-7. Summarised soil analyses highlighting abnormal test results in the grassland monitoring sites in 2017.

Method		*Nutrient*		*Units*	TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27	RGrass01	RGrass02	RGrass03	*Indicative guidelines only*
	Morgan 1	Calcium	Ca	mg/kg	894	1201	833	1989	1001	1113	5855	747	4095	*750*
		Magnesium	Mg		661	721	403	654	467	704	738	463	475	*105*
		Potassium	K		101	58	248	221	237	135	171	91	265	*75*
	KCl	Sulfur	S	mg/kg	20.1	22.6	5.9	3.6	7.6	8.9	3.8	6.3	5.1	*8.0*
	DTPA	Manganese	Mn	mg/kg	11	5	29	10	44	27	16	42	37	*22*
		Iron	Fe		18	18	19	13	32	31	25	92	34	*22*
		Copper	Cu		4.8	4.3	19.0	17.0	9.6	39.7	4.0	3.5	4.6	*2.0*
	$CaCl_2$	Silicon	Si	mg/kg	77	53	72	42	76	57	26	80	39	*45*
	Total Acid Extractable	Copper	Cu	mg/kg	40.8	37.7	180.1	258.6	95.4	452.4	44.7	21.5	49.9	*20 - 50 Cu*
	Total Acid Extractable	Chromium	Cr	mg/kg	20	23	25	18	33	23	34	20	40	*<25 Cr*

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

8.15 Grassland rehabilitation site performance towards meeting completion criteria targets

Table 8-8 indicates the performance of the grassland rehabilitation monitoring site against a selection of proposed Primary Completion and Secondary Performance Indicators obtained for grassland sites during the 2017 monitoring period. The selection of indicators have been presented in order of ecosystem successional processes, beginning with landform establishment (orange) and ending with indicators of ecosystem stability (blue) as per the ESG3 Guidelines. The range values are amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have been identified with a shaded colour box and are therefore deemed to have met the respective ecological target. 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 2017. 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 targets using the adopted methodology.

Table 8-8. Performance of the grassland rehabilitation monitoring site against a selection of proposed Primary Completion and Secondary Performance Indicators in 2017.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2017		TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27-01
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2017	2017	2017	2017	2017	2017
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	13	13	14	12	15	15
	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
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)	6.5	7.7	7.5	8.2	6.9	7.8	6.8	7.2
			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)	3.0	5.4	1.7	0.6	4.7	2.3	2.8	3.1
			Phosphorous	Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (50)	19.7	23.6	21.3	16.1	30.8	22.3	46.6	26.2
Phase 4: Ecosystem & Landuse Establishment	Landscape Function Analysis (LFA): Landform	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		%	67.5	78.0	75.5	67.4	68.5	70.0	67.0	71.9

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2017		TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27-01
	stability and organisation		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	83	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	0	0	1	1	2	0	0	2
					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	0	0	100	100	100	0	0	100
			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	15	19	14	12	12	11	14	17
	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	0	0	1	1	2	0	0	173
	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	0	0	0	0	0	0	0	0
			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	0	1	1	2	1	0	3
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	21	23	16	12	11	19	12	19
			Grasses	The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	7	18	11	9	6	7	7	11
			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	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	Grassland ecosystem range 2017		TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27-01
			Ferns		The number of ferns comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0	0
			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
			Parasite		The number of parasite species comprising the vegetation community is comparable to that of the local remnant vegetation		0	0	0	0	0	0	0	0
Phase 5: Ecosystem & Landuse Sustainability	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		%	43.0	51.3	38.5	36	48.9	40.9	46.3	48.4
			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		%	41.8	50.6	46.4	36	45.9	41.3	44.1	47.5
	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	%	50	68	58.5	49.5	64	71.5	73	58
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	11	15	9.5	12	31.5	12	25.5	22.5
			Cryptogam cover		Percent ground cover provided by cryptogams (e.g mosses, lichens) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0	0
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	2	0	0.5
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	1	3	0	16.5	0	0	0	5

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2017		TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27-01
			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		%	21	37	32	22	4.5	14.5	1.5	14.0
			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	100	100	83.5	100	100	100	95
	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	2	3	2	1.6	0.6	1.2	0.4	0.2
			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 vegetation	< species/m^2	4	5	3.2	4.2	2	3.8	2.2	2.4
	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		%	43	48	52.8	35.9	15.8	22.2	17.9	12.5
	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	0	0	1	1	1	0	0	38
			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	0	0	3	0	0	0	79
			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	0	1	0	0	0	43

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators Description	Secondary Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2017		TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27-01
			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	13
			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	0	0	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 0.5 – 2.0m vertical Height stratum indicates the community Structure is comparable to that of the Local remnant vegetation	% cover	0	2.5	0	0	17	0	0	12
			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	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	0	0	0	0	0	0	0	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	0	0	0	0	0	0	0	0
	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	0	0	0	0	0	0	0	1
					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	%	0	0	0	0	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	Grassland ecosystem range 2017		TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27-01
	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	0	0	0	0	0	0	0	1
			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	0	0	0	0	0	0	0	12
	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	0	0	0	0	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	0	0	0	0	0	0	0	100
			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	0	0	0	0	0	0	0	0
			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	0	0	0	0	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	0	0	0	0	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
			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	0	0	0	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	Grassland ecosystem range 2017		TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27-01
			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		0	0	0	0	0	0	0	0

9 Species of interest

9.1 Priority weeds

No priority weeds listed for the Central West LLS were recorded in the range of monitoring sites in 2017.

9.2 Environmental weeds

Exotic perennial grasses may be useful for erosion control and livestock fodder however in most cases they become very dominant and are capable of forming single species stands. Many species are recognised as environmental weeds with more than a hundred species occurring in NSW. The listing of "Invasion of native plant communities by exotic perennial grasses" as a key threatening process has been made in recognition of the increasing evidence that some perennial grass species have significant adverse impacts on biodiversity (http://www.environment.nsw.gov.au/threatenedSpeciesApp/profile.aspx?id=20018).

When exotic perennial grasses become mature they often exist as tall dead rank tussocks which are not preferentially eaten and can become significant fire risks. For these reasons, it would be best to avoid sowing species such as these in rehabilitation areas, particularly when more suitable alternatives are available. Species often used for erosion control or pasture crops which can become environmental weeds include *Phalaris aquatica* (Phalaris), *Eragrostis curvula* (African Lovegrass), *Cenchrus ciliaris* (Buffel Grass), *Pennisetum clandestinum* (Kikuyu) and *Chloris gayana* (Rhodes Grass). These species should be avoided in any future rehabilitation program.

At NPM *Chloris gayana* (Rhodes Grass) was recorded in TSF2-2, TSF2-03, E26-02 and E27-01.

9.3 Threatened species

No threatened species were recorded within the range of monitoring sites in 2017.

10 Recommendations and management actions

The results of the 2017 monitoring program have been summarised in Table 10-1 which aims to identify any shortfalls associated with the individual rehabilitation areas and provide some management recommendations that will assist in improving long-term rehabilitation outcomes to ensure completion targets will be met.

