2020 Cadia Valley Operations Rehabilitation Monitoring Report

for
Newcrest Mining Limited

Prepared by
DnA Environmental
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Executive summary

Cadia Valley Operations (CVO) is one of Australia's largest gold mining operations and is 100 per cent owned by Newcrest. It is located approximately 25 kilometres from the city of Orange in central west New South Wales. Rehabilitation activities at the Cadia Valley Operations aim to generate safe and sustainable landforms at the mine site and on CHPL-owned land.

Final land use goals are broadly based on the pre-existing land uses within the Cadiangullong Creek Valley, with these being agriculture (predominantly grazing) with scattered paddock trees and woodland conservation. The pre-existing landform of undulating hills would be replicated through mine rehabilitation landforms so that these landforms are typical of the surrounding topography. Specific future post mining land use goals include:

- High quality agriculture (Grazing) areas where there is a low risk of erosion, degradation and damage by grazing livestock using a species composition and carrying capacity similar to the surrounding agricultural areas.
- Woodland (conservation) to establish similar vegetation communities to the surrounding remnant woodlands and to increase the extent and connectivity of woodlands in the local area.

Other post-miming rehabilitation objectives will allow for future needs of the community through retaining key infrastructure where appropriate (pending future negotiations with regulatory bodies / community. Progressive rehabilitation of mining disturbed lands would be undertaken throughout the life of the Project, where practicable.

The 2020 rehabilitation monitoring program was undertaken by DnA Environmental on behalf of Newcrest Mining Limited, Cadia Valley Operations (CVO). The purpose of this report is to present the results of the ongoing annual rehabilitation monitoring program that first commenced in 2008. The monitoring program compares the progress of rehabilitated landforms towards fulfilling long-term landuse objectives by comparing a selection of ecological performance targets or completion criteria against areas of remnant vegetation not impacted by mining activities that are representative of the final landuse and vegetation assemblage (reference sites). It also aims to comply and be consistent with conditions specified within a range of approval documents and associated Management Plans and align with the regulatory guidelines whilst addressing the range of technical issues associated with mine rehabilitation.

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

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

In September 2013 NSW Department of Industry (Planning & Environment), (formerly NSW Trade and Investment - Division of Resources and Energy) or the Department released the revised ESG3 MOP guidelines (T& I 2013) which detailed a revised process for monitoring and managing progression towards successful rehabilitation outcomes quantified by completion criteria. The ESG3 MOP is used by the Department to monitor the progress of mining and rehabilitation activities across the life of a mine. The ESG3 MOP guidelines detailed a process for monitoring and managing progression towards successful rehabilitation outcomes quantified by completion criteria, which are applicable to each of the similar land management units within the mine site. Rehabilitation Phases where the post mining land use is a native plant ecosystem according to the MOP guidelines include:

- Decommissioning;
- Landform Establishment and Stability;
- Growth medium development;
- Ecosystem and Landuse Establishment; and
- Ecosystem and Land Use Sustainability.

Reference sites provide a range of ecological performance indicators or completion criteria against which rehabilitation progress can be compared and provide the ability to monitor ecological indicators of an existing natural ecosystem and changes in that ecosystem as a result of climatic variations and disturbance events (such as drought, fire, flood etc.). The reference sites are used as a benchmark for the final rehabilitated landscape and provide a time series record of ecosystem change and development. All ecological performance indicators are quantified by range values measured annually from these reference sites which form *upper* and *lower* ecological performance indicator 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

Since its inception the CVO monitoring program has adopted this process of comparing rehabilitation areas against reference sites in logical successional phases and has adapted the methodology with the various revisions of the Departments regulatory guidelines.

CVO Rehabilitation monitoring program

At CVO, the agreed post mining land use aims to establish a combination of grazing land and endemic woodland on final landforms and add value to the current vegetation corridor program of CVO farmland. Three main vegetation communities form the basis of the rehabilitation objectives and these include woodland (open woodland with grassy understorey), riparian woodlands and perennial pastures (exotic grassland suitable for grazing). Replicated sites representing each of these main community types (reference sites) were established to provide a range of ecological performance targets or completion criteria. Reference sites were spread out where possible to maximise the spatial distribution and subsequent variations in community composition across the local landscape and all are now situated on Cadia owned land.

At CVO, rehabilitation has been progressive since the inception of the monitoring program and subsequently the number of rehabilitation monitoring sites has typically grown over the years. A review of the monitoring program has been undertaken on numerous occasions prompting the need to simplify and refine the methodology without losing the heterogeneity of the local ecology and to align more adequately with the various changes in the MOP reporting guidelines. Major rehabilitation has been undertaken on the main Waste Emplacements in 2008 (South Dump) and in 2014/2015 and 2018 (North and South Dump). Subsequently there have been some changes in the quantity, locations and frequency of monitoring of the rehabilitation sites.

This year the monitoring program included monitoring of:

- Three woodland reference sites;
- Nine woodland rehabilitation sites including:
    - South Dump 04 – 10 (excluding 06);
    - North Dump 01 – 03.

Some of the older more stable woodland and riparian rehabilitation sites and farmland revegetation areas have been monitored on a three year rotation in an attempt to keep the number of monitoring sites to a manageable numb. Three farmland revegetation sites (Willunga DS 01 – 02 and Ashleigh Park) and two riparian rehabilitation sites (Creek Diversion, Cadiangullong Creek) and the riparian reference sites were last assessed 2019.

The monitoring methodology is consistent with that used in previous years and includes a combination of Landscape Function Analyses (LFA) and an assessment of ecosystem characteristics using an adaptation of methodologies derived by the Biometric Model. Soil analyses and permanent transects and photo-points have been established to record changes in these attributes over time.

Data obtained from within replicated reference sites were used to provide upper and lower ecological performance indicator limits or "completion criteria". Primary completion 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 completion 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 ecological performance indicator are adapted annually to reflect climatic variations and local disturbance events. Monitoring has been undertaken in autumn by Dr Donna Johnston and Mr Andrew Johnston (DnA Environmental) in all monitoring years to reduce variations in seasonal conditions**.** This year monitoring was undertaken during 30th March – 7th April.

Rainfall

The long-term annual average rainfall recorded at Orange Airport is 846mm however below average annual rainfall has been experienced since 2014. The lowest annual rainfall was recorded during 2017 and 2018 with only just over half of the expected annual rainfall being received. In 2016, above average rainfall events from May through to September which collectively caused extensive flooding throughout the Central Western Region. This flood event was the result of 610mm or close to 70% of the annual average of rainfall over five consecutive winter months.

Since October 2016, rainfall has typically been well below the monthly averages and very dry conditions continued to be experienced throughout most of 2018, until November, where 97mm of rain fell. Above average was recorded in January and March 2019 as a result of extreme storm activity, but in April, only 0.5mm of rain was recorded with very limited rainfall being recorded for the remainder of the year. In January and February this year, some rain was experienced but these were lower than average, however expected rainfall was received in March and above average rainfall was recorded in April with 147mm being recorded in that month.

Subsequently there have been extremes in climatic conditions, with droughts, followed by floods in 2016, followed by another three consecutive years of drought which has typically been reflected in the range of ecological monitoring data. This year improved growing conditions were experienced just prior to the monitoring event which resulted in a flush of plant growth and the germination of annual ground cover species.

Progress of the woodland rehabilitation sites

All of the rehabilitation sites established on the South Dump (South Dump 04 – South Dump 09) since 2014 have previously demonstrated significant increases in functional patch area. Despite the loss of many of the original troughs and banks due to erosive process over the first few years, there has typically been a concurrent increase in plant and litter covers. In 2017, prolonged dry conditions and increased grazing and disturbance by animals has resulted in a deterioration of functional patch area and stability in most of the rehabilitation sites, especially in South Dump 05, 07 and 09.

This year South Dump 05 continued to be subjected by heavy disturbance by macropods, while active rilling and sheet erosion created unstable conditions for the establishment of cryptogams and other ground cover vegetation in the steeper slopes of South Dump 04 and South Dump 09, and parts of South Dump 07. In the remaining rehabilitation sites, there tended to be an increase in litter and ground cover vegetation and in some sites, there has been an increase in shrub cover and/or cryptogams were relatively abundant. Rehabilitation sites South

Dump 08 and all three sites on the North Dump had LFA stability indices comparable to the woodland reference sites this year, however no rehabilitation site yet had an infiltration or recycling capacity that was comparable to the local woodlands.

The woodland reference sites continued to be the most ecologically functional sites with total scores of 191 and 169. Rehabilitation sites North Dump 02 and South Dump 08 were functionally similar to each other with scores of 151 and 147 respectively, with these sites having a maturing canopy, scattered perennial ground covers and developing litter layers. Sites South Dump 05 and North Dump 01 and 03 were functionally very similar to each other with a sum of scores ranging from 130 – 138, with South Dump 05 having the highest function of these sites. Sites South Dump 09, 04, 07 and the new site South Dump 10 were the lowest performing rehabilitation sites with indices of 99 – 120.

Tree and shrub seedlings have continued to establish, with low numbers of mature individuals (>5cm dbh) being recorded in all rehabilitation sites, except South Dump 08 and 10. The densities of mature acacias had been significantly increasing in South Dump 05 and North Dump 02 over the past few years, however this year 65% and 48% of these have died as the mature acacias become senescent, and the remaining individuals were stressed. In the other sites that had trees or mature shrubs, most individuals were in healthy condition.

The ongoing drought has also resulted in a decline in shrub and juvenile tree densities (<5cm dbh), with a declining shrub population also being recorded in the reference site RWood05 this year. Despite these losses, there continued to be a higher density and diversity of shrubs and juvenile trees compared to the local woodlands. Most individuals were 1.0 - 1.5m tall however there was also a large number (12%) of individuals that exceeded 2.0m in height. Most species were local endemic species, but there were a low number of individuals which are not local to the Cadia area.

Most rehabilitation sites had an increase in total ground cover except South Dump 04 and 10. On the South Dump, total ground cover ranged from a low of 43% in South Dump 10 to a high of 90% at South Dump 08. On the North Dump, total ground cover ranged from 80.5 – 96.5%. This year, sites North Dump 01 and North Dump 02 had a total ground cover that was comparable to the woodland reference sites.

There was an increase in dead litter and annual plant cover in most rehabilitation monitoring sites due to the recent rainfall that stimulated a flush of new annual plant growth. Cryptogams were establishing in most sites and provided up to 12% cover in a several sites. Some perennial ground cover was provided by the low growing branches of the establishing shrubs, but typically perennial ground cover had declined in all sites due to the drought and high shrub mortality. Nonetheless all rehabilitation sites had adequate perennial ground cover compared to the reference sites, except South Dump 10. In North Dump 02, where perennial plant cover was the highest, perennial grasses provided 31% cover this year.

Native ground cover was also highly variable within the rehabilitation areas and similarly to the woodland reference sites, there was a decrease in the percent cover provided by native plants in most rehabilitation sites, due to the increased abundance of exotic annual plant cover. A minor increase in native plant cover was however recorded in South Dump 05 and 08. In the rehabilitation areas, exotic species tended to provide the most ground cover, with the annual pasture species *Trifolium subterraneum* (Subterraneum Clover) providing the most ground cover in South Dump 08 and North Dump 01, 02 and 03. *Phalaris aquatica* (Phalaris) was also abundant in North Dump 02, while annual species *Modiola caroliniana* (Red-flowered Mallow) and *Petrorhagia nanteuilii (*Proliferous Pink) were the most abundant in North Dump 01 and 03 this year. Despite being dominated by exotic ground covers, most rehabilitation areas had a percent native plant cover within the range provided by the reference sites, except the new area of rehabilitation at South Dump 10 and North Dump 02 and 03.

All rehabilitation sites had an acceptable diversity of native species, however all sites except South Dump 07 and 09 contained a higher diversity of exotic species. In the South Dump there was an appropriate diversity of trees, shrubs and grasses. This year, there was a low diversity of tree species in South Dump 04 and all three areas on the North Dump.

Much of the minor rilling recorded in previous years has declined as ground covers have become more established, however minor rilling continued to be recorded in South Dump 05, 07, 09 and North Dump 01. The extent of rilling has also slightly increased in South Dump 07 and North Dump 01, where the rip lines along the steeper slopes have let go, and in North Dump 01, some tunnelling was occurring and had also increased in extent over the past year. This year some rilling was also recorded in RfWood01, where water has flowed down animal tracks during heavy rainfall.

Rehabilitation sites South Dump 05, 07, 08 and 09 have soils which are strongly to very strongly acidic and the soils are saline in South Dump 10. All sites were very low in organic matter. The results of the soil analyses also indicate there are numerous elements which occur at elevated levels in the rehabilitation sites, however most of these also have been recorded at elevated levels within the selection of woodland reference sites suggesting various elements and heavy metals can occur at "naturally" high levels around the Cadia Mine and are likely to be related to the long agricultural and mining history of the area. Copper was however recorded in higher concentrations in many rehabilitation sites, especially those on the North Dump. In the rehabilitation areas on the South Dump, there were also high concentrations of Sulfur, especially in South Dump 04, 05, 07 and 08 with these concentrations being far in excess of the guidelines and these have increased over the last year.

Performance of the woodland rehabilitation sites against primary completion performance indicators

The table below indicates the performance of the woodland rehabilitation monitoring sites against a selection of primary completion performance indicators during the 2020 monitoring period. The selection of criteria has been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) and ending with indicators of ecosystem sustainability (blue) as per NSW T&I ESG3 guidelines (2013).

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 meet completion criteria targets this year. 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 the same year. 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.

Performance of the woodland rehabilitation sites against primary completion performance indicators in 2020.

Rehabilitation Phase	Aspect or ecosystem component	Performance Indicators	Unit of measurement	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
Performance indicators are quantified by the range of values obtained from replicated reference sites assessed in 2020				Lower KPI	Upper KPI	2020								
Phase 2: Landform establishment and stability	Landform slope, gradient	Slope	Degrees (<18°)	10	14	18	18	16	0	16	17	14	15	2
	Active erosion	No. Rills/Gullies	No.	0	4	0	2	8	0	6	0	3	0	0
Phase 3: Growth medium development	Soil chemical, physical properties and amelioration	pH	pH (5.6-7.3)	6.1	7.0	5.6	5.4	5.2	5.4	5.1	5.8	6.7	6.6	6.2
		Organic Matter	% (>4.5)	7.6	10.2	1.8	2.2	3.1	3.0	2.0	2.4	1.9	2.9	1.7
		Phosphorous	mg/kg (50)	15.4	36.7	9.8	16.1	16.7	56.1	9.2	19.7	43.0	43.6	25.9
Phase 4: Ecosystem & Landuse Establishment	Landscape Function Analysis (LFA): Landform stability and organisation	LFA Stability	%	61.8	67.5	61.2	61.5	60.9	66.6	58.7	53.9	62.0	67.7	64.9
		LFA Landscape organisation	%	64	100	30	66	39	72	37	17	79	92	93

Rehabilitation Phase	Aspect or ecosystem component	Performance Indicators	Unit of measurement	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
	Vegetation diversity	Diversity of shrubs and juvenile trees	% population	0	100	100	99	99	97	98	100	100	100	100
		Total species richness	No./area	19	41	24	25	34	47	31	21	35	32	36
	Vegetation density	Density of shrubs and juvenile trees	No./area	0	58	122	390	404	622	484	6	198	384	55
	Ecosystem composition	Trees	No./area	1	3	0	1	3	5	6	1	0	0	0
		Shrubs	No./area	0	6	4	9	15	15	10	3	7	5	4
		Grasses	No./area	5	7	10	5	7	7	9	2	7	6	7
Phase 5: Ecosystem & Landuse Sustainability	Landscape Function Analysis (LFA): Landform function and ecological performance	LFA Infiltration	%	52.9	62.2	28.2	37.2	27.1	38.9	30.0	24.5	34.2	42.0	35.5

Rehabilitation Phase	Aspect or ecosystem component	Performance Indicators	Unit of measurement	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
		LFA Nutrient recycling	%	48.5	61.5	29.1	38.9	27.6	41.3	31.0	20.4	33.6	41.3	35.7
	Protective ground cover	Perennial plant cover (< 0.5m)	%	1.0	15.0	7.5	8.5	7.5	22	5	0.5	3	30.5	2
		Total Ground Cover	%	92.5	98.0	65.0	82.0	57.0	90	46.5	43.0	94	96.5	80.5
	Ground cover diversity	Native understorey abundance	> species/m^2	0.4	3.0	0.4	0.6	1.4	1.6	0.8	0.2	0.8	0.8	0.2
	Native ground cover abundance	Percent ground cover provided by native vegetation <0.5m tall	%	7.1	85.0	15	12.5	56.3	43.2	33.3	1.7	13.6	7	1.8
	Ecosystem growth and natural recruitment	shrubs and juvenile trees 0 - 0.5m in height	No./area	0	68.0	20	26	32	22	6	5	0	24	0

Rehabilitation Phase	Aspect or ecosystem component	Performance Indicators	Unit of measurement	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
		shrubs and juvenile trees 1.5 - 2m in height	No./area	0	0.0	10	114	34	12	86	0	24	128	15
	Ecosystem structure	Foliage cover 0.5 - 2 m	% cover	0	0.0	11	44	19	30	26	0	16	26	0
		Foliage cover 2 - 4m	% cover	0	2.0	0	7	0	0	0	0	0	4	0
		Foliage cover >6m	% cover	37.0	42.0	0	0	0	0	0	0	0	0	0
	Tree diversity	Tree diversity	% endemic	100.0	100.0	100	100	100	0	100	0	100	100	100
	Tree density	Tree density	No./area	9.0	48.0	2	52	4	0	2	0	1	24	1

Rehabilitation Phase	Aspect or ecosystem component	Performance Indicators	Unit of measurement	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
	Ecosystem health	Healthy trees	% population	**8.3**	**11.1**	**100**	**0**	**100**	**0**	**100**	**0**	**100**	**0**	**0**
		Flowers/fruit: Trees	% population	**16.7**	**88.9**	**100**	**0**	**0**	**0**	**0**	**0**	**100**	**0**	**0**

Conclusion

While no rehabilitation sites yet met all primary completion criteria, many sites had been demonstrating a significant increase in ecological function up until the drought conditions that have been experienced since 2017. Despite a decline in ecological function these degrading attributes can be directly attributed to the prolonged dry seasonal conditions and increased grazing and disturbance by animals, especially Eastern Grey Kangaroos, with the decline in many performance indicators also being reflected in the range of woodland reference sites.

While there has been some loss of seedlings and mature shrubs, these have typically been species of acacia which presently occur in much higher numbers than would be expected in the local woodlands. The high densities of acacias are a crucial part of the successional development of the rehabilitation areas, especially in the development of the soil profile as their stems assist in accumulating mobilised resources (alive or dead), their roots improve soil characteristics and the extensive addition of dead leaves and spent pods add nutrients and improve the extent and decomposition of the litter layers.

The low abundance of eucalypts within numerous rehabilitation areas, especially on the North Dump where none have been recorded will affect tree density and diversity completion targets and compromise the structural integrity of the rehabilitated woodland communities in the longer-term. This will be particularly important as many mature acacias decline from these ecosystems as part of the natural successional development. This has previously been observed at the older South Dump 01, 02 and 03 sites, and this year also at South Dump 05 and North Dump 02. Sites without or with low densities of eucalypts are likely to require rehabilitation intervention to ensure appropriate eucalypt densities are established. The long-term goal should be to have approximately 80 – 410 stems of one to three eucalypt species per hectare.

Exotic annual weeds which have voluntarily and successfully colonised large areas of rehabilitation are playing a particularly important role in the ecological development, function and stability of the sites. This is largely due to the provision of protective ground cover and development of the litter layers which lead to increased stability and coherency of the soil profile. In addition, many annual weeds have become naturalised within the local area, thus in some cases many may always be persistent, but not necessarily problematic. In addition, much of the annual ground covers this year were clovers or medics which are useful pasture species. Over time, the abundance of many “weedy” annual weed species are likely to decline, as the disturbed rehabilitation areas undergo successional development phases and the dead litter layers accumulate and decompose and perennial ground covers become more abundant. It is however imperative that overgrazing and heavy disturbances are kept to a minimum as they reduce the integrity of the protective ground covers, promote “weediness” and decrease the rate of natural succession development which has the potential to lead result in rehabilitation failure if left unchecked.

The drought conditions over three consecutive years have not been conducive to significant developments in the rehabilitation areas, however many areas have maintained or even slightly improved in ecological function, largely due to the establishment of these exotic annual plants, but also due to the establishment of tree and shrub seedlings, especially in South Dump 08. More vulnerable rehabilitation areas, such as those occurring on the steeper slopes (South Dump 04, 07 and 09 and North Dump 01) have tended to have a higher degree of erosion resulting in a more unstable environment where ground cover plants and cryptogams have been much slower to establish.

There were some differences in soil chemistry between the soils applied onto rehabilitation areas and the soils occurring in the local woodlands and some rilling continued to be recorded in the steeper rehabilitation slopes. Copper was recorded in high concentrations in many rehabilitation sites, especially those on the North Dump. In the rehabilitation areas on the South Dump, the soils were acidic and there were also high concentrations of Sulfur, especially in South Dump 04, 05, 07 and 08 with these concentrations being far in excess of the guidelines

and these concentrations have increased over the last year. These should continue to be monitored, as increasing concentrations may inhibit the establishment of protective ground cover and have an adverse effect of the development of wider rehabilitation areas. In the newest site South Dump 10, the soils were also saline. Testing of waste rock materials and topsoils prior to application on rehabilitation areas should be regularly undertaken to ensure suitable substrates are used prior to spreading onto rehabilitation areas.

Some species of acacia were not strictly local endemic species, and several annual weeds including *Bidens pilosa* (Cobbler's Peg) and *Verbena litoralis* (Coastal Verbena) are weed species that were noted in low numbers on the newer areas of rehabilitation and are not usually associated with the Cadia area. Additional care should be taken to ensure local provenance seed collection and/or biosecurity measures are put into practice.

While no formal survey for fauna is undertaken by DnA Environmental, a range of wildlife have been or were observed within the rehabilitation areas. Increased habitat such as large logs and fallen trees would enhance rehabilitation sites. Additional perching sites could also be made available by erecting (upside down) fallen trees in appropriate locations across the rehabilitation areas. This practice has been undertaken with very successful outcomes in the Hunter Valley. Birds using the perching sites assist rehabilitation outcomes by introducing native plant seed (especially those with fleshy drupes) that may not otherwise colonise large rehabilitation areas. A range of other wildlife may also assist with the natural dispersal of seeds, create germination niches and micro-sites and assist with nutrient recycling across the wider rehabilitation areas.

Feral and pest animals (and noxious weeds) also require monitoring and targeted control programs may need to be implemented, in consultation with advice from relevant experts and authorities to determine the levels of management intervention required and the most effective methods.

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1 Introduction: 2020 CVO Rehabilitation monitoring report

1.1 Background

Cadia Valley Operations (CVO) is one of Australia's largest gold mining operations and is 100 per cent owned by Newcrest. It is located approximately 25 kilometres from the city of Orange in central west New South Wales and is 250 kilometres west of Sydney (http://www.newcrest.com.au/our-business/operations/cadia-nsw/).

CVO comprises three mines - the Cadia East underground panel cave mine which commenced commercial production on 1 January 2013, the Ridgeway underground mine (currently in care and maintenance) and the Cadia Hill open pit mine (currently in care and maintenance).

At CVO, Newcrest produces gold doré from a gravity circuit and gold-rich copper concentrates from a flotation circuit. Gold doré from CVO is refined at the Perth Mint and concentrates are piped to a dewatering plant at nearby Blayney and sent by rail to Port Kembla in New South Wales for export mainly to Eastern Asia. In the financial year ending 30 June 2016, CVO produced 668,773 ounces of gold and 64,130 tonnes of copper. Over 9 million ounces of gold has been produced from CVO since commercial production commenced in 1999.

1.2 CVO Post mining landuse objectives

Final land use goals are broadly based on the pre-existing land uses within the Cadiangullong Creek Valley being agriculture (predominantly grazing) with scattered paddock trees and woodland conservation (Newcrest 2013a, 2013b; Newcrest Mining Limited, 2020). The pre-existing landform of undulating hills would be replicated through mine rehabilitation landforms so that these landforms generally / reasonably blend in with surrounding topography. Specific future post mining land use goals include:

- High quality agriculture (Grazing) areas where deemed to be sustainable and low risk of erosion, degradation, damage. Similar species composition and carrying capacity to surrounding areas.
- Woodland (conservation). Increasing the amount of conserved woodland in the district for future flora and fauna protection. Replacing / replicating Endangered Ecological Communities where applicable. Similar vegetation types / composition to surrounding / local remnant vegetation.
- Allowing for future needs of the community through retaining key infrastructure where appropriate (pending future negotiations with regulatory bodies / community). Considerations may include regional
- water reticulation network, future industrial use of the site, landfill (within Cadia Hill Pit), roads, power assets etc.

The overall rehabilitation goal is to generate enduring land value, including both ecological value (e.g. biological diversity and other environmental values) and agricultural value (i.e. the ability to produce agricultural goods). Rehabilitation activities at Cadia aim to generate safe and sustainable landforms at the mine site, CHPL-owned land and the region as a whole, by rehabilitating mine disturbed lands to:

- add value to the current vegetation corridor programme (ecological value);
- allow for the future land use of grazing, where appropriate and sustainable (agricultural value);
- retain areas that may be important for future industry and infrastructure needs; and
- provide safe and stable landforms and minimise any adverse potential impacts so that there is no future liability for Newcrest or the community.

1.3 Rehabilitation and land management strategy

The primary objectives of rehabilitation and revegetation of post-mining disturbance areas at Cadia are summarised in the following points:

- If possible, allow for future industrial use of site infrastructure and resources.
- Create safe and stable, sustainable and productive landforms which conform to the natural topography of the Cadia area.
- Ensure there is no future or residual liability from the site (e.g. from soil or water contamination) for Newcrest or the wider community;
- Create sustainable ecological and if applicable, production (agricultural) ecosystems which are comparable to local reference / analogue sites (Mine Closure Criteria) or similar vegetation associations.
- Increase areas (compared to pre-mining) of native woodland with a long term land use of conservation to increase overall habitat availability for native fauna.
- Rigorously assess any mine disturbed areas with a future land use for agriculture / grazing to ensure it remains a sustainable land use and will not be subject to degradation (erosion).
- Incorporate 'chain of ponds' concepts into riparian system restoration.
- Protect the wider environment from potential long-term environmental impacts (e.g. impacts from Acid and Metalliferous Drainage AMD) via best practice design and rehabilitation.
- Consult with future user groups and other stakeholders regarding post mining land use and rehabilitation objectives.
- Control weeds and pests to meet mine closure criteria.
- Prevent, control and repair areas of erosion.
- Manage bushfire fuels and plan for emergencies, taking into consideration conservation objectives.
- Maximise the harvesting of topsoil and clay resources.

CHPL would aim to provide a balanced rehabilitation outcome, recognising the alternative land uses that exist in the region and aiming to establish a combination of grazing land and indigenous woodland on final landforms.

Rehabilitation programmes would be adjusted over the life of the Project as necessary, based on the outcomes of research trials, community and regulatory consultation, regional infrastructure requirements and industry knowledge. Progressive rehabilitation would be undertaken throughout the life of the Project, where practicable.

1.4 CVO rehabilitation commitments

1.4.1 Primary mine disturbed areas

The following section provides a brief overview of the rehabilitation and mine closure considerations for the primary mine disturbed areas that are being progressively rehabilitated at CVO according to CVO Land and Biodiversity Management Plan (Newcrest 2013a, 2013b, 2020). Presently two major areas of rehabilitation are progressively being rehabilitated including areas situated on the North and South Waste Rock Dumps. A map showing the conceptual final landuse for these areas is provided in Figure 1-1. A map showing the various phases of the progressive mine rehabilitation is provided in Figure 1-2, including areas that have already been rehabilitated (Newcrest 2013a, 2013b).

1.4.1.1 **North Waste Rock Dump**

- The North Waste Rock Dump would have maximum batter slopes of 1:3, with 15 to 20 metre (m) wide, step-back, reverse graded berms and rock lined drains;
- PAF material contained in the dump would be encapsulated by covering with 0.5 m of compacted clay followed by 2 to 3 m of non-acid forming (NAF) material;
- This would be covered by 20 to 30 centimetres (cm) of topsoil. Where possible topsoil will be used that has been stripped from an area with a consistent final land use;
- Drainage control structures would be installed where necessary, utilising 'chain of ponds' concepts where appropriate; and
- The North Waste Rock Dump would be revegetated with indigenous bushland species with a final land use of conservation.

1.4.1.2 **South Waste Rock Dump (SWRD)**

- The revegetation objective for the South Waste Rock Dump is to provide woodland across the dump surface and batters with a final land use of conservation;
- Selective encapsulation of PAF waste rock with a low permeability seal followed by NAF material and topsoil;
- 20 to 30 centimetres (cm) of topsoil will be placed as the surface substrate. Where possible topsoil will be used that has been stripped from an area with a consistent final land use;
- Grading the final surface of the dump to blend in with the natural topography of the area, with an overall outer batter slope of 1:4 comprising 1:3 outer slopes and 15 to 20 m wide, step-back, reverse graded berms;
- Installation of rock lined drains and detention ponds to channel runoff safely to constructed outlet areas;
- Creation of additional habitat using trees cleared from disturbance areas supplemented with additional habitat structures targeting threatened and declining woodland species (e.g nesting boxes, bat boxes, salvaged hollows etc);
- The woodland areas will be linked to other conservation areas in the Cadia Valley through the vegetation corridor programme;
- Rehabilitation trials would be conducted by CHPL to determine the best combination of techniques for the establishment of native woodland species (including soil treatments, seed mixes, sowing methods etc).

1.4.1.3 **SWRD Water Management**

- The top surface of the South Waste Rock Dump would be designed with a slight dish shape that would generally drain towards the north. Rock lined channels would be installed along the northern edge of the top surface to provide a stable means for surface water runoff to drain from the top of the SWRD;
- On the batters of the dump, surface water runoff would flow perpendicularly down the slope to the toe of each batter where it would be re-directed by the 15 to 20 m wide reverse graded berms. The water would gradually flow short distances along the berms to rock lined channels which would be constructed at regular intervals down the faces of the batters. These channels would enable water from one berm to be channelled in a controlled manner down the face of the batter to the next berm and ultimately to the base of the dump;

- Rock lined channels would be used at the base of the dump to direct runoff into natural creek lines, the surface of the NTSF, or the Rodds Creek Water Holding Dam;
- Drainage control structures would utilise 'chain of ponds' concepts where appropriate; and
- The existing sediment ponds and leachate collection ponds downstream of the dump would be retained until the revegetated surface of the dump is stable and the runoff water quality is acceptable.

1.4.2 Guiding principles

The following guiding principles will be implemented for the Mine Disturbed Landscape (Newcrest 2013a, 2013b).

- Rehabilitation for the post mining land use of woodland, forest or native communities to use:
    - A range of indigenous species (trees, shrubs, grasses, forbs (and aquatic species where applicable);
    - Seed that has been locally collected; and
    - A range of species to provide diversity (including structural diversity) consistent with the target vegetation association (based on soil type, aspect, slope and adjacent (or pre-existing) communities).
- Rehabilitation for the post mining land use of agriculture / grazing to use:
    - Predominantly perennial species (supplemented with annual species as required such as legumes etc);
    - Ranges of native and / or introduced pasture species where suitable; and
    - Scattered paddock trees to match the surrounding agricultural landscape.
- Species will be selected based on the target vegetation community and derived from vegetation survey species lists from a similar community type or monitoring reference site. (Refer to Appendix B Cadia East Environmental Assessment (CHPL 2009));
- Where possible attempt to re-create communities consistent with local Endangered Ecological Communities (EEC);
- The recovery and use of habitat and rehabilitation resources from remnant areas destined for clearance / subsidence should be maximised to enhance the success and colonisation of rehabilitated sites;
- Locally uncommon species from remnant areas or species that are difficult to propagate should be re-located / re-planted prior to approved clearing;
- Native seed to be collected from within 20km of mine lease boundary or within an acceptable distribution radius;
- Where possible immediately re-spread harvested topsoil to take advantage of seed banks and soil biota and to reduce damage to soil structure through rehandling;
- Utilise topsoil from areas with a similar post mining land use to take advantage of available seed banks; and
- Undertake annual monitoring of rehabilitation sites and compare a range of parameters against selected reference sites.

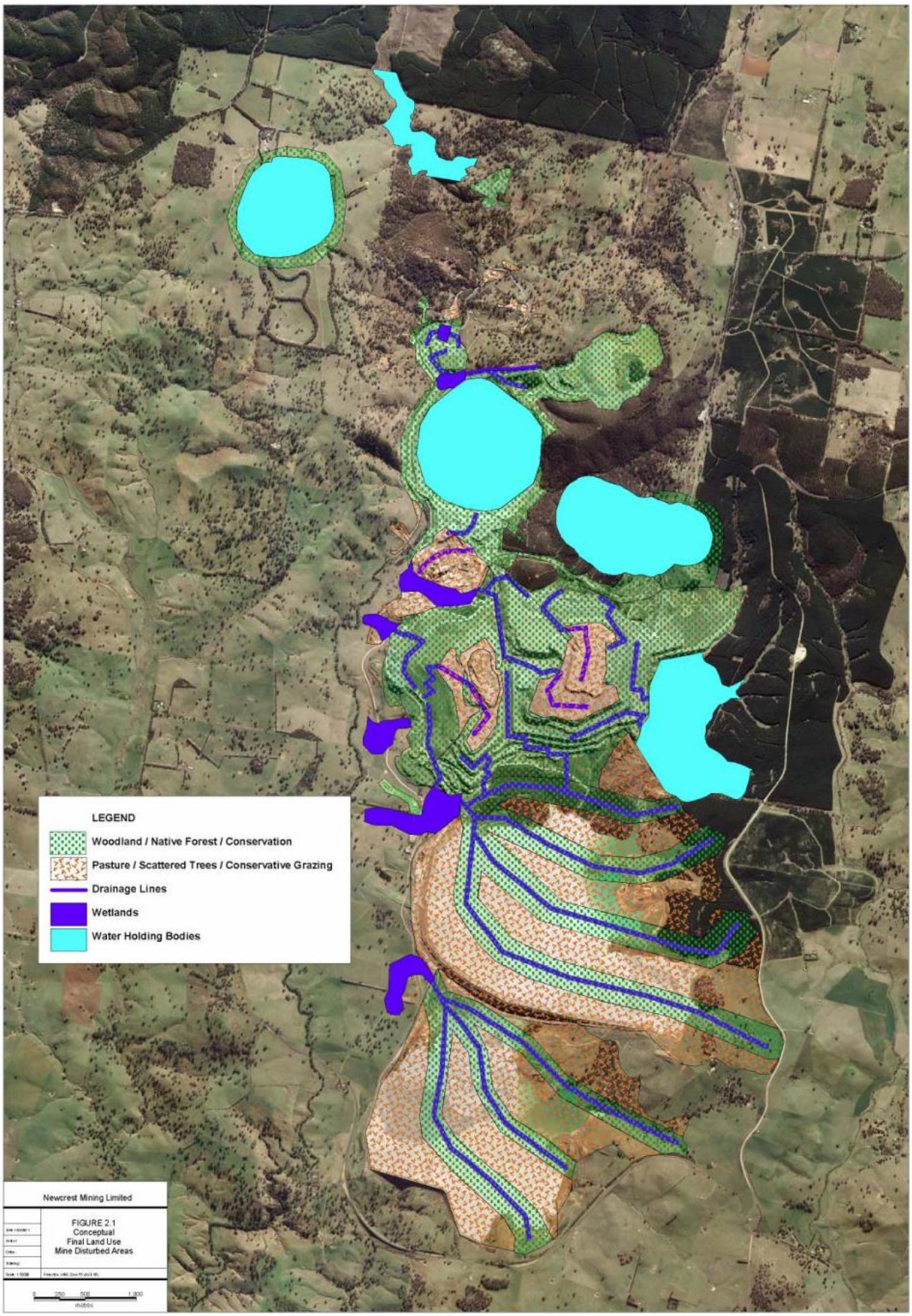


Figure 1-1. Conceptual final land use of mine disturbed areas (Newcrest 2013b).