Table 10-1. Sites summary and management recommendation

Site	Site summary and issues associated with long-term management outcomes	Management requirements	Priority
Rehabilitated Mining areas			
All new mining rehabilitation areas	Unsuitable spoil characteristics which may affect plant establishment and site development	The use of suitable topsoil material in rehabilitation areas should be a priority management action which should involve adhering to stockpiling protocols and testing of soil stockpiles and spoil material prior to use in rehabilitation. Suitable topsoil material should contain similar physical and chemical attributes as those within the woodland and/or grassland reference sites or within desirable levels prescribed by the agricultural industry.	High
	Increase physical patch area of newly established rehabilitation areas and reduce soil sodicity if required.	Create a sequence of troughs and banks to increase the "patch" of the slope and to act as a temporary but physical erosion prevention measure until the vegetation can become established. The troughs and banks can be created by cross ripping using a dozer with three tynes to 600mm, after gypsum is spread over the prepared topsoil at the appropriate rate if required. Any rocks brought to the surface will provide additional erosion protection and micro-sites for plant establishment	High
	Provide immediate soil surface protection and increased diversity of native ground cover species	New mining rehabilitation areas should be treated with a sterile cover crop and an application of native pasture hay containing mature seeds where possible. These methods will improve rehabilitation outcomes, accelerate ecosystem recovery and assist in meeting many ecological completion targets, including those associated with native ground cover diversity. Management of local native pastures for the purpose of native grass harvesting could be a cost effective management strategy	High
Woodland rehabilitation sites			
Future woodland revegetation sites	Retain existing ecological integrity of native grasslands or recovering cropping paddocks and enhance revegetation objectives. Grading and blanket spraying can severely compromise the integrity of otherwise intact and functional ecosystems with increased risks of further degradation such as erosion, weed invasion and unbeneficial substrate characteristics.	Future revegetation (tree planting) projects should aim to limit ground disturbances especially in areas of native grassland to retain relatively high levels of ecological function, diversity and composition of the existing native ecosystems. Rather deep ripping and strip spraying in narrow rows (~1m wide) prior to tubestock planting will more rapidly achieve ecological outcomes and completion targets.	High

Site	Site summary and issues associated with long-term management outcomes	Management requirements	Priority
LFO-01	A woodland offset area planted in 2009 with a long cropping history. This site has shown a significant transformation since 2009 with the bare inter-rows now well colonised with annual and perennial vegetation and cryptogams and litter cover was high. This year LFA Landscape Organisation, stability and infiltration targets were met but nutrient recycling fell short of meeting targets. There was an appropriate diversity of shrubs and juvenile trees but the densities were too low. This year there was an appropriate diversity and density of mature trees and shrubs (>5cm dbh). The site was low in total and native species diversity and there was a high diversity of exotic species. The site was dominated by exotic plants and was more weedy than desired. While there was good total ground cover, the site and lacked suitable proportions of perennial ground cover. The soils were characteristically similar to the local woodlands but had low OM and CEC and were high in P.	Limit site disturbances (such as spraying and grading) and allow the colonising vegetation to become well established. The site weediness is expected to decline as more desirable perennial species become more dominant. Continue to monitor macropod predation. Additional planting may be required in the absence of natural recruitment to increase shrub densities.	Low
LFO-02	A woodland offset area planted in 2009 with a long agricultural history but has not been cropped. This site has also shown a significant transformation since 2009 with the sprayed inter-rows now well colonised with annual and perennial vegetation and litter cover was high. This year all LFA targets were met. There was an appropriate diversity of shrubs and juvenile trees but the densities were too low. This year there was an appropriate diversity and density of mature trees and shrubs (>5cm dbh). The site was low in total and native species diversity and there was a high diversity of exotic species. The site was dominated by exotic plants and was more weedy than desired. While there was good total ground cover, the site and lacked suitable proportions of perennial ground cover. The soils were characteristically similar to the local woodlands but had low OM and CEC.	Limit site disturbances (such as spraying and grading) and allow the colonising vegetation to become well established. The site weediness is expected to decline as more desirable perennial species become more dominant. Continue to monitor macropod predation. Additional planting may be required in the absence of natural recruitment to increase shrub densities.	Low
Grassland rehabilitation sites			
TSF2-02	This grassland rehabilitation site is located on the north-east wall of TSF2 and had scattered tussocks of native perennial grasses (*Walwhalleya proluta)* and in 2009 a heavy cover of *Medicago polymorpha*. In 2010, there was evidence of extensive soil erosion from the bare upper slope which contained numerous rills, but the eroded materials were captured within the plant patches down slope. The site continued to meet all LFA targets. The site was low in total and native species diversity and had low perennial ground cover. a low number of herb and grass species. The site was dominated by exotic species but these were in comparable proportions to the reference sites. There was no active rilling within the monitoring site. The soils were neutral, deficient in organic matter and nitrate and sodic.	In the bare rows which extend along the contour above the site, there continues to be minor rilling which could be ameliorated via the application of more suitable topsoil materials and/or the application of rock mulch, sterile cover crop and native pasture hay. Application of native pasture hay would provide immediate benefits and would be encouraged but perhaps not essential. The use of suitable topsoil material should be a priority management action which should involve testing of soil stockpiles and spoil material prior to use in rehabilitation, as required.	Medium

Site	Site summary and issues associated with long-term management outcomes	Management requirements	Priority
	There were elevated levels of sulfur and silicon.		
TSF2-03	This grassland rehabilitation site contained scattered tussocks of native perennial grasses (*Walwhalleya proluta)*. The site failed to meet any LFA targets. The site was low in total ground but had an acceptable cover of perennial ground cover. There was a low total and native species diversity and a low number of herbs. The site was dominated by exotic species but these were in comparable proportions to the reference sites. There was no active rilling within the monitoring site. The soils were moderately alkaline, deficient in organic matter, phosphorous and nitrate and were sodic. There were elevated levels of sulfur and silicon.	Continue to monitor the site.	Medium
E22-01	E22-01 is located on the western batter of the waste emplacement surrounding the E22 open cut and is an open grassy area on the upper slope of the batter. Below the site there are some small planted tree lots with little to no ground cover with severe tunnel erosion observed nearby. This site met all LFA related targets and had an ecological function and soil chemistry comparable to the local grasslands but there were significantly high levels of copper and elevated levels of silicon. The site was low in total and native species diversity and was weedier than desired due to the relatively high cover of exotic annual plants. While total ground cover was high, there was a low cover of perennial ground cover plants and there was a low diversity of herbs and grasses.	Active tunnel erosion in the vicinity of the tree lots require amelioration and revegetated using an application of more suitable topsoil materials and/or the application of rock mulch, sterile cover crop and native pasture hay.	High
E22-02	Site E22-02 is located on the northern batter of the waste rock emplacement that surrounds E22 open cut. It is a rocky north facing slope that appears to have been deep ripped after shaping. This site met LOI and stability targets but failed to meet infiltration and nutrient recycling targets. The large active rill previously recorded has now become well stabilised with vegetative cover. The soils were moderately alkaline and deficient inorganic matter. There were significantly high levels of copper. There was low total species diversity and the site was dominated by exotic annuals plants. While total ground cover was high, there was a low cover of perennial ground cover plants and there was a low diversity of herbs.	Further investigation for active rilling across the larger E22 area should also be undertaken and if required treated appropriately. The use of suitable topsoil material should be a priority management action which should involve testing of soil stockpiles and spoil material prior to use in rehabilitation.	Medium
E26-02	E26-02 is located on a topsoil stockpile west of the E26 subsidence zone. This site met most LFA KPI targets but was slightly unstable. The soils were characteristically similar to the surrounding grassland areas but the soils were low in OM and there were elevated levels of chromium. The site was low in total and native species diversity and was weedier than desired due to the relatively high cover of exotic annual plants. While total ground cover was high, there was a low cover of perennial ground cover plants and there was a low diversity of herbs.	Limit site disturbances.	Low

Site	Site summary and issues associated with long-term management outcomes	Management requirements	Priority
E27-01	E27-01 is located on the eastern side of the E27 open cut waste rock emplacement. The site continued to meet all LFA targets. The soils were characteristically similar to the surrounding grassland areas but there were significantly high levels of copper. The site was dominated by exotic annual plants and was weedier. While total ground cover was high, there was a low cover of perennial ground cover plants and there was a low diversity of herbs.	Limit site disturbances. Continue to monitor macropod predation.	Low - Medium

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Appendix 1. List of flora species recorded in the rehabilitation sites in 2017