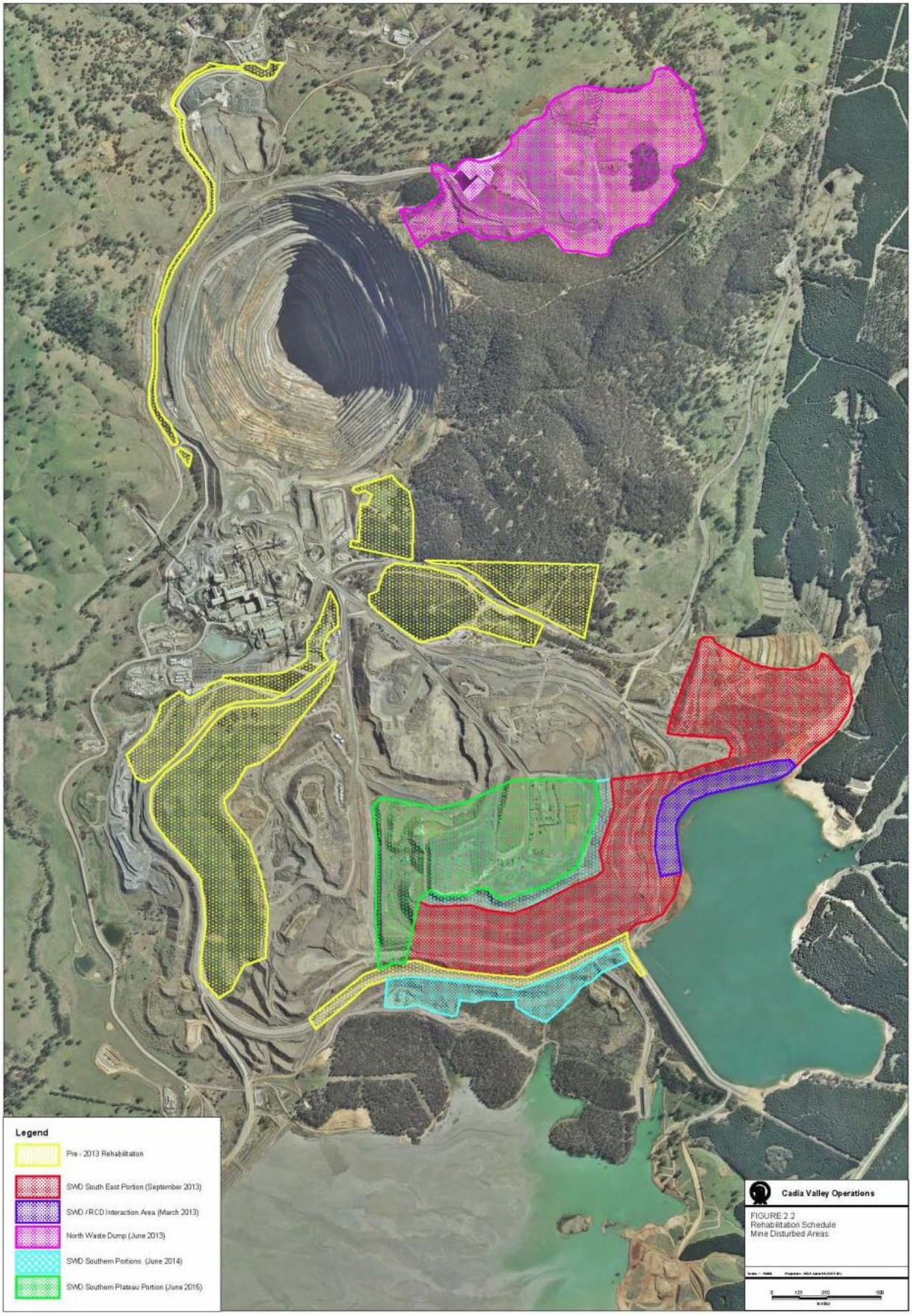


Figure 1-2. Rehabilitation schedule of mine disturbed areas (Newcrest 2013a).

1.4.3 Vegetation corridor program.

1.4.3.1 Aim of CVO Vegetation Corridor Program

The aim of the CVO Vegetation Corridor Program is to generate enduring land value, including both ecological and agricultural value. This aim will be achieved through meeting the following objectives throughout the life of the plan (Newcrest 2013b):

- Conserve and enhance areas of isolated remnant vegetation;
- Link significant areas of remnant vegetation;
- Provide habitat for native fauna;
- Allow the movement of genetic material between flora and fauna populations; and
- Increase the sustainability and biodiversity of CVO farms and environs.

1.4.3.2 Considerations for Vegetation Corridors

The following considerations will be taken into account when planning and implementing the Vegetation Corridor Program. Figure 1-3 shows the status of the Vegetation Corridor Program (Newcrest 2013b). Figure 1-4 shows how the Vegetation Corridor Program aligns with the proposed mine site rehabilitation concepts to extend corridor linkages across Newcrest owned land (Newcrest 2013b).

- Existing viable remnants should be protected wherever possible;
- Protection is to extend to all strata and native life forms including trees, shrubs, grasses, other herbs and forbs, ground litter, fungi, logs etc;
- Existing remnants should be enlarged or connected by revegetating with the appropriate indigenous species in the landscape;
- Ensure revegetation areas are of sufficient size (nominally >5ha or > 100m wide) where possible to maximise sustainability and biodiversity outcomes;
- Revegetation areas should provide a wide range of habitat features and provide specific habitat for threatened and locally significant fauna species;
- Rehabilitation planning should recognise that physiographic and topographic controls as well as land use objectives may make some areas better suited to pasture and agriculture;
- Rehabilitation planning would be conducted in consultation with the Community Consultative Committee (CCC) and key government stakeholder agencies (e.g NSW Office of Environment and Heritage (OEH) (Formally NSW Department of Environment, Climate Change and Water) , NSW Department of Trade and Investment, Regional Infrastructure and Services (formally Industry & Investment (I&I NSW) and NSW Office of Water (NOW)), and Councils through the AEMR process;
- Rehabilitation planning should be recognised as a dynamic activity requiring stakeholder consultation, the conduct of trials and design studies and the preparation of appropriate management plans prior to implementation;
- Allow for the protection and enhancement of threatened species, communities and locally significant species; and
- Planning for rehabilitation works will take into consideration livestock movement, stock water access, farm operational needs and future mining projects.

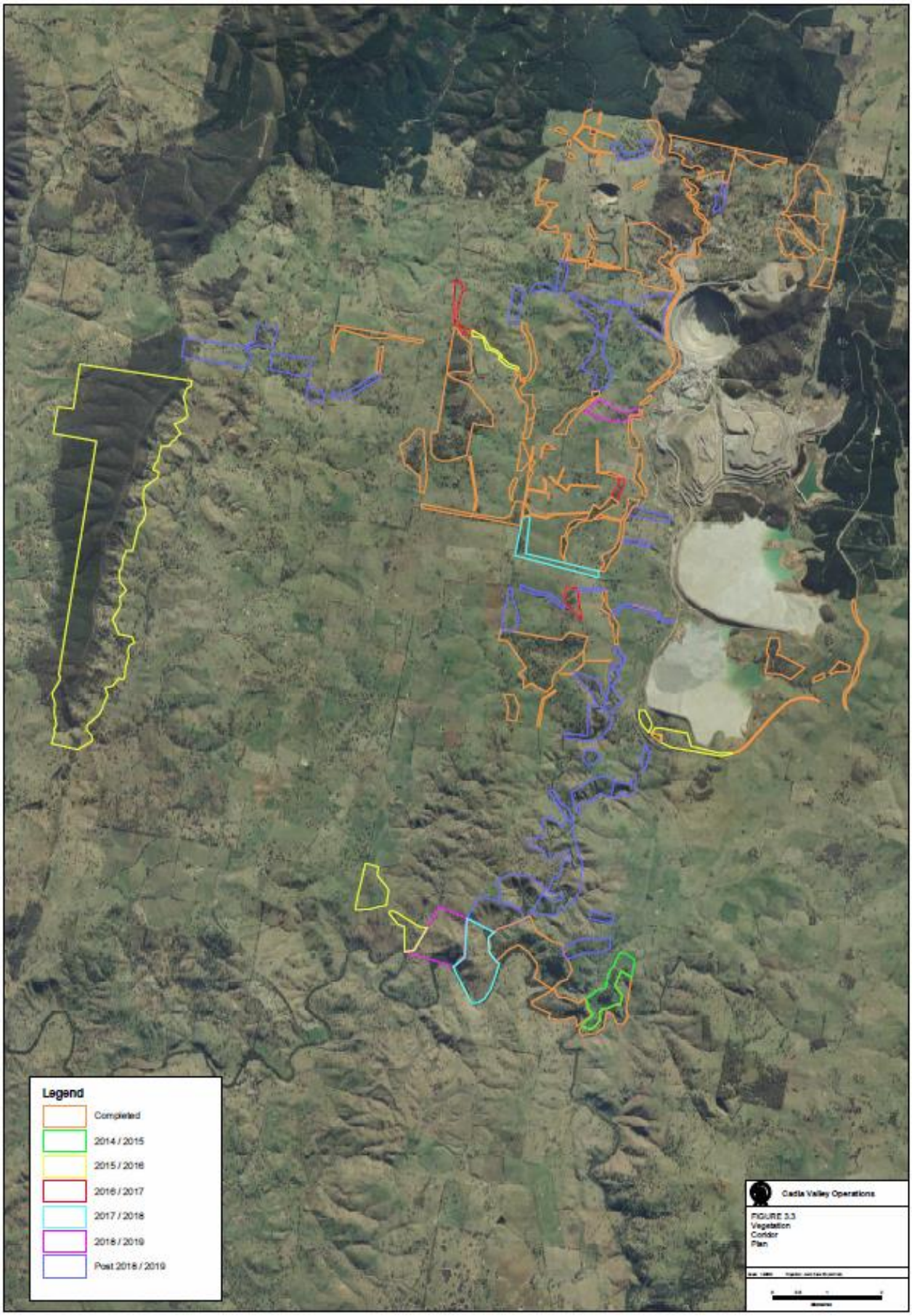


Figure 1-3. Vegetation Corridor Program (Newcrest 2013 b).

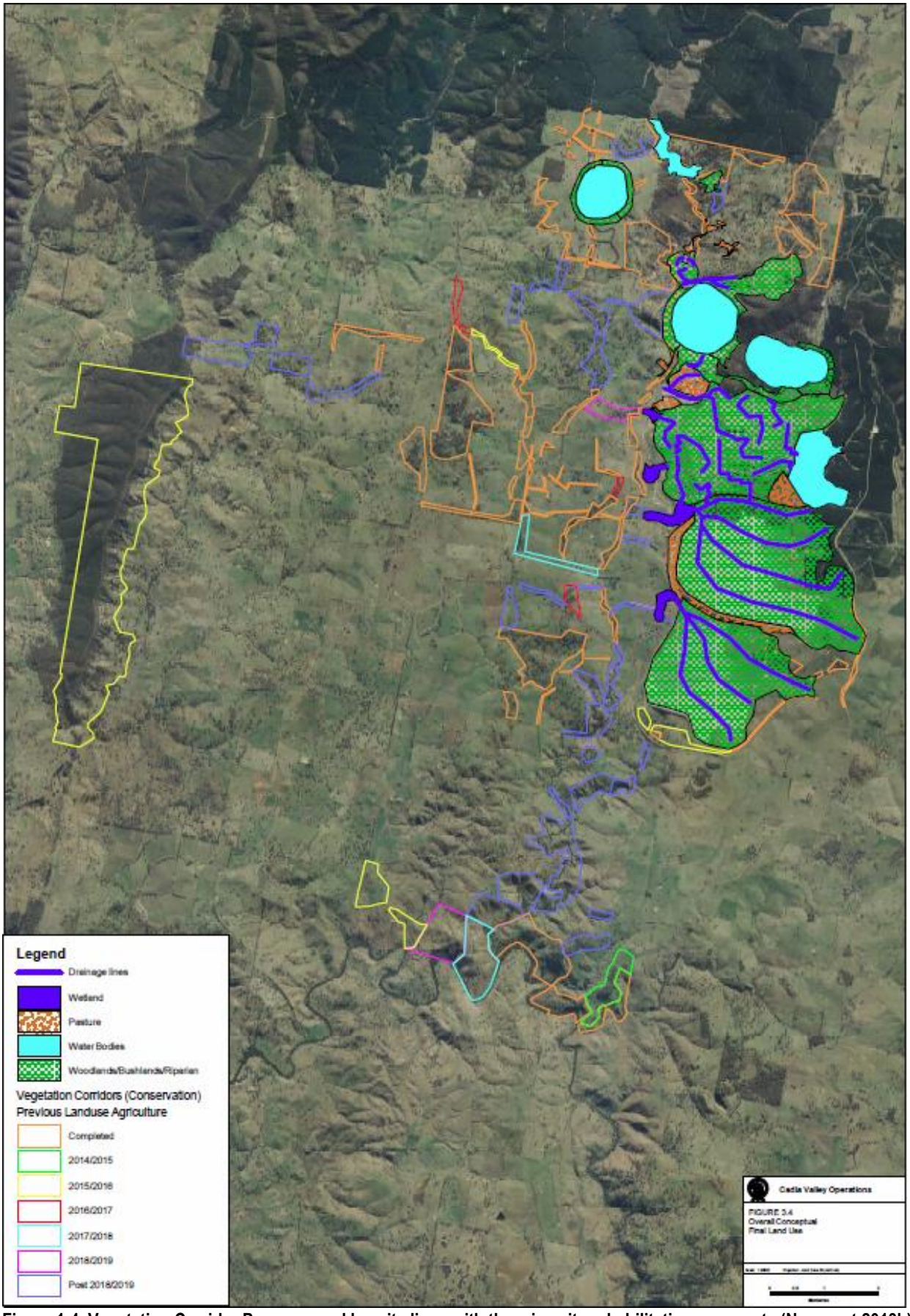


Figure 1-4. Vegetation Corridor Program and how it aligns with the mine site rehabilitations concepts (Newcrest 2013b).

1.5 ESG3 MOP Guidelines

In NSW, mining operations must be carried out in accordance with a Mining Operations Plan (MOP) that has been approved by the NSW Department of Industry (Resource and Energy) (the Department) (formerly NSW Trade and Investment - Division of Resources and Energy. 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) detailed a 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). These guidelines will soon be superseded by the Rehabilitation Management Plan and Associated Annual rehabilitation Report and Forward Program for large mines Codes of Practice (NSW Department of Planning 2018).

1.5.1 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.

1.5.2 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). 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 CGO 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).

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, drought 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).

1.6 Completion criteria and key performance indicators

At CVO, 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 (or three year monitoring cycle) from these reference sites which form an *upper* and *lower* KPI target. 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 have been further separated into "*Primary performance indicators*" and "*Secondary performance indicators"*. Primary performance indicators are those chosen as essential completion criteria targets, and have been identified as those that will satisfy requirements 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.

2 CVO rehabilitation monitoring program

2.1 Primary objectives

The primary objective of the CVO rehabilitation monitoring program was to compare the progress of rehabilitated landforms and revegetated conservation 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. This involved developing a set of completion criteria consistent with CVOs Landscape Management Plan (CPHL 2009), Rehabilitation Strategy (Newcrest Mining Ltd 2013a), Land and Biodiversity – Landscape Management Plan (Newcrest 2013b), community expectations as well as relevant NSW legislation, policies and best practice guidelines (NSW I&I 2010, NSW T&I 2012, NSW T&I 2013).

The primary objectives in establishing completion criteria is to establish clearly defined, repeatable and consistent methodologies for monitoring changes in various aspects of ecosystem stability, recovery and long-term sustainability. Part of this process includes:

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

2.2 Establishing suitable reference sites

Three main vegetation community types were identified as being rehabilitated onto mining disturbed areas or CVO farmland areas and included:

- Grassy woodland;
- Introduced pastures; and
- Riparian woodlands.

All reference sites have been subjected to some form of prior disturbance, in particular clearing for agriculture and livestock grazing and all woodland sites were regrowth, with some invasion from introduced species. These sites, despite their disturbance history were typical of the local area and help set realistic rehabilitation targets and provide a benchmark for transitional processes that can be expected or that are presently occurring in the rehabilitation areas.

Data obtained from these reference sites quantified the range of key ecological performance indicators and resulting completion criteria. The reference sites were spread out where possible to maximise the spatial distribution and subsequent variations in community composition across the local landscape and all are now situated on Cadia owned land.

Since 2016, the number of reference sites has included:

- Four grassy woodland;
- Two riparian woodland; and
- Two exotic pastures.

2.3 General description of the reference sites

2.3.1 Grassy woodland reference sites

The grassy woodlands were comprised of low various densities of *E. albens* (White Box) or *E. melliodora* trees but *E. blakelyi* (Blakely's Red Gum), *E. macrorhyncha* (Red Stringybark), *E. bridgesiana* (Apple Box) and/or or *E. goniocalyx* (Bundy Box) may also have been present. Scattered old growth trees were present as well as younger regrowth and some relatively recent natural eucalypt recruitment was present in all sites. There was an absence of a shrub layer in two sites however in the other woodland site, there were some scattered *Acacia dealbata* (Silver Wattle) and *A. implexa* (Hickory) and eucalypt regeneration was present. There may also have been occasional exotic shrubs in some woodland areas *(ie. Rubus fruticosus* (Blackberry), *Rosa rubiginosa* (Sweet Briar). The understoreys were usually dominated by native perennial grasses and common native forbs and all sites contained a high cover of leaf litter. There were also scattered exotic annuals and pockets of exotic grasses or weeds especially in old stockcamp areas.

2.3.2 Riparian woodland reference sites

The two riparian woodland sites were quite different to each other, but both were characteristically open grassy woodland. One site was comprised of scattered old growth trees of *E. camaldulensis (*River Red Gum)*, E. melliodora* and *E. bridgesiana* (Apple Box) and had an understorey dominated by *Phalaris aquatica* (*Phalaris*) and *Dactylis glomerata (Cocksfoot)* with patches of introduced annual grasses and native grass and herbs. The second site was also comprised of scattered old growth trees dominated by *E. viminalis* (Ribbon Gum)*, E. melliodora* and *E. bridgesiana* and a relatively intact and diverse native grassy understorey and contained some patches of shrubs including *Acacia melanoxylon* (Blackwood) and *A. dealbata*. Both sites however contained various noxious weeds and floods waters continue to alter the stream morphology.

2.3.3 Introduced pasture reference sites

The two introduced pasture sites were dominated by *Phalaris aquatica* and contained various combinations of other pasture species such as *Dactylis glomerata* (Cocksfoot), *Lolium* sp (Ryegrass) and *Trifolium* species (Clovers). At RfPast03, *Puccinellia stricta* (Australian Saltmarsh Grass) was also very abundant. These sites are intermittently grazed by sheep and cattle but both sites contained very high ground cover levels and had very few weeds.

2.4 CVO Rehabilitation monitoring sites

At CVO, rehabilitation has been progressive since the inception of the monitoring program and subsequently the number of rehabilitation monitoring sites has typically grown over the years. Major rehabilitation was undertaken on the main Waste Emplacements in 2008 (South Dump) and in 2014/2015 (North and South Dump).

In 2008, seven rehabilitation sites were first established and were a combination of bushland, woodland and riparian communities. In 2010, one additional woodland site (SouthDump03) was established on the Southern waste rock emplacement. The rehabilitation monitoring sites were considered to be representative of the rehabilitation area as a whole or were similar to and representative of other areas of rehabilitation.

In 2014 - 2015, large areas of rehabilitation had been completed on the Northern and Southern Waste Rock emplacements and three new rehabilitation monitoring sites were established in both rehabilitation areas to provide a representation of the progress of the rehabilitation on the various batters and time of rehabilitation.

"Ashleigh Park" the direct seeded rehabilitation site and "Cadiangullong Creek" and "Creek Diversion", both riparian woodland corridor rehabilitation projects were not monitored in 2014 or 2015 in an attempt to keep the number of monitoring sites to a manageable number. While these sites may have fell short in meeting some completion targets, previous monitoring has indicated that both of these rehabilitation sites were very stable and were establishing well with changes in ecological condition usually occurring as a response to seasonal conditions and grazing pressure. These sites will continue to be monitored at three yearly intervals and thus they were included in the 2016 and 2019 monitoring events. There are presently no exotic pasture rehabilitation areas, therefore there has been no further requirement to monitoring the exotic pasture reference sites again this year.

In 2015 a new grassy woodland reference site was established to replace a reference site situated on a reserve but leased by a local landholder which was rapidly being degraded by invasive weeds. The new reference site was dominated by *E. melliodora – E. macrorhyncha* and has a similar sloping topography and ecotonal transition as the rehabilitation areas and is located on CVO property adjacent to the main access road. RWood04 was considered to be a more suitable analogue for the woodland rehabilitation areas.

A significant area (~60ha) of additional rehabilitation had been undertaken on the South Dump in February 2015 with new rehabilitation monitoring sites being established in 2016 to provide a representation of the progress of the rehabilitation on the various batters. In 2019 one more monitoring site (South Dump 10), which was seeded in February 2018, was established on the western batter of the South Dump.

The reference site RWood04 and rehabilitation site South Dump 06 are now unable to be accessed due to closure of the surrounding area due to mine subsidence and are no longer able to be part of the monitoring program.

2.5 Summary and location of the monitoring sites

Table 2-1 shows a summary of the monitoring sites assessed as part of the CVO monitoring program, including the general locality, year of establishment, community type and frequency of monitoring. Figure 2-1 shows the location of the reference and rehabilitation monitoring sites. GPS coordinates and other site specific information is provided in Appendix 1.

Table 2-1. Summary of the monitoring sites.

Site type	Vegetation community	Site name	Rehabilitation method	Year established	3 year monitoring rotation	Monitored in 2016	Monitored in 2017	Monitored in 2018	Monitored in 2019	Monitored in 2020
Reference site	Woodland - Ashleigh Park	RfWood01	-	2008		1	1	1	1	1
	Woodland - Bundarra	RfWood02	-	2008		1	1	1	1	1
	Woodland - CVO Access Rd	RWood04	-	2015		1	1	1	subsidence	subsidence
	Woodland - Cadiangullong Dam	RWood05	-	2008		1	1	1	1	1
	Pasture - Bundarra	RfPast01	-	2008	☑ 2019	1			1	
	Pasture - Willunga	RfPast03	-	2008	☑ 2019	1			1	
	Riparian - Bakers Shaft	RrRip02	-	2008	☑ 2019	1			1	
	Riparian - Cadiangullong Ck CVO	RrRip03	-	2008	☑ 2019	1			1	
	Total reference sites					**8**	**4**	**4**	**8**	**3**
Rehabilitation sites	Woodland	Ashleigh Park	Direct Seeded Farmland	2008	☑ 2019	1			1	
	Woodland	South Dump 01	Aerial seeding + tubestock planting	2008	☑ 2019	1		1	1	
	Woodland	South Dump 02	Aerial seeding + tubestock planting	2008	☑ 2019	1		1	1	
	Woodland	South Dump 03	Aerial seeding + tubestock planting	2010	☑ 2019	1		1	1	
	Woodland	WillungaDS01	Direct seeded farmland	2008	☑ 2019	1			1	
	Woodland	WillungaDS02	Direct seeded farmland	2008	☑ 2019	1			1	
	Riparian woodland	Cadiangullong Creek	Direct seeded farmland	2008	☑ 2016	1			1	
	Riparian woodland	Creek Diversion	Tubestock planting	2008	☑ 2019	1			1	
	Woodland	North Dump 01	Aerial seeding	2014		1	1	1	1	1
	Woodland	North Dump 02	Aerial seeding	2014		1	1	1	1	1
	Woodland	North Dump 03	Aerial seeding	2014		1	1	1	1	1
	Woodland	South Dump 04	Aerial seeding	2014		1	1	1	1	1
	Woodland	South Dump 05	Aerial seeding	2014		1	1	1	1	1
	Woodland	South Dump 06	Aerial seeding	2014		1	1	1	subsidence	Subsidence
	Woodland	South Dump 07	Aerial seeding	2016		1	1	1	1	1
	Woodland	South Dump 08	Aerial seeding	2016		1	1	1	1	1
	Woodland	South Dump 09	Aerial seeding	2016		1	1	1	1	1
	Woodland	South Dump 10	Seeded	2018					1	1
	Total rehabilitation monitoring sites					**17**	**9**	**16**	**17**	**9**
Total No sites						**25**	**13**	**16**	**25**	**12**

Figure 2-1. Map of the CVO monitoring sites.

3 Rehabilitation monitoring methodology

The primary objective of the CVO rehabilitation monitoring program was to establish an annual rehabilitation monitoring program and develop set of completion criteria that complies and is consistent with conditions specified within a range of approval documents and conditions and associated CVO Management Plans including the CVO Rehabilitation Strategy (CVO 2013) and CVO Land and Biodiversity – Landscape Management Plan (CVO 2013). It has also been amended to align with the Rehabilitation and Environmental Management Plan (REMP) Guidelines (NSW I&I 2010) and the Departments ESG3 MOP guidelines (NSW T&I 2012, 2013), whilst addressing the range of technical issues identified in the ACARP project (Nichols 2005).

The monitoring methods adopted to obtain completion targets included a combination Landscape Function Analyses (LFA; CSIRO Tongway & Hindley 1996), accredited soil analyses and an assessment of ecosystem diversity and habitat values using an adaptation of methodologies derived from the Biometric Manual (Gibbons *et al* 2005, DECCW 2011). The methodology used for undertaking the monitoring has been provided in "Rehabilitation monitoring methodology and determination of completion criteria" (DnA Environmental 2011) and have been referenced in previous monitoring reports.

Ecological monitoring has been undertaken by Dr Donna Johnston and Andrew Johnston (DnA Environmental) in autumn in all monitoring years and this year occurred from 30th March – 7th April.

3.1 Limitations

3.1.1 Species identification

In some cases there may have been a lack of critical features and/or reproductive structures (due to heavy grazing or browsing, new germinants etc) that may be required for the positive identification of some plant genera, and therefore some species may have only been identified to the genera level.

4 Rainfall

Total annual and monthly rainfall averages recorded at CVO from 2014 to the end of April 2020 compared to long term monthly averages recorded at Orange Airport are provided in Figure 4-1 and Figure 4-2. The long term annual average rainfall recorded at Orange Airport is 846mm. The graph indicates that with the exception of 2016, below average annual rainfall has been experienced since 2014, with the lowest annual rainfall occurring during 2017 and 2018 with a total of 487 and 496mm respectively, with these being only slightly more than half the expected rainfall.

Despite the apparently low rainfall activity in most years, the monthly averages indicate there has been high variability and erratic rainfall activity over these years. In 2015, there was below average rainfall during September and October and in February 2016 almost no rainfall was recorded at all, and only 19mm was received in March, thus providing very dry conditions preceding the 2016 monitoring event.

Relief from these hot dry conditions occurred in April 2016 with above average rainfall events from May through to September which collectively caused extensive flooding throughout the Central Western Region. This flood event was the result of 610mm or close to 70% of the annual average of rainfall over five consecutive winter months. In 2016, a total of 927mm was recorded. Since November 2016, rainfall was typically well below the monthly averages with only 3mm being recorded in February 2017. In March 2017 however, there was a much needed 110mm of rain which was well above the monthly average, followed by the monthly average of 45mm in April.

From October 2017 to January 2018 rainfall conditions were close to the expected monthly averages, however very dry conditions continued to be experienced throughout most of 2018, until November, where 97mm of rain fell. Above average rainfall was also recorded in January and March 2019 as a result of extreme storm activity, but in April, only 0.5mm of rain was recorded, with very limited rainfall being recorded for the remainder of the year. In January and February this year, some rain was experienced but these were lower than average, however expected rainfall was received in March and above average rainfall was recorded in April with 147mm being recorded in that month.

There have been extremes in climatic conditions, with floods in 2016 followed by three consecutive years of drought which has typically been reflected in the monitoring data. This year improved growing conditions were experienced resulting in a flush of plant growth and the germination of annual ground cover species.

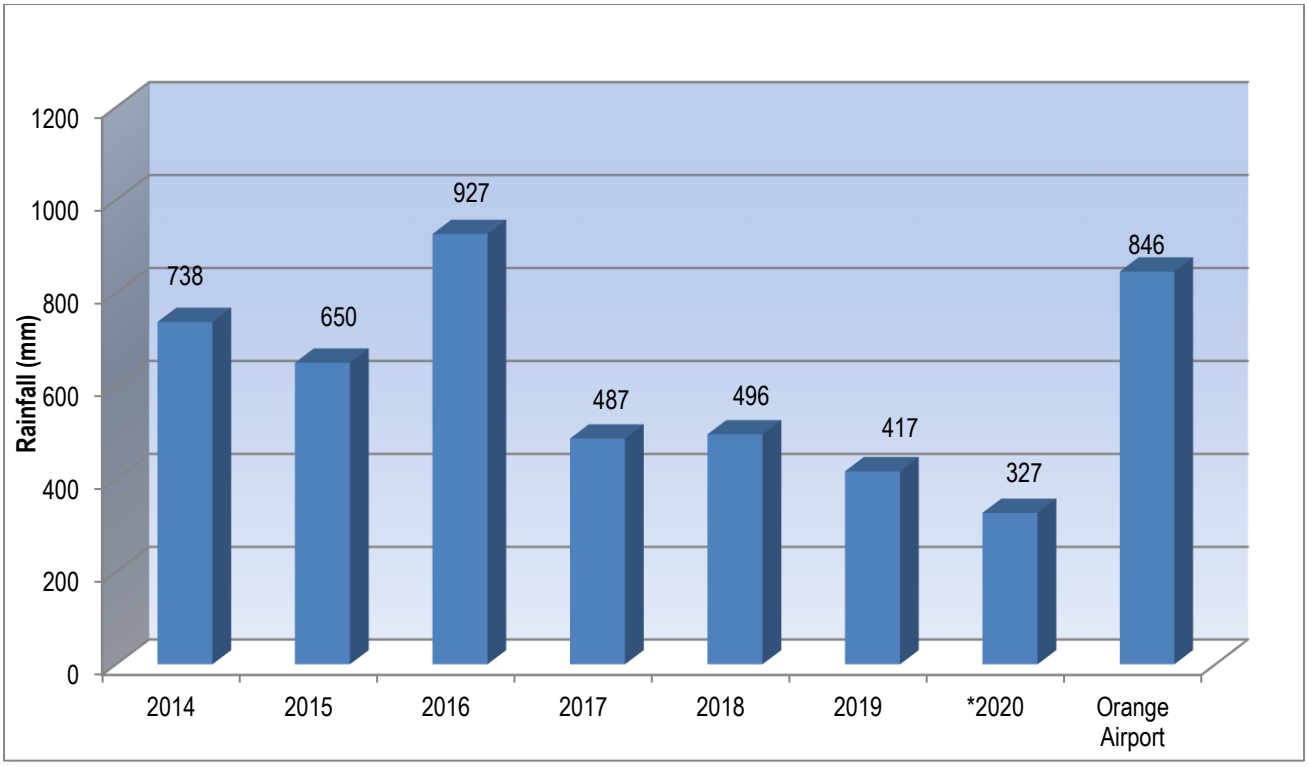


Figure 4-1. Annual average rainfall recorded at Cadia Valley Operations 2014 - April 2020 compared to long term monthly averages recorded at Orange Airport.

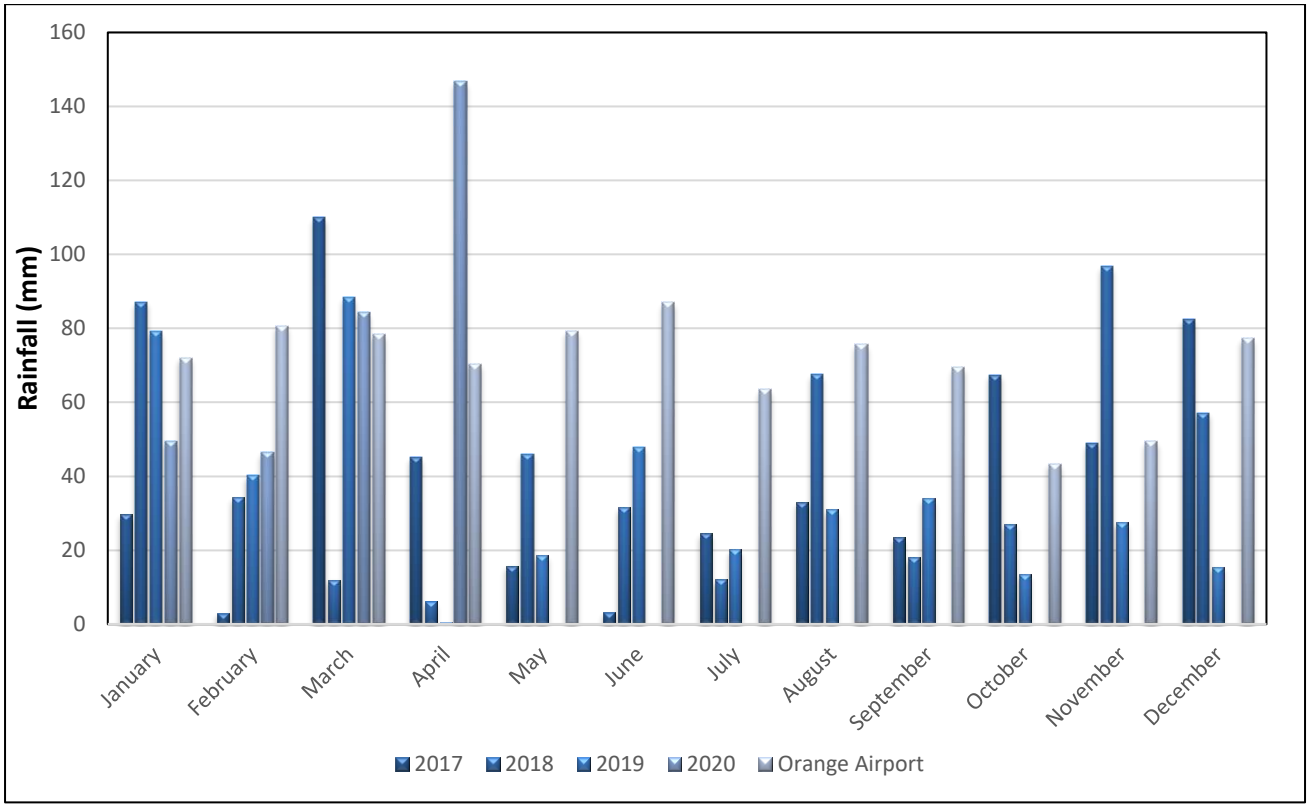


Figure 4-2. Average monthly rainfall recorded at Cadia Valley Operations January 2017 – April 2020 compared to long term monthly mean rainfall recorded at Orange Airport.

5 Results: Woodland monitoring sites

5.1 Descriptions and photo-points of the woodland reference sites

Table 5-1 provides a series of photographs taken from a permanent photo-point along the vegetation transect 2008 – 2020. Photos from numerous years have been excluded for ease of presentation of the increasing quantity of data. The GPS co-ordinates and other site specific information of the reference sites are provided in Appendix 1.

Table 5-1. General description and permanent photo-point along the vegetation transect in the reference monitoring sites 2008 - 2020.

Site name	2008	2012	2016	2020
RfWood01: "Ashleigh Park"				
RfWood02: "Bundarra"				

Site name	2008	2012	2016	2020
RWood05: Cadiangullong Dam				

5.2 Descriptions and photo-points of rehabilitation areas on the south and north dumps

Table 5-2 provides a photograph taken from the permanent monitoring point along the vegetation transect of rehabilitation sites established on the South and North Dumps from 2014 to 2020. North Dump 03 and South Dump 08 are relatively flat, while the remainder are on slopes. Sites South Dump 04 and 05 and North Dump 01, 02 and 03 were aerial seeded during November 2013 with a blend of native trees and shrubs and exotic pasture species. Sites on the North Dump were over sown with Japanese Millet while sites on the South Dump were over sown with Cereal Rye, Couch, Cocksfoot, Phalaris, Subterranean Clover, Perennial Ryegrass and the native grass *Bothriochloa macra* (Redgrass). In October 2015, sites South Dump 04 and 05 were cross ripped and re-seeded to reduce the compaction layer. Sites South Dump07, 08 and 09 were also aerial sown in February 2015 with a mix of endemic native, shrubs and ground cover species. South Dump10 was sown in February 2018. GPS co-ordinates and other site specific information of the rehabilitation sites are provided in Appendix 1.

Table 5-2. Permanent photo-point of the rehabilitation monitoring sites on the south and north dumps 2014 - 2020.

Site name	2014	2016	2018	2020
South Dump 04				
South Dump 05				

Site name	2014	2016	2018	2020
South Dump 07	N/A			
South Dump 08	N/A			
South Dump 09	N/A			

Site name	2014	2016	2018	2020
South Dump 10	N/A	N/A		
North Dump 01				
North Dump 02				

Site name	2014	2016	2018	2020
North Dump 03				

5.3 Ecological trends and performance against a selection of ecological performance indicators

The following section provides a summary of the ecological trends and performance of woodland rehabilitation sites against a selection of performance indicators obtained from the three woodland reference sites. As the rehabilitation monitoring program has been undertaken annually since 2008 many of the original sites (pre 2010) have reached a stable and functional state and are now being assessed every three years. These sites were not assessed this year.

In terms of data analyses, the majority of young rehabilitation sites were established and first assessed in 2014. Data obtained prior to 2014 from the older sites has been omitted from the report for ease of presentation. For early reference of data obtained from these older rehabilitation sites please refer to 2009 – 2016 CVO annual rehabilitation monitoring reports (DnA Environmental 2009 – 2016).

5.3.1 Landscape Function Analyses

5.3.1.1 Landscape Organisation Index

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 woodland reference sites were characterised by having a mature tree canopy and in two sites, there was a well developed, decomposing leaf litter layer and a sparse cover of native perennial forbs and grasses. The other sites tended to have much more dominant perennial grass cover. The extended dry conditions since 2017 has caused a reduction in perennial ground covers and increased disturbances by animals has created some bare interpatch areas in RfWood01 and RfWood02, thus lowering LOIs in these sites. This year there was 64.0 – 100% functional patch area in the woodland reference sites (Figure 5-1).

All of the younger rehabilitation sites established on the South Dump (South Dump 04 – South Dump 09) have previously demonstrated significant increases in functional patch area (Figure 5-1). Despite the loss of many of the original troughs and banks due to erosive process, there was a concurrent increase in plant and litter covers. During 2017 - 2019 however, prolonged dry conditions and increased grazing and disturbance by animals resulted in a deterioration of functional patch area in all of these rehabilitation sites.

This year, the continuing drought conditions, heavy grazing and increased erosion was recorded in several rehabilitation areas including South Dump 04 and South Dump 09, and a minor decrease was also recorded in North Dump 01. In the remaining sites, increased patch area was recorded largely due to the relatively recent germination of annual plant covers.

LOIs or functional patch areas were highly variable over the South Dump rehabilitation area and ranged from a low of 17% in the new rehabilitation site South Dump 10, to a high of 72% in South Dump 08. The functional patch areas on the North Dump ranged from 79% at North Dump 01 to a high of 93% at North Dump 03.

This year, South Dump 05, South Dump 08 and all three sites on the North Dump had an LOI comparable to the woodland reference sites (Figure 5-1).

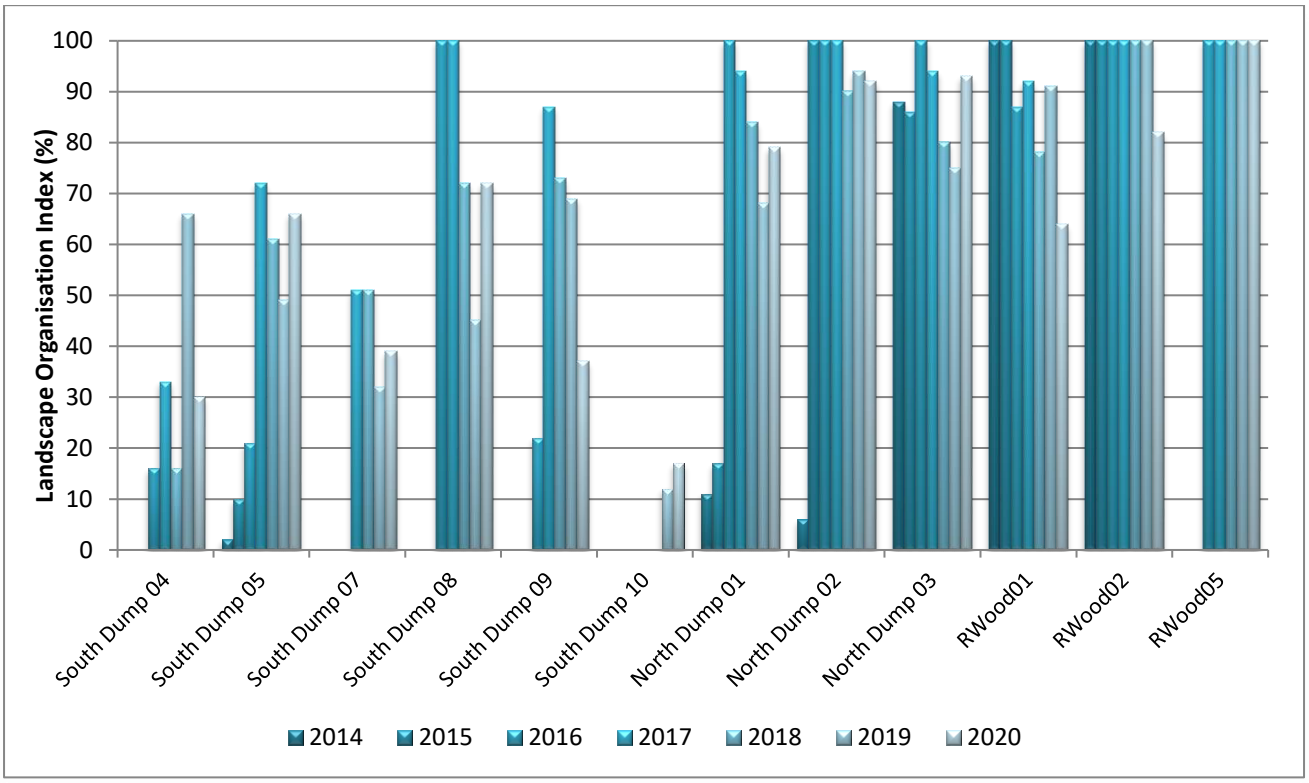


Figure 5-1. Landscape Organisation Indices recorded in the woodland monitoring sites.

5.3.1.2 **Soil surface assessments**

5.3.1.2.1 Stability

Changes in stability in the various woodland reference sites have tended to fluctuate according to seasonal conditions and total grazing pressure and these have been variable between sites. In 2016, there was an increase in stability in most of the monitoring sites as a result of the improved seasonal conditions, which typically promoted live annual and perennial plant cover. Since 2017, extended dry conditions and increased grazing and disturbance caused by animals has typically resulted in a reduction in the stability of the woodland reference sites. This year the stability range was lower with indices of 61.8 – 67.5 (Figure 5-2).

The stability of the rehabilitation areas on the South Dump were variable, with a marginal decline also being recorded in South Dump 04, 05, and 09 this year. South Dump 05 continued to be subjected by heavy disturbance by macropods, while active rilling and sheet erosion created unstable conditions for the establishment of cryptogam and ground cover vegetation in South Dump 04 and South Dump 09.

In the remaining sites, there tended to be an increase in litter and ground cover vegetation, and in some sites, there has been an increase in shrub cover and/or cryptogams were abundant. Stability in rehabilitation sites on the South Dump ranged from a low of 53.9 in the new area of rehabilitation at South Dump 10, to a high of 66.6 at South Dump 08.

Annual weeds had become well colonised on the North Dump rehabilitation area and due to the litter accumulation, all three sites had a well developed and mostly stable litter layer. While overgrazing by herbivores was prevalent in all three sites resulting in the exposure of small bare patches mostly on the top of old rip lines where some isolated erosion may be occurring, sheeting had become more evident in North Dump 01 where a slight decline in stability continued to be recorded. This year stability on the North Dump ranged from 62.0 – 67.7.

Rehabilitation sites South Dump 08 and all three sites on the North Dump had stability indices comparable to the woodland reference sites this year.

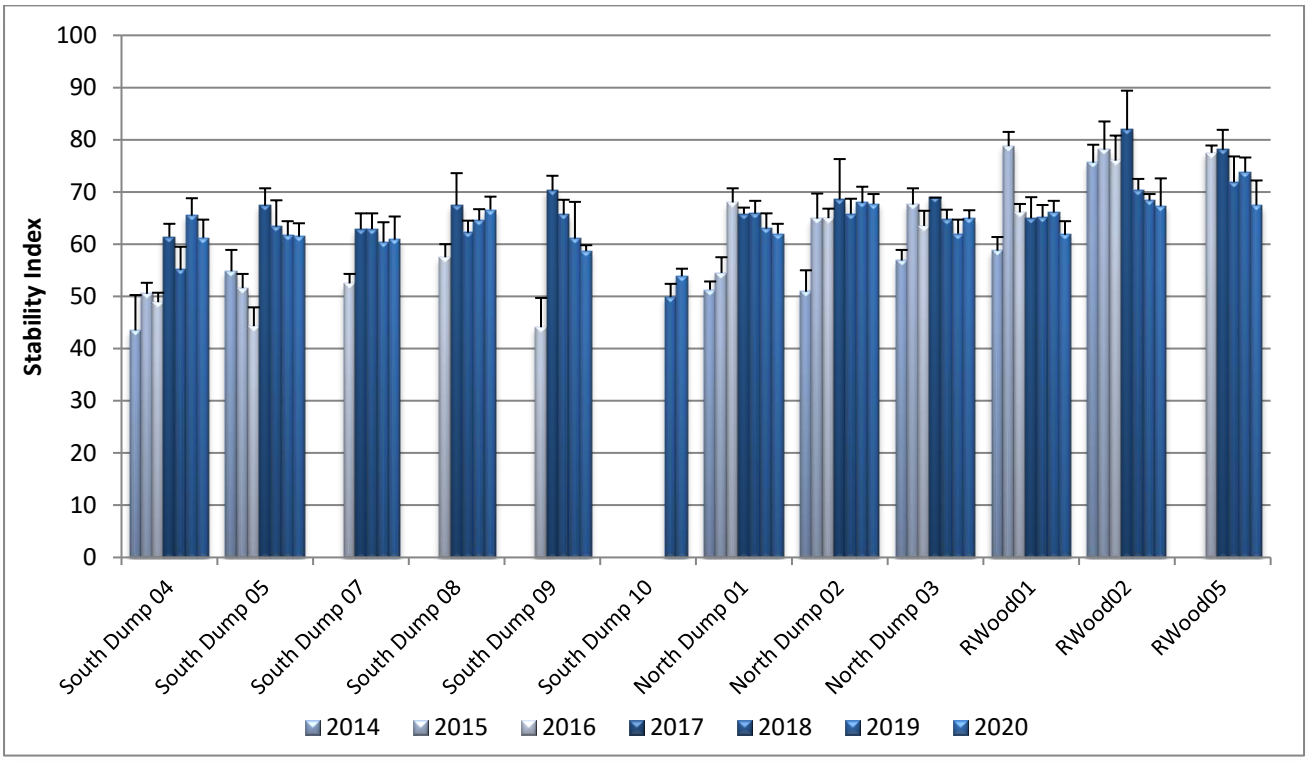


Figure 5-2 LFA stability indices recorded in the woodland monitoring sites.

5.3.1.2.2 Infiltration

The LFA infiltration indices recorded in the woodland reference sites have decreased this year as a result of the prolonged drought, with these ranging from 52.9 to 62.2 (Figure 5-3). In the rehabilitation sites, a decline in infiltration capacity was also recorded in some sites, including South Dump 04, 09 and 10 and all three sites on the North Dump. In some sites, including South Dump 04, 07 and, 09 the topsoil had washed away exposing the very hard and compacted clay layer, thus reducing the ability of rainfall to enter the soil profile. A marginal increase in infiltration was recorded in the remaining sites largely due to a slightly higher levels of ground covers and the concurrent increase in the litter development of the soil profile.

Infiltration capacity of rehabilitation sites on the South Dump ranged from a low of 24.5 at South Dump 10 to a high of 38.9 at South Dump 08. On the North Dump, infiltration indices ranged from 34.2 (North Dump 01) – 42.0 (North Dump 02).

No rehabilitation site had an infiltration capacity that was comparable to the woodland reference sites again this year.

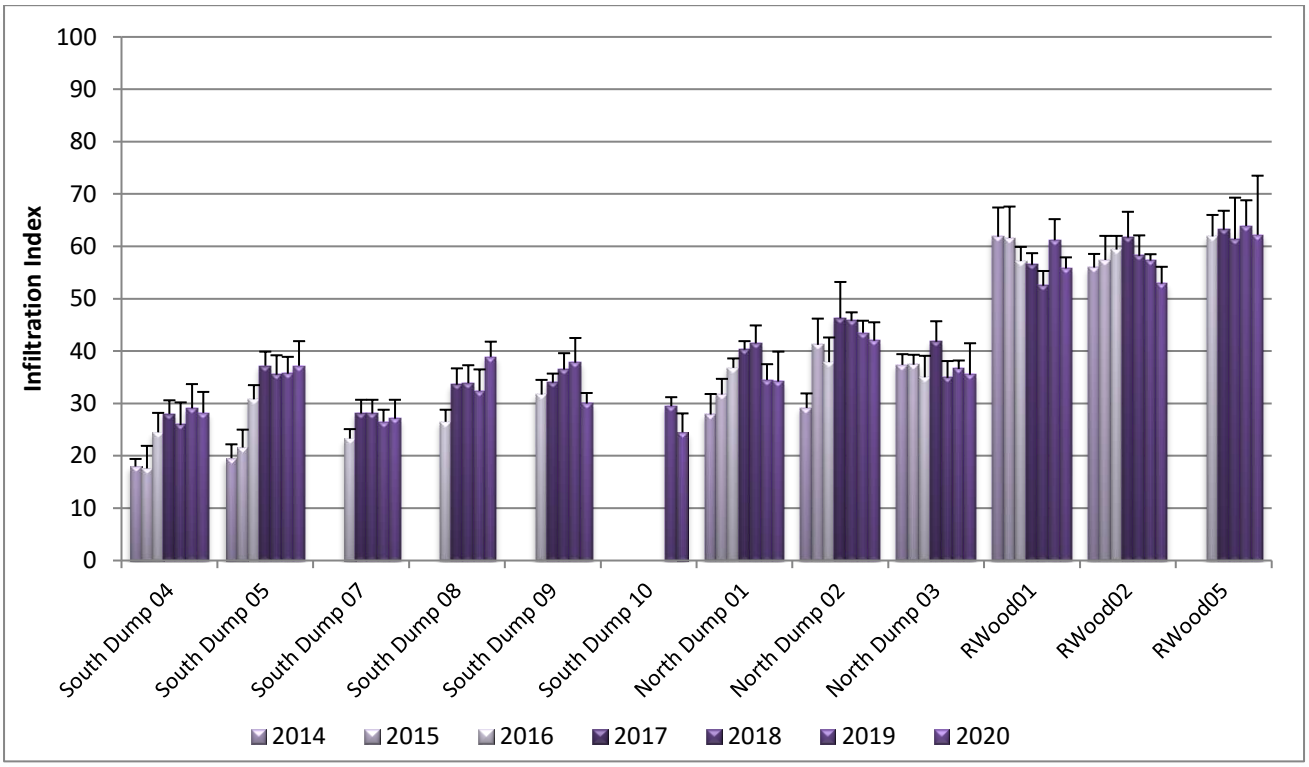


Figure 5-3. LFA infiltration indices recorded in the woodland monitoring sites.

5.3.1.2.3 Nutrient recycling

The nutrient recycling indices followed similar trends as infiltration capacity of the sites. They also tended to be influenced by the increase levels of perennial canopy and ground cover, litter cover and decomposition as well as cover provided by cryptogams. The LFA nutrient recycling indices for the woodland reference sites were variable between sites and this year they provided a lower minimum target range of 48.5 – 61.5 (Figure 5-4).

There was a slight improvement in nutrient recycling capacity in several sites on the South Dump including 05, 07 and 08 however in the remaining sites, nutrient recycling capacity marginally declined as there tended to be a loss of perennial ground cover and/or integrity of the litter layer. Nutrient recycling indices for rehabilitation sites on the South Dump ranged from a low of 20.4 on the new South Dump 10 site, to a high of 41.3 at South Dump 08. On the North Dump, nutrient recycling was slightly higher in all three sites and ranged from a low of 33.6 (North Dump 01) to a high of 41.3 (North Dump 02).

No rehabilitation site had a nutrient recycling capacity that was comparable to the woodland reference sites again this year.

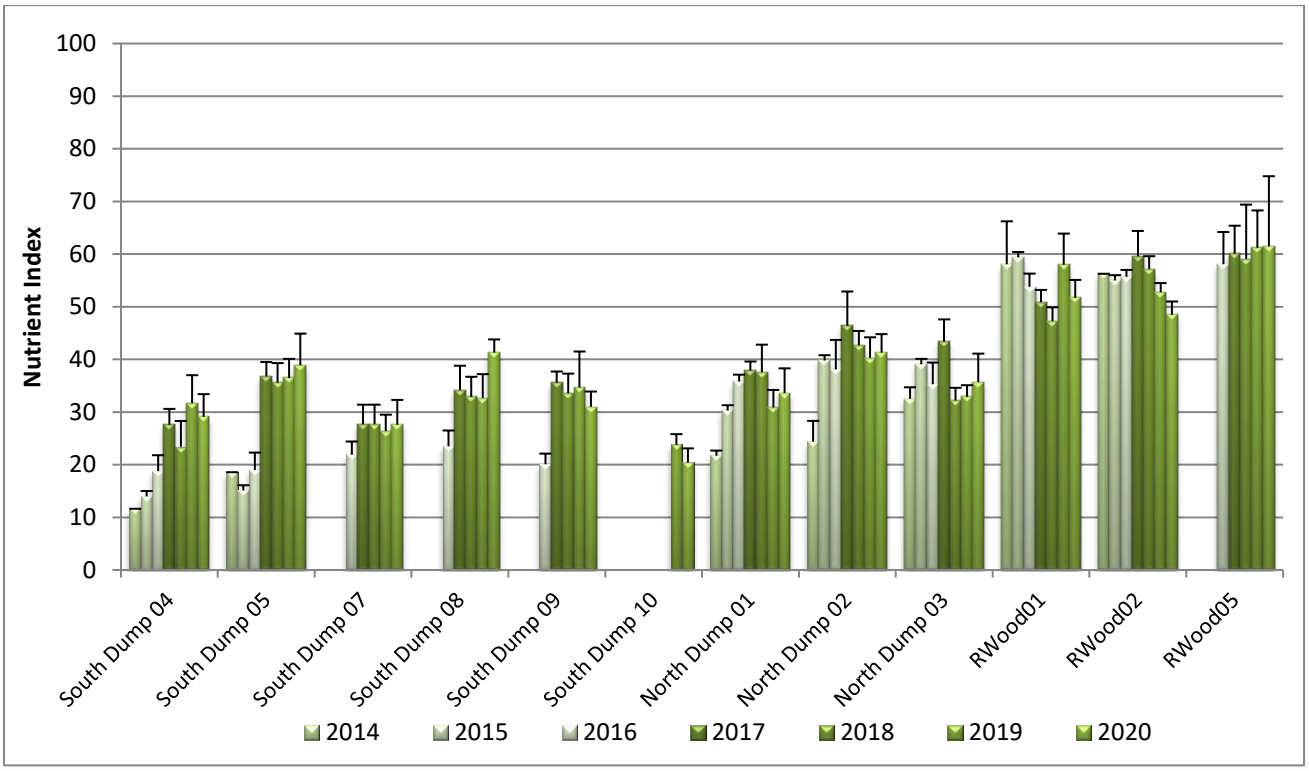


Figure 5-4 LFA nutrient recycling indices recorded in the woodland monitoring sites.

5.3.1.2.4 Most functional sites

The sum of the LFA stability, infiltration and nutrient recycling components provides an indication of the most functional to least functional monitoring site recorded in 2020 (Figure 5-5). The maximum score possible is 300.

This year, the woodland reference sites were the most ecologically functional sites with total scores of 191 and 169, with RfWood01 and RfWood02 being functionally equivalent this year. These sites contained high patch areas, mature tree canopies, high abundance of protective perennial ground covers. Most importantly, they also had a well developed and decomposing litter layer which had developed a spongy humus layer with little to no soil surface crusting.

Sites North Dump 02 and South Dump 08 were functionally similar to each other with scores of 151 and 147 respectively, with these sites having a maturing canopy, scattered perennial ground covers and developing litter layer. Sites South Dump 05 and North Dump 01 and 03 were functionally very similar to each other with a sum of scores ranging from 130 – 138, with South Dump 05 having the highest function of these sites. Sites South Dump 09, 04 and 07 were developing at similar rates to each other with scores of 120 – 116, while the newest area of rehabilitation South Dump 10 had the lowest ecological function with a score of 99.

Examples of the substrates and vegetation covers in the woodland monitoring sites have been illustrated in Table 5-3.

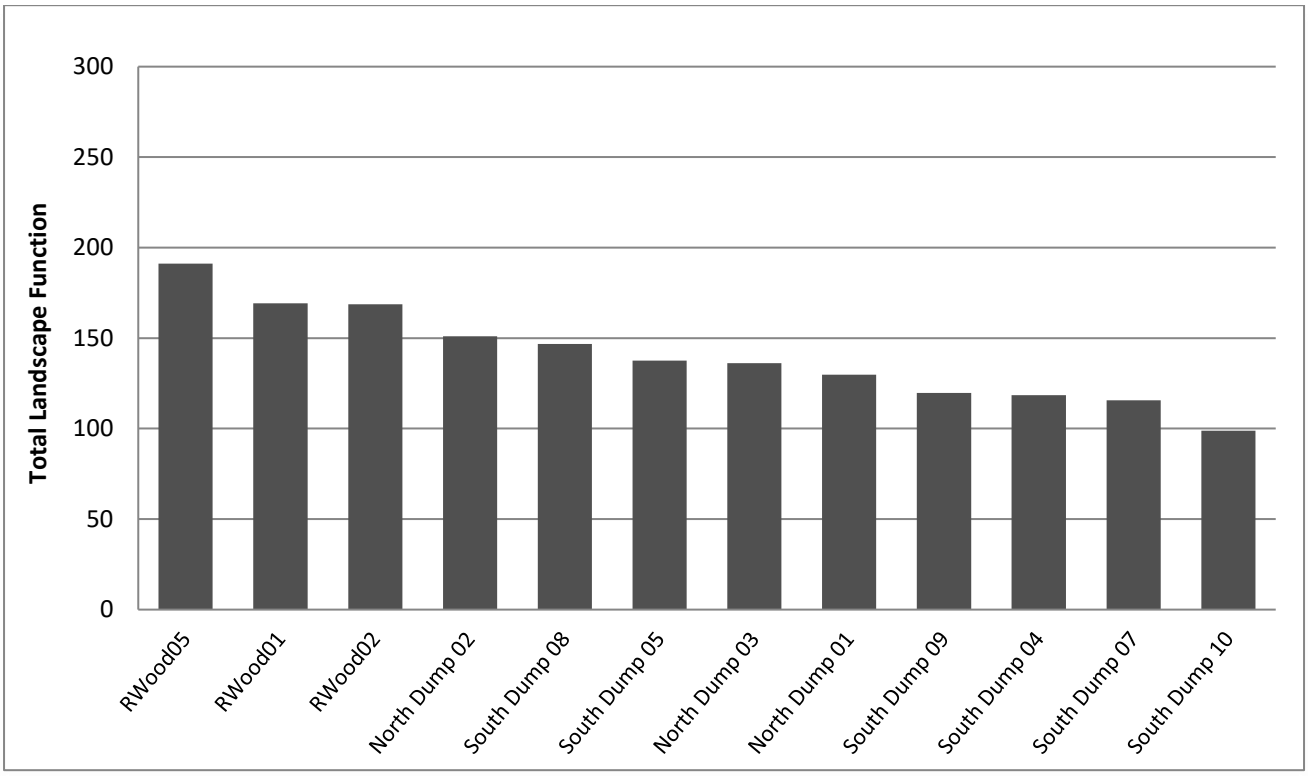
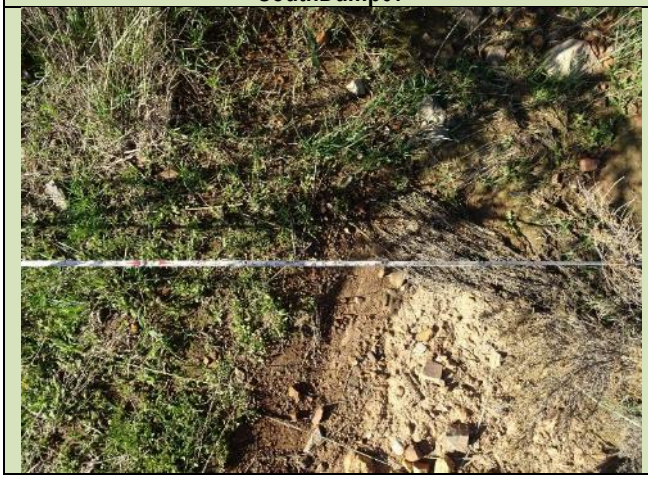
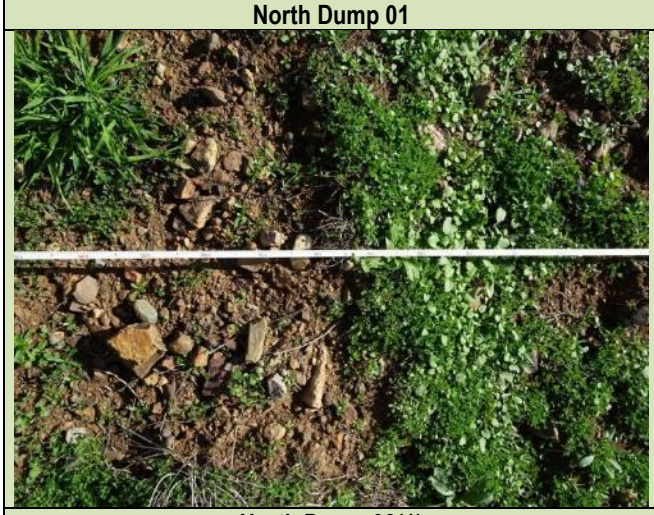
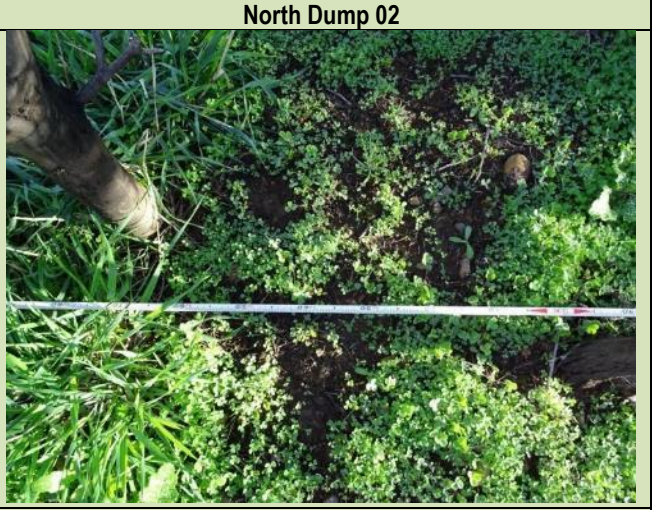


Figure 5-5. Sum of the LFA stability, infiltration and nutrient recycling components indicating the most functional to least functional monitoring site recorded in 2020.

Table 5-3. Examples of the different ground covers in the woodland monitoring sites in 2020.

SouthDump04	SouthDump05
	
SouthDump07	**SouthDump08**
	

SouthDump09	SouthDump10
	
North Dump 01	**North Dump 02**
	
North Dump 03(1)	**RfWood01**
	

RfWood02	RWood05
	

5.3.2 Tree and mature shrub populations

5.3.2.1 **Density**

The density of live mature trees (>5cm dbh) recorded in the woodland reference sites was highly variable with a marginal decrease in density recorded in RWood05 this year, as a mature acacia had died. The resultant tree densities were 8 – 41 trees per 50 x 20m (0.1 ha) plot, equating to a stem density of 80 – 410 trees per hectare (Figure 5-6).

In the younger rehabilitation sites, young trees and mature shrubs had established in several areas of rehabilitation, with significant increases in densities in South Dump 05 and North Dump 02 up until this year, where significant acacia mortality was recorded. Mature shrub densities had been reduced to 18 and 10 individuals > 5cm dbh respectively in these two sites. There continued to be two to four individuals in South Dump 04 and South Dump 07 and there was an additional one recorded in South Dump 09. In the remaining rehabilitation sites on the South Dump, growth rates of the seedlings have been slower, with none yet having > 5 cm dbh. On the North Dump only one individual was recorded at both North Dump 01 and 03.

Despite significant losses of mature acacias this year, sites South Dump 05 and North Dump 02 continued to have a tree and mature shrub density comparable to the reference sites.

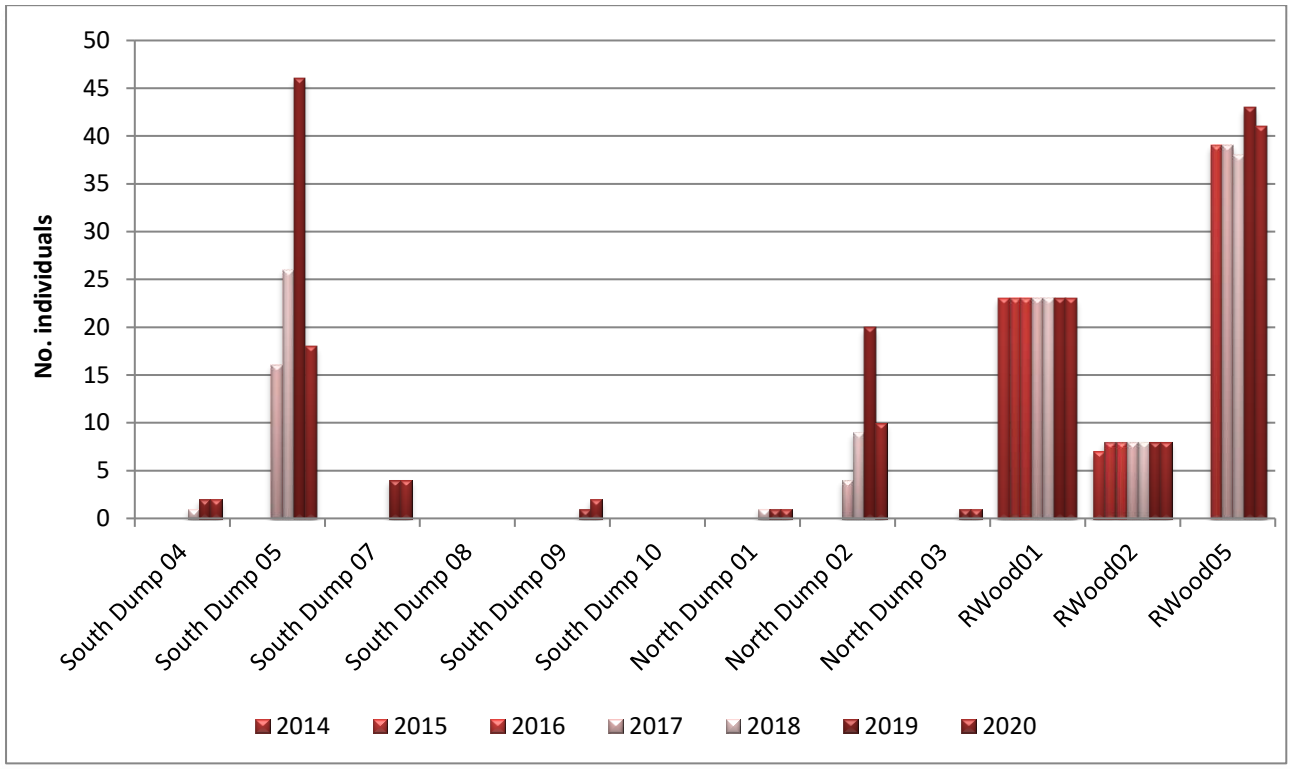


Figure 5-6. Tree and mature shrub densities (>5cm dbh) in the woodland monitoring sites.

5.3.2.2 **Diameter at breast height**

The average dbh recorded in the reference sites ranged from 25 – 68 cm with the smallest being 5 cm and the largest 95 cm. The average trunk diameter in rehabilitation sites on the South and North Dump ranged from 7 – 10 cm, with the maximum diameter being recorded in South Dump 05 with a dbh of 10 cm (Table 5-4). On the North Dump the average dbh was 6 – 8cm.

5.3.2.3 **Condition**

Trees and mature shrubs in the woodland reference sites were predominantly in moderate health this year however, a small number were stressed in RfWood01 and RWood05, and two sites contained a small number of dead stags. In the reference sites 17 – 89% of the tree population contained reproductive structures such as buds, flowers or fruits this year (Table 5-4). RfWood02 and RWood05 contained tree hollows (>5cm) with 44% and 6% of the tree populations bearing suitable habitat hollows respectively. Mistletoe was not recorded in any site this year.

In South Dump 05 and North Dump 02, 65% and 48% had died as the mature acacias become senescent, and the remaining individuals were stressed. In the other sites that had trees or mature shrubs, most individuals were in healthy condition. Two sites South Dump 04 and North Dump 01 had some individuals bearing reproductive structures but the rehabilitation areas were still too young to provide hollows or support mistletoe.

5.3.2.4 **Species Composition**

In the reference sites, the tree populations were comprised of 1 – 4 species of tree and mature shrubs (Table 5-4). The most dominant species were *Eucalyptus melliodora* (Yellow Box), *E. albens* (White Box) and *E.*

goniocalyx (Bundy Box), with *E. macrorhyncha* (Red Stringybark), *E. bridgesiana* (Apple Box), *Acacia dealbata* (Silver Wattle) and *A. implexa* (Hickory) typically occurring in fewer numbers.

The rehabilitation sites on the South and North Dump typically had tree populations comprised only of mature *A. dealbata.* The exceptions included South Dump 07 which had a small number of *Eucalyptus bridgesiana* and South Dump 09 which had *E. bridgesiana* and *E. viminalis* saplings.

Table 5-4. Trunk diameters and condition of the trees and mature shrubs in the woodland monitoring sites in 2020.