Group	Family	exotic	Scientific Name	Common Name	Habit	LFO-01	LFO-02	E22-01	E22-02	E26-02	E27-01	TSF2-02	TSF2-03
Coniferopsida	Cupressaceae		*Callitris glaucophylla*	White Cypress Pine	t	1	1						
Dicotyledon	Asteraceae	*	*Aster subulatus*	Wild Aster	h								1
Dicotyledon	Asteraceae	*	*Carthamus lanatus*	Saffron Thistle	h	1	1		1		1	1	
Dicotyledon	Asteraceae	*	*Centaurea melitensis*	Maltese Cockspur	h	1			1		1		
Dicotyledon	Asteraceae	*	*Cirsium vulgare*	Spear Thistle	h					1	1	1	1
Dicotyledon	Asteraceae	*	*Conyza bonariensis*	Fleabane	h						1		
Dicotyledon	Asteraceae	*	*Hypochaeris glabra*	Smooth Catsear	h	1							
Dicotyledon	Asteraceae	*	*Lactuca saligna*	Wild Lettuce	h							1	
Dicotyledon	Asteraceae	*	*Lactuca serriola*	Prickly Lettuce	h	1				1			1
Dicotyledon	Asteraceae		*Leiocarpa panaetioides*	Woolly Buttons	h				1			1	
Dicotyledon	Asteraceae	*	*Scorzonera laciniata*	Scorzonera	h								1
Dicotyledon	Asteraceae		*Senecio quadridentatus*	Cotton Fireweed	h	1	1		1				1
Dicotyledon	Asteraceae	*	*Sonchus oleraceus*	Milk Thistle	h		1	1	1	1	1	1	1
Dicotyledon	Asteraceae		*Vittadinia cuneata var. cuneata*	Fuzzweed	h			1			1		
Dicotyledon	Asteraceae		*Vittadinia cuneata var. hirsuta*	Fuzzweed	h	1	1					1	
Dicotyledon	Asteraceae		*Vittadinia gracilis*	A Fuzzweed	h	1	1		1		1		
Dicotyledon	Asteraceae		*Vittadinia sulcata*	A Fuzzweed	h				1	1	1		1
Dicotyledon	Asteraceae		*Xerochrysum bracteatum*	Golden Everlasting	h	1	1						
Dicotyledon	Brassicaceae	*	*Lepidium africanum*	Peppercress	h	1				1			
Dicotyledon	Brassicaceae	*	*Rapistrum rugosum*	Turnip Weed	h			1	1		1	1	1
Dicotyledon	Brassicaceae	*	*Sisymbrium irio*	London Rocket	h	1							
Dicotyledon	Campanulaceae		*Wahlenbergia gracilenta*	Australian Bluebell	h	1							
Dicotyledon	Caryophyllaceae	*	*Petrorhagia nanteuilii*	Proliferous Pink	h	1							
Dicotyledon	Casuarinaceae		*Allocasuarina luehmannii*	Bulloak	t	1							
Dicotyledon	Chenopodiaceae		*Atriplex semibaccata*	Creeping Saltbush	ss			1					1
Dicotyledon	Chenopodiaceae		*Einadia nutans*	Climbing Saltbush	h	1	1		1		1		
Dicotyledon	Chenopodiaceae		*Enchylaena tomentosa*	Ruby Saltbush	ss			1			1		
Dicotyledon	Chenopodiaceae		*Maireana brevifolia*	Yanga Bush	s			1	1		1	1	1

Group	Family	exotic	Scientific Name	Common Name	Habit	LFO-01	LFO-02	E22-01	E22-02	E26-02	E27-01	TSF2-02	TSF2-03
Dicotyledon	Convolvulaceae		*Convolvulus erubescens*	Australian Bindweed	h		1		1			1	1
Dicotyledon	Convolvulaceae		*Dichondra repens*	Kidney Weed	h	1	1				1		
Dicotyledon	Euphorbiaceae		*Chamaesyce drummondii*	Caustic Weed	h				1		1		
Dicotyledon	Fabaceae (Caesalpinoideae)		*Senna artemisioides subsp. X artemisioides*	Silver Cassia	s						1		
Dicotyledon	Fabaceae (Caesalpinoideae)		*Senna artemisioides subsp. zygophylla*	Senna	s		1						
Dicotyledon	Fabaceae (Faboideae)	*	*Medicago minima*	Small Woolly Burr Medic	h								1
Dicotyledon	Fabaceae (Faboideae)	*	*Medicago polymorpha*	Burr Medic	h	1	1	1	1	1	1	1	
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium angustifolium*	Narrow-leaf Clover	h			1		1			1
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium arvense*	Haresfoot Clover	h	1							
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium glomeratum*	Clustered Clover	h	1							
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium hirtum*	Rose Clover	h				1			1	
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium subterraneum*	Subterraneum Clover	h		1						
Dicotyledon	Fabaceae (Faboideae)	*	*Vicia villosa*	Vetch	h			1		1	1	1	1
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia brachystachya*	Umbrella Mulga	s						1		
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia deanei*	Green Wattle	s		1						
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia decora*	Western Golden Wattle	s		1	1					
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia hakeoides*	Hakea Wattle	s		1						
Dicotyledon	Geraniaceae		*Geranium solanderi*	Native Geranium	h							1	
Dicotyledon	Lamiaceae	*	*Marrubium vulgare*	Horehound	h		1	1		1	1		
Dicotyledon	Lamiaceae	*	*Salvia verbenaca*	Wild Sage	h		1	1	1				
Dicotyledon	Malvaceae	*	*Modiola caroliniana*	Red-flowered Mallow	h				1				
Dicotyledon	Malvaceae		*Sida corrugata*	Corrugated Sida	h		1	1	1			1	
Dicotyledon	Malvaceae		*Sida trichopoda*	Hairy Sida	h				1				
Dicotyledon	Myoporaceae		*Eremophila debilis*	Amulla	ss						1	1	
Dicotyledon	Myrtaceae		*Eucalyptus microcarpa*	Grey Box	t	1	1						
Dicotyledon	Myrtaceae		*Eucalyptus populnea*	Bimble Box	t	1	1						
Dicotyledon	Nyctaginaceae		*Boerhavia dominii*	Tar Vine	h		1						
Dicotyledon	Oxalidaceae		*Oxalis perennans*	Yellow Wood-sorrel	h					1	1		
Dicotyledon	Plantaginaceae	*	*Echium plantagineum*	Paterson's Curse	h	1	1	1	1	1	1	1	
Dicotyledon	Polygonaceae	*	*Rumex crispus*	Curled Dock	h	1	1	1		1	1	1	

Group	Family	exotic	Scientific Name	Common Name	Habit	LFO-01	LFO-02	E22-01	E22-02	E26-02	E27-01	TSF2-02	TSF2-03
Dicotyledon	Sapindaceae		*Dodonaea viscosa subsp. cuneata*	Wedge-leaf Hopbush	s	1							
Dicotyledon	Solanaceae		*Solanum esuriale*	Quena	h		1		1		1	1	
Monocotyledon	Cyperaceae		*Carex inversa*	Knob Sedge	r		1				1		
Monocotyledon	Poaceae		*Austrostipa bigeniculata*	Tall Speargrass	g			1					
Monocotyledon	Poaceae		*Austrostipa scabra subsp. scabra*	Rough Speargrass	g				1		1		
Monocotyledon	Poaceae	*	*Avena fatua*	Wild Oats	g	1	1	1	1	1	1	1	1
Monocotyledon	Poaceae	*	*Bromus diandrus*	Great Brome	g			1		1	1	1	
Monocotyledon	Poaceae	*	*Bromus molliformis*	Soft Brome	g	1							
Monocotyledon	Poaceae	*	*Chloris gayana*	Rhodes Grass	g					1	1	1	1
Monocotyledon	Poaceae		*Chloris truncata*	Windmill Grass	g							1	1
Monocotyledon	Poaceae		*Dichanthium sericeum*	Queensland Bluegrass	g				1			1	1
Monocotyledon	Poaceae		*Elymus scaber*	Common Wheatgrass	g	1						1	
Monocotyledon	Poaceae		*Enteropogon acicularis*	Curly Windmill Grass	g				1	1	1	1	
Monocotyledon	Poaceae	*	*Hordeum leporinum*	Barley Grass	g	1	1				1		
Monocotyledon	Poaceae	*	*Lolium rigidum*	Wimmera Ryegrass	g	1		1	1	1	1	1	1
Monocotyledon	Poaceae		*Panicum decompositum*	Native Millet	g								1
Monocotyledon	Poaceae	*	*Phalaris aquatica*	Phalaris	g						1		
Monocotyledon	Poaceae		*Rytidosperma bipartitum*	Wallaby Grass	g	1			1		1	1	1
Monocotyledon	Poaceae		*Rytidosperma setaceum*	Small-flowered Wallaby Grass	g			1			1	1	1
Monocotyledon	Poaceae		*Rytidosperma spp.*	Wallaby Grass	g		1			1			
Monocotyledon	Poaceae	*	*Vulpia spp.*	Rat's-tail Fescue	g	1							
Monocotyledon	Poaceae		*Walwhalleya proluta*	Rigid Panic	g		1	1	1	1	1	1	1
Pteridophyta	Adiantaceae		*Cheilanthes sieberi subsp. sieberi*	Rock Fern	f	1							

Appendix 2. List of flora species recorded in the reference sites in 2017

Group	Family	exotic	Scientific Name	Common Name	Habit	RWood01	RWood02	RWood03	RWood04	RGrass01	RGrass02	RGrass03
Coniferopsida	Cupressaceae		*Callitris glaucophylla*	White Cypress Pine	t	1	1		1			
Dicotyledon	Acanthaceae		*Rostellularia adscendens var. Pogonanthera*	Pink Tongues	h	1						
Dicotyledon	Amaranthaceae		*Ptilotus exaltatus*	Lambs Tails	h	1		1			1	
Dicotyledon	Asteraceae		*Calotis anthemoides*	Cut-leaved Burr-daisy	h	1	1					
Dicotyledon	Asteraceae		*Calotis cuneifolia*	Purple Burr Daisy	h	1	1	1				
Dicotyledon	Asteraceae		*Calotis lappulacea*	Yellow Burr Daisy	h	1	1	1				
Dicotyledon	Asteraceae	*	*Carthamus lanatus*	Saffron Thistle	h		1		1	1	1	1
Dicotyledon	Asteraceae	*	*Centaurea melitensis*	Maltese Cockspur	h		1		1	1	1	1
Dicotyledon	Asteraceae	*	*Cirsium vulgare*	Spear Thistle	h	1	1	1	1	1		1
Dicotyledon	Asteraceae	*	*Conyza bonariensis*	Fleabane	h					1		
Dicotyledon	Asteraceae		*Cymbonotus lawsonianus*	Bear's Ear	h		1					
Dicotyledon	Asteraceae	*	*Hedypnois rhagadioloides subsp. cretica*	Cretan Weed	h		1		1	1	1	
Dicotyledon	Asteraceae	*	*Hypochaeris glabra*	Smooth Catsear	h		1		1	1	1	
Dicotyledon	Asteraceae	*	*Hypochaeris radicata*	Flatweed	h			1				
Dicotyledon	Asteraceae	*	*Lactuca serriola*	Prickly Lettuce	h		1		1		1	
Dicotyledon	Asteraceae		*Leiocarpa panaetioides*	Woolly Buttons	h			1		1	1	1
Dicotyledon	Asteraceae		*Minuria leptophylla*	Minnie Daisy	h	1						
Dicotyledon	Asteraceae		*Senecio quadridentatus*	Cotton Fireweed	h		1		1			
Dicotyledon	Asteraceae	*	*Sonchus oleraceus*	Milk Thistle	h	1	1	1	1	1	1	1
Dicotyledon	Asteraceae		*Vittadinia cuneata*	Fuzzweed	h			1			1	
Dicotyledon	Asteraceae		*Vittadinia cuneata var. cuneata*	Fuzzweed	h	1	1					1
Dicotyledon	Asteraceae		*Vittadinia cuneata var. hirsuta*	Fuzzweed	h		1	1	1	1		
Dicotyledon	Asteraceae		*Vittadinia gracilis*	A Fuzzweed	h	1	1		1			
Dicotyledon	Asteraceae		*Vittadinia tenuissima*	Western New Holland Daisy	h						1	
Dicotyledon	Asteraceae		*Xerochrysum bracteatum*	Golden Everlasting	h		1		1			1
Dicotyledon	Brassicaceae	*	*Lepidium africanum*	Peppercress	h		1		1			
Dicotyledon	Brassicaceae	*	*Sisymbrium irio*	London Rocket	h				1			
Dicotyledon	Campanulaceae		*Wahlenbergia gracilenta*	Australian Bluebell	h				1			

Group	Family	exotic	Scientific Name	Common Name	Habit	RWood01	RWood02	RWood03	RWood04	RGrass01	RGrass02	RGrass03
Dicotyledon	Caryophyllaceae	*	*Petrorhagia nanteuilii*	Proliferous Pink	h				1	1		
Dicotyledon	Casuarinaceae		*Allocasuarina luehmannii*	Bulloak	t	1		1				
Dicotyledon	Chenopodiaceae		*Atriplex semibaccata*	Creeping Saltbush	ss	1						
Dicotyledon	Chenopodiaceae		*Chenopodium desertorum subsp. anidiophyllum*	Mallee Goosefoot	ss			1				
Dicotyledon	Chenopodiaceae		*Einadia nutans*	Climbing Saltbush	h	1						
Dicotyledon	Chenopodiaceae		*Einadia nutans subsp. nutans*	Climbing Saltbush	h		1	1	1			
Dicotyledon	Chenopodiaceae		*Enchylaena tomentosa*	Ruby Saltbush	ss			1				
Dicotyledon	Chenopodiaceae		*Maireana enchylaenoides*	Wingless Fissure Weed	h			1				
Dicotyledon	Chenopodiaceae		*Maireana microphylla*	Eastern Cottonbush	ss	1		1		1		1
Dicotyledon	Chenopodiaceae		*Maireana villosa*	Blue Pearlbush	ss				1			
Dicotyledon	Chenopodiaceae		*Salsola australis*	Buckbush	ss	1		1				
Dicotyledon	Chenopodiaceae		*Sclerolaena diacantha*	Grey Copperburr	ss	1	1	1				
Dicotyledon	Chenopodiaceae		*Sclerolaena muricata*	Black Roly Poly	ss						1	
Dicotyledon	Convolvulaceae		*Convolvulus erubescens*	Australian Bindweed	h	1		1	1	1	1	1
Dicotyledon	Convolvulaceae		*Dichondra repens*	Kidney Weed	h	1	1	1	1	1		
Dicotyledon	Euphorbiaceae		*Chamaesyce drummondii*	Caustic Weed	h	1	1	1				
Dicotyledon	Fabaceae		*Cullen tenax*	Emu Foot	h					1		
Dicotyledon	Fabaceae (Caesalpinoideae)		*Senna artemisioides subsp. zygophylla*	Senna	s			1				
Dicotyledon	Fabaceae (Faboideae)		*Glycine clandestina*	Climbing Glycine	h	1		1				
Dicotyledon	Fabaceae (Faboideae)		*Glycine tabacina*	Variable Glycine	h		1					
Dicotyledon	Fabaceae (Faboideae)	*	*Medicago minima*	Small Woolly Burr Medic	h							1
Dicotyledon	Fabaceae (Faboideae)	*	*Medicago polymorpha*	Burr Medic	h		1	1	1	1		
Dicotyledon	Fabaceae (Faboideae)	*	*Medicago truncatula*	Barrel Medic	h		1				1	
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	
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium glomeratum*	Clustered Clover	h				1		1	
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium hirtum*	Rose Clover	h		1			1		
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium scabrum*	Rough Clover	h					1	1	1
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium spp.*	A Clover	h							1