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
South Dump 04	1	10	10	10	2	0	100	100	0	0	0	0	100	0
South Dump 05	1	7	10	5	52	4	35	0	23	12	65	0	0	0
South Dump 07	1	7	8	6	4	0	100	100	0	0	0	0	0	0
South Dump 08	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South Dump 09	2	7	7	7	2	0	100	100	0	0	0	0	0	0
South Dump 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North Dump 01	1	8	8	8	1	0	100	100	0	0	0	0	100	0
North Dump 02	1	6	8	5	24	8	42	0	25	17	58	0	0	0
North Dump 03	1	1	6	6	1	0	100	0	100	0	0	0	0	0
RfWood01	**2**	**32**	**89**	**8**	**24**	**10**	**96**	**8**	**79**	**8**	**0**	**0**	**17**	**0**
RfWood02	**1**	**68**	**95**	**31**	**9**	**1**	**89**	**11**	**78**	**0**	**11**	**0**	**89**	**44**
RWood05	**4**	**25**	**70**	**5**	**48**	**14**	**85**	**10**	**56**	**19**	**15**	**0**	**38**	**6**

5.3.3 Shrubs and juvenile trees

5.3.3.1 Density

The density of shrubs and/or juvenile trees (<5cm dbh) recorded in the woodland reference sites was highly variable with none recorded in RfWood01 while 75 were recorded in RWood05 this year. The number of shrubs had significantly declined in RWood05 this year due to the drought and heavy browsing.

The density of shrubs and/or juvenile trees (<5cm dbh) recorded in the woodland rehabilitation sites was also highly variable between sites. In sites on the South and North Dump, shrub densities have declined in all sites largely due to drought mortality and or natural senescence. In some cases, some individuals may have grown and were now recorded a mature tree (>5 cm dbh). It was noted that numerous relatively tall *A. dealbata* individuals were very stressed or had recently died in pockets throughout several of the rehabilitation areas.

All of the woodland rehabilitation sites on the South Dump, except South Dump 10 continued to have a high density of shrubs compared to the reference sites, which ranged from 122 individuals in South Dump 04 to 638 individuals in South Dump 08. The new site South Dump 10 had only 6 individuals. Shrub densities on the North Dump ranged from 55 - 384 (Figure 5-7, Table 5-5).

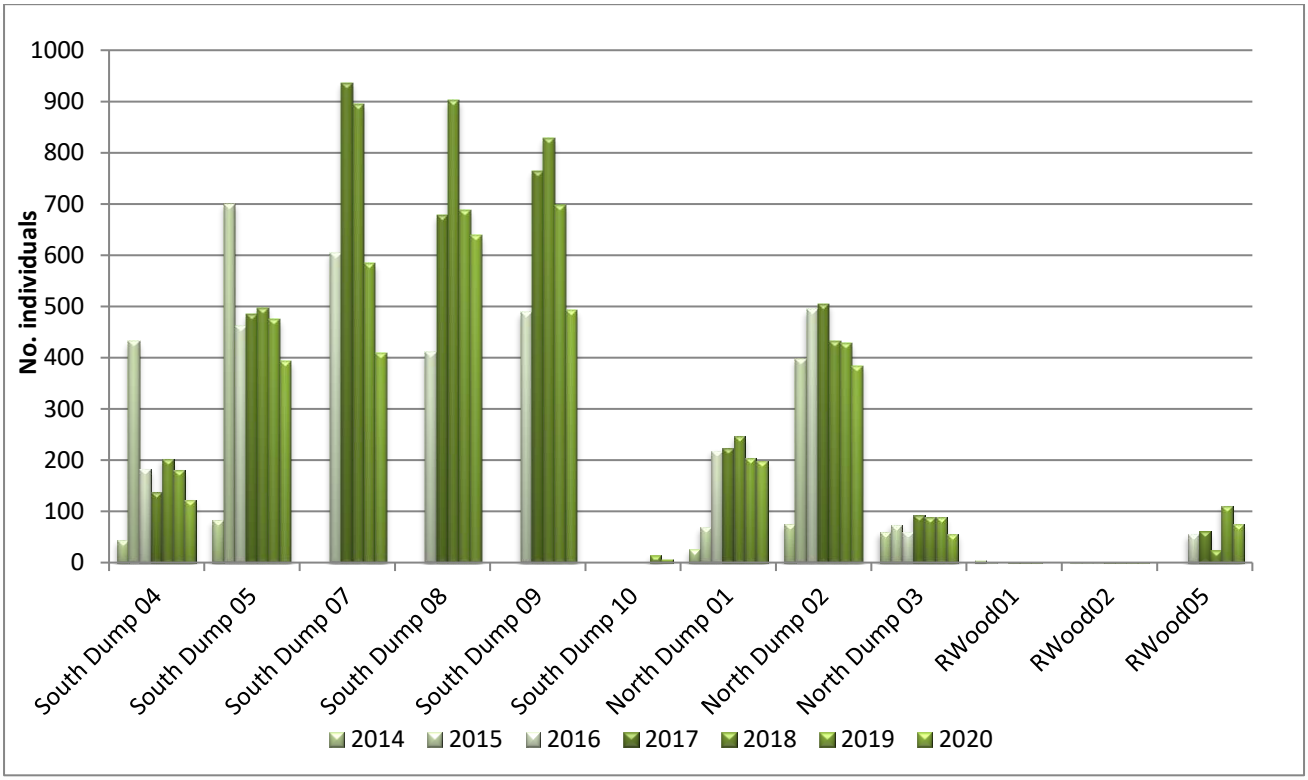


Figure 5-7. Population densities of shrubs and juvenile trees recorded in the woodland monitoring sites.

Table 5-5. Shrubs and juvenile trees recorded in each height class in the woodland monitoring sites in 2020.

Site Name	0-0.5m	0.5-1.0m	1.0-1.5m	1.5-2.0m	>2.0m	Total	No. species	% endemic
South Dump 04	20	32	58	10	2	122	3	100
South Dump 05	26	16	54	114	182	392	9	99
South Dump 07	32	166	150	34	26	408	15	99
South Dump 08	22	290	296	12	18	638	18	97
South Dump 09	6	72	288	86	40	492	11	98
South Dump 10	5	1	0	0	0	6	4	100
North Dump 01	0	54	106	24	14	198	4	100
North Dump 02	24	36	148	128	48	384	5	100
North Dump 03	0	9	30	15	1	55	4	100
RfWood01	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
RfWood02	**1**	**0**	**0**	**0**	**0**	**1**	**1**	**100**
RWood05	**68**	**5**	**0**	**0**	**2**	**75**	**7**	**77**

5.3.3.2 **Diversity**

In the reference sites the juvenile tree and shrub populations were comprised of 1 – 7 species. The most common shrubs and juvenile tree species in the woodland reference site RWood05 were *A. dealbata* and *A. implexa,* with one or two *Cassinia arcuata* and juvenile *E. goniocalyx.* There were numerous exotic shrubs including *Crataegus monogyna* (Hawthorn), *Rubus fruticosus* (Blackberry) and *Rosa rubiginosa* (Sweet Briar) which comprised 33% of the shrub population. In RfWood02, there was a juvenile *E. albens*.

The rehabilitation sites on the South and North Dump had a relatively high diversity of shrubs and juvenile trees with 3 - 18 different species with these typically containing a proportionately high density and diversity of acacias. The lowest diversity was recorded in South Dump 04 with three different species, while at South Dump 08 there were 18 different species.

A. buxifolia tended to be the most abundant species followed by *A. dealbata* and *A. vestita*. Other occasional species may have included *A. spectabilis* (Mudgee Wattle), *A. gunnii* (Ploughshare Wattle), *A. verniciflua* (Varnish Wattle), *A. penninervis* (Mountain Hickory), *A. decora* (Western Golden Wattle), *A. filicifolia* (Fern leaved Wattle), *A. melanoxylon* (Blackwood) and *A. paradoxa* (Kangaroo Thorn). Volunteer *Cassinia arcuata* (Chinese Shrub) was often abundant and was recorded in most some sites. Other occasional species may have included *Hakea sp., Pultenaea sp*., *Exocarpos cupressiformis* and the native vine *Hardenbergia violacea* (Happy Wanderer).

In South Dump 07, 08 and 09, eucalypts were recorded more frequently with common species being juvenile *Eucalyptus albens, E. blakelyi*, *E. bridgesiana, E. goniocalyx, E. viminalis* (Ribbon Gum), *E. dives* (Broad-leaved Peppermint), *E. melliodora, E. polyanthemos* (Red Box) and *E. macrorhyncha.* Sites that did not presently contain eucalypts included South Dump 04 and 05 and North Dump 01, 02 and 03.

Native non endemic species to the CVO area were *A. decurrens* (Early black Wattle), *A. falcata* (Hickory Wattle, South Dump 09) and *A. filicifolia* (Fern-leaved Wattle) which were recorded in low densities in several sites. It is also questionable if *A. spectabilis* should be included as endemic to the CVO area.

5.3.3.3 **Height class**

In the reference site which contained a good shrub population (RWood05) most seedlings tending to be less than 0.5m in height. In the rehabilitation areas, most individuals were 1.0 - 1.5 m tall however there was also a large number of taller individuals with a total of 331 individuals (12%) collectively that exceeded 2.0m in height. Site South Dump 05 had the highest density of large individuals with 182 individuals > 2.0 m, while South Dump 04 had the lowest (Table 5-5, Figure 5-8).

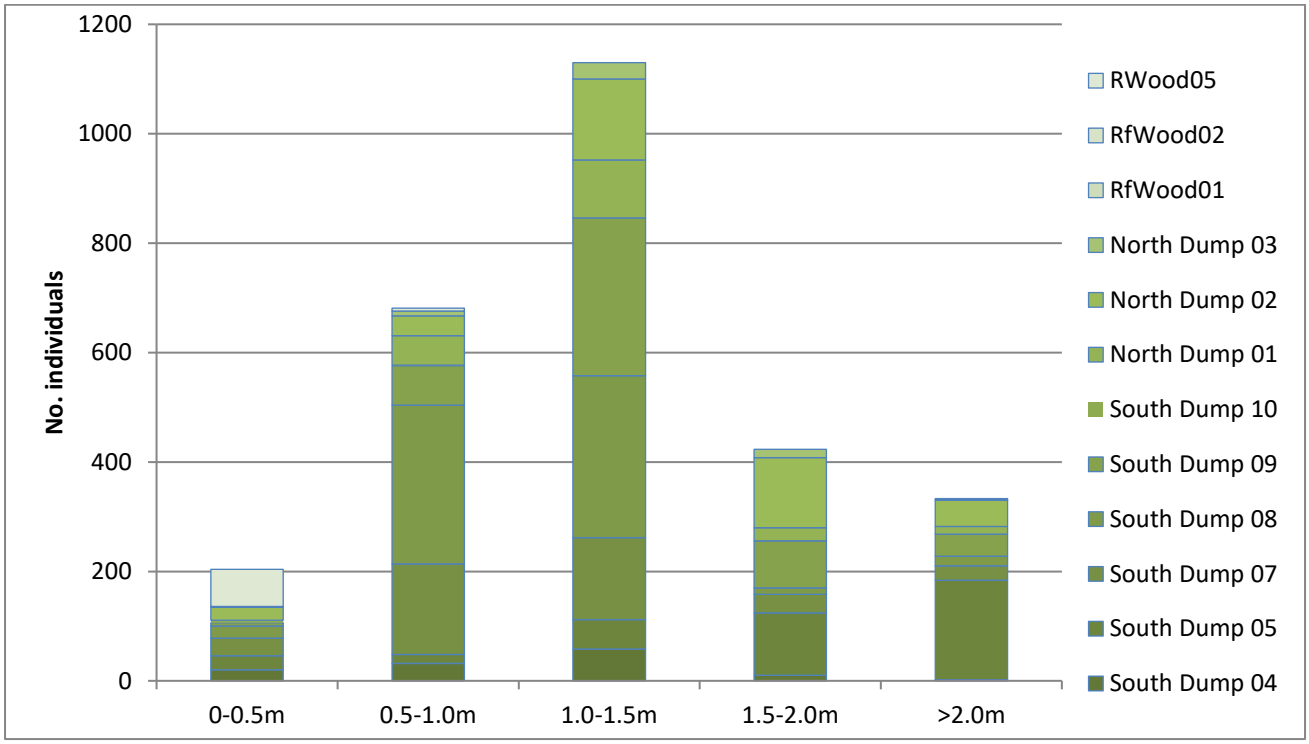


Figure 5-8. Number of individuals within the five height classes.

5.3.4 Total ground cover

Total ground cover is a combination of leaf litter, annual plants, cryptogams, rocks, logs and live perennial plants (<0.5m in height). In the woodland reference sites there was a marginal decrease in total ground cover due to animal tracks and camps which led to erosion, with 92.5 – 98.0 % ground cover along the vegetation transects this year (Figure 5-9).

In 2017 improved seasonal conditions resulted in a significant increase in ground cover in all rehabilitation areas, however in 2018 and 2019 many rehabilitation areas were affected by the prolonged dry conditions with some also being heavily impacted on by macropods. As a result, total ground cover tended to decline in most but not all rehabilitation sites.

Despite the ongoing drought, many rehabilitation areas had an increase in annual plant cover as a result of more recent rainfall, with increased cover recorded in all rehabilitation sites except South Dump 04 and South Dump 10. On the South Dump, total ground cover ranged from a low of 43.0% in South Dump 10 to a high of 90% at South Dump 08. On the North Dump, total ground cover ranged from 80.5 – 96.5%. This year, sites North Dump 01 and North Dump 02 had a total ground cover that was comparable to the woodland reference sites.

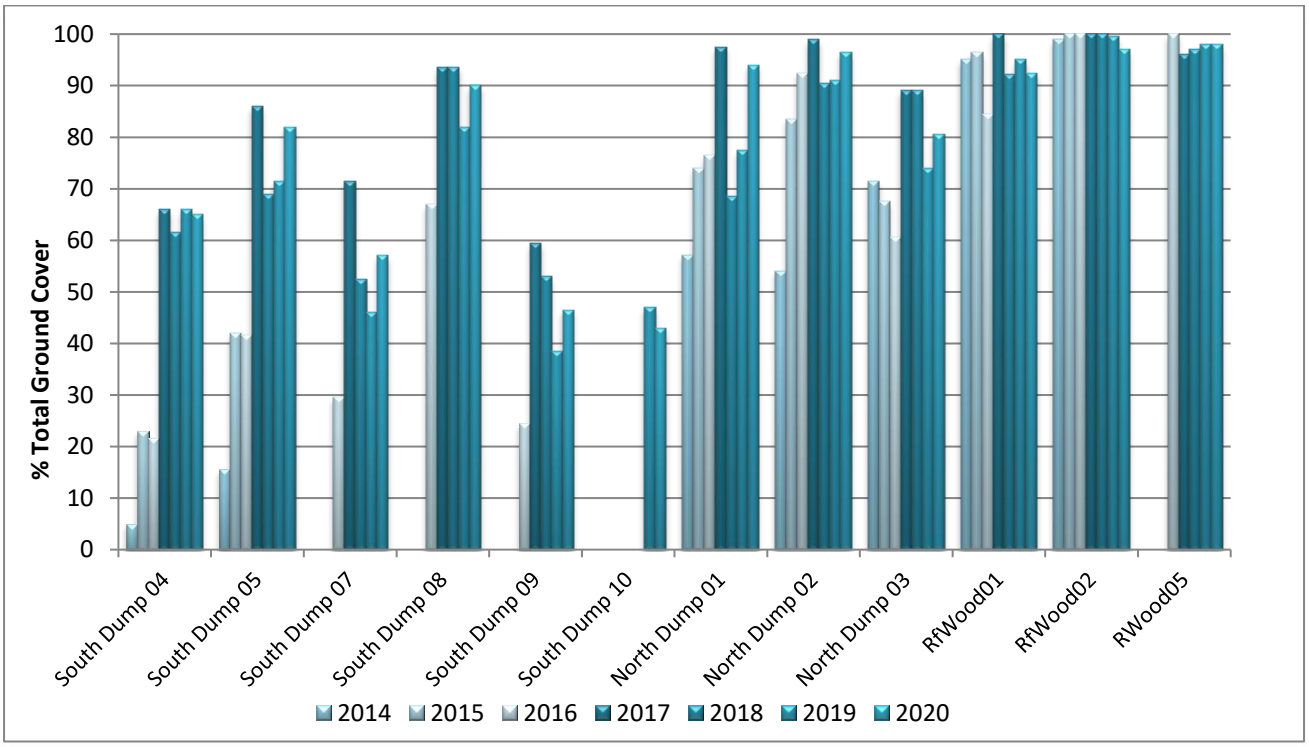


Figure 5-9. Total ground cover recorded in the woodland monitoring sites.

5.3.5 Structural composition

This year all reference sites continue to be dominated by dead leaf litter that provided 65 – 94.5% cover, and annual and perennial ground cover plants were sparse. There may have been a small amount of cover from fallen branches and some rock cover was recorded in RfWood02 due to a rocky granite outcrop. Cryptogam cover was absent due to the high levels of plant and litter covers (Figure 5-10).

This year there was an increase in annual and dead litter cover ground cover in most rehabilitation monitoring sites due to the recent rainfall that stimulated a flush of new growth in most sites. Some perennial ground cover was provided by the low growing branches of the establishing shrubs, but typically perennial ground cover had declined in all sites due to the dry conditions and high shrub mortality. Cryptogams were establishing in most sites

and provided up to 12% cover in a couple of sites. There continued to be bare ground in all sites due to disturbance by animals tracks and camps, and/or ongoing erosion.

Sites that did not have perennial ground cover comparable to the reference sites this year include the new area of rehabilitation at South Dump 10.

Three woodland reference sites contained a mature canopy cover (>6.0 m) but typically there was limited foliage cover recorded in the lower height classes, a characteristic feature of open woodland communities. In the rehabilitation areas on the South and North Dump the establishing tree and shrub seedlings provided some foliage cover 0.5 – 2.0 m in height in all sites except South Dump 10 and North Dump 03.

Rehabilitation sites South Dump 05 and North Dump 02 had some vertical foliage cover 2.0 - 4.0 m in height. In South Dump 05 there was previously also some canopy cover 4.0 – 6.0 m and >6.0 m in height, however these individuals have since died. The rehabilitation sites presently do not yet meet many structural diversity targets largely due to their immaturity and limited developmental time.

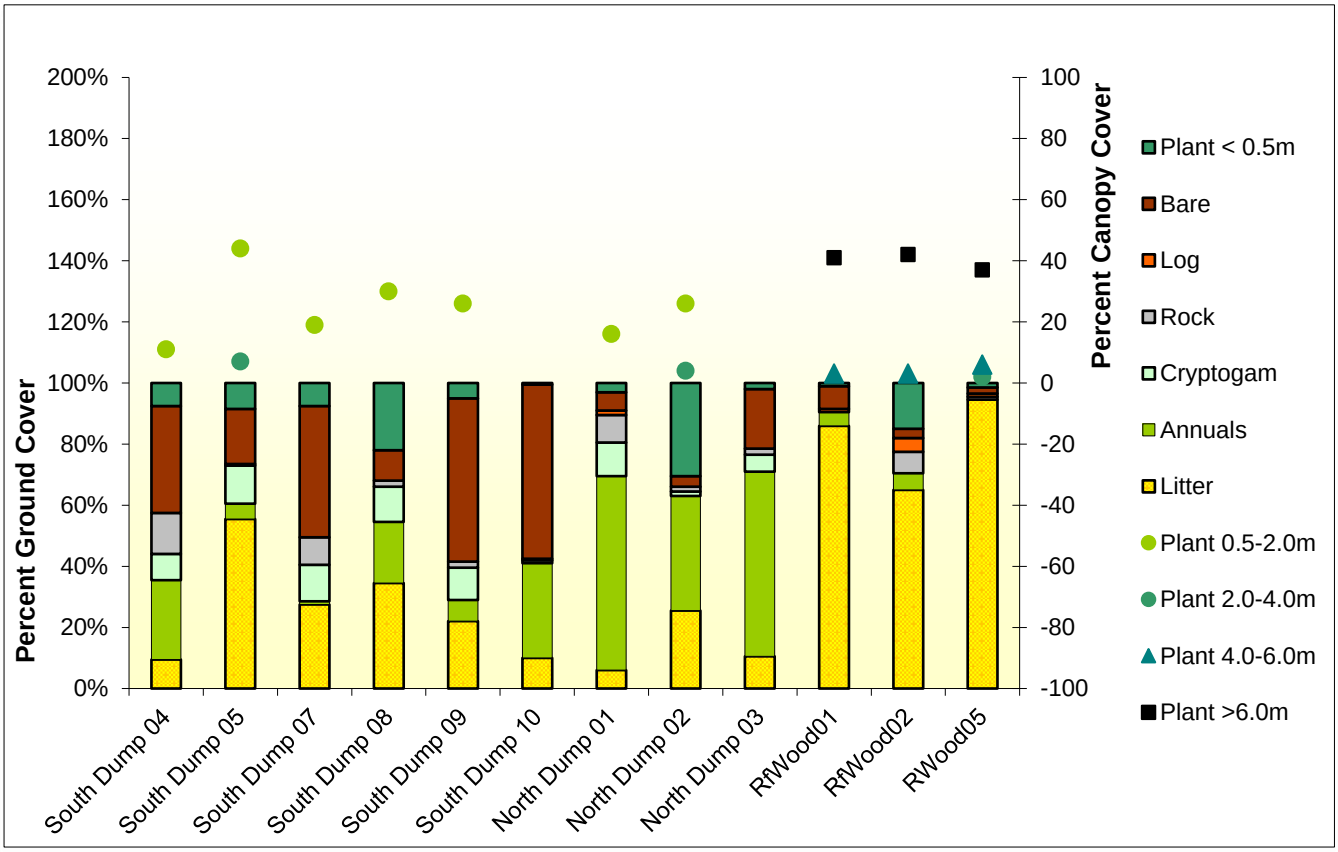


Figure 5-10. Average percent ground cover and projected foliage cover recorded in the woodland monitoring sites in 2020.

5.3.6 Floristic Diversity

There has been no consistent change in total species diversity across the range of monitoring sites however the level of diversity has tended to fluctuate with the seasonal conditions and degree of grazing intensity. In the rehabilitation areas floristic diversity may also be associated with the successional development and/or management intervention of the area. In 2016, the seasonal conditions were particularly dry at the time of monitoring and despite heavy winter rainfall, hot dry summer conditions were experienced into 2017. Good but late rainfall in autumn in 2017 initiated a flush of plant growth with all monitoring sites demonstrating an increase in total species diversity in that year (Figure 5-11) with a total of 12 – 53 plant species recorded in the 0.1 ha woodland reference site monitoring quadrats.

In 2018, total floristic diversity significantly declined in almost all sites as a result of the prolonged dry conditions and in the woodland reference sites there were only 5 – 35 species. All rehabilitation areas had more than five species with the highest diversity being recorded in South Dump 08 with 33 species, while the lowest number was recorded in South Dump 01 with seven species.

In 2019 floristic diversity had increased in all monitoring sites largely as a result of recent rainfall prior to monitoring which stimulated a flush of growth, with 21 - 44 species being recorded in the reference sites. All rehabilitation areas had a floristic diversity higher than the reference sites with the highest diversity being recorded in South Dump 08 with 56 species, while the lowest number was recorded in South Dump 10 with 24 species. This year there were 19 – 41 species in the reference sites and 21 – 47 species in the rehabilitation sites.

The diversity of native species followed similar trends and this year there were 7 – 31 native species recorded in the reference sites with all rehabilitation sites containing at least the minimum threshold (Figure 5-12). The most native species were recorded in South Dump 08 with 30 species, while the lowest number was recorded in South Dump 10 with eight native species.

In the reference sites there were 10 – 12 exotic species with most rehabilitation sites containing a higher diversity of exotic species. South Dump 07 and 09 however had an acceptable diversity of exotic species (Figure 5-13). The highest diversity of exotic species was recorded in North Dump 02 and 03 with 23 and 26 exotic species respectively.

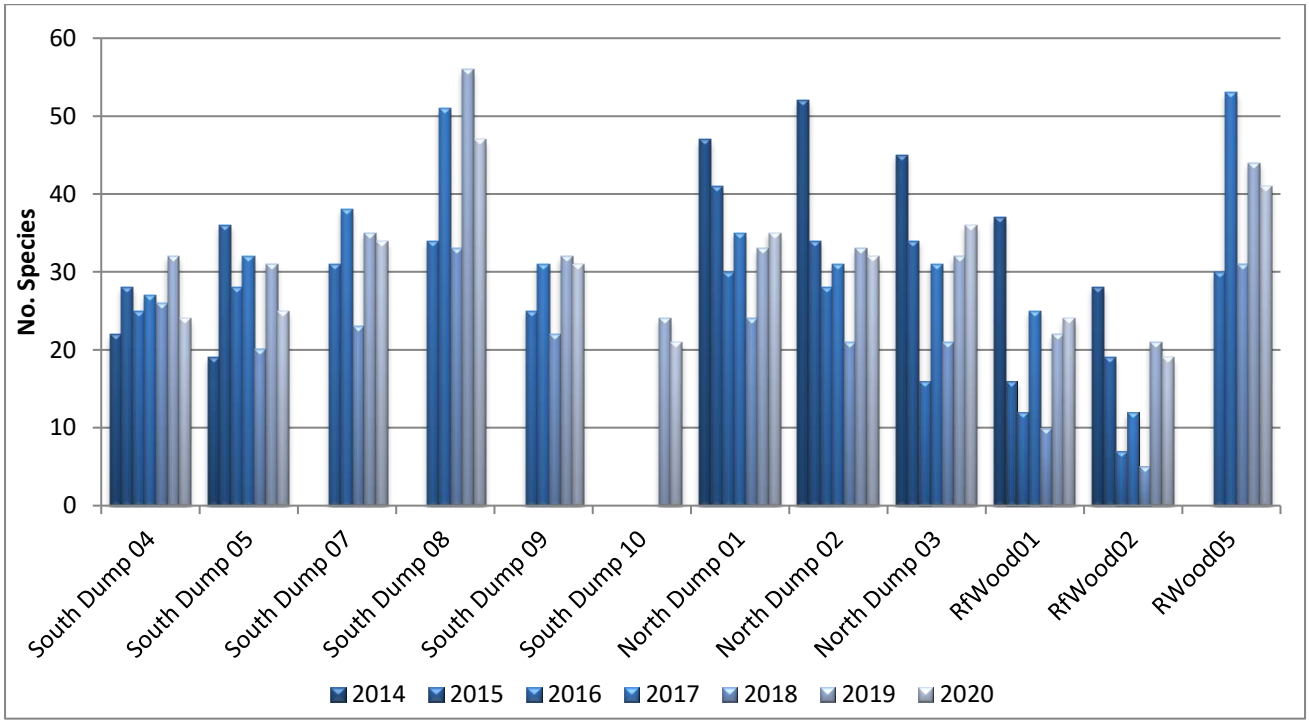


Figure 5-11. Total species diversity recorded in the woodland sites.

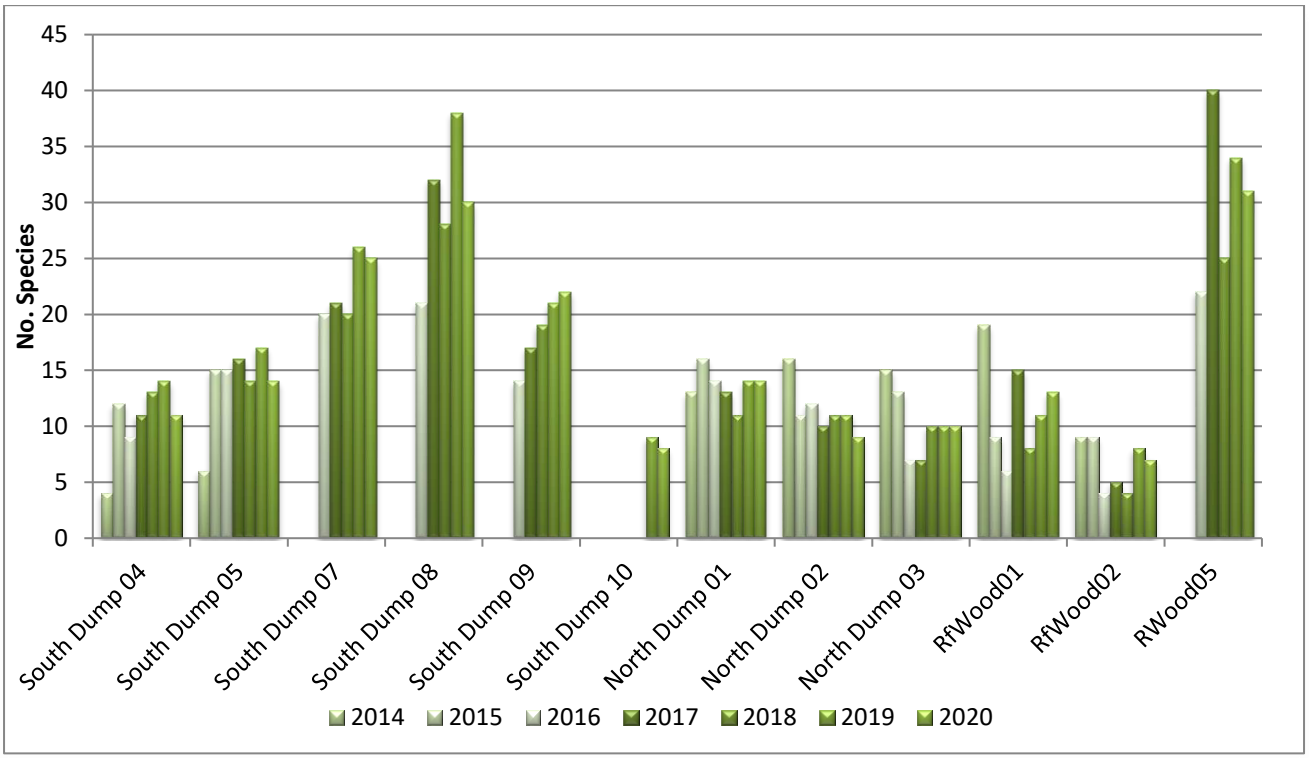


Figure 5-12. Native species diversity recorded in the woodland monitoring sites.

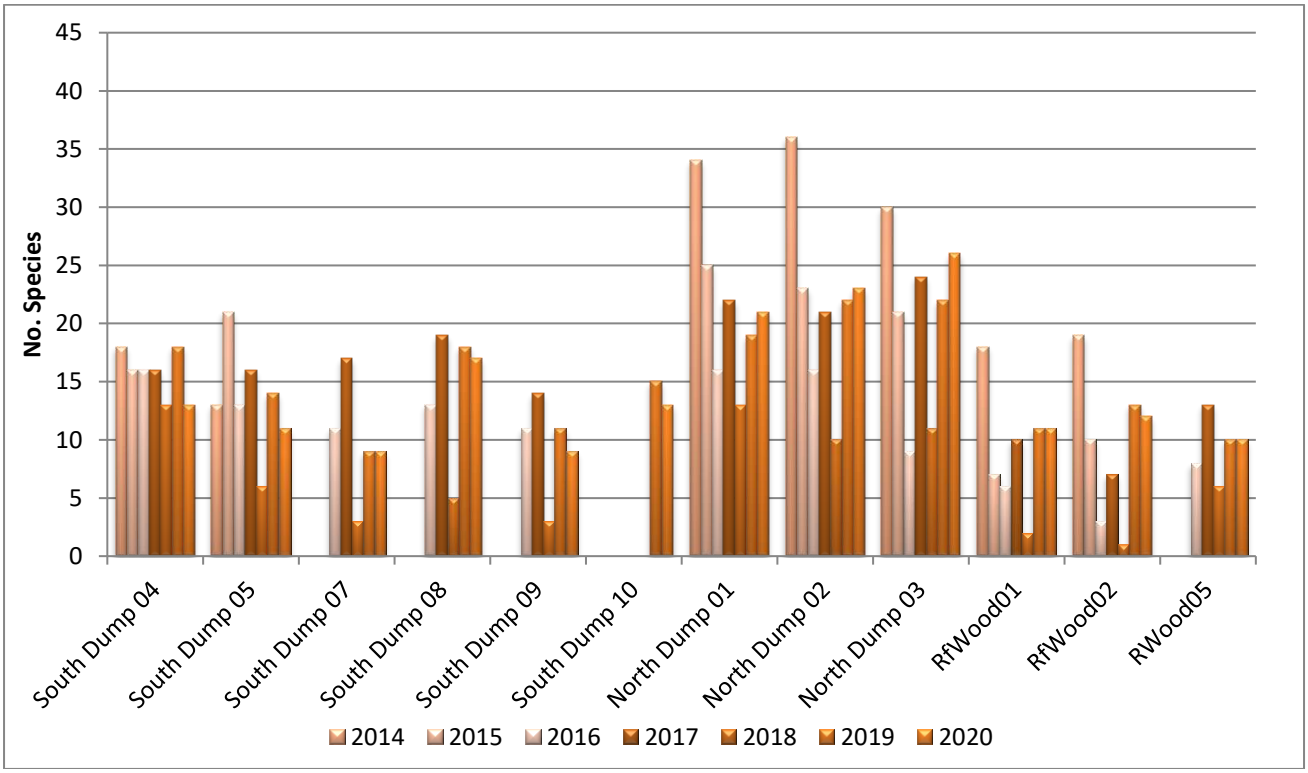


Figure 5-13. Exotic species diversity recorded in the woodland monitoring sites.

5.3.7 Native ground cover abundance

Native ground cover abundance is an additional ecological indicator which provides a measure of the cover abundance of the native vegetation and an indication of the overall weediness of the sites (Figure 5-14). Similarly, to the floristic diversity data, the proportionate ground cover provided by native plants has also been strongly

influenced by the seasonal conditions and degree of grazing pressure. Dry conditions usually result in the lower abundance of exotic annual plants thus tending to increase the cover provided by live native perennial species.

In 2014 exotic annual species were prevalent due to the autumn rainfall which resulted in a low proportion of cover provided by native species. In 2015 and 2016, the prolonged dry conditions have resulted in the limited abundance of exotic annuals and an increased proportion of native plant cover. In 2017 improved seasonal conditions has again resulted in an increase in exotic annual ground covers, thus the proportion of native plant covers were lower. In 2018, exotic annuals and perennial pasture plants were low in abundance however native plants provided more than 80% of the live plant cover in three of the four sites, while in RfWood01 only 17% of the live plant cover was provided by native species.

In 2019, exotic plant cover increased thus lowering the proportionate cover of native plants in all monitoring sites. There continued to be sparse plant cover in RfWood01 and RWood05 and exotic pastures species had increased in RfWood02. Subsequently endemic ground cover targets were highly variable between the woodland reference sites and ranged from 3.2 – 77.4%. This year there was 7.1 – 85% native plant cover.

Native ground cover was also highly variable within the rehabilitation areas and similarly to the woodland reference sites, there was a decrease in the percent cover provided by native plant in some rehabilitation sites, while a minor increase was recorded in others. Apart from the new area of rehabilitation at South Dump 10 and North Dump 02 and 03, all rehabilitation areas had percent native plant cover within the range provided by the reference sites.

Of the live plant cover, native plants provide the highest cover in South Dump 07 with 56.3% cover.