Group	Family	exotic	Scientific Name	Common Name	Habit	RWood01	RWood02	RWood03	RWood04	RGrass01	RGrass02	RGrass03
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium subterraneum*	Subterraneum Clover	h							1
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia deanei*	Green Wattle	s		1					
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia hakeoides*	Hakea Wattle	s	1		1				
Dicotyledon	Gentianaceae		*Sebaea ovata*	Yellow Centaury	h						1	
Dicotyledon	Geraniaceae		*Erodium crinitum*	Blue Storksbill	h				1			
Dicotyledon	Geraniaceae		*Geranium solanderi*	Native Geranium	h		1					1
Dicotyledon	Goodeniaceae		*Goodenia pinnatifida*	Scrambled Eggs	h	1	1	1				1
Dicotyledon	Lamiaceae	*	*Marrubium vulgare*	Horehound	h		1		1			1
Dicotyledon	Lamiaceae	*	*Salvia verbenaca*	Wild Sage	h	1	1		1	1		1
Dicotyledon	Linaceae		*Linum marginale*	Native Flax	h						1	
Dicotyledon	Loranthaceae		*Amyema linophyllum subsp. orientale*	Slender-leaf Mistletoe	p	1						
Dicotyledon	Malvaceae		*Sida corrugata*	Corrugated Sida	h	1	1	1	1			
Dicotyledon	Malvaceae		*Sida fibulifera*	Pin Sida	h						1	
Dicotyledon	Malvaceae		*Sida trichopoda*	Hairy Sida	h						1	
Dicotyledon	Myoporaceae		*Eremophila debilis*	Amulla	ss	1	1	1			1	1
Dicotyledon	Myrtaceae		*Eucalyptus albens*	White Box	t		1					
Dicotyledon	Myrtaceae		*Eucalyptus melliodora*	Yellow Box	t				1			
Dicotyledon	Myrtaceae		*Eucalyptus microcarpa*	Grey Box	t	1		1				
Dicotyledon	Myrtaceae		*Eucalyptus populnea*	Bimble Box	t		1		1			
Dicotyledon	Oxalidaceae		*Oxalis perennans*	Yellow Wood-sorrel	h	1			1		1	
Dicotyledon	Plantaginaceae	*	*Echium plantagineum*	Paterson's Curse	h	1			1	1	1	1
Dicotyledon	Plantaginaceae		*Plantago debilis*	Plantain	h	1	1	1				
Dicotyledon	Primulaceae	*	*Anagallis arvensis*	Scarlet Pimpernel	h					1	1	
Dicotyledon	Rubiaceae		*Asperula conferta*	Common Woodruff	h							1
Dicotyledon	Rutaceae		*Geijera parviflora*	Wilga	t			1				
Dicotyledon	Sapindaceae		*Alectryon oleifolius*	Rosewood	t	1						
Dicotyledon	Sapindaceae		*Dodonaea viscosa subsp. cuneata*	Wedge-leaf Hopbush	s	1		1				
Dicotyledon	Schrophulariaceae		*Brunoniella australis*	Blue Trumpet	h	1		1				
Dicotyledon	Solanaceae		*Solanum esuriale*	Quena	h				1			
Dicotyledon	Sterculiaceae		*Brachychiton populneus*	Kurrajong	t		1					

Group	Family	exotic	Scientific Name	Common Name	Habit	RWood01	RWood02	RWood03	RWood04	RGrass01	RGrass02	RGrass03
Monocotyledon	Anthericaceae		*Dichopogon spp.*	Chocolate Lily	h				1			
Monocotyledon	Asphodelaceae	*	*Asphodelus fistulosus*	Onion Weed	h							1
Monocotyledon	Cyperaceae		*Carex inversa*	Knob Sedge	r			1	1			
Monocotyledon	Juncaceae		*Juncus aridicola*	Tussock Rush	r						1	
Monocotyledon	Juncaceae		*Juncus usitatus*		r		1					
Monocotyledon	Lomandraceae		*Lomandra multiflora*	Many-flowered Mat-rush	h			1	1			
Monocotyledon	Phormiaceae		*Dianella revoluta*	Native Flax Lily	h		1					
Monocotyledon	Poaceae		*Aristida behriana*	Bunch Wiregrass	g		1					
Monocotyledon	Poaceae		*Aristida jerichoensis var. jerichoensis*	Jericho Wiregrass	g		1					
Monocotyledon	Poaceae		*Aristida leptopoda*	White Wiregrass	g			1		1		1
Monocotyledon	Poaceae		*Aristida ramosa*	Threeawn Grass	g		1			1		1
Monocotyledon	Poaceae		*Austrostipa bigeniculata*	Tall Speargrass	g		1			1	1	1
Monocotyledon	Poaceae		*Austrostipa nitida?*	Speargrass	g			1				
Monocotyledon	Poaceae		*Austrostipa nodosa*	A Speargrass	g	1	1					1
Monocotyledon	Poaceae		*Austrostipa scabra*	Speargrass	g				1			
Monocotyledon	Poaceae		*Austrostipa scabra subsp. falcata*	Speargrass	g		1	1				
Monocotyledon	Poaceae		*Austrostipa scabra subsp. scabra*	Rough Speargrass	g	1	1	1				
Monocotyledon	Poaceae	*	*Avena fatua*	Wild Oats	g		1		1	1	1	1
Monocotyledon	Poaceae		*Bothriochloa macra*	Red-leg Grass	g	1	1	1				1
Monocotyledon	Poaceae	*	*Bromus cartharticus*	Prairie Grass	g		1					
Monocotyledon	Poaceae	*	*Bromus diandrus*	Great Brome	g							1
Monocotyledon	Poaceae	*	*Bromus molliformis*	Soft Brome	g				1	1		1
Monocotyledon	Poaceae		*Chloris truncata*	Windmill Grass	g	1		1		1		
Monocotyledon	Poaceae		*Cymbopogon refractus*	Barbed-wire Grass	g		1	1				
Monocotyledon	Poaceae		*Dichanthium sericeum*	Queensland Bluegrass	g					1	1	1
Monocotyledon	Poaceae		*Digitaria divaricatissima*	Umbrella Grass	g							1
Monocotyledon	Poaceae		*Elymus scaber*	Common Wheatgrass	g	1	1	1	1			
Monocotyledon	Poaceae		*Enteropogon acicularis*	Curly Windmill Grass	g	1	1	1			1	
Monocotyledon	Poaceae	*	*Hordeum leporinum*	Barley Grass	g	1			1			
Monocotyledon	Poaceae	*	*Lolium rigidum*	Wimmera Ryegrass	g	1	1	1	1	1	1	1