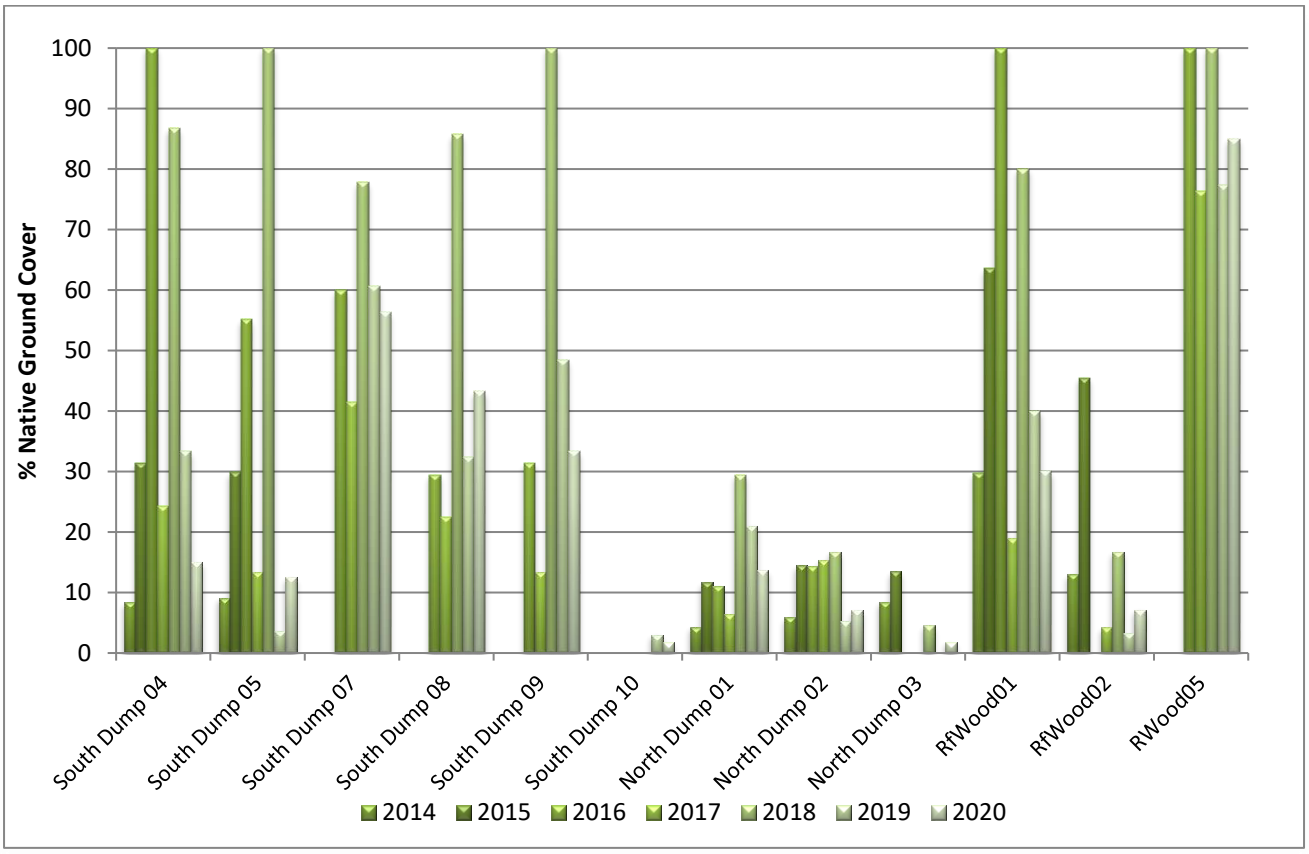


Figure 5-14. Native cover abundance recorded in the woodland monitoring sites.

5.3.8 Most common species

The most common species, those that were recorded in at least six woodland rehabilitation sites in 2020 is given in Table 5-6. The native shrub *A. vestita* and the exotic pasture species *Phalaris aquatica* (Phalaris) have remained common to all rehabilitation sites, with the exotic annuals *Echium plantagineum* (Paterson's Curse), *Lolium rigidum* (Wimmera Ryegrass) and *Trifolium subterraneum* (Subterraneum Clover) also being very common this year, including within the reference sites.

The natives *Acacia buxifolia* and *Oxalis perennans* (Yellow Wood-sorrel) were recorded in eight rehabilitation sites while other common natives included *Cassinia arcuata* (Chinese Shrub), *Acacia dealbata* (Silver Wattle) and *Rytidosperma* spp. (Wallaby Grass). Relatively common exotic species included *Arctotheca calendula* (Capeweed), *Modiola caroliniana* (Red-flowered Mallow), *Silybum marianum* (Silybum marianum) and *Sonchus oleraceus* (Milk Thistle).

In most cases, species recorded in the rehabilitation areas were sown as part of the rehabilitation program or were volunteer species. In numerous cases the volunteer species were also recorded in the woodland reference sites, reflecting their natural distribution within the local area. A comprehensive list of species recorded in all woodland monitoring sites in 2020 has been included in Appendix 4.

Table 5-6. Species that were recorded in at least six woodland rehabilitation sites in 2020 and their occurrence in the woodland reference sites.

exotic	Scientific Name	Common Name	Habit	South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03	Total	RfWood01	RfWood02	RWood05
	Acacia vestita	Boree	s	1	1	1	1	1	1	1	1	1	**9**			
*	*Echium plantagineum*	Paterson's Curse	h	1	1	1	1	1	1	1	1	1	**9**	1		
*	*Lolium rigidum*	Wimmera Ryegrass	g	1	1	1	1	1	1	1	1	1	**9**	1	1	
*	*Phalaris aquatica*	Phalaris	g	1	1	1	1	1	1	1	1	1	**9**		1	
*	*Trifolium subterraneum*	Subterraneum Clover	h	1	1	1	1	1	1	1	1	1	**9**		1	1
	Acacia buxifolia	Box-leaved Wattle	s	1	1	1	1	1		1	1	1	**8**			
	Oxalis perennans	Yellow Wood-sorrel	h		1	1	1	1	1	1	1	1	**8**	1	1	1
*	*Arctotheca calendula*	Capeweed	h	1	1	1	1	1			1	1	**7**	1		
	Cassinia arcuata	Chinese Shrub	s		1	1	1	1	1		1	1	**7**			1
	Acacia dealbata	Silver Wattle	s	1	1	1				1	1	1	**6**			1
*	*Modiola caroliniana*	Red-flowered Mallow	h		1		1		1	1	1	1	**6**			
	Rytidosperma spp.	Wallaby Grass	g	1			1	1		1	1	1	**6**			
*	*Silybum marianum*	Variegated Thistle	h		1		1		1	1	1	1	**6**		1	
*	*Sonchus oleraceus*	Milk Thistle	h		1	1	1			1	1	1	**6**		1	

5.3.9 Most abundant species

The most abundant species recorded in each of the rehabilitation monitoring sites this year are provided in Table 5-7. The most abundant species were those that collectively summed to a Braun-blanquet total of 10 or more

from the five replicated samples along the vegetation transect. The maximum score that can be obtained by any one species is 30.

The composition of the grassy understorey has remained variable between the woodland reference sites and this year only *Phalaris aquatica* (Phalaris) was the only species to occur in any abundance that meets the minimum abundance criteria in the reference site RfWood02.

In the rehabilitation areas, exotic species also tended to provide the most ground cover, with the annual pasture species *Trifolium subterraneum* (Subterraneum Clover) providing the most ground cover in South Dump 08 and North Dump 01, 02 and 03. *Phalaris aquatica* (Phalaris) was also abundant in North Dump 02, while annual species *Modiola caroliniana* (Red-flowered Mallow) and *Petrorhagia nanteuilii* (Proliferous Pink) were the most abundant in North Dump 01 and 03.

Table 5-7. The most abundant species recorded in the woodland monitoring sites in 2020.

exotic	Scientific Name	Common Name	South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03	RfWood01	RfWood02	RWood05
*	*Trifolium subterraneum.*	*Subterraneum* Clover				14			15	16	10			
*	*Phalaris aquatica*	Phalaris								14			10	
*	*Modiola caroliniana*	Red-flowered Mallow							13		19			
*	*Petrorhagia nanteuilii*	Proliferous Pink							16		10			

5.3.10 **Vegetation composition**

The composition of the vegetation as categorised by eight different growth forms is given in Figure 5-15, with these being highly variable between the sites. The reference sites were comprised by a high diversity of herbs with 13 - 24 species followed by grasses with 5 – 7 species. There were 1 – 3 species of tree and up to 6 different shrubs and a reed species may have been present. There were no sub-shrubs, vines or ferns recorded this year.

In the South Dump there was an appropriate diversity of trees, shrubs and grasses, but there was a low diversity of herbs in South Dump 04, 05, 07 and 09. This year, there was a low diversity of tree species in South Dump 04 and all three areas on the North Dump.

Shrub diversity was high in South Dump 07, 08 and 09 as a result of the seeding program with up to 15 species recorded in South Dump 07 and 08. Two reed species were recorded in South Dump 08, while *Hardenbergia violacea* (Happy Wanderer) a native vine/twiner was recorded in rehabilitation sites South Dump 05, 07 and 08.

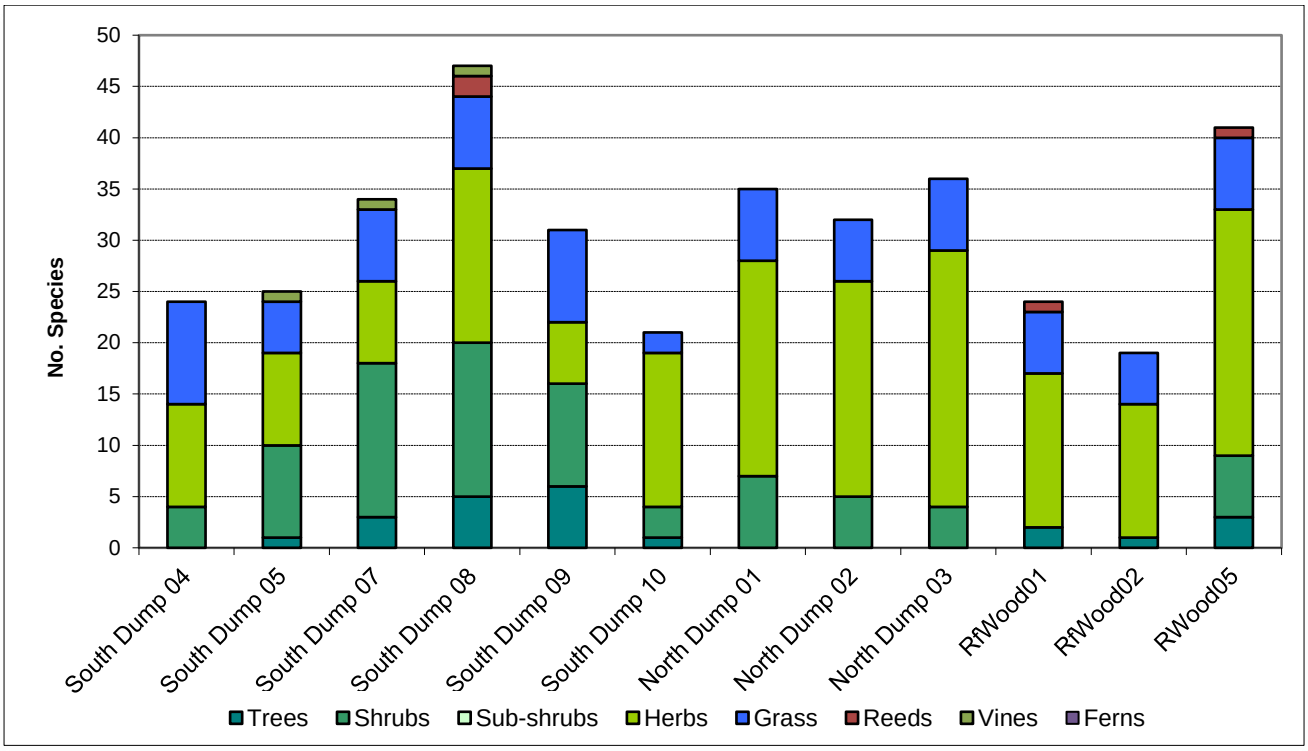


Figure 5-15. Vegetation composition of the woodland monitoring sites in 2020.

5.3.11 **Rill Assessment**

Much of the minor rilling recorded in previous years has declined as ground covers have become more established, however minor rilling continued to be recorded in South Dump 05, 07, 09 and North Dump 01 this year. The extent of rilling has also slightly increased in South Dump 07 and North Dump 01, where the rip lines along the steeper slopes have let go, and in North Dump 01, some tunnelling was occurring and had also increased in extent over the past year. Some rilling was also recorded in RfWood01, as water has flowed down animal tracks during high rainfall activity.

In South Dump 05 and 09 the extent of rilling appears to be declining as the vegetation becomes more established. The most extensive rilling however continued to be recorded in South Dump 09, where 5 large rills continue to be active with a total cross-sectional of 0.44 m^2 (Figure 5-16).

Significant erosion events were also noted to have occurred near South Dump 05 in 2019, above and below the rehabilitation batter which was likely to have been initiated by a freak rainfall event. This area appears to have undergone amelioration earthworks, with reduced levels of erosion having been recorded and/or observed this year.

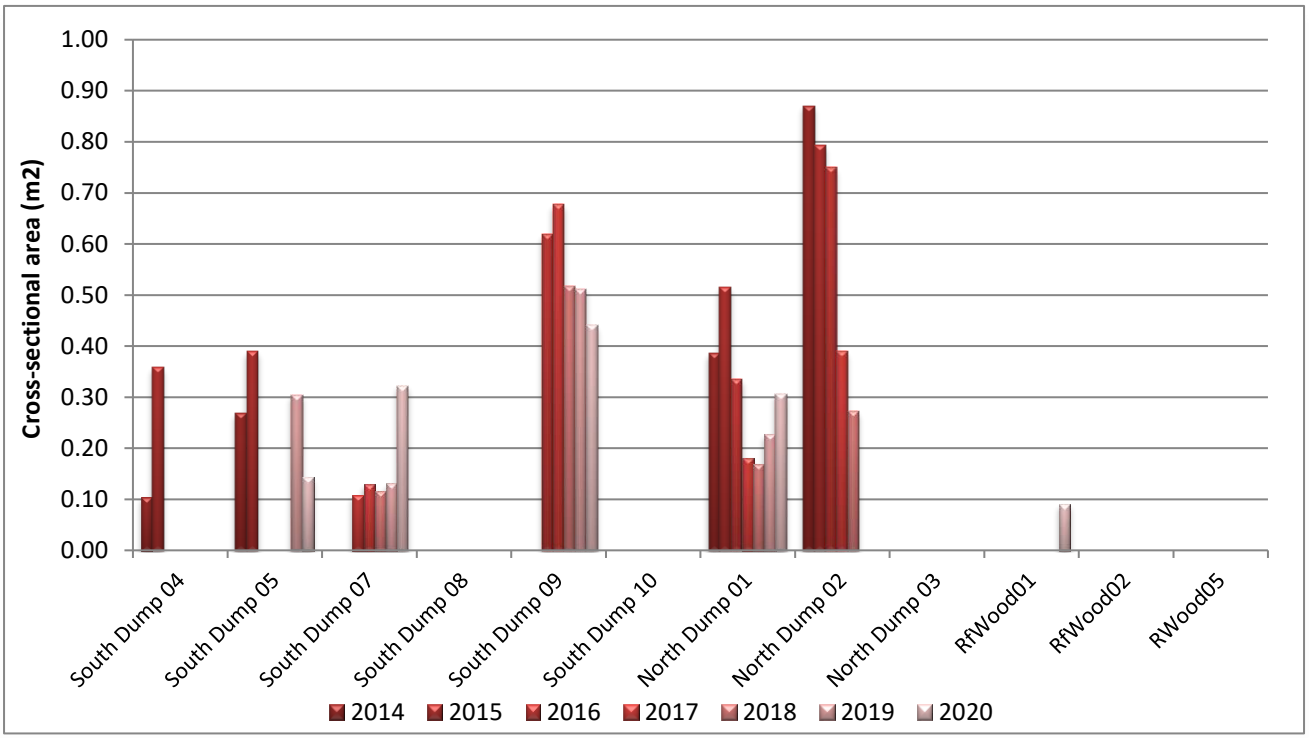


Figure 5-16. Sum of the cross-sectional area of the rills recorded in the woodland monitoring sites.

5.3.12 **Soil Analyses**

5.3.12.1 **pH**

Figure 5-17 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 data indicates that there has been no consistent change in soil pH (1:5 water) across the range of woodland monitoring sites with most changes being minor and probably associated with inherent variations in the soils and random sampling techniques. This year the woodland reference sites had soil pH which ranged 6.10 – 6.99 indicating the soils in the local woodlands can be slightly acidic to neutral and within desirable agricultural levels (Bruce & Rayment 1982).

The more recent rehabilitation sites on the South Dump typically had low soil pH which ranged from a low of 5.08 (South Dump 09) to a high of 5.83 (South Dump 10). Sites South Dump 05, 07, 08 and 09 have soils which are strongly to very strongly acidic (Bruce & Rayment 1982) with these being lower than the local woodland pH ranges and desirable agricultural levels this year. Soils at South Dump 04 and 10 were typically moderately acidic and were just within acceptable levels. On the North Dump, the soils were slightly acidic to neutral and within acceptable levels.

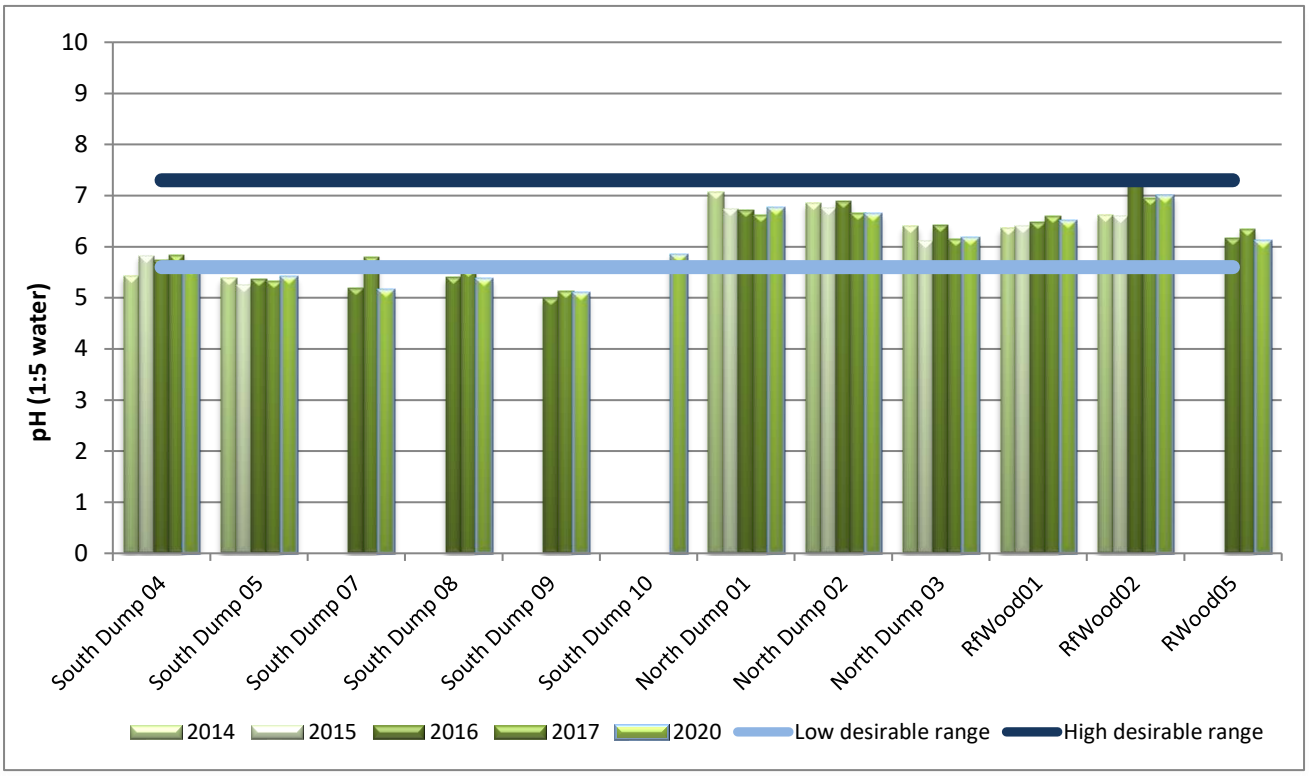


Figure 5-17. Soil pH recorded in the rehabilitation sites compared to the woodland reference sites and desirable agricultural range.

5.3.12.2 Conductivity

Figure 5-18 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. There has been no consistent trend in the changes in Electrical Conductivity (EC) across the range of reference sites and in 2016 there was an unexplained and significant increase in EC was recorded in RfWood02.

This year increased EC was recorded in two reference sites with EC ranging from 0.055 – 0.142 dS/cm and despite being higher they continued to be classified as non-saline (Slavich & Petterson 1993). There was also an increase in EC in all rehabilitation monitoring sites on the South Dump, except in South Dump 05 which has continued to demonstrate and declining trend since 2016. This year the EC ranged from a low of 0.062 dS/cm in South Dump 05 to a high of 0.272 dS/cm in South Dump 10. EC in all rehabilitation sites except the new rehabilitation area South Dump 10, were similar to the local woodlands or within agricultural thresholds. In South Dump 10, the soils are considered to be slightly saline.

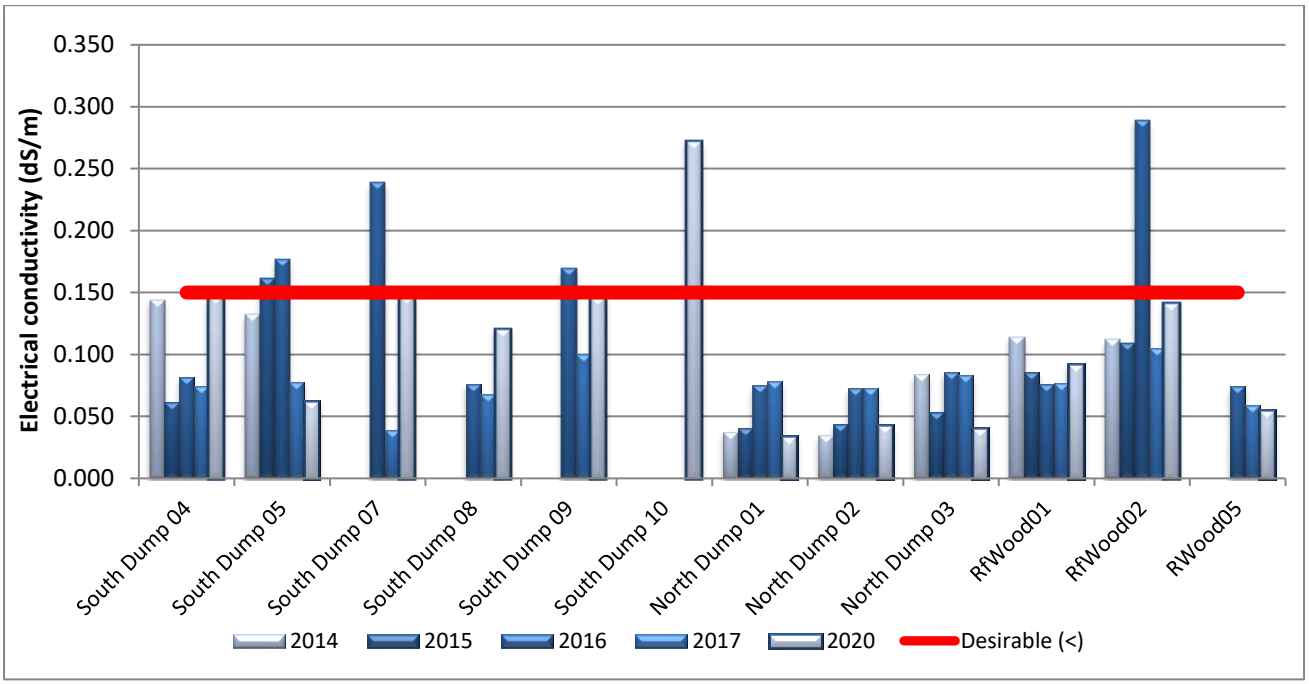


Figure 5-18. Electrical Conductivity recorded in the rehabilitation sites compared to the woodland reference sites and desirable agricultural levels.

5.3.12.3 Organic Matter

Organic Matter (OM) levels recorded in the woodland reference sites have been quite variable between sites as well as over the years probably as a result of inherent soil and sampling techniques. This year there was a slight decrease in OM in two reference sites. The resultant OM range in the upper soil profile in the woodland reference sites remained very high and was 7.6 – 10.2% (Figure 5-19). In the mine rehabilitation areas on the South and North Dumps there was a minor increase in some sites however OM in all rehabilitation areas were very low and ranged from 1.7% in North Dump 01 to a high of 3.1% in South Dump 07.

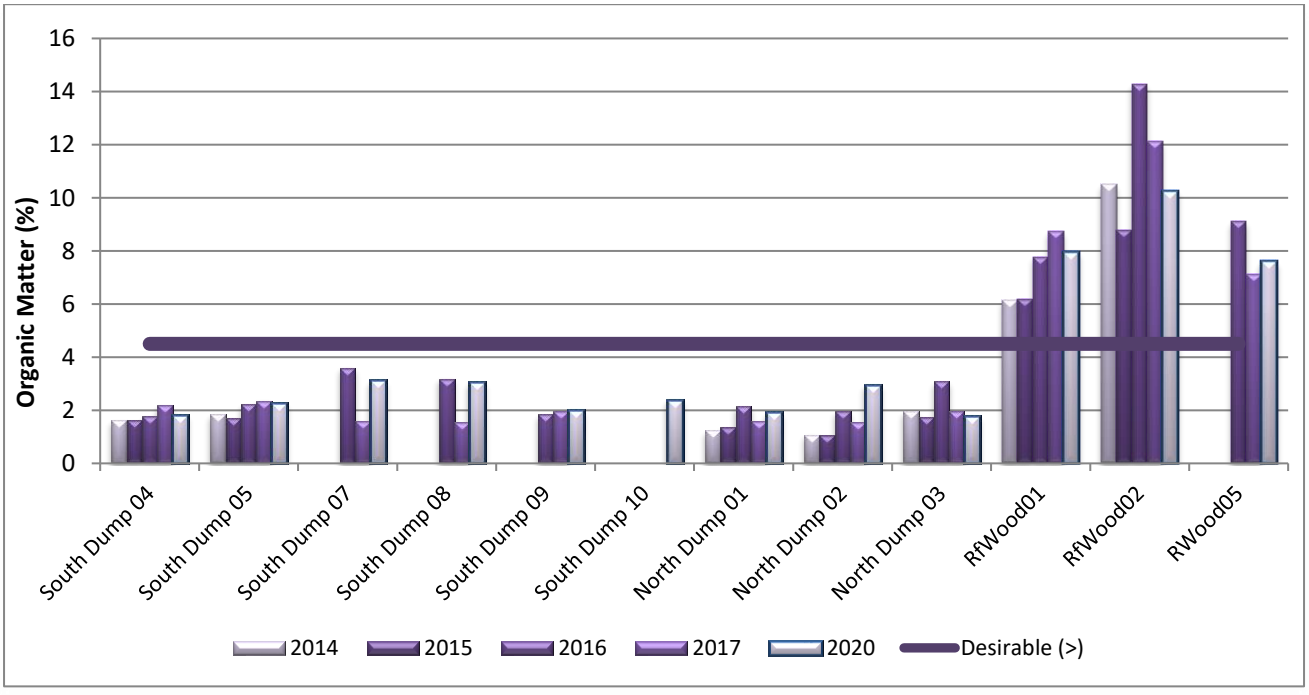


Figure 5-19. Organic Matter concentrations recorded in the rehabilitation sites compared to the woodland reference sites and desirable agricultural levels.

5.3.12.4 Phosphorous

There has been no consistent change in Phosphorous (P) levels across the range of woodland monitoring sites. This year there were minor changes, and P concentrations remained highly variable between the reference sites and ranged from 15 mg/kg in RWood05 and to 37 mg/kg in RfWood01. Most of the rehabilitation sites had P concentrations which fell within this range, with the exception of South Dump 04 and South Dump 09 which had a slightly lower P of 10 mg/kg and 9 mg/kg respectively (Figure 5-20).

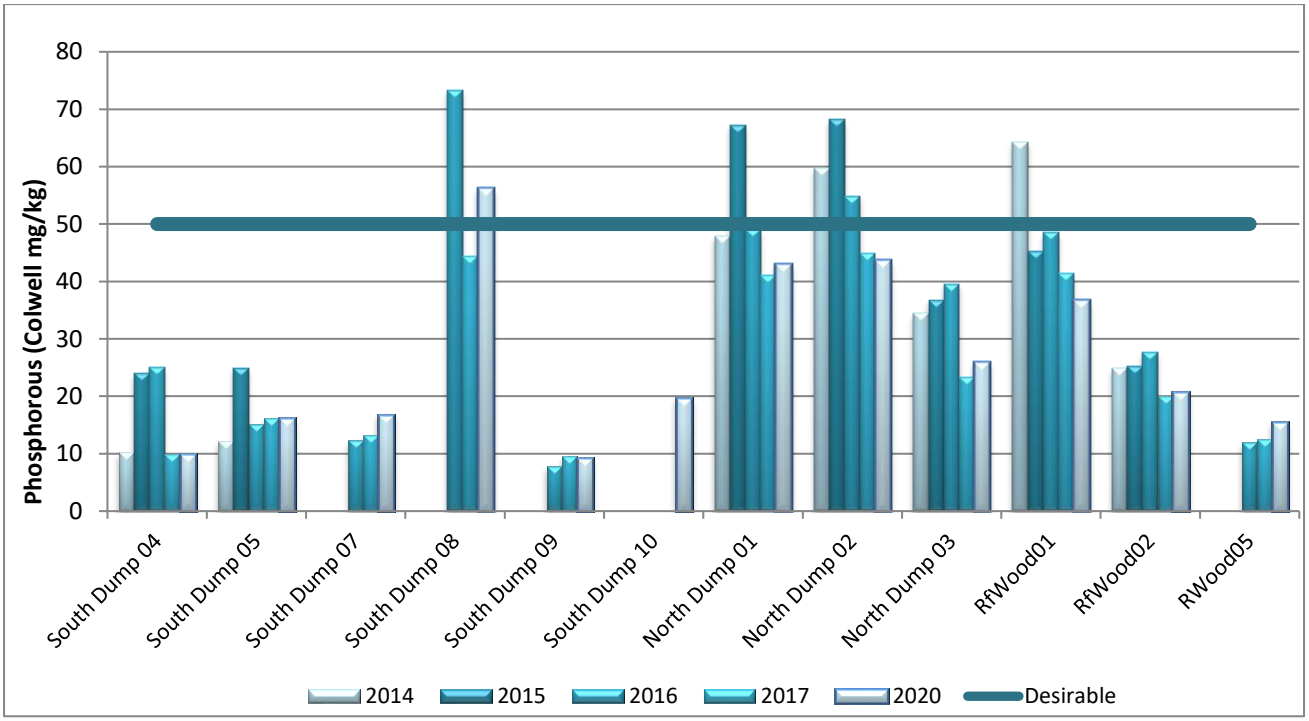


Figure 5-20. Phosphorous (Colwell) concentrations recorded in the rehabilitation sites compared to the woodland reference sites and desirable agricultural levels.

5.3.12.5 Nitrate

Nitrate (N) levels are often highly variable and have not shown any consistent trend across the range of sites. This year N ranged from 2.1 – 37.7 mg/kg in the woodland reference sites, with N levels in RfWood2 above the agricultural threshold this year (Figure 5-21). N concentrations in the rehabilitation sites were also highly variable with many demonstrating an increase over the past year. All rehabilitation sites had N levels within local or acceptable concentrations except sites South Dump 09 and South Dump 10, where N concentrations were particularly high with 77.9 mg/kg and 134 mg/kg respectively.

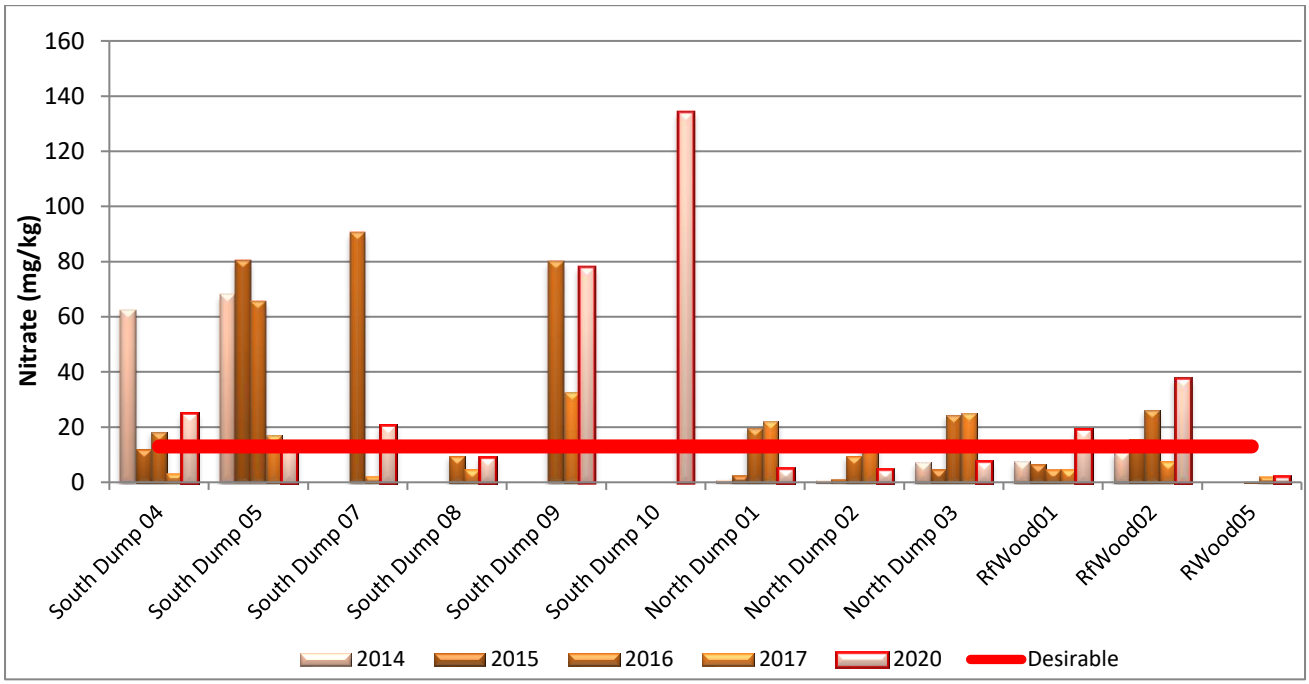


Figure 5-21. Nitrate concentrations recorded in the rehabilitation sites compared to the woodland reference sites and desirable agricultural levels.

5.3.12.6 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. There was no consistent trend in changes in CEC across the range of monitoring sites but in the reference sites and these were highly variable between sites and ranged from 13.2 – 29.9 cmol+/Kg, with RfWood02 continuing to far exceed the desirable level (Figure 5-22). Rehabilitation sites on the South Dump had very low CECs which ranged from 5.2 cmol+/Kg on South Dump 09 to 7.8 cmol+/Kg at South Dump 07. At the North Dump, CECs were slightly higher and ranged between 11.7 – 18.3 cmol+/Kg, with these being close to local and desirable levels, or marginally lower.