Group	Family	exotic	Scientific Name	Common Name	Habit	RWood01	RWood02	RWood03	RWood04	RGrass01	RGrass02	RGrass03
Monocotyledon	Poaceae		*Panicum spp.*		g		1	1				1
Monocotyledon	Poaceae		*Paspalidium constrictum*	Knottybutt Grass	g	1		1				
Monocotyledon	Poaceae		*Rytidosperma bipartitum*	Wallaby Grass	g							1
Monocotyledon	Poaceae		*Rytidosperma caespitosum*	Wallaby Grass	g	1	1	1				
Monocotyledon	Poaceae		*Rytidosperma erianthum*	Hill Wallaby Grass	g	1	1		1	1		
Monocotyledon	Poaceae		*Rytidosperma racemosum*	Wallaby Grass	g				1			1
Monocotyledon	Poaceae		*Rytidosperma setaceum*	Small-flowered Wallaby Grass	g		1	1		1	1	1
Monocotyledon	Poaceae		*Rytidosperma spp.*	Wallaby Grass	g							1
Monocotyledon	Poaceae	*	*Vulpia spp.*	Rat's-tail Fescue	g							1
Monocotyledon	Poaceae		*Walwhalleya proluta*	Rigid Panic	g			1		1	1	1
Pteridophyta	Adiantaceae		*Cheilanthes sieberi subsp. sieberi*	Rock Fern	f		1	1	1			

Appendix 3. ROUTINE AGRICULTURAL SOIL ANALYSIS REPORT– Woodland Sites

Soil samples supplied by DnA Environmental on 23rd October, 2017 - Lab Job No. G4238

				Site	LFO-01	LFO-02	RWood01	RWood02	RWood03	RWood04	*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*	*G4238/1*	*G4238/2*	*G4238/9*	*G4238/10*	*G4238/11*	*G4238/12*	*Indicative guidelines only- refer Note 6*			
Morgan 1		Calcium	Ca	mg/kg	461	463	539	986	694	858	*1150*	*750*	*375*	*175*
		Magnesium	Mg		111	124	294	314	437	199	*160*	*105*	*60*	*25*
		Potassium	K		243	327	188	231	132	213	*113*	*75*	*60*	*50*
		Phosphorus	P		2.3	1.7	1.7	3.0	2.2	2.2	*15*	*12*	*10*	*5.0*
Bray1		Phosphorus	P	mg/kg	18.9	7.2	8.5	5.1	4.3	3.9	*45 note 8*	*30 note 8*	*24 note 8*	*20 note 8*
Colwell					73	32	36	28	22	24	*80*	*50*	*45*	*35*
Bray2					34	12	18	13	8	7	*90 note 8*	*60 note 8*	*48 note 8*	*40 note 8*
KCl		Nitrate Nitrogen	N	mg/kg	1.9	3.8	1.5	7.2	1.3	2.9	*15*	*13*	*10*	*10*
		Ammonium Nitrogen			4.4	2.4	2.8	9.4	2.3	5.2	*20*	*18*	*15*	*12*
		Sulfur	S		5.8	5.0	4.1	5.7	4.5	9.4	*10.0*	*8.0*	*8.0*	*7.0*
1:5 Water		pH		units	5.85	6.03	6.57	6.74	6.71	6.26	*6.5*	*6.5*	*6.3*	*6.3*
		Conductivity		dS/m	0.034	0.045	0.043	0.061	0.059	0.056	*0.200*	*0.150*	*0.120*	*0.100*
Calculation		Estimated Organic Matter		% OM	2.7	2.7	3.7	5.2	3.9	5.1	*>5.5*	*>4.5*	*>3.5*	*>2.5*
Ammonium Acetate + Calculations		Calcium	Ca	$cmol^+/Kg$	5.39	5.26	6.85	11.51	8.96	10.18	*15.6*	*10.8*	*5.0*	*1.9*
				kg/ha	2418	2361	3075	5167	4021	4572	*7000*	*4816*	*2240*	*840*
				mg/kg	1079	1054	1373	2307	1795	2041	*3125*	*2150*	*1000*	*375*
		Magnesium	Mg	$cmol^+/Kg$	1.76	1.92	4.74	4.59	7.28	3.06	*2.4*	*1.7*	*1.2*	*0.60*
				kg/ha	480	522	1290	1250	1982	833	*650*	*448*	*325*	*168*
				mg/kg	214	233	576	558	885	372	*290*	*200*	*145*	*75*

				Site	LFO-01	LFO-02	RWood01	RWood02	RWood03	RWood04	*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	1.56	1.92	1.34	1.33	0.97	1.38	*0.60*	*0.50*	*0.40*	*0.30*
				kg/ha	1364	1677	1175	1166	848	1209	*526*	*426*	*336*	*224*
				mg/kg	609	749	524	521	379	540	*235*	*190*	*150*	*100*
		Sodium	Na	cmol⁺/Kg	0.05	0.03	0.41	0.05	0.55	0.10	*0.3*	*0.26*	*0.22*	*0.11*
				kg/ha	23	16	211	28	281	53	*155*	*134*	*113*	*57*
				mg/kg	10	7	94	13	126	24	*69*	*60*	*51*	*25*
	KCl	Aluminium	Al	cmol⁺/Kg	0.12	0.04	0.02	0.02	0.01	0.02	*0.6*	*0.5*	*0.4*	*0.2*
				kg/ha	24	8	4	5	3	5	*121*	*101*	*73*	*30*
				mg/kg	11	4	2	2	1	2	*54*	*45*	*32*	*14*
	Acidity Titration	Hydrogen	H^+	cmol⁺/Kg	0.14	0.08	0.00	0.00	0.00	0.04	*0.6*	*0.5*	*0.4*	*0.2*
				kg/ha	3	2	0	0	0	1	*13*	*11*	*8*	*3*
				mg/kg	1	1	0	0	0	0	*6*	*5*	*4*	*2*
	Calculation	Effective Cation Exchange Capacity (ECEC)		cmol⁺/Kg	9.01	9.25	13.36	17.51	17.77	14.79	*20.1*	*14.3*	*7.8*	*3.3*
	Base Saturation Calculations	Calcium	Ca	%	59.8	56.9	51.3	65.7	50.4	68.8	*77.6*	*75.7*	*65.6*	*57.4*
		Magnesium	Mg		19.5	20.7	35.5	26.2	41.0	20.7	*11.9*	*11.9*	*15.7*	*18.1*
		Potassium	K		17.3	20.7	10.0	7.6	5.4	9.3	*3.0*	*3.5*	*5.2*	*9.1*
		Sodium - ESP	Na		0.5	0.3	3.1	0.3	3.1	0.7	*1.5*	*1.8*	*2.9*	*3.3*
		Aluminium	Al		1.3	0.4	0.2	0.1	0.1	0.2	*6.0*	*7.1*	*10.5*	*12.1*
		Hydrogen	H^+		1.6	0.9	0.0	0.0	0.0	0.3				
	Calculation	Calcium / Magnesium Ratio		ratio	3.1	2.7	1.4	2.5	1.2	3.3	*6.5*	*6.4*	*4.2*	*3.2*
	DTPA	Zinc	Zn	mg/kg	1.0	1.5	1.2	1.1	0.5	5.0	*6.0*	*5.0*	*4.0*	*3.0*
		Manganese	Mn		78	68	165	46	49	98	*25*	*22*	*18*	*15*