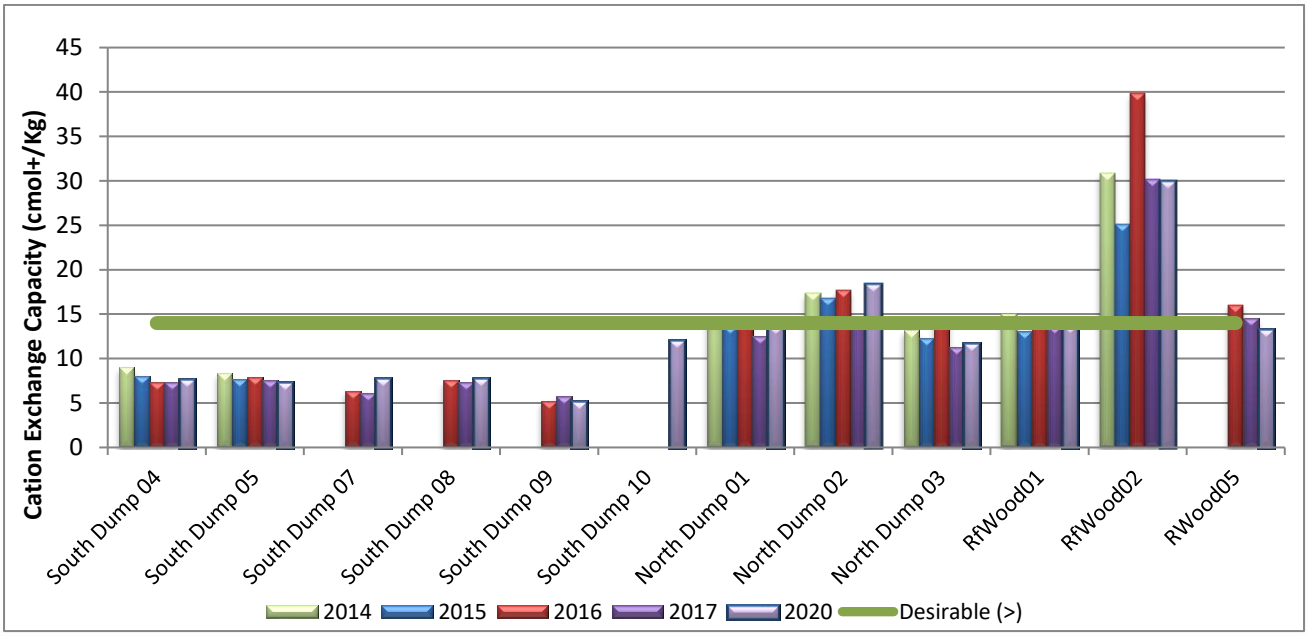


Figure 5-22. Cation Exchange Capacity recorded in the woodland rehabilitation sites compared to the upper and lower values from the woodland reference sites and desirable agricultural levels.

5.3.12.7 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.

There has continued to be negligible changes in ESP recorded in the woodland reference sites with all reference sites having a very low ESP of 0.33 – 0.59% and non-sodic (Figure 5-23). On the South Dump, a slight increase in ESP was recorded in numerous sites with ESPs ranging from a low of 1.28% (South Dump 07) to a high of 2.73% in South Dump 09 and these soils can be considered to be non-sodic. On the North Dump ESP ranged from 0.43 – 0.70 % and were all considered non sodic.

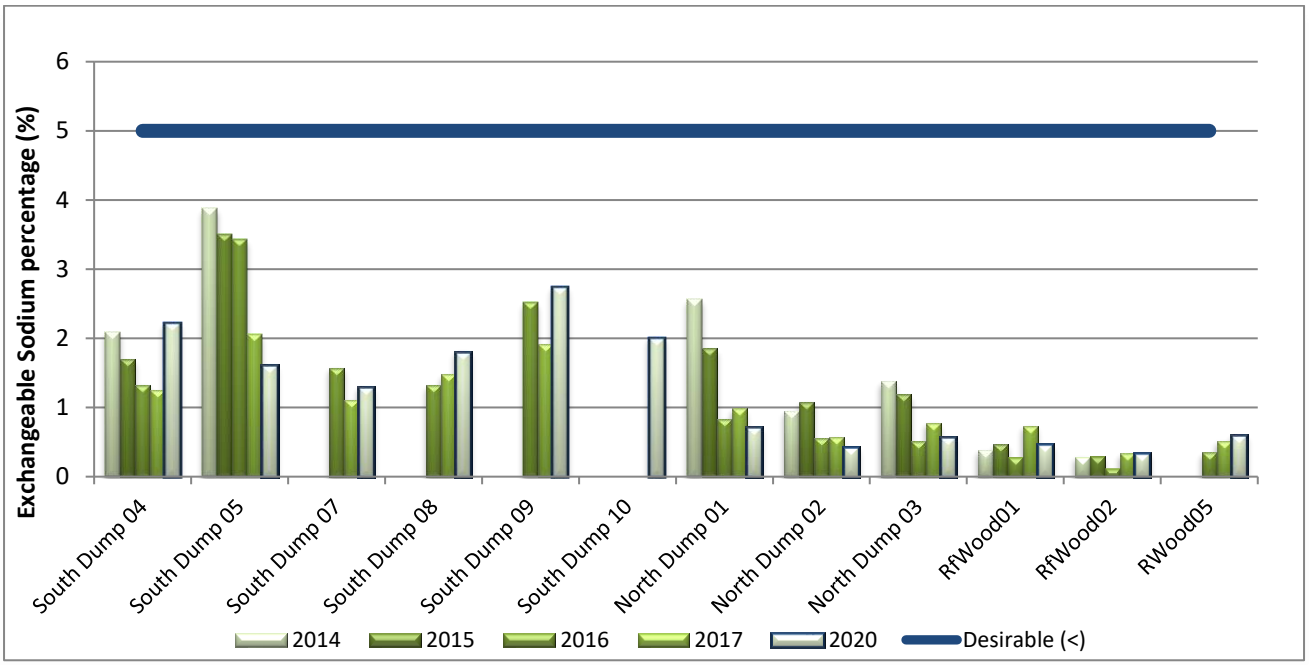


Figure 5-23. ESP recorded in the rehabilitation sites compared to the woodland reference sites and desirable agricultural levels.

5.3.12.8 Other soil test results

The full results of the soil analysis are provided in Appendix 5 with a summarised version highlighting elevated results provided in Table 5-8. The soil results have been compared to EPA guidelines. The EPA indicative fertility guidelines are based on Albrecht and Reams concepts for achieving ideal soil fertility in clay loam soils. The EPA Contaminant guidelines are based on limits for 'Residential A - Residential with gardens and accessible soil including children's daycare centres, preschools, primary schools, town houses or villas' soils (NSW EPA 1998). Further detail can be found in the “End notes” of the Soil Analyses results (Appendix 3). Sites which contained elevated levels compared to these guidelines have been shaded to provide a general indication of how much an element or heavy metal may exceed acceptable concentrations. The colour coding used when comparing against these recommended guidelines is as follows. Green = slightly elevated; Yellow = high; Red = very high; Brown = significantly high; Purple = excessive.

The results indicate there are numerous elements which occur at elevated levels in the rehabilitation sites, however most of these also have been recorded at elevated levels within the selection of woodland reference sites suggesting various elements and heavy metals can occur at “naturally” high levels around the Cadia Mine

and are likely to be related to the long agricultural and mining history of the area. In particular, there may have been elevated concentrations of Calcium, Magnesium, Potassium, Manganese, Iron and Iron.

Copper was also recorded in high concentrations in many rehabilitation sites, especially those on the North Dump. In the rehabilitation areas on the South Dump, there were also high concentrations of Sulfur, especially in South Dump 04, 07 and 08 with these concentrations being far in excess of the guidelines and these concentrations have increased over the last year.

Table 5-8. Summarised soil analyses highlighting elevated test results in the woodland monitoring sites in 2020.

Parameter	South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03	RfWood 01	RfWood 02	RWood 05	Indicative guidelines - refer to Notes 6 and 8
Soluble Calcium (mg/kg)	595	398	572	426	319	892	998	1,089	825	934	2,125	844	*750*
Soluble Magnesium (mg/kg)	228	240	192	214	149	257	375	512	351	272	428	315	*105*
Soluble Potassium (mg/kg)	78	78	<50	75	53	157	78	83	<50	219	283	144	*75*
Sulfur (mg/kg S)	61	16	67	38	15	27	5.3	8.4	11	5.6	7.7	2.6	*8.0*
Manganese (mg/kg)	25	51	35	45	66	35	17	11	15	38	62	109	*22*
Iron (mg/kg)	41	98	83	66	76	73	34	39	41	84	41	129	*22*
Copper (mg/kg)	2.1	1.5	2.1	4.4	1.1	2.8	21	28	14	0.74	5.7	3.3	*2.0*
Boron (mg/kg)	0.33	0.30	0.26	0.25	0.22	0.30	0.15	0.17	0.14	0.30	0.52	0.19	*1.7*
Silicon (mg/kg Si)	40	37	40	33	30	58	53	56	47	58	47	46	*45*
Total Zinc (mg/kg)	22	24	27	26	15	25	61	77	47	20	42	42	*20–50 Zn*
Total Iron (mg/kg)	26,795	19,859	22,674	36,733	14,413	18,114	36,398	41,897	35,387	19,015	35,561	64,116	*1000–50 000 Fe*
Total Copper (mg/kg)	28	17	22	52	12	26	215	279	128	11	79	44	*20–50 Cu*
Total Molybdenum (mg/kg)	0.62	0.41	0.64	0.67	0.48	0.31	3.3	3.5	2.4	0.71	0.55	0.48	*0.5–3.0 Mo*

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

5.4 Woodland rehabilitation site performance towards meeting ecological performance indicators

Table 5-9 indicates the performance of the rehabilitation monitoring sites against the range of primary completion and secondary ecological performance indicators recorded in the woodland reference sites in 2020. The performance indicators have been presented in order of rehabilitation phases and ecosystem succession, beginning with Phase 2 Landform establishment and stability (Orange) followed by Phase 3 Growth Medium Development (Brown), Phase 4 Ecosystem & Landuse Establishment (Green) and ending with Phase 5 Ecosystem & Landuse Sustainability (Blue).

Rehabilitation sites meeting or exceeding the range values of the reference sites have been identified with a shaded colour box and have therefore been deemed to meet the ecological targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites. 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 agricultural" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 5-9. Performance of the woodland rehabilitation monitoring sites against primary and secondary ecological performance indicators in 2020.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
Performance indicators are quantified by the range of values obtained from replicated reference sites assessed in 2020							Lower KPI	Upper KPI	2020								
Phase 2: Landform establishment and stability	**Landform slope, gradient**	Landform suitable for final landuse and generally compatible with surrounding topography and final landform design	Slope	Landform is generally compatible within the context of the local topography and final landform design.		Degrees (<18°)	10	14	18	18	16	0	16	17	14	15	2
	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	4	0	2	8	0	6	0	3	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	m^2	0.00	0.09	0	0.142	0.322	0	0.440	0	0.306	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)	6.1	7.0	5.6	5.4	5.2	5.4	5.1	5.8	6.7	6.6	6.2
			EC		Electrical Conductivity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	< dS/m (<0.150)	0.055	0.142	0.146	0.062	0.146	0.120	0.146	0.272	0.033	0.043	0.040
			Organic Matter	Organic Matter levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	7.6	10.2	1.8	2.2	3.1	3.0	2.0	2.4	1.9	2.9	1.7
			Phosphorous	Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		mg/kg (50)	15.4	36.7	9.8	16.1	16.7	56.1	9.2	19.7	43.0	43.6	25.9

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
			Nitrate		Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	mg/kg (>12.5)	2.1	37.7	25.0	12.9	20.4	8.9	77.9	134.0	4.9	4.6	7.5
			CEC		Cation Exchange Capacity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	Cmol+/kg (>14)	13.2	29.9	7.7	7.3	7.8	7.7	5.2	12.1	13.6	18.3	11.7
			ESP		Exchangeable Sodium Percentage (a measure of sodicity) is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	% (<5)	0.3	0.6	2.2	1.6	1.3	1.8	2.7	2.0	0.7	0.4	0.6
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		%	61.8	67.5	61.2	61.5	60.9	66.6	58.7	53.9	62.0	67.7	64.9
			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		%	64	100	30	66	39	72	37	17	79	92	93
	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	7	3	9	15	18	11	4	4	5	4

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
				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	100	100	99	99	97	98	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	19	41	24	25	34	47	31	21	35	32	36
			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	7	31	11	14	25	30	22	8	14	9	10
			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	10	12	13	11	9	17	9	13	21	23	26
			Ratio of native to exotic species		The ratio of live native species compared to live exotic plant species provides an indication of the relative native species richness of the site and that it is more than or comparable to the local remnant vegetation	>	0.6	3.1	0.8	1.3	2.8	1.8	2.4	0.6	0.7	0.4	0.4
	Vegetation density	Vegetation contains a density of species comparable to that of the local	Density of shrubs and juvenile trees		The total density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation	No./area	0	75	122	392	408	638	492	6	198	384	55

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
		remnant vegetation		The density of endemic shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation		No./area	0	58	122	390	404	622	484	6	198	384	55
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees	The number of tree species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	1	3	0	1	3	5	6	1	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	6	4	9	15	15	10	3	7	5	4
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0	0	0	0	0
			Herbs		The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	13	24	10	9	8	17	6	15	21	21	25
			Grasses	The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	5	7	10	5	7	7	9	2	7	6	7
			Reeds		The number of reed, sedge or rush species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	1	0	0	0	2	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
			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	1	1	1	0	0	0	0	0
			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	0	0	0
			Aquatic		The number of aquatic plants comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0	0	0	0	0
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		%	52.9	62.2	28.2	37.2	27.1	38.9	30.0	24.5	34.2	42.0	35.5
			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		%	48.5	61.5	29.1	38.9	27.6	41.3	31.0	20.4	33.6	41.3	35.7
	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	%	65.0	94.5	9.5	55.5	27.5	34.5	22	10	6.0	25.5	10.5
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	0.0	5.5	26	5	1	20	7	31	63.5	37.5	60.5

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0.0	0.0	8.5	12.5	12	11.5	10.5	1	11	1.5	5.5
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0.0	7.0	13.5	0.5	9	2	2	0.5	9	1.5	2
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	1.0	4.5	0	0	0	0	0	0	1.5	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	2.0	7.5	35.0	18.0	43.0	10	53.5	57.0	6	3.5	19.5
			Perennial plant cover (< 0.5m)	Percent ground cover provided by live perennial vegetation (<0.5m in height) is comparable to that of the local remnant vegetation		%	1.0	15.0	7.5	8.5	7.5	22	5	0.5	3	30.5	2
			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		%	92.5	98.0	65.0	82.0	57.0	90	46.5	43.0	94	96.5	80.5

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
	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	**0.4**	**3.0**	**0.4**	**0.6**	**1.4**	**1.6**	**0.8**	**0.2**	**0.8**	**0.8**	**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	**0.4**	**2.8**	**4**	**3**	**1.6**	**2.2**	**1.8**	**6.4**	**4**	**3.8**	**5**
	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) compared to exotic species is comparable to that of the local remnant vegetation		%	**7.1**	**85.0**	**15**	**12.5**	**56.3**	**43.2**	**33.3**	**1.7**	**13.6**	**7**	**1.8**
	Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	shrubs and juvenile trees 0 - 0.5m in height	The number of shrubs or juvenile trees <0.5m in height provides an indication of establishment success and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation		No./area	**0**	**68.0**	**20**	**26**	**32**	**22**	**6**	**5**	**0**	**24**	**0**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
			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	5.0	32	16	166	290	72	1	54	36	9
			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	58	54	150	296	288	0	106	148	30
			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	10	114	34	12	86	0	24	128	15
			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	2.0	2	182	26	18	40	0	14	48	1

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
	Ecosystem structure	The vegetation is developing in structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5 - 2 m	Projected foliage cover provided by perennial plants in the 0.5 - 2m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover	**0**	**0.0**	**11**	**44**	**19**	**30**	**26**	**0**	**16**	**26**	**0**
			Foliage cover 2 - 4m	Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover	**0**	**2.0**	**0**	**7**	**0**	**0**	**0**	**0**	**0**	**4**	**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	**3.0**	**6.0**	**0**	**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	**37.0**	**42.0**	**0**	**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/ area	**1**	**4**	**1**	**1**	**1**	**0**	**2**	**0**	**1**	**1**	**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		% endemic	**100.0**	**100.0**	**100**	**100**	**100**	**0**	**100**	**0**	**100**	**100**	**100**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
	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	**9.0**	**48.0**	**2**	**52**	**4**	**0**	**2**	**0**	**1**	**24**	**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	**25.0**	**68.0**	**10**	**7**	**7**	**0**	**7**	**0**	**8**	**6**	**6**
	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	**85.4**	**95.8**	**100**	**35**	**100**	**0**	**100**	**0**	**100**	**42**	**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	**8.3**	**11.1**	**100**	**0**	**100**	**0**	**100**	**0**	**100**	**0**	**0**
			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	**56.3**	**79.2**	**0**	**23**	**0**	**0**	**0**	**0**	**0**	**25**	**100**
			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**	**18.8**	**0**	**11.5**	**0**	**0**	**0**	**0**	**0**	**16.7**	**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**	**14.6**	**0**	**65**	**0**	**0**	**0**	**0**	**0**	**58**	**0**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	2020 Woodland ecosystem range		South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03
			Mistletoe		The percentage of the tree population which have mistletoe provides an indication of community health and habitat value and that the percentage is comparable to the local remnant vegetation	% population	0	0.0	0	0	0	0	0	0	0	0	0
			Flowers/fruit: Trees	The presence of 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	16.7	88.9	100	0	0	0	0	0	100	0	0
			Hollows		The presence of hollows provides evidence that the ecosystem is maturing, and can provide habitat resources comparable to that of the local remnant vegetation	% population	0	44.4	0	0	0	0	0	0	0	0	0

6 Conclusion

While no rehabilitation sites yet met all primary completion criteria, many sites had been demonstrating a significant increase in ecological function up until the drought conditions that have been experienced since 2017. Despite a decline in ecological function these degrading attributes can be directly attributed to the prolonged dry seasonal conditions and increased grazing and disturbance by animals, especially Eastern Grey Kangaroos, with the decline in many performance indicators also being reflected in the range of woodland reference sites.

While there has been some loss of seedlings and mature shrubs, these have typically been species of acacia which presently occur in much higher numbers than would be expected in the local woodlands. The high densities of acacias are a crucial part of the successional development of the rehabilitation areas, especially in the development of the soil profile as their stems assist in accumulating mobilised resources (alive or dead), their roots improve soil characteristics and the extensive addition of dead leaves and spent pods add nutrients and improve the extent and decomposition of the litter layers.

The low abundance of eucalypts within numerous rehabilitation areas, especially on the North Dump where none have been recorded, will affect tree density and diversity completion targets and compromise the structural integrity of the rehabilitated woodland communities in the longer-term. This will be particularly important as many mature acacias decline from these ecosystems as part of the natural successional development. This has previously been observed at the older South Dump 01, 02 and 03 sites, and this year also at South Dump 05 and North Dump 02. Sites without or with low densities of eucalypts are likely to require rehabilitation intervention to ensure appropriate eucalypt densities are established. The long-term goal should be to have approximately 80 – 410 stems of one to three eucalypt species per hectare.

Exotic annual weeds which have voluntarily and successfully colonised large areas of rehabilitation are playing a particularly important role in the ecological development, function and stability of the sites. This is largely due to the provision of protective ground cover and development of the litter layers which lead to increased stability and coherency of the soil profile. In addition, many annual weeds have become naturalised within the local area, thus in some cases many may always be persistent, but not necessarily problematic. In addition, much of the annual ground covers this year were clovers or medics which are useful pasture species. Over time, the abundance of many “weedy” annual weed species are likely to decline, as the disturbed rehabilitation areas undergo successional development phases and the dead litter layers accumulate and decompose and perennial ground covers become more abundant. It is however imperative that overgrazing and heavy disturbances are kept to a minimum as they reduce the integrity of the protective ground covers, promote “weediness” and decrease the rate of natural succession development which has the potential to lead result in rehabilitation failure if left unchecked.

The drought conditions over three consecutive years have not been conducive to significant developments in the rehabilitation areas, however many areas have maintained or even slightly improved in ecological function, largely due to the establishment of these exotic annual plants, but also due to the establishment of tree and shrub seedlings, especially in South Dump 08. More vulnerable rehabilitation areas, such as those occurring on the steeper slopes (South Dump 04, 07 and 09 and North Dump 01) have tended to have a higher degree of erosion resulting in a more unstable environment where ground cover plants and cryptogams have been much slower to establish.

There were some differences in soil chemistry between the soils applied onto rehabilitation areas and the soils occurring in the local woodlands and some rilling continued to be recorded in the steeper rehabilitation slopes. Copper was recorded in high concentrations in many rehabilitation sites, especially those on the North Dump. In the rehabilitation areas on the South Dump, the soils were acidic and there were also high concentrations of

Sulfur, especially in South Dump 04, 05, 07 and 08 with these concentrations being far in excess of the guidelines and these concentrations have increased over the last year. These should continue to be monitored, as increasing concentrations may inhibit the establishment of protective ground cover and have an adverse effect of the development of wider rehabilitation areas. In the newest site South Dump 10, the soils were also saline. Testing of waste rock materials and topsoils prior to application on rehabilitation areas should be regularly undertaken to ensure suitable substrates are used prior to spreading onto rehabilitation areas.

Some species of acacia were not strictly local endemic species, and several annual weeds including *Bidens pilosa* (Cobbler's Peg) and *Verbena litoralis* (Coastal Verbena) are weed species that were noted in low numbers on the newer areas of rehabilitation and are not usually associated with the Cadia area. Additional care should be taken to ensure local provenance seed collection and/or biosecurity measures are put into practice.

While no formal survey for fauna is undertaken by DnA Environmental, a range of wildlife have been or were observed within the rehabilitation areas. Increased habitat such as large logs and fallen trees would enhance rehabilitation sites. Additional perching sites could also be made available by erecting (upside down) fallen trees in appropriate locations across the rehabilitation areas. This practice has been undertaken with very successful outcomes in the Hunter Valley. Birds using the perching sites assist rehabilitation outcomes by introducing native plant seed (especially those with fleshy drupes) that may not otherwise colonise large rehabilitation areas. A range of other wildlife may also assist with the natural dispersal of seeds, create germination niches and micro-sites and assist with nutrient recycling across the wider rehabilitation areas.

Feral and pest animals (and noxious weeds) also require monitoring and targeted control programs may need to be implemented, in consultation with advice from relevant experts and authorities to determine the levels of management intervention required and the most effective methods.

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Appendix 1. Monitoring site location data

GPS co-ordinates and other site specific information for the reference sites.

Site Reference	LFA Start	LFA Finish	LFA slope°	LFA bearing°	Veg transect start	Veg transect finish	Veg transect bearing°
RfWood01 (Ashleigh Park)	55680871 6295705	55680880 6295718	10	30 NE	55680875 6295715	55680903 6295677	120 SE
RfWood02 (Bundarra)	55683151 6290452	55683159 6290441	14	145 SE	55683154 6290447	55683114 6290436	236 NW
RWood04 (CVO access) (Right - left transect)	55687596 6296337	55687589 6296351	10	310 W	55687591 6296345	55687554 6296316	220 SW
RWood05 (CVO Cadiangullong Dam)	55 684994 6298928	55 685013 6298922	12	94	55 685005 6298924	55 684987 6298876	184 S
RfPast01 (Bundarra)	55 683406 6290780	55 683423 6290790	10	45 NE	55 683415 6290785	55 683439 6290742	140 SE
RfPast03 (Willunga)	55 687926 6298533	55 687911 6298546	8	300 NW	55 687918 6298540	55 687948 6298579	25 N
RrRip02 (Bakers Shaft)	55 686614 6279287	55 686622 6279263	10	170 S	55 686622 6279272	55 686573 62792710	260 W
RrRip03 (CVO Cadiang Ck)	55 685302 6298471	55 685314 6298478	14	44	55 685306 6298475	55 685327 6298431	140 SE

GPS co-ordinates and other site specific information for the rehabilitation monitoring sites.

Site	LFA Start	LFA Finish	LFA slope°	LFA bearing°	Veg transect start	Veg transect finish	Veg transect bearing°
Ashleigh Park 01	55 680874 6294881	55 680864 6294899	5	320 NW	55 680887 6294887	55 680873 6294904	320 NW
South Dump 01	55 685304 6294460	55 685308 6294478	22	351 N	55 685307 6294468	55 685353 6294467	79 E
South Dump 02	55 685118 6294354	55 685108 6294369	17	302 NW	55 685113 6294362	55 685146 6294401	33 NE
South Dump 03	55685250 6293838	55685231 6293838	18	245W	55685240 6293838	55685239 6293886	348 NW
South Dump 04	55686455 6293539	55686453 6293524	18	173S	55686454 6293535	686407 6293533	264 W
South Dump 05	55687089 6294032	687108 6294029	18	88E	687100 6294032	687092 6293982	175 S
South Dump 06	687551 6294645	55687570 6294653	1	231SW	55687561 6294649	55687579 6294603	144 SE

Site	LFA Start	LFA Finish	LFA slope°	LFA bearing°	Veg transect start	Veg transect finish	Veg transect bearing°
South Dump 07	55686973 6294252	55686991 6294252	16	76 E	55686983 6294254	55686981 6294200	168 S
South Dump 08	55686632 6293878	55686643 6293860	0	142 SE	55686638 6293868	55686594 6293845	232 SW
South Dump 09	55685920 6294044	55685900 6294046	16	260 W	55685911 6294045	55685915 6294096	350 N
South Dump 10	55684896 6293929	55684878 6293915	17	216 SW	55684888 6293919	55684853 6293957	305 NW
North Dump 01	55686596 6296978	55686582 6296967	14	217SW	55686589 6296973	55686555 6297013	307 NW
North Dump 02	55686375 6296954	55686362 6296942	15	220SW	55686369 6296947	55686339 6296986	309 NW
North Dump 03	55687148 6297228	55687130 6297227	1	260W	55687139 6297226	55687139 6297277	350 N
Willunga DS01	55 687586 6298689	55 687579 6298710	6	320 NW	55 687601 6298700	55 687568 6298737	320 NW
Willunga DS02	55 687266 6208927	55 687260 6298910	10	180 S	55 687248 6298929	55 872473 6298883	182 S
Cadiangullong Creek	55 684249 6294028	55 684242 6294015	5	180 S	55 684244 6294017	55 684199 6294037	275 W
Creek Diversion	55 685350 6297515	55 685346 6297501	8	165 S	55 685346 6297511	55 685296 6297506	257 W

Appendix 2. Descriptions and photo-points of the older woodland and farmland rehabilitation monitoring sites

General description and photo from the permanent photo-point at the rehabilitation monitoring sites 2008 - 2019.

2008	2012	2014	2016	2018	2019
Ashleigh Park 01: Bushland revegetation: The site was direct seeded in 2004. The adjacent remnant vegetation is dominated by *E. macrorhyncha, E. melliodora* and some *E. polyanthemos* with little to no shrubby understorey. Native pasture species are dominant in the grassy understorey but have been heavily grazed in the past. In 2010, the site had recently been heavily grazed but had recovered in 2011 with the understorey dominated by native grasses. The shrubs had grown significantly with the rows starting to join in places and there was some acacia suckers/regeneration. In 2012, there was light grazing by cattle and combined with macropods and rabbits, the grass was very short but retained good ground cover and the tree and shrubs had significantly grown. In 2013 the site has been heavily grazed and there was little active plant growth in the grassy understorey. The trees and shrubs continue to grow but rabbits continue to be a problem. In 2016 there was limited live ground cover and these were grazed very low by livestock?, macropods and rabbit grazing, but overgrazing and scratching have caused bare patches to develop. Some acacias had died and the lower foliage cover had died off as the shrubs grew in height. There were pockets of acacias suckering. In 2019, a track had been graded through the site, to rip and destroy rabbit warrens in the area. The revegetation area was severely overgrazed. Numerous acacias had died, but persisting trees and shrubs were large and the eucalypts were developing mature canopies. Scattered acacia suckers.					
		N/A		N/A	
South Dump 01: Woodland rehabilitation: North facing slope of the southern waste emplacement. This section of the waste emplacement was shaped and covered in 2006 followed by aerial seeding with a range of local native trees and shrub species. It was reseeded in 2007. In 2011, there was increased ground cover and only a few small pockets of bare ground. The site remains weedy but there was higher perennial grass cover. Several acacias had died but others appear very healthy and have grown considerably and there was an echidna hole. In 2012 there was an increase in ground cover and tubestock had grown significantly, but galls were present in some of the acacias. Macropods/rabbits have kept grasses short in patches. Rabbits (and foxes?) require baiting. Small skinks were present. In 2013 there was low ground cover and many of the shrubs had died due to the prolonged dry conditions. In 2014 more shrubs had died but the remaining shrubs had further grown. In 2015 the site was very dry with little active ground cover growth. Austrodanthonia and Dactylis glomerata were dominant but very stressed. There has been heavy browsing by macropods and rabbits with some bare patches especially under thicker acacias. Many acacias had further died leaving the site much more open. The persisting shrubs were in bud and mostly healthy, but the A. implexa often had galls. In 2016 there was limited live ground cover and these were grazed very low by a macropod and rabbit grazing but overgrazing and scratching have caused bare patches to develop. Some acacias had died and the lower foliage cover had died off as the shrubs grew in height. There were pockets of acacias suckering. In 2018 the site was grazed very low by a macropod and rabbits and there was limited live ground cover. Overgrazing, scratching, tracks and camps have continued to degrade the rehabilitation sites and many more acacias had died. This site was not assessed in 2019.					
					N/A
South Dump 02: Woodland rehabilitation: West facing slope of the southern waste emplacement. This section of the waste emplacement was shaped and covered in 2006 followed by aerial seeding with a range of local native trees and shrub species. It was reseeded in 2007. In 2011 the perennial grasses (Phalaris, Cocksfoot) were scattered but were becoming tall and rank and kangaroo tracks have left a few bare areas. There has been significant growth of the shrubs especially *A. dealbata* and there were relatively few weeds. Old rills have stabilised but there were some small bare area towards end of veg transect. In 2012 there was an increase in ground cover and tubestock had grown significantly. Macropods have kept grasses short in patches and camps and heavy browsing were evident. The site was noticeably very dry with most annual species being dead. There was little evidence of rabbits. In 2013 there was low ground cover and many of the shrubs had died due to the prolonged dry conditions. In 2014 more shrubs had died but the remaining shrubs had further grown. In 2015 the site was very dry with little active ground cover growth.					

2008	2012	2014	2016	2018	2019
Phalaris tussocks were very stressed and appearing dead. There has been heavy browsing by Macropods and rabbits with some bare patches especially under thicker acacias. Many acacias had further died leaving the site much more open but there was some scattered Acacia suckers. The A buxifolia often suffered from scale. In 2016 there was limited live ground cover, and these were grazed very low by a macropod and rabbit grazing, but overgrazing and scratching have caused bare patches to develop. Some acacias had died, and the lower foliage cover had died off as the shrubs grew in height. There were pockets of acacias suckering. In 2018 the site was grazed very low by a macropod and rabbits and there was limited live ground cover. Overgrazing, scratching, tracks and camps have continued to degrade the rehabilitation sites and many more acacias had died. This site was not assessed in 2019.					
					N/A
South Dump 03: Woodland rehabilitation: West facing slope of the southern waste emplacement. This section of the waste emplacement was shaped and covered in 2006 followed by aerial seeding with a range of local native trees and shrub species. It was reseeded in 2007. This site was not monitored until 2010. In 2011 there had been an increased growth of perennial grasses and shrubs and was very stable. There were some roo tracks and camps beneath the shrubs. In 2012 there was an increase in ground cover and tubestock had grown significantly. There were many small wrens and a Grey Fantail. In 2013 there was low ground cover and many of the shrubs had died due to the prolonged dry conditions. In 2014 more shrubs had died but the remaining shrubs had further grown. In 2015 the site was very dry with little active ground cover growth. Phalaris tussocks were very stressed and appearing dead. There has been heavy browsing by Macropods and rabbits with some bare patches especially under thicker acacias. Many acacias had further died leaving the site much more open but there were numerous Acacia suckers. In 2016 there was limited live ground cover and these were grazed very low by a macropod and rabbit grazing but overgrazing and scratching have caused bare patches to develop. Some acacias had died and the lower foliage cover had died off as the shrubs grew in height. There were pockets of acacias suckering. In 2018 the site was grazed very low by a macropod and rabbits and there was limited live ground cover. Overgrazing, scratching, tracks and camps have continued to degrade the rehabilitation sites and many more acacias had died. This site was not assessed in 2019.					
N/A					N/A
Willunga DS01: Woodland rehabilitation: Willunga property, southern side of gully behind complex. The area was direct seeded in 2005 and 2006 and had been heavily grazed by sheep and cattle prior to the 2008 monitoring. In 2011, the site had remained ungrazed and there had been a considerable improvement in native and exotic grasses and there were fewer weeds, but there was a large patch of dead *Carthamus lanatus* (Saffron Thistle) at end of veg transect. The trees and shrubs have grown considerably but some subject to insect attack and had been defoliated. Some *E. bridgesiana* now had >5cm dbh. There were a few Blackberries. In 2012 the trees and shrubs had significantly grown and the site remained ungrazed. The understorey was dominated by exotic perennials but large patches of *Microlaena stipoides* were present. There were fewer weeds and the Saffron's had almost compete disappeared. There was an increase in Blackberries. In 2013, macropods have kept the grass short and their camps have created large bare along the rows of establishing trees. The Blackberries had been sprayed and they were dead. In 2014 the site had not been grazed and the kangaroo camps were recovering. There were many small acacia suckers and numerous small Blackberries. In 2015 and 2016 the site appears to have been heavily grazed but not recently. The ground cover was very low and retains patches of Phalaris, dead litter and Microlaena. There were few other ground cover plants present but numerous Acacia suckers have persisted with many being chewed right back. The old kangaroo camps have persisted beneath the tree line, but the trees appear to be healthy. Most of the Blackberry was dead but a few small seedlings remain. In 2019, the area remains overgrazed and was currently being grazed by cattle, with large bare patches beginning to develop. There was some recent germination of annuals and reshooting of perennial ground covers. A large patch of *Echium vulgare* (Viper's Bugloss) has developed at end of the plot. Some acacias have died outright, however the surviving trees and shrubs had significantly grown and the Acacias were suckering but grazed.					

2008	2012	2014	2016	2018	2019
				N/A	
Willunga DS02: Woodland rehabilitation: Willunga property. Paddock adjacent to Ridgeway access road. It is a rocky knoll with native pastures that has been fenced off to restrict grazing. The area was direct seeded in 2005 and 2006, with sparse scattering of seedlings now present. Some tubestock were planted in the lower section of the monitoring area. The site is largely ungrazed and dominated by tall rank *Bothriochloa macra*, and there appeared to more weeds (Skeleton weed, dead Saffron Thistle and Blackberry). In 2012, the site remained ungrazed, but the large patches of Blackberries had been sprayed. There continued to a dense sward of native grasses with relatively few weeds. The trees and shrubs have continued to grow with a couple of individuals being affected by spray drift. Many small Blackberries were observed so follow up spraying will be essential. In 2013, macropods have kept the grass short and while the Blackberries had been sprayed will continue to require some follow up. In 2014 the site remained ungrazed and there were a scattering of small Blackberries. The site had not been recently grazed and had retained a moderate cover of native grasses and Skeleton weed was abundant. A few Blackberry canes remain and occasional Blackberry persist. While many acacias have died over the years the remaining trees have grown and appear healthy. There were few annual grasses present this year. In 2016 there was limited live ground cover and these were grazed very low by a combination of recent strategic stock grazing and macropods. In 2019, the area was being grazed by cattle but good ground cover was retained. There was some recent germination of annuals and reshooting of perennial ground covers. The surviving trees and shrubs had significantly grown, and the Acacias were suckering.					
				N/A	

Appendix 3. Descriptions and photo-points of the riparian monitoring sites

General description and permanent photo-point along the vegetation transect in the riparian reference monitoring sites 2008 - 2019.

2008	2010	2012	2014	2016	2019
RrRip02 Riparian patch: reserve Bakers Shaft Reserve. Open woodland dominated by *E. camaldulensis, E. melliodora* and *E. bridgesiana*. Understorey dominated by *Phalaris aquatica* and *Dactylis glomerata* with patches of introduced annual grasses and native grass and herbs. Some *E. camaldulensis* regeneration occurring along the rocky banks. In 2011 the site was ungrazed and was dominated by a dense sward of exotic perennial grasses with thistles beneath the tree canopies. The young saplings had significantly grown. There was evidence of high flood waters. In 2012, the area contained long rank perennial grasses and several "shrubs" had been chopped down by campers. There were many small Blackberry bushes growing. Flood waters have altered the stream morphology with litter and debris evident high amongst tree branches. In 2013 the site was overgrazed by sheep but retained relatively good ground levels. The continued to be many small Blackberries. In 2016 there was limited live ground cover, and these were grazed very low by a combination of recent strategic stock grazing and macropods. A walking track was developing across the site but presently probably had little impact on the vegetation data. In 2019 the site was being grazed by cattle and continued to be dominated by a dense sward of exotic and native perennial grasses. A couple of large tree branches have fallen down. *Nassella neesiana* (Chilean Needlegrass) was spreading and there were scattered Hypericum perforatum (St John's Wort). The river was the lowest observed. The eucalypt saplings had grown.					
					
RrRip03 Cadiangullong creek CVO. Open woodland dominated by *E. viminalis, E. melliodora* and *E. bridgesiana* and a relatively intact native understorey. Large old growth trees and midstorey shrubs including *Acacia melanoxylon* and *A. dealbata*. Very weedy on the opposing banks and in patches along the sloping banks. Bank drops steeply down to the creek with some erosion occurring on the kangaroo tracks. Willows have been removed further downstream. In 2011 two large trees had fallen down within the site. In 2011 and 2012, high flood waters have continued to alter the stream morphology with loss of aquatic vegetation and pools, with bank slumping and undercutting. In 2013 the creek beds had stabilised and there continued to be good ground cover and some acacia recruitment. No orchids have been sighted since 2010. There were many small noxious shrub species which had been browsed by macropods, despite evidence of active weed control being undertaken. In 2016 there was limited live ground cover, and these were grazed very low by a macropods. In 2019, the site was grazed very low by macropods and continued to contain a range of weeds. The creek was very low and reduced to deep pools but remains clear and very slow flowing. A large branch had fallen across the LFA transect and a new transect was established 10m along the veg transect. There was an active wombat hole.					
			N/A		

General description and photo from the permanent photo-point at the riparian rehabilitation monitoring sites 2008 - 2019.

2008	2010	2012	2014	2016	2019
Creek Diversion: Riparian restoration: Start of Cadiangullong Creek diversion (photo from rear). Planted with tubestock in 2005. Heavy grazing by wallabies and kangaroos. In 2011 there was an improvement in ground cover and the Phalaris was tall and rank and the shrubs have grown. The creek bed was densely vegetated with Water Couch, pockets of Cumbungi and some *A. melanoxylon* saplings were establishing on the banks. The bottom remained rocky with occasional rocky pools. The banks remained intact despite intense flooding. Water was clear and flowing. In 2012, the grass was long and rank and there was an improvement in ground cover along the veg transect. There was less evidence of macropod grazing. The Creek itself retains a dense bed of Water Couch with a narrow stream of water flowing through. The banks remained stable despite floods. Some shrubs had died and the clovers had been frosted. In 2013 and 2014, there continued to be low be low but typically good ground cover but a notable absence of clovers due to the prolonged dry conditions and several more shrubs had died. The creek was well vegetated and gently flowing. In 2016 macropods have trampled and grazed low the grasses leaving scattered dry Phalaris tussocks. Litter cover is good and cryptogams persist in bare areas, but rabbits scratching were evident. Creek contained a dense sward of Cumbungi and Water Couch, with occasional *A. melanoxylon* and Casuarinas on the creek banks. In 2019, the surviving tubestock were very large. Most of the site was grazed very low by macropods and quite weedy. The creek was very low and reduced to deep pools. Willows have regrown.					
					
Cadiangullong Creek: Riparian restoration: Below Clark's hardstand. It contains remnant riparian vegetation with an overstorey of *Casuarina cunninghamiana* and a small patch of *A. dealbata* on the creek bank which has some patchy regeneration present. The area was direct seeded in 2006. The understorey remained dominated by Phalaris. Saplings damaged by past grazing (2009) have recovered and grown considerably. In 2011, flood water had spilled onto the floodplain leaving piles of debris scattered across the site. In 2012 the site remains ungrazed with long dense exotic perennial grasses continuing to dominate the site and there continued to be low species diversity. The scattered trees and shrubs continue to grow, but macropods have grazed many small acacia suckers along the creek banks. The creek was fast flowing with changed morphology and loss of bed after floods. Some minor scouring of the banks. Some of the mature casuarinas trees continued to be "sick". In 2013 the site had been past grazed and maintained low species diversity. The creek was clear flowing. In 2016 cattle have recently trampled and grazed low the grasses leaving scattered dry Phalaris tussocks. The creek bank had stabilised and the creek was clear and slow flowing. The trees and shrubs have significantly grown. In 2019, the surviving tubestock had become very large. Most of the site was grazed by cattle/macropods and remained dominated by Phalaris. The creek was dry and reduced to deep pools.					
			N/A		

Appendix 4: Flora species recorded in the woodland monitoring sites 2020

*Note: "1" denotes the presence of that species at a particular site and is not a measure of cover abundance.

Group	Family	exotic	Scientific Name	Common Name	Habit	South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03	RfWood01	RfWood02	RWood05
Dicotyledon	Amaranthaceae	*	*Amaranthus albus*	Tumbleweed	h						1	1		1			
Dicotyledon	Apiaceae		*Daucus glochidiatus*	Australian Carrot	h										1		
Dicotyledon	Araliaceae		*Hydrocotyle laxiflora*	Stinking Pennywort	h												1
Dicotyledon	Asteraceae	*	*Arctotheca calendula*	Capeweed	h	1	1	1	1	1			1	1	1		
Dicotyledon	Asteraceae	*	*Bidens pilosa*	Cobbler's Peg	h	1			1								
Dicotyledon	Asteraceae	*	*Carthamus lanatus*	Saffron Thistle	h	1			1			1	1	1			
Dicotyledon	Asteraceae		*Cassinia aculeata*	Dolly Bush	s				1								
Dicotyledon	Asteraceae		*Cassinia arcuata*	Chinese Shrub	s		1	1	1	1	1		1	1			1
Dicotyledon	Asteraceae		*Cassinia laevis*	Cough Bush	s							1					
Dicotyledon	Asteraceae	*	*Chondrilla juncea*	Skeleton Weed	h					1		1		1	1		1
Dicotyledon	Asteraceae	*	*Cirsium vulgare*	Spear Thistle	h									1	1	1	1
Dicotyledon	Asteraceae		*Cymbonotus lawsonianus*	Bear's Ear	h												1
Dicotyledon	Asteraceae	*	*Hypochaeris glabra*	Smooth Catsear	h												1
Dicotyledon	Asteraceae	*	*Hypochaeris radicata*	Flatweed	h									1			
Dicotyledon	Asteraceae		*Senecio hispidulus*	Hill Fireweed	h												1
Dicotyledon	Asteraceae		*Senecio prenanthoides*		h												1
Dicotyledon	Asteraceae		*Senecio quadridentatus*	Cotton Fireweed	h	1					1						
Dicotyledon	Asteraceae	*	*Silybum marianum*	Variegated Thistle	h		1		1		1	1	1	1		1	
Dicotyledon	Asteraceae		*Solenogyne dominii*	Smooth Solenogyne	h												1
Dicotyledon	Asteraceae	*	*Sonchus asper*	Prickly Sowthistle	h											1	
Dicotyledon	Asteraceae	*	*Sonchus oleraceus*	Milk Thistle	h		1	1	1			1	1	1		1	
Dicotyledon	Asteraceae		*Vittadinia cuneata*	Fuzzweed	h	1											
Dicotyledon	Asteraceae		*Vittadinia spp.*	Fuzzweed	h				1								
Dicotyledon	Asteraceae	*	*Xanthium spinosum*	Bathurst Burr	h						1					1	
Dicotyledon	Boraginaceae		*Cynoglossum australe*	Australian Hounds Tounge	h							1					1
Dicotyledon	Brassicaceae	*	*Brassica juncea*	Chinese Mustard	h						1	1	1		1	1	
Dicotyledon	Brassicaceae	*	*Lepidium africanum*	Peppercress	h		1				1						
Dicotyledon	Campanulaceae		*Wahlenbergia luteola*	Australian Bluebell	h										1		
Dicotyledon	Caryophyllaceae	*	*Petrorhagia nanteuilii*	Proliferous Pink	h							1	1	1			
Dicotyledon	Caryophyllaceae	*	*Stellaria media*	Chickweed	h										1		

Group	Family	exotic	Scientific Name	Common Name	Habit	South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03	RfWood01	RfWood02	RWood05
Dicotyledon	Chenopodiaceae	*	*Chenopodium album*	Fat Hen	h						1						
Dicotyledon	Chenopodiaceae		*Chenopodium pumilio*	Small Crumbweed	h						1					1	
Dicotyledon	Chenopodiaceae		*Einadia nutans subsp. nutans*	Climbing Saltbush	h						1						
Dicotyledon	Convolvulaceae		*Convolvulus erubescens*	Australian Bindweed	h	1											
Dicotyledon	Convolvulaceae		*Dichondra repens*	Kidney Weed	h												1
Dicotyledon	Fabaceae (Faboideae)		*Daviesia leptophylla*	Slender Bitter-Pea	s				1								
Dicotyledon	Fabaceae (Faboideae)		*Desmodium varians*	Slender Tick-trefoil	h												1
Dicotyledon	Fabaceae (Faboideae)		*Glycine clandestina*	Climbing Glycine	h			1									1
Dicotyledon	Fabaceae (Faboideae)		*Hardenbergia violacea*	Happy Wanderer	v		1	1	1								
Dicotyledon	Fabaceae (Faboideae)		*Pultenaea spinosa*	Spiny Bush-pea	s				1								
Dicotyledon	Fabaceae (Faboideae)		*Pultenaea spp.*	Bush-pea	s			1									
Dicotyledon	Fabaceae (Faboideae)		*Pultenaea spp.*	Bush-pea	s				1								
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium angustifolium*	Narrow-leaf Clover	h								1				
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium arvense*	Haresfoot Clover	h	1											
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium spp.*	A Clover	h							1	1	1	1		
Dicotyledon	Fabaceae (Faboideae)	*	*Trifolium subterraneum*	Subterraneum Clover	h	1	1	1	1	1	1	1	1	1		1	1
Dicotyledon	Fabaceae (Faboideae)	*	*Vicia sativa*	Common Vetch	h								1				
Dicotyledon	Fabaceae (Mimosoideae		*Acacia filicifolia*	Fern-leaved Wattle	s		1	1	1	1							
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia buxifolia*	Box-leaved Wattle	s	1	1	1	1	1		1	1	1			
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia dealbata*	Silver Wattle	s	1	1	1				1	1	1			1
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia decora*	Western Golden Wattle	s	1	1	1			1						
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia decurrens*	Early black Wattle	s			1	1	1							
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia falcata*	A Wattle	s				1	1							
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia gunnii*	Ploughshare Wattle	s		1	1	1								
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia implexa*	Hickory	s		1	1	1	1							1
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia melanoxylon*	Blackwood	s							1					
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia paradoxa*	Kangaroo Thorn	s		1	1	1	1		1					
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia penninervis*	Mountain Hickory	s			1	1	1							
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia spectabilis*	Mudgee Wattle	s							1	1				
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia verniciflua*	Varnish Wattle	s			1	1	1							
Dicotyledon	Fabaceae (Mimosoideae)		*Acacia vestita*	Boree	s	1	1	1	1	1	1	1	1	1			
Dicotyledon	Geraniaceae	*	*Erodium botrys*	Long Storksbill	h					1				1		1	
Dicotyledon	Geraniaceae	*	*Erodium cicutarium*	Common Crowsfoot	h			1	1					1			

Group	Family	exotic	Scientific Name	Common Name	Habit	South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03	RfWood01	RfWood02	RWood05
Dicotyledon	Geraniaceae		*Geranium solanderi*	Native Geranium	h		1		1			1	1	1	1	1	1
Dicotyledon	Haloragaceae		*Gonocarpus elatus*	Hill Raspwort	h				1								
Dicotyledon	Lamiaceae	*	*Marrubium vulgare*	Horehound	h							1	1	1			
Dicotyledon	Lamiaceae		*Scutellaria humilis*	Dwarf Scullcap	h												1
Dicotyledon	Malaceae	*	*Crataegus monogyna*	Hawthorn	s												1
Dicotyledon	Malvaceae	*	*Modiola caroliniana*	Red-flowered Mallow	h		1		1		1	1	1	1			
Dicotyledon	Myrtaceae		*Eucalyptus albens*	White Box	t			1		1						1	
Dicotyledon	Myrtaceae		*Eucalyptus blakelyi*	Blakely's Red Gum	t		1		1	1	1				1		
Dicotyledon	Myrtaceae		*Eucalyptus bridgesiana*	Apple Box	t				1	1							
Dicotyledon	Myrtaceae		*Eucalyptus goniocalyx*	Bundy Box	t			1	1	1							1
Dicotyledon	Myrtaceae		*Eucalyptus macrorhyncha*	Red Stringybark	t			1		1							1
Dicotyledon	Myrtaceae		*Eucalyptus melliodora*	Yellow Box	t				1						1		1
Dicotyledon	Myrtaceae		*Eucalyptus polyanthemos*	Red Box	t				1								
Dicotyledon	Myrtaceae		*Eucalyptus viminalis*	Ribbon Gum	t					1							
Dicotyledon	Oxalidaceae		*Oxalis perennans*	Yellow Wood-sorrel	h		1	1	1	1	1	1	1	1	1	1	1
Dicotyledon	Papaveraceae	*	*Papaver spp.*	Poppy	h							1		1			
Dicotyledon	Plantaginaceae	*	*Echium plantagineum*	Paterson's Curse	h	1	1	1	1	1	1	1	1	1	1		
Dicotyledon	Plantaginaceae	*	*Echium vulgare*	Vipers Bugloss	h	1			1			1	1	1			
Dicotyledon	Plantaginaceae	*	*Plantago lanceolata*	Ribwort	h									1			1
Dicotyledon	Plantaginaceae		*Veronica plebeia*	Trailing Speedwell	h										1		
Dicotyledon	Polygonaceae	*	*Acetosella vulgaris*	Sheep Sorrel	h			1				1	1				
Dicotyledon	Polygonaceae	*	*Polygonum aviculare*	Wireweed	h						1			1			
Dicotyledon	Polygonaceae		*Rumex brownii*	Swamp Dock	h				1			1	1		1	1	1
Dicotyledon	Polygonaceae	*	*Rumex crispus*	Curled Dock	h								1	1			
Dicotyledon	Primulaceae	*	*Lysimachia arvensis*	Scarlet Pimpernel	h							1		1	1		
Dicotyledon	Proteaceae		*Grevillea ramosissima*	Fan Grevillea	s			1									
Dicotyledon	Proteaceae		*Hakea spp.*	Needlewood	s			1									
Dicotyledon	Rosaceae		*Acaena novae-zelandiae*	Biddy-biddy	h												1
Dicotyledon	Rosaceae		*Acaena ovina*	Sheep's Burr	h												1
Dicotyledon	Rosaceae	*	*Rosa rubiginosa*	Sweet Briar	s												1
Dicotyledon	Rosaceae	*	*Rubus fruticosus*	Blackberry	s												1
Dicotyledon	Rubiaceae		*Pomax umbellata*	Pomax	h												1
Dicotyledon	Solanaceae	*	*Solanum nigrum*	Blackberry Nightshade	h				1		1		1	1		1	1

Group	Family	exotic	Scientific Name	Common Name	Habit	South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03	RfWood01	RfWood02	RWood05
Dicotyledon	Solanaceae	*	*Solanum triflorum*	Three-flowered Nightshade	h							1					
Dicotyledon	Urticaceae	*	*Urtica urens*	Small Nettle	h								1				
Dicotyledon	Verbenaceae	*	*Verbena litoralis*	Coastal Verbena	h				1								
Dicotyledon	Violaceae		*Viola betonicifolia*	Showy Violet	h												1
Monocotyledon	Anthericaceae		*Dichopogon fimbriatus*	Nodding Chocolate Lily	h										1		
Monocotyledon	Cyperaceae		*Carex spp.*		r										1		1
Monocotyledon	Juncaceae		*Juncus subsecundus*		r				1								
Monocotyledon	Juncaceae		*Juncus usitatus*		r				1								
Monocotyledon	Lomandraceae		*Lomandra filiformis*	Wattle Mat-rush	h												1
Monocotyledon	Poaceae		*Austrostipa scabra*	Speargrass	g	1		1		1				1	1		
Monocotyledon	Poaceae		*Bothriochloa macra*	Red-leg Grass	g							1		1			1
Monocotyledon	Poaceae	*	*Bromus cartharticus*	Prairie Grass	g								1		1		
Monocotyledon	Poaceae	*	*Bromus diandrus*	Great Brome	g		1	1		1			1	1		1	
Monocotyledon	Poaceae		*Cynodon dactylon*	Couch	g	1		1		1		1					
Monocotyledon	Poaceae	*	*Dactylis glomerata*	Cocksfoot	g	1			1	1		1					1
Monocotyledon	Poaceae	*	*Digitaria sanguinalis*	Summer Grass	g										1		
Monocotyledon	Poaceae		*Echinopogon ovatus*	Forest Hedgehog Grass	g												1
Monocotyledon	Poaceae		*Elymus scaber*	Common Wheatgrass	g			1		1							1
Monocotyledon	Poaceae	*	*Hordeum leporinum*	Barley Grass	g	1			1								
Monocotyledon	Poaceae	*	*Lolium perenne*	Perennial Ryegrass	g	1	1		1								
Monocotyledon	Poaceae	*	*Lolium rigidum*	Wimmera Ryegrass	g	1	1	1	1	1	1	1	1	1	1	1	
Monocotyledon	Poaceae		*Microlaena stipoides*	Weeping Rice-grass	g										1	1	1
Monocotyledon	Poaceae	*	*Nassella trichotoma*	Serrated Tussock	g	1						1	1				
Monocotyledon	Poaceae		*Panicum spp.*		g									1			
Monocotyledon	Poaceae	*	*Phalaris aquatica*	Phalaris	g	1	1	1	1	1	1	1	1	1		1	
Monocotyledon	Poaceae		*Poa sieberiana*	Fine-leaf Tussock	g												1
Monocotyledon	Poaceae		*Poa spp.*		g				1								
Monocotyledon	Poaceae		*Rytidosperma racemosum*	Wallaby Grass	g			1							1	1	1
Monocotyledon	Poaceae		*Rytidosperma richardsonii*	Wallaby Grass	g	1	1			1							
Monocotyledon	Poaceae		*Rytidosperma spp.*	Wallaby Grass	g	1			1	1		1	1	1			

Appendix 5: Comprehensive soil analysis: Woodland monitoring sites 2020

12 samples supplied by DnA Environmental on 14/04/2020. Lab Job No.J2619

	Parameter	Method reference	South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03	RfWood 01	RfWood 02	RWood 05	*Heavy Soil Clay*	*Medium Soil Clay Loam*	*Light Soil Loam*	*Sandy Soil Loamy Sand*
			J2619/1	J2619/2	J2619/3	J2619/4	J2619/5	J2619/6	J2619/7	J2619/8	J2619/9	J2619/10	J2619/11	J2619/12	Indicative guidelines - refer to Notes 6 and 8			
	Soluble Calcium (mg/kg)	**Inhouse S10 - Morgan 1	595	398	572	426	319	892	998	1,089	825	934	2,125	844	1150	750	375	175
	Soluble Magnesium (mg/kg)		228	240	192	214	149	257	375	512	351	272	428	315	160	105	60	25
	Soluble Potassium (mg/kg)		78	78	<50	75	53	157	78	83	<50	219	283	144	113	75	60	50
	Soluble Phosphorus (mg/kg)		<1	<1	<1	<1	<1	1.3	2.6	2.3	1.3	5.7	4.5	2.5	15	12	10	5.0
	Phosphorus (mg/kg P)	**Rayment & Lyons 2011 - 9E2 (Bray 1)	2.1	1.9	4.1	24	2.1	4.4	13	9.0	5.9	19	4.5	3.1	45[n ote 8]	30[n ote 8]	24[n ote 8]	20[n ote 8]
		**Rayment & Lyons 2011 - 9B2 (Colwell)	9.8	16	17	56	9.2	20	43	44	26	37	21	15	80	50	45	35
		**Inhouse S3A (Bray 2)	4.8	3.9	12	43	3.8	7.6	26	24	14	33	7.7	4.1	90[n ote 8]	60[n ote 8]	48[n ote 8]	40[n ote 8]
	Nitrate Nitrogen (mg/kg N)	**Inhouse S37 (KCl)	25	13	20	8.9	78	134	4.9	4.6	7.5	19	38	2.1	15	13	10	10
	Ammonium Nitrogen (mg/kg N)		2.5	2.8	5.7	4.2	17	36	1.9	2.4	1.1	4.6	4.7	10	20	18	15	12
	Sulfur (mg/kg S)		61	16	67	38	15	27	5.3	8.4	11	5.6	7.7	2.6	10.0	8.0	8.0	7.0
	pH	Rayment & Lyons 2011 - 4A1 (1:5 Water)	5.60	5.40	5.15	5.36	5.08	5.83	6.74	6.63	6.15	6.48	6.99	6.10	6.5	6.5	6.3	6.3
	Electrical Conductivity (dS/m)	Rayment & Lyons 2011 - 3A1 (1:5 Water)	0.146	0.062	0.146	0.120	0.146	0.272	0.033	0.043	0.040	0.092	0.142	0.055	0.200	0.150	0.120	0.100
	Estimated Organic Matter (% OM)	**Calculation: Total Carbon x 1.75	1.8	2.2	3.1	3.0	2.0	2.4	1.9	2.9	1.7	7.9	10	7.6	> 5.5	>4.5	> 3.5	> 2.5
	Exchangeable Calcium (cmol+/kg)	Rayment & Lyons 2011 - 15D3 (Ammonium Acetate)	4.4	3.5	4.6	4.0	2.6	7.9	8.6	11	7.1	9.5	23	8.4	15.6	10.8	5.0	1.9
	Exchangeable Calcium (kg/ha)		1,968	1,567	2,076	1,790	1,159	3,558	3,872	4,909	3,184	4,268	10,350	3,775	7000	4816	2240	840
	Exchangeable Calcium (mg/kg)		879	700	927	799	517	1,588	1,728	2,191	1,421	1,905	4,620	1,685	3125	2150	1000	375
	Exchangeable Magnesium (cmol+/kg)		2.6	2.7	2.2	2.5	1.7	3.0	4.4	6.8	4.2	3.1	5.2	4.0	2.4	1.7	1.2	0.60
	Exchangeable Magnesium (kg/ha)		718	746	609	694	452	821	1,200	1,838	1,138	853	1,429	1,078	650	448	325	168

			Site	South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03	RfWood 01	RfWood 02	RWood 05	*Heavy Soil Clay*	*Medium Soil Clay Loam*	*Light Soil Loam*	*Sandy Soil Loamy Sand*
		(mg/kg)		320	333	272	310	202	367	536	821	508	381	638	481	*290*	*200*	*145*	*75*
	Exchangeable Potassium	(cmol$_+$/kg)		0.43	0.46	0.31	0.51	0.35	0.87	0.48	0.54	0.29	1.00	1.5	0.73	*0.60*	*0.50*	*0.40*	*0.30*
		(kg/ha)		376	404	269	445	309	762	421	471	250	872	1,278	641	*526*	*426*	*336*	*224*
		(mg/kg)		168	180	120	199	138	340	188	210	112	389	571	286	*235*	*190*	*150*	*100*
	Exchangeable Sodium	(cmol$_+$/kg)		0.17	0.12	0.10	0.14	0.14	0.24	0.10	0.08	0.07	<0.065	0.10	0.08	*0.3*	*0.26*	*0.22*	*0.11*
		(kg/ha)		88	60	51	71	73	125	49	40	34	<33	51	40	*155*	*134*	*113*	*57*
		(mg/kg)		39	27	23	32	32	56	22	18	15	<15	23	18	*69*	*60*	*51*	*25*
	Exchangeable Aluminium	(cmol$_+$/kg)	**Inhouse S37 (KCl)	0.05	0.36	0.43	0.46	0.35	0.04	0.03	0.03	0.03	0.04	0.03	0.03	*0.6*	*0.5*	*0.4*	*0.2*
		(kg/ha)		9.4	72	87	92	71	7.2	6.0	6.4	6.9	7.2	5.9	6.5	*121*	*101*	*73*	*30*
		(mg/kg)		4.2	32	39	41	32	3.2	2.7	2.9	3.1	3.2	2.6	2.9	*54*	*45*	*32*	*14*
	Exchangeable Hydrogen	(cmol$_+$/kg)	**Rayment & Lyons 2011 - 15G1 (Acidity Titration)	0.01	0.08	0.06	0.06	0.08	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	*0.6*	*0.5*	*0.4*	*0.2*
		(kg/ha)		<1	1.8	1.3	1.4	1.9	<1	<1	<1	<1	<1	<1	<1	*13*	*11*	*8*	*3*
		(mg/kg)		<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	*6*	*5*	*4*	*2*
	Effective Cation Exchange Capacity (ECEC) (cmol$_+$/kg)		**Calculation: Sum of Ca,Mg,K,Na,Al,H (cmol$_+$/kg)	7.7	7.3	7.8	7.7	5.2	12	14	18	12	14	30	13	*20.1*	*14.3*	*7.8*	*3.3*
	Calcium (%)		**Base Saturation Calculations - Cation cmol$_+$/kg / ECEC x 100	57	48	60	52	50	66	63	60	61	69	77	64	*77.6*	*75.7*	*65.6*	*57.4*
	Magnesium (%)			34	38	29	33	32	25	32	37	36	23	18	30	*11.9*	*11.9*	*15.7*	*18.1*
	Potassium (%)			5.6	6.4	4.0	6.6	6.8	7.2	3.5	2.9	2.5	7.3	4.9	5.5	*3.0*	*3.5*	*5.2*	*9.1*
	Sodium - ESP (%)			2.2	1.6	1.3	1.8	2.7	2.0	0.70	0.43	0.56	0.46	0.33	0.59	*1.5*	*1.8*	*2.9*	*3.3*
	Aluminium (%)			0.61	4.9	5.6	6.0	6.8	0.30	0.22	0.17	0.29	0.26	0.10	0.24	*6.0*	*7.1*	*10.5*	*12.1*
	Hydrogen (%)			0.13	1.1	0.76	0.80	1.6	0.00	0.00	0.00	0.00	0.00	0.00	0.08				
	Calcium/Magnesium Ratio		**Calculation: Calcium / Magnesium (cmol$_+$/kg)	1.7	1.3	2.1	1.6	1.6	2.6	2.0	1.6	1.7	3.0	4.4	2.1	*6.5*	*6.4*	*4.2*	*3.2*

		Site	South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03	RfWood 01	RfWood 02	RWood 05	*Heavy Soil Clay*	*Medium Soil Clay Loam*	*Light Soil Loam*	*Sandy Soil Loamy Sand*
	Zinc (mg/kg)	Rayment & Lyons 2011 - 12A1 (DTPA)	0.83	0.76	0.59	<0.5	<0.5	1.0	1.9	1.8	1.2	1.9	3.0	0.91	*6.0*	*5.0*	*4.0*	*3.0*
	Manganese (mg/kg)		25	51	35	45	66	35	17	11	15	38	62	109	*25*	*22*	*18*	*15*
	Iron (mg/kg)		41	98	83	66	76	73	34	39	41	84	41	129	*25*	*22*	*18*	*15*
	Copper (mg/kg)		2.1	1.5	2.1	4.4	1.1	2.8	21	28	14	0.74	5.7	3.3	*2.4*	*2.0*	*1.6*	*1.2*
	Boron (mg/kg)	**Rayment & Lyons 2011 - 12C2 (Hot $CaCl_2$)	0.33	0.30	0.26	0.25	0.22	0.30	0.15	0.17	0.14	0.30	0.52	0.19	*2.0*	*1.7*	*1.4*	*1.0*
	Silicon (mg/kg Si)	**Inhouse S11 (Hot CaCl2)	40	37	40	33	30	58	53	56	47	58	47	46	*50*	*45*	*40*	*35*
	Total Carbon (%)	Inhouse S4a (LECO Trumac Analyser)	1.0	1.3	1.8	1.7	1.1	1.4	1.1	1.7	1.00	4.5	5.9	4.3	*> 3.1*	*> 2.6*	*> 2.0*	*> 1.4*
	Total Nitrogen (%)		0.07	0.09	0.10	0.10	0.08	0.11	0.08	0.14	0.07	0.27	0.37	0.23	*> 0.30*	*> 0.25*	*> 0.20*	*> 0.15*
	Carbon/Nitrogen Ratio	**Calculation: Total Carbon/Total Nitrogen	14	15	18	17	14	12	14	12	15	17	16	19	*10–12*	*10–12*	*10–12*	*10–12*
	Basic Texture	**Inhouse S65	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	..	..	..	..
	Basic Colour		Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	..	..	..	..
	Chloride Estimate (equiv. mg/kg)	**Calculation: Electrical Conductivity x 640	94	40	94	77	93	174	21	27	26	59	91	35	..	..	..	..
	Total Calcium (mg/kg)	Rayment & Lyons 2011 - 17C1 Aqua Regia	1,074	780	1,324	1,124	540	1,803	2,602	3,210	2,338	3,151	13,980	3,272	*1000–10 000 Ca*			
	Total Magnesium (mg/kg)		1,245	1,261	800	1,720	681	1,246	3,605	5,169	3,089	1,315	3,332	2,792	*500–5000 Mg*			
	Total Potassium (mg/kg)		1,119	1,048	740	1,369	719	1,241	1,258	1,365	977	1,254	1,928	1,317	*200–2000 K*			
	Total Sodium (mg/kg)		53	52	<50	65	<50	69	60	65	57	<50	68	64	*100–500 Na*			
	Total Sulfur (mg/kg)		140	106	166	263	81	108	84	137	80	185	377	176	*100–1000 S*			
	Total Phosphorus (mg/kg)		299	211	241	786	139	328	699	667	567	412	521	414	*400–1500 P*			
	Total Zinc (mg/kg)		22	24	27	26	15	25	61	77	47	20	42	42	*20–50 Zn*			
	Total Manganese (mg/kg)		641	615	260	544	318	790	851	632	687	835	1,334	1,365	*200–2000 Mn*			

Site	South Dump 04	South Dump 05	South Dump 07	South Dump 08	South Dump 09	South Dump 10	North Dump 01	North Dump 02	North Dump 03	RfWood 01	RfWood 02	RWood 05	*Heavy Soil Clay*	*Medium Soil Clay Loam*	*Light Soil Loam*	*Sandy Soil Loamy Sand*
Total Iron (mg/kg)	26,795	19,859	22,674	36,733	14,413	18,114	36,398	41,897	35,387	19,015	35,561	64,116	*1000–50 000 Fe*			
Total Copper (mg/kg)	28	17	22	52	12	26	215	279	128	11	79	44	*20–50 Cu*			
Total Boron (mg/kg)	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	7.6	2.4	*2–50 B*			
Total Silicon (mg/kg)	461	263	308	380	349	319	318	323	351	346	561	396	*1000–3000 Si*			
Total Aluminium (mg/kg)	11,557	11,729	11,233	13,797	8,907	10,857	16,375	18,734	16,697	7,166	20,089	14,629	*2000–50 000 Al*			
Total Molybdenum (mg/kg)	0.62	0.41	0.64	0.67	0.48	0.31	3.3	3.5	2.4	0.71	0.55	0.48	*0.5–3.0 Mo*			
Total Cobalt (mg/kg)	15	10	5.4	9.0	5.6	12	19	16	18	11	23	38	*5–50 Co*			
Total Selenium (mg/kg)	<0.5	<0.5	0.56	1.6	<0.5	<0.5	<0.5	0.89	0.57	<0.5	<0.5	<0.5	*0.1–2.0 Se*			
Total Cadmium (mg/kg)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	*<1 Cd*			
Total Lead (mg/kg)	16	13	9.8	10	9.8	11	13	12	12	14	6.4	9.0	*2–200 Pb*			
Total Arsenic (mg/kg)	7.0	3.2	4.8	25	2.5	6.7	10	9.0	8.7	17	3.6	4.6	*1–50 As*			
Total Chromium (mg/kg)	28	20	14	49	12	21	32	39	37	12	21	59	*5–1000 Cr*			
Total Nickel (mg/kg)	11	9.8	5.9	12	4.5	9.5	14	16	17	5.0	13	12	*5–500 Ni*			
Total Mercury (mg/kg)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	*< 0.2 Hg*			
Total Silver (mg/kg)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	*.. Ag*			

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 - Australasia.*CSIRO Publishing: Collingwood.
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH (unless requested).
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and LaMotte Soil Handbook.
5. Guidelines for phosphorus have been reduced for Australian soils.

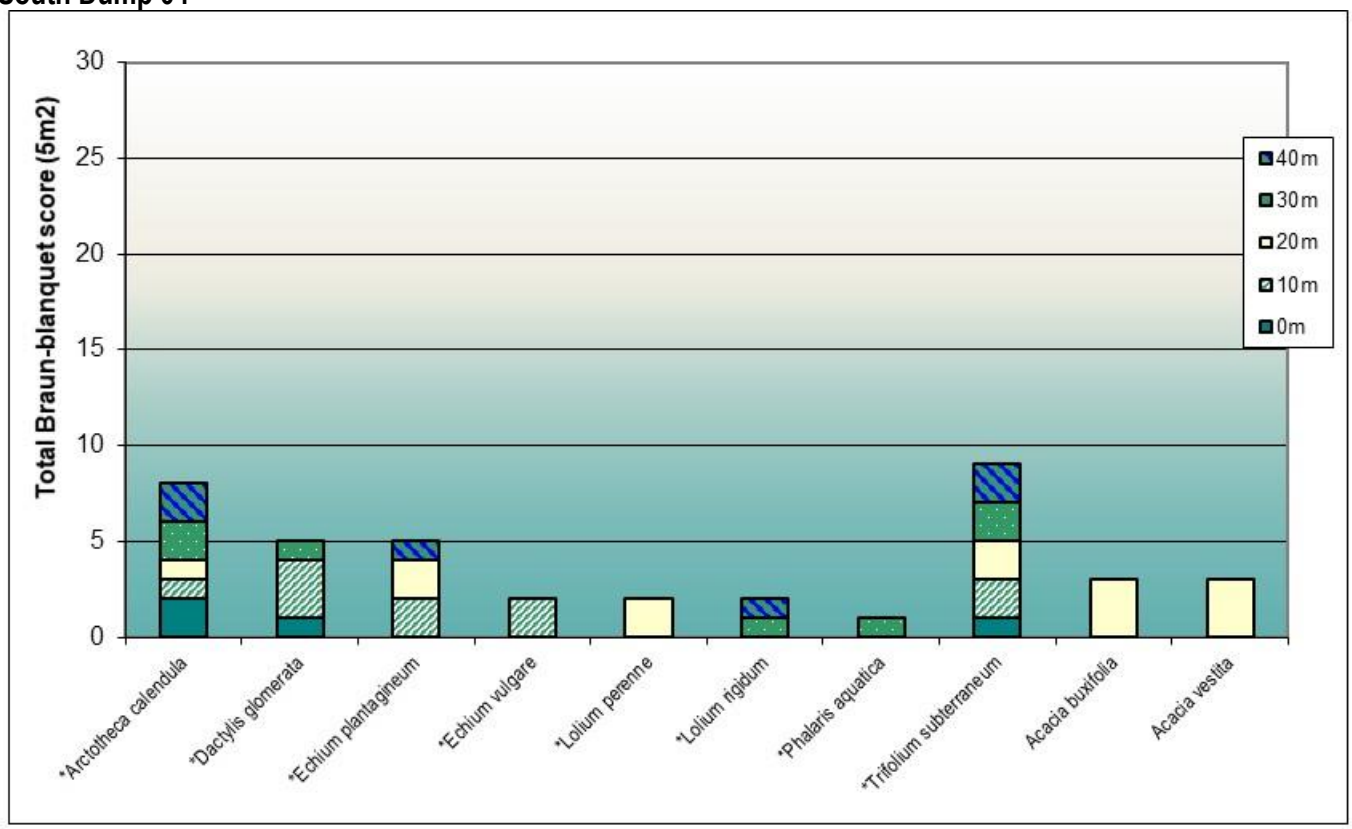
6. Indicative guidelines are based on 'Albrecht' and 'Reams' concepts.
7. Total Acid Extractable Nutrients indicate a store of nutrients.
8. National Environmental Protection (Assessment of Site Contamination) Measure 2013,
   Schedule B(1) - Guideline on Investigation Levels for Soil and Groundwater. Table 5-A Background Ranges.
9. Information relating to testing colour codes is available on sheet 2 - 'Understanding your agricultural soil results'.
10. Conversions for 1 $cmol_+/kg$ = 230 mg/kg Sodium, 390 mg/kg Potassium,

11. Conversions to kg/ha = mg/kg x 2.24
12. The chloride calculation of Cl mg/L = EC x 640 is considered an estimate, and most likely an over-estimate
13. ** NATA accreditation does not cover the performance of this service.
14. Analysis conducted between sample arrival date and reporting date.
15. This report is not to be reproduced except in full. Results only relate to the item tested.
16. All services undertaken by EAL are covered by the EAL Laboratory Services Terms and Conditions (refer scu.edu.au/eal).
17. This report was issued on 22/04/2020.