					Site	LFO-01	LFO-02	RWood01	RWood02	RWood03	RWood04	*Heavy Soil e.g Clay*	*Medium Soil e.g Clay Loam*	*Light Soil e.g Loam*	*Sandy Soil e.g Loamy Sand*
		Iron	Fe			44	45	48	31	34	41	*25*	*22*	*18*	*15*
		Copper	Cu			10.5	14.7	4.4	7.0	3.4	18.4	*2.4*	*2.0*	*1.6*	*1.2*
	$CaCl_2$	Boron	B	mg/kg		0.56	0.53	0.70	0.76	0.97	0.72	*2.0*	*1.7*	*1.4*	*1.0*
		Silicon	Si	mg/kg		70	65	61	59	77	71	*50*	*45*	*40*	*35*
	LECO IR Analyser	Total Carbon	C	%		1.55	1.57	2.12	2.95	2.20	2.94	*>3.1*	*>2.6*	*>2.0*	*>1.4*
		Total Nitrogen	N	%		0.11	0.13	0.10	0.21	0.12	0.16	*>0.30*	*>0.25*	*>0.20*	*>0.15*
	Calculation	Carbon/ Nitrogen Ratio		ratio		13.7	12.2	20.4	14.3	17.7	18.0	*10-12*	*10-12*	*10-12*	*10-12*
		Basic Texture				Loam	Loam	Loam	Loam	Loam	Loam	..	..	..	..
		Basic Colour				Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	..	..	..	..
	Calculation	Chloride Estimate		equiv. ppm		22	29	28	39	38	36	..	..	..	..
	Total Acid Extractable	Calcium	Ca	mg/kg		1,403	1,614	1,740	3,599	2,306	3,137	*1,000 - 10,000 Ca*			
		Magnesium	Mg			2,312	2,325	1,502	3,303	1,985	3,412	*500 - 5,000 Mg*			
		Potassium	K			2,758	2,769	2,152	2,507	1,594	2,942	*200 - 2,000 K*			
		Sodium	Na			<50	<50	206	104	223	68	*100 - 500 Na*			
		Sulfur	S			128	138	131	176	117	158	*100 - 1,000 S*			
	Total Acid Extractable	Phosphorus	P	mg/kg		573	426	285	315	180	343	*400 - 1,500 P*			
	Total Acid Extractable	Zinc	Zn	mg/kg		53	72	32	45	22	178	*20 - 50 Zn*			
		Manganese	Mn			1,427	1,332	3,856	982	712	2,581	*200 - 2,000 Mn*			
		Iron	Fe			40,951	38,549	22,431	51,359	21,717	44,532	*1,000 - 50,000 Fe*			
		Copper	Cu			98.1	110.5	39.1	77.9	31.2	154.8	*20 - 50 Cu*			
		Boron	B			3	2	2	4	3	3	*2 - 50 B*			
		Silicon	Si			3,222	2,477	4,069	2,289	3,083	2,539	*1,000 - 3,000 Si*			
		Aluminium	Al			18,436	17,017	14,258	17,796	14,099	21,228	*2,000 - 50,000 Al*			

				Site	LFO-01	LFO-02	RWood01	RWood02	RWood03	RWood04	*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		0.9	0.7	0.7	0.5	0.6	1.6	*0.5 - 3 Mo*			
		Cobalt	Co	mg/kg	16	16	16	17	7	17	*5 - 50 Co*			
		Selenium	Se		<0.5	0.7	0.6	0.5	<0.5	0.9	*0.1 - 2.0 Se*			
	Total Acid Extractable	Cadmium	Cd		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	*< 5 Cd*			
		Lead	Pb		23	18	15	12	13	19	*< 75 Pb*			
		Arsenic	As		7	6	4	4	3	8	*< 25 As*			
		Chromium	Cr	mg/kg	30	24	25	96	20	24	*<25 Cr*			
		Nickel	Ni		10	10	10	25	8	11	*<150 Ni*			
		Mercury	Hg		<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*< 3.75 Hg*			
		Silver	Ag		<1	<1	<1	<1	<1	<1	*.. Ag*			

EAL Soil Testing Notes

1. All results presented as a 40°C oven dried weight. Soil sieved and lightly crushed to <2 mm
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods*
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and Lamonte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts
7. Total Acid Extractable Nutrients indicate a store of nutrients
8. Contaminant Guides based on 'Residential with gardens and accessible soil including childrens daycare centres,
preschools, primary schools, town houses or villas' (NSW EPA 1998).
9. Information relating to testing colour codes is available on Sheet 2 - "*Understanding you soil results*"

Calculations

1. For conductivity 1 dS/m = 1 mS/cm = 1000 µS/cm
2. 1 $cmol^+/Kg$ = 1 meq/100g; 1 Lb/Acre = 2 ppm (parts per million); kg/ha = 2.24 x ppm; mg/kg = ppm
3. Conversions for 1 cmol+/Kg = 230 mg/Kg Sodium, 390 mg/Kg Potassium, 122 mg/Kg Magnesium, 200 mg/K Calcium
4. Organic Matter = %C x 1.75
5. Chloride Estimate = EC x 640 (most likely over-estimate)
6. ECEC = sum of the exchangeable cations $cmol^+/Kg$
7. Base saturation calculations = (cation cmol+/Kg) /ECEC x 100
8. Ca / Mg ratio from the exchangeable $cmol^+/Kg$ results

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.

Appendix 4. ROUTINE AGR CULTURAL SOIL ANALYSIS REPORT– Grassland Sites

Soil samples supplied by DnA Environmental on 23rd October, 2017 - Lab Job No. G4238

		Site			TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27	RGrass01	RGrass02	RGrass03	*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*	*G4238/3*	*G4238/4*	*G4238/5*	*G4238/6*	*G4238/7*	*G4238/8*	*G4238/13*	*G4238/14*	*G4238/15*	*Indicative guidelines only- refer Note 6*			
	Morgan 1	Calcium	Ca	mg/kg	894	1201	833	1989	1001	1113	5855	747	4095	*1150*	*750*	*375*	*175*
		Magnesium	Mg		661	721	403	654	467	704	738	463	475	*160*	*105*	*60*	*25*
		Potassium	K		101	58	248	221	237	135	171	91	265	*113*	*75*	*60*	*50*
		Phosphorus	P		1.3	1.1	2.3	1.8	2.4	1.8	2.7	1.9	3.2	*15*	*12*	*10*	*5.0*
	Bray1	Phosphorus	P	mg/kg	3.3	2.1	5.8	3.9	10.9	4.7	2.5	2.3	2.5	*45 note 8*	*30 note 8*	*24 note 8*	*20 note 8*
	Colwell				21	16	31	22	47	26	22	20	24	*80*	*50*	*45*	*35*
	Bray2				7	6	11	33	20	10	6	4	7	*90 note 8*	*60 note 8*	*48 note 8*	*40 note 8*
	KCl	Nitrate Nitrogen	N	mg/kg	4.1	0.7	4.7	5.5	13.1	7.7	2.5	2.5	4.1	*15*	*13*	*10*	*10*
		Ammonium Nitrogen			1.8	2.3	2.8	1.5	5.3	2.4	3.3	3.3	2.9	*20*	*18*	*15*	*12*
		Sulfur	S		20.1	22.6	5.9	3.6	7.6	8.9	3.8	6.3	5.1	*10.0*	*8.0*	*8.0*	*7.0*
	1:5 Water	pH		units	7.49	8.17	6.87	7.81	6.82	7.22	7.69	6.48	7.42	*6.5*	*6.5*	*6.3*	*6.3*
		Conductivity		dS/m	0.133	0.173	0.075	0.128	0.142	0.092	0.198	0.050	0.242	*0.200*	*0.150*	*0.120*	*0.100*
	Calculation	Estimated Organic Matter		% OM	1.7	0.6	4.7	2.3	2.8	3.1	4.0	3.0	5.4	*>5.5*	*>4.5*	*>3.5*	*>2.5*
	Ammonium Acetate + Calculations	Calcium	Ca	$cmol^+/Kg$	12.18	16.08	11.27	18.81	10.89	14.67	46.42	8.95	29.25	*15.6*	*10.8*	*5.0*	*1.9*
				kg/ha	5466	7216	5061	8444	4890	6584	20836	4016	13129	*7000*	*4816*	*2240*	*840*
				mg/kg	2440	3222	2259	3770	2183	2939	9302	1793	5861	*3125*	*2150*	*1000*	*375*
		Magnesium	Mg	$cmol^+/Kg$	13.26	14.43	7.05	10.83	7.43	12.81	13.11	8.78	6.20	*2.4*	*1.7*	*1.2*	*0.60*
				kg/ha	3609	3929	1920	2948	2023	3488	3569	2390	1688	*650*	*448*	*325*	*168*
				mg/kg	1611	1754	857	1316	903	1557	1593	1067	754	*290*	*200*	*145*	*75*