Quality Checked: Kris Saville
Agricultural Co-Ordinator

Appendix 6: Species cover abundance at individual woodland monitoring sites in 2020

South Dump 04



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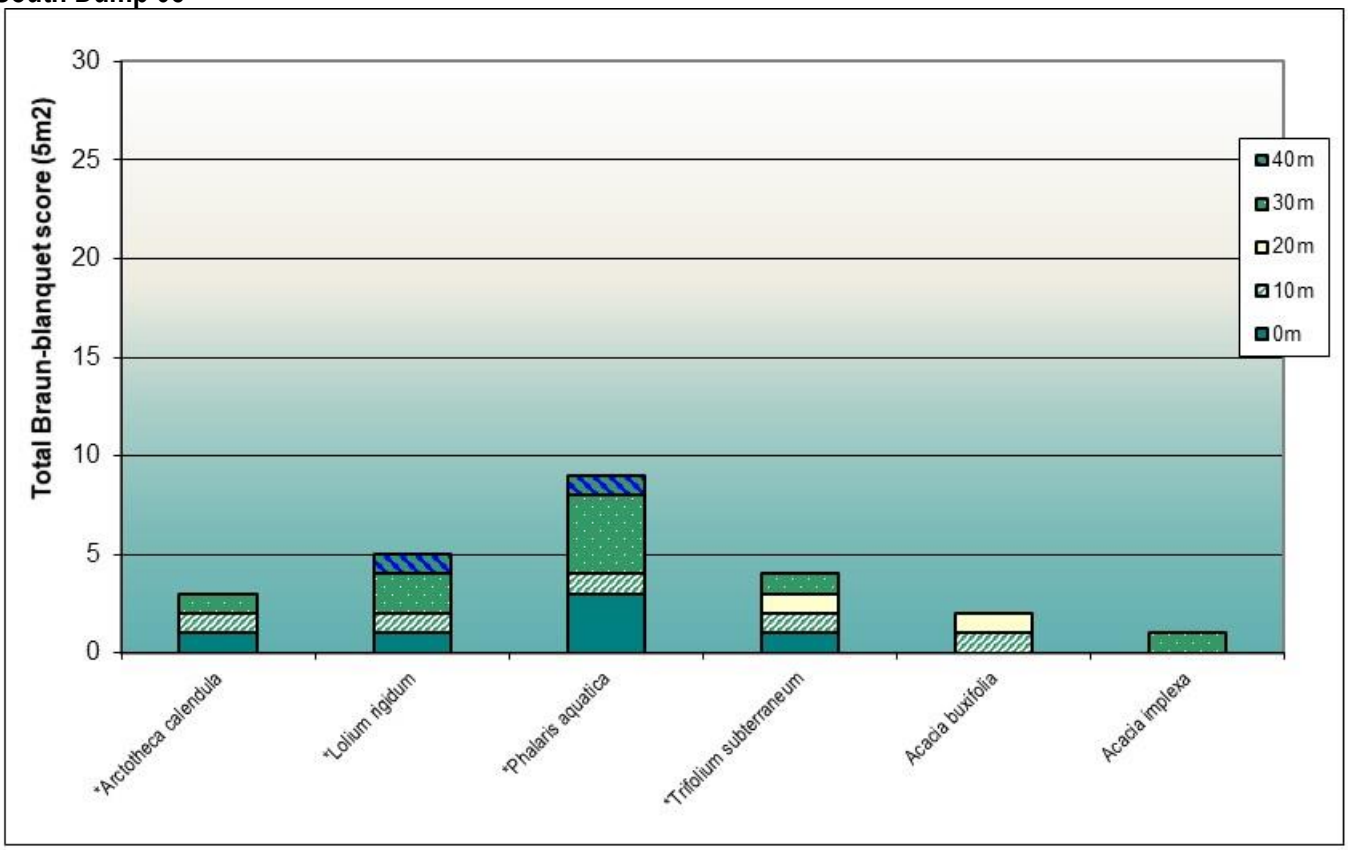

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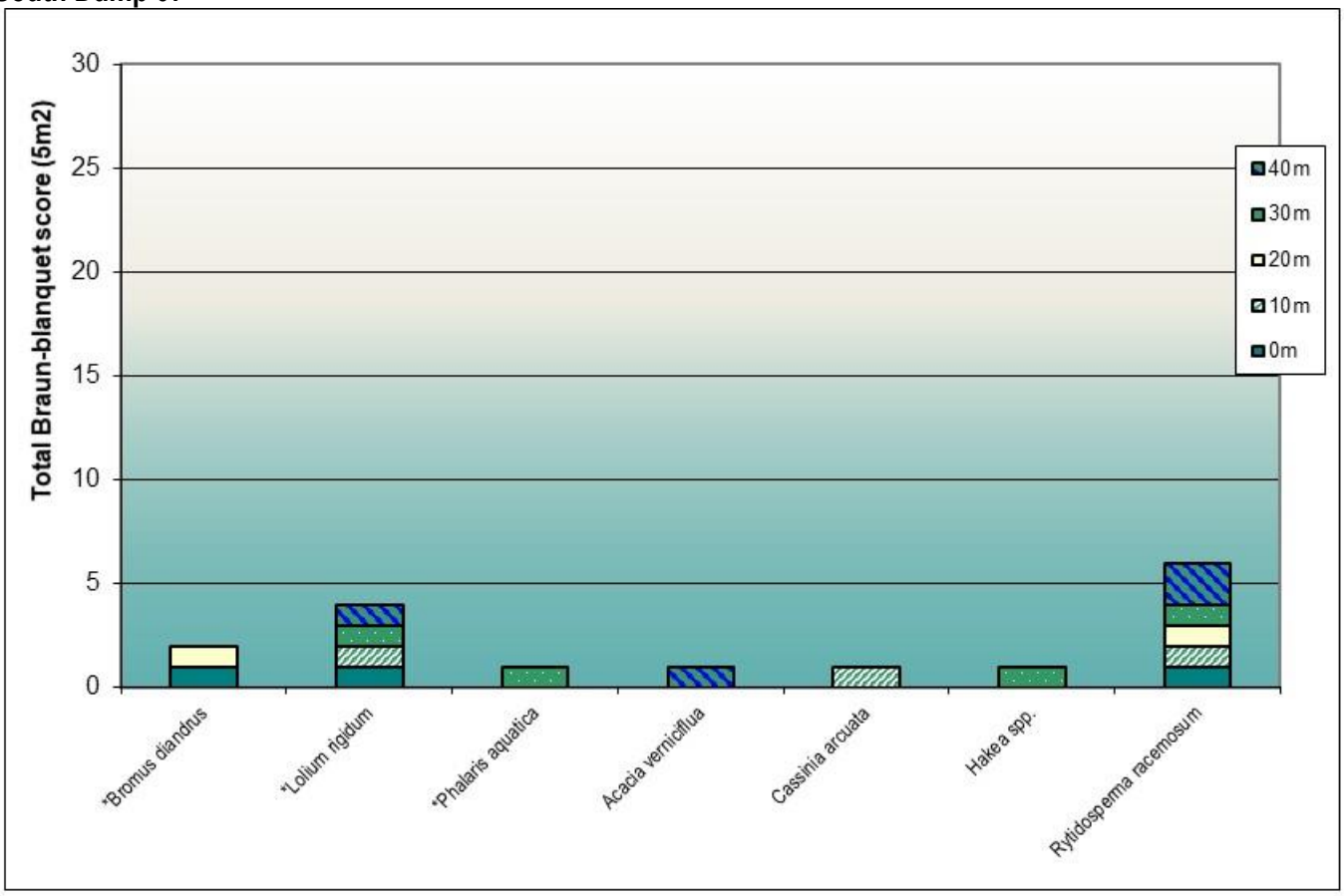

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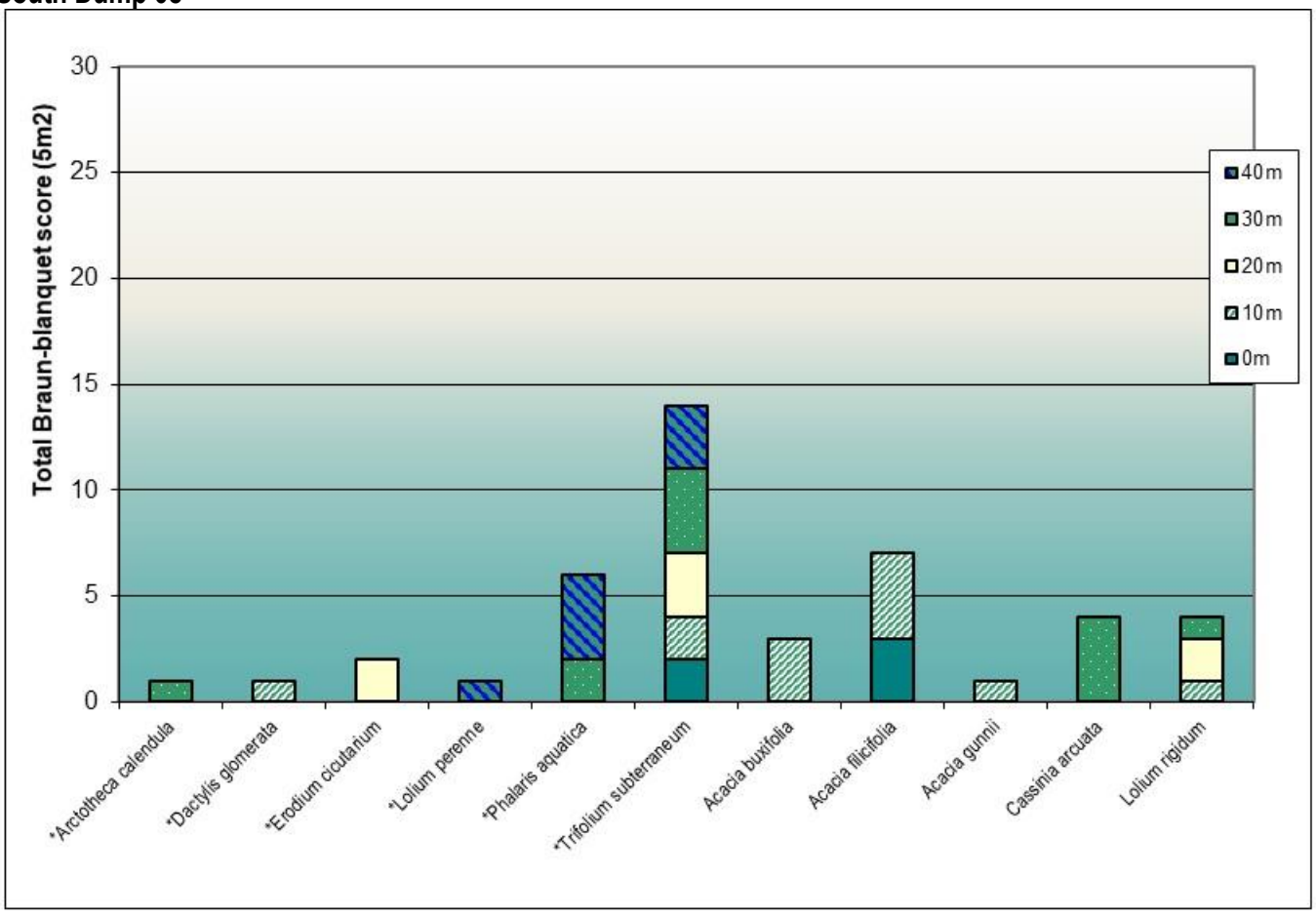

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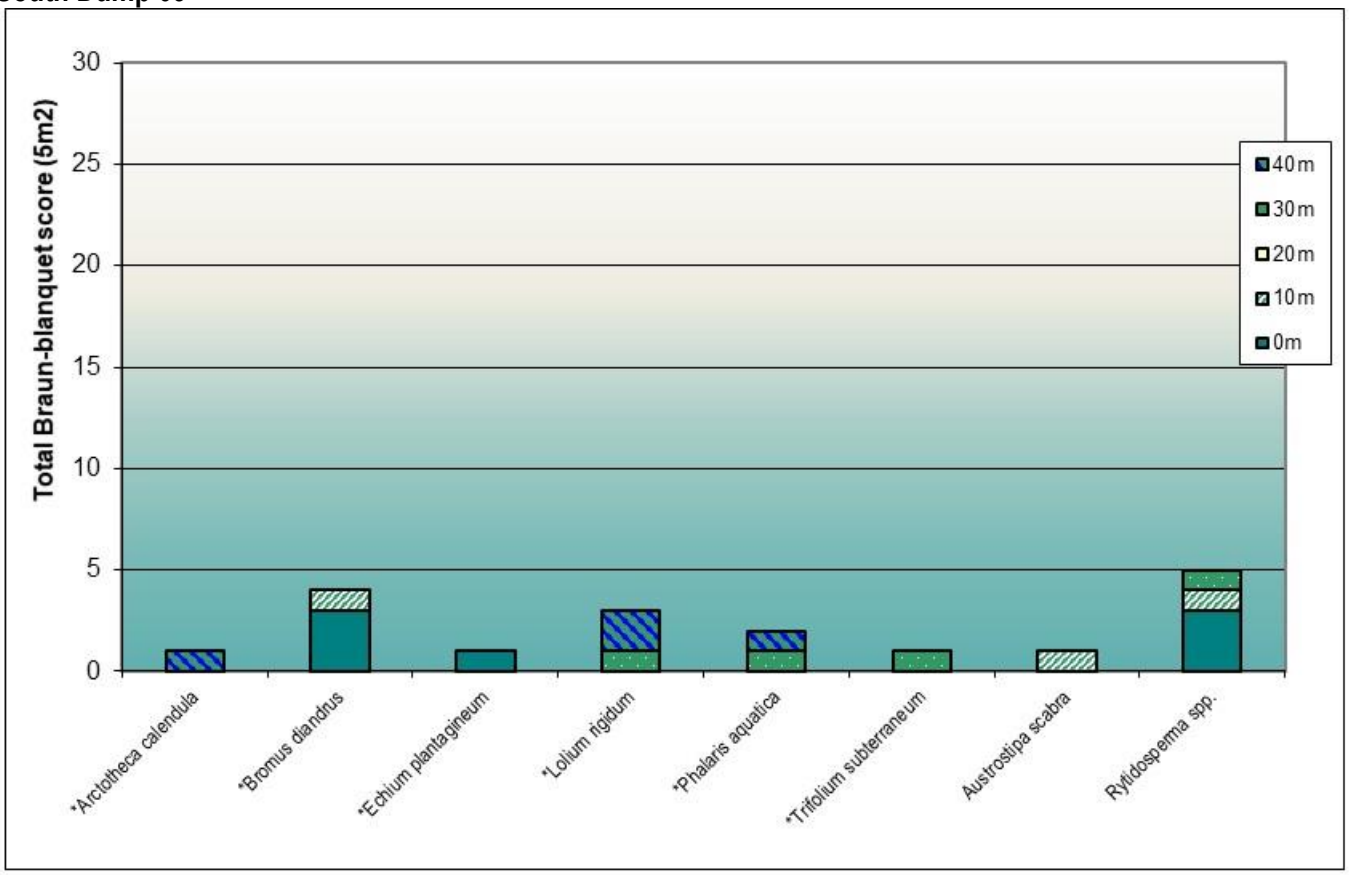
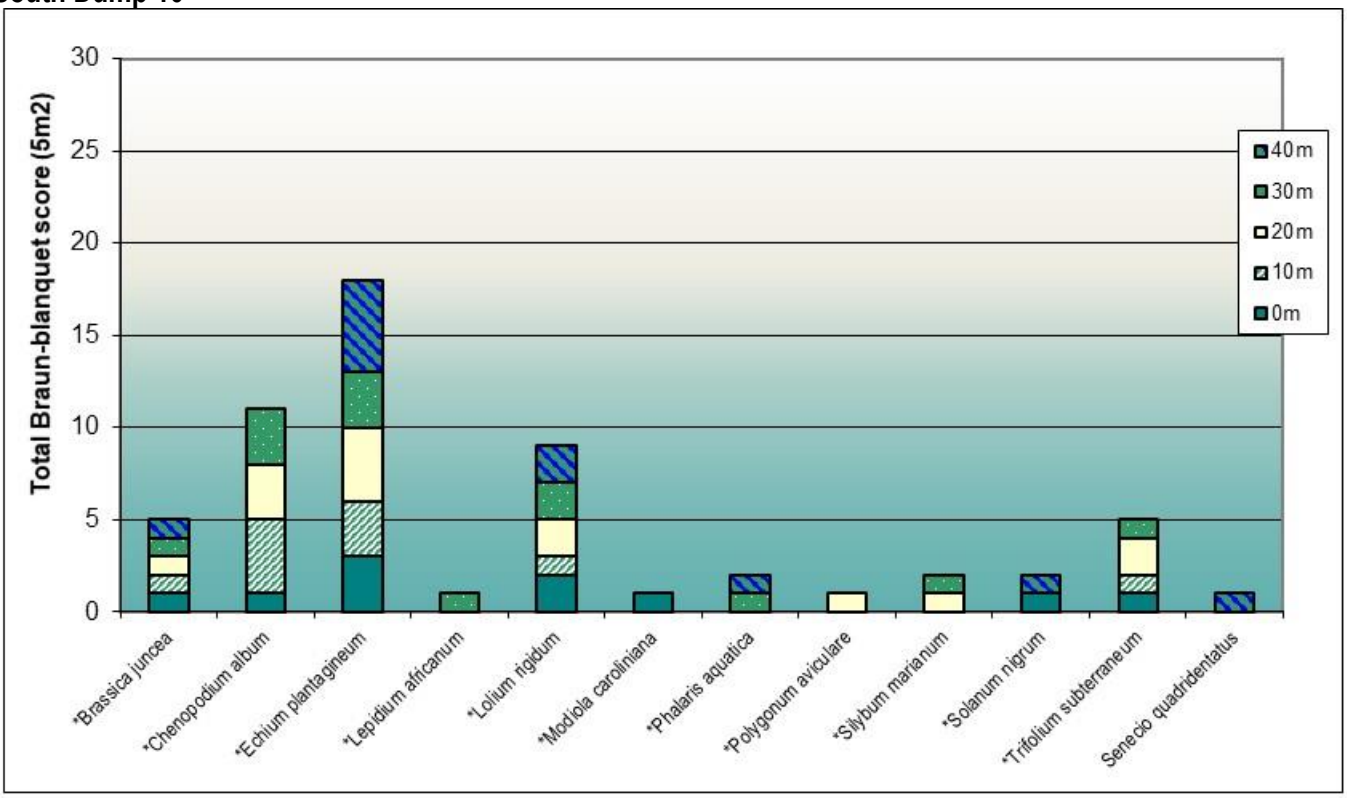
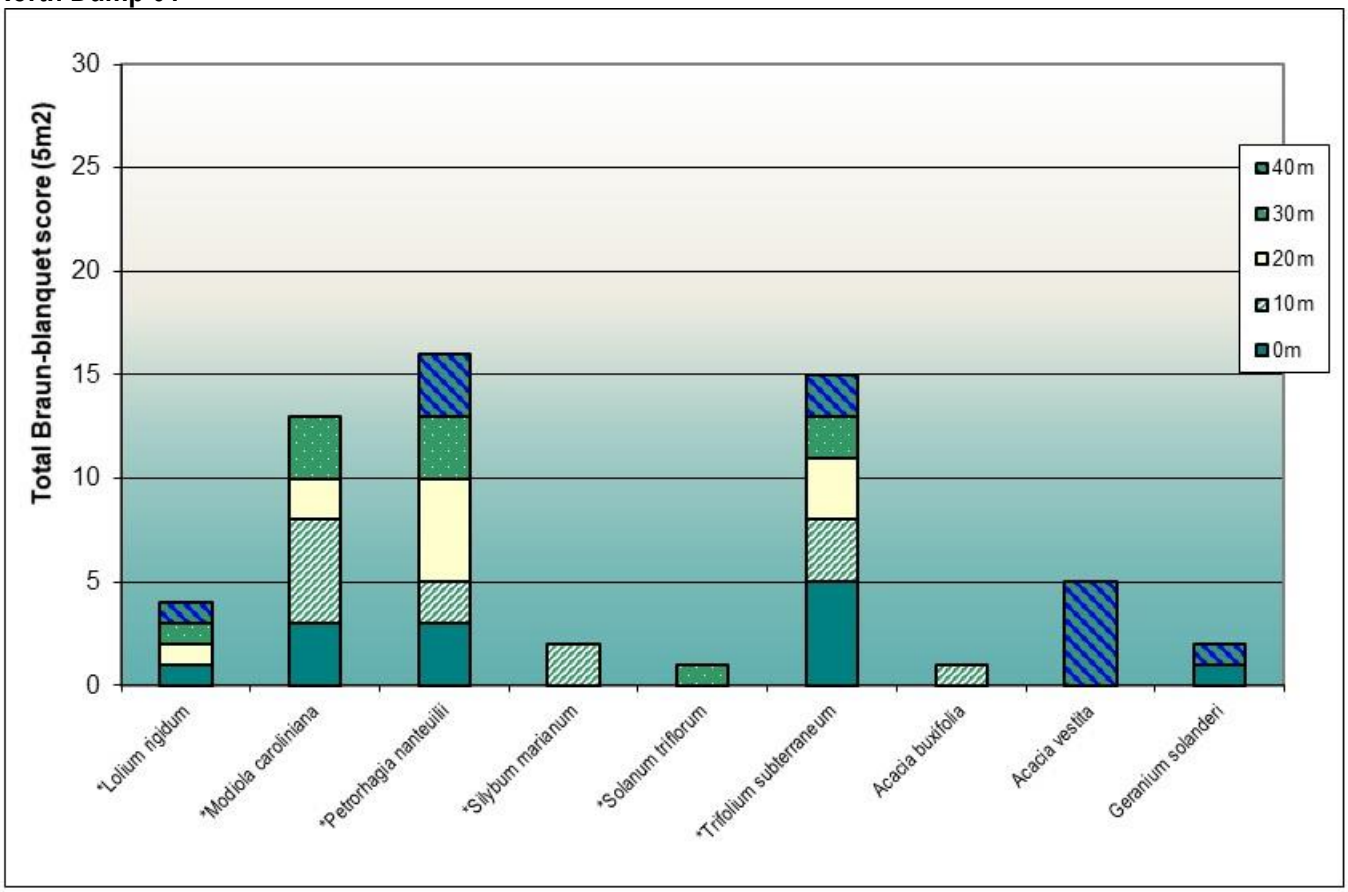


South Dump 10



North Dump 01



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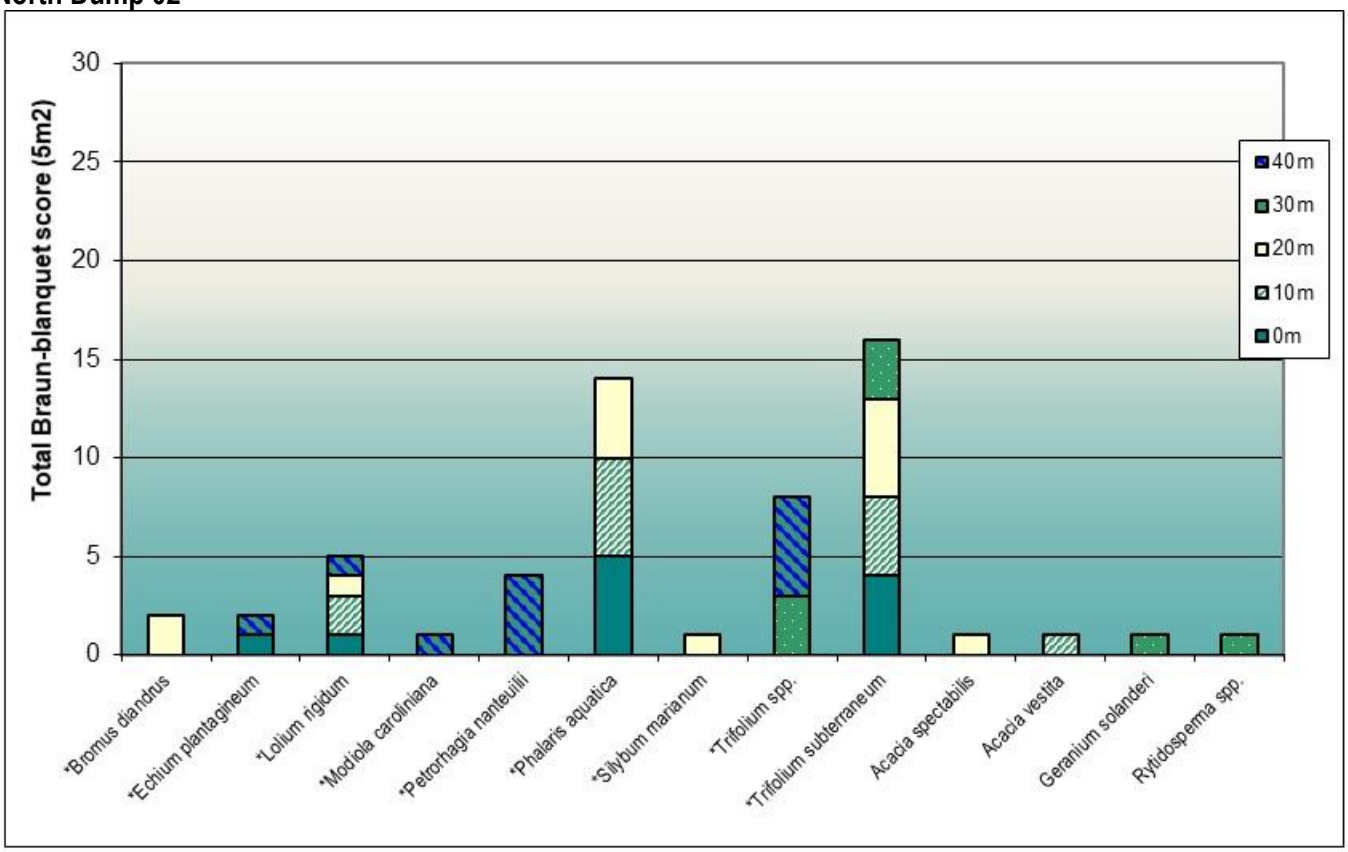

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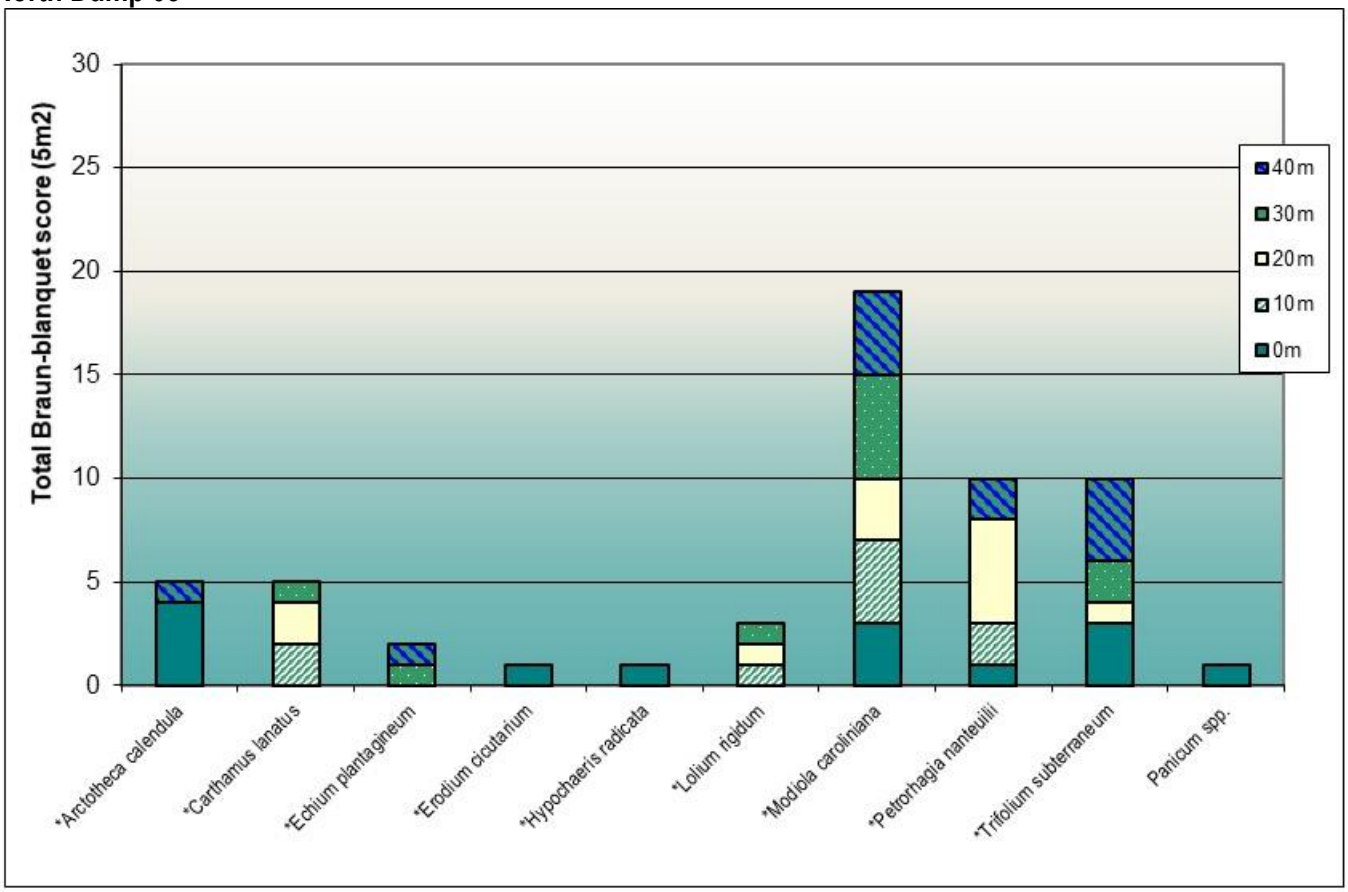
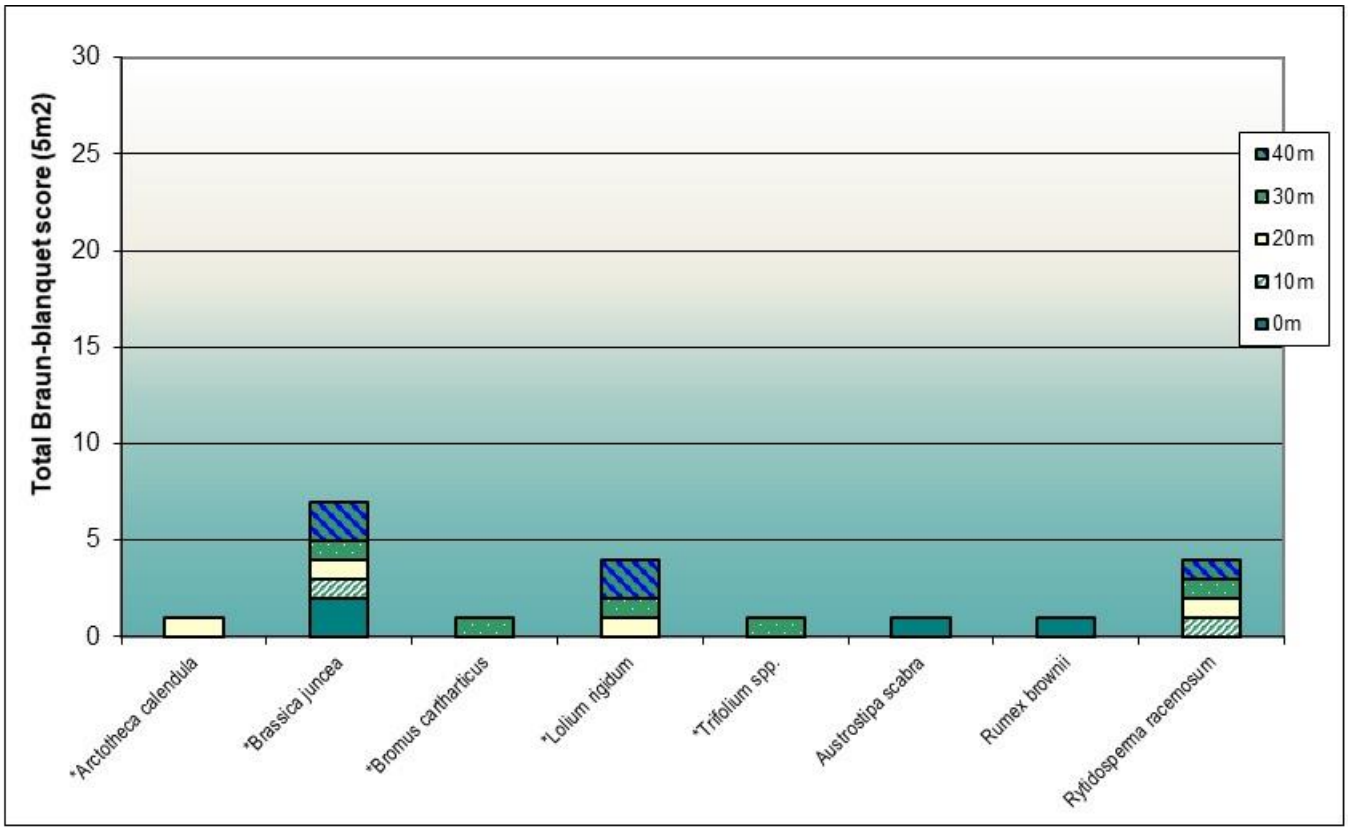