				Site	TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27	RGrass01	RGrass02	RGrass03	*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	0.86	0.63	1.90	1.73	1.74	1.26	2.31	0.78	2.00	*0.60*	*0.50*	*0.40*	*0.30*
				kg/ha	755	554	1667	1514	1526	1103	2023	684	1754	*526*	*426*	*336*	*224*
				mg/kg	337	247	744	676	681	492	903	305	783	*235*	*190*	*150*	*100*
		Sodium	Na	cmol⁺/Kg	1.85	1.88	0.36	0.17	0.56	0.37	0.22	0.68	0.14	*0.3*	*0.26*	*0.22*	*0.11*
				kg/ha	951	968	184	89	288	191	112	352	72	*155*	*134*	*113*	*57*
				mg/kg	425	432	82	40	128	85	50	157	32	*69*	*60*	*51*	*25*
	KCl	Aluminium	Al	cmol⁺/Kg	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.03	0.02	*0.6*	*0.5*	*0.4*	*0.2*
				kg/ha	2	2	2	1	3	2	4	5	5	*121*	*101*	*73*	*30*
				mg/kg	1	1	1	1	2	1	2	2	2	*54*	*45*	*32*	*14*
	Acidity Titration	Hydrogen	H^+	cmol⁺/Kg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	*0.6*	*0.5*	*0.4*	*0.2*
				kg/ha	0	0	0	0	0	0	0	1	0	*13*	*11*	*8*	*3*
				mg/kg	0	0	0	0	0	0	0	0	0	*6*	*5*	*4*	*2*
	Calculation	Effective Cation Exchange Capacity (ECEC)		cmol⁺/Kg	28.15	33.03	20.60	31.55	20.64	29.12	62.07	19.25	37.62	*20.1*	*14.3*	*7.8*	*3.3*
	Base Saturation Calculations	Calcium	Ca	%	43.2	48.7	54.7	59.6	52.8	50.4	74.8	46.5	77.7	*77.6*	*75.7*	*65.6*	*57.4*
		Magnesium	Mg		47.1	43.7	34.2	34.3	36.0	44.0	21.1	45.6	16.5	*11.9*	*11.9*	*15.7*	*18.1*
		Potassium	K		3.1	1.9	9.2	5.5	8.4	4.3	3.7	4.1	5.3	*3.0*	*3.5*	*5.2*	*9.1*
		Sodium - ESP	Na		6.6	5.7	1.7	0.5	2.7	1.3	0.3	3.5	0.4	*1.5*	*1.8*	*2.9*	*3.3*
		Aluminium	Al		0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.1	0.1	*6.0*	*7.1*	*10.5*	*12.1*
		Hydrogen	H^+		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0				
	Calculation	Calcium / Magnesium Ratio		ratio	0.9	1.1	1.6	1.7	1.5	1.1	3.5	1.0	4.7	*6.5*	*6.4*	*4.2*	*3.2*
	DTPA	Zinc	Zn	mg/kg	0.4	0.1	1.1	0.4	0.7	0.4	0.6	0.5	0.8	*6.0*	*5.0*	*4.0*	*3.0*
		Manganese	Mn		11	5	29	10	44	27	16	42	37	*25*	*22*	*18*	*15*

					Site	TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27	RGrass01	RGrass02	RGrass03	*Heavy Soil e.g Clay*	*Medium Soil e.g Clay Loam*	*Light Soil e.g Loam*	*Sandy Soil e.g Loamy Sand*
		Iron	Fe			18	18	19	13	32	31	25	92	34	*25*	*22*	*18*	*15*
		Copper	Cu			4.8	4.3	19.0	17.0	9.6	39.7	4.0	3.5	4.6	*2.4*	*2.0*	*1.6*	*1.2*
	$CaCl_2$	Boron	B	mg/kg		0.98	1.20	0.86	0.65	0.98	0.66	0.30	0.67	0.41	*2.0*	*1.7*	*1.4*	*1.0*
		Silicon	Si			77	53	72	42	76	57	26	80	39	*50*	*45*	*40*	*35*
	LECO IR Analyser	Total Carbon	C	%		0.95	0.37	2.71	1.30	1.60	1.76	2.29	1.69	3.07	*>3.1*	*>2.6*	*>2.0*	*>1.4*
		Total Nitrogen	N	%		0.09	0.02	0.19	0.10	0.11	0.12	0.15	0.13	0.24	*>0.30*	*>0.25*	*>0.20*	*>0.15*
	Calculation	Carbon/ Nitrogen Ratio		ratio		10.2	19.5	14.6	12.6	14.0	14.2	15.2	13.4	12.9	*10-12*	*10-12*	*10-12*	*10-12*
		Basic Texture				Clay Loam	Clay Loam	Loam	Loam	Loam	Clay Loam	Loam	Clay Loam	Loam	..	..	..	..
		Basic Colour				Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	..	..	..	..
	Calculation	Chloride Estimate		equiv. ppm		85	111	48	82	91	59	127	32	155	..	..	..	..
	Total Acid Extractable	Calcium	Ca	mg/kg		2,603	3,556	2,848	5,342	2,539	3,657	14,020	1,962	10,777	*1,000 - 10,000 Ca*			
		Magnesium	Mg			3,311	4,155	2,475	5,662	2,443	4,662	5,169	2,301	3,280	*500 - 5,000 Mg*			
		Potassium	K			1,292	1,159	2,646	2,376	2,550	2,402	2,955	1,304	2,814	*200 - 2,000 K*			
		Sodium	Na			565	624	160	124	235	198	87	255	96	*100 - 500 Na*			
		Sulfur	S			138	119	207	299	153	169	165	134	231	*100 - 1,000 S*			
	Total Acid Extractable	Phosphorus	P	mg/kg		159	82	335	321	288	206	179	131	262	*400 - 1,500 P*			
	Total Acid Extractable	Zinc	Zn	mg/kg		22	21	43	45	32	36	36	19	36	*20 - 50 Zn*			
		Manganese	Mn			537	375	1,166	1,082	865	1,023	823	740	1,357	*200 - 2,000 Mn*			
		Iron	Fe			22,967	22,624	33,305	24,818	33,207	29,884	33,153	16,279	38,549	*1,000 - 50,000 Fe*			
		Copper	Cu			40.8	37.7	180.1	258.6	95.4	452.4	44.7	21.5	49.9	*20 - 50 Cu*			
		Boron	B			4	5	4	4	4	4	3	<2	4	*2 - 50 B*			
		Silicon	Si			1,579	2,105	2,313	1,282	2,820	2,008	1,704	1,872	2,805	*1,000 - 3,000 Si*			
		Aluminium	Al			15,949	18,565	19,607	20,955	18,306	21,478	23,561	14,428	18,610	*2,000 - 50,000 Al*			

					Site	TSF2-02	TSF2-03	E22-01	E22-02	E26-02	E27	RGrass01	RGrass02	RGrass03	*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		0.6	0.4	1.2	1.2	1.6	0.9	0.4	0.4	0.5	*0.5 - 3 Mo*			
		Cobalt	Co			9	7	16	14	11	15	15	10	24	*5 - 50 Co*			
		Selenium	Se			0.5	0.6	0.5	<0.5	0.8	0.8	0.6	0.6	0.7	*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	*< 5 Cd*			
		Lead	Pb			12	9	20	34	20	14	10	11	10	*< 75 Pb*			
		Arsenic	As			3	4	5	4	5	4	3	2	3	*< 25 As*			
		Chromium	Cr			20	23	25	18	33	23	34	20	40	*<25 Cr*			
		Nickel	Ni			8	8	11	10	13	11	16	9	18	*<150 Ni*			
		Mercury	Hg			<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	*.. Ag*			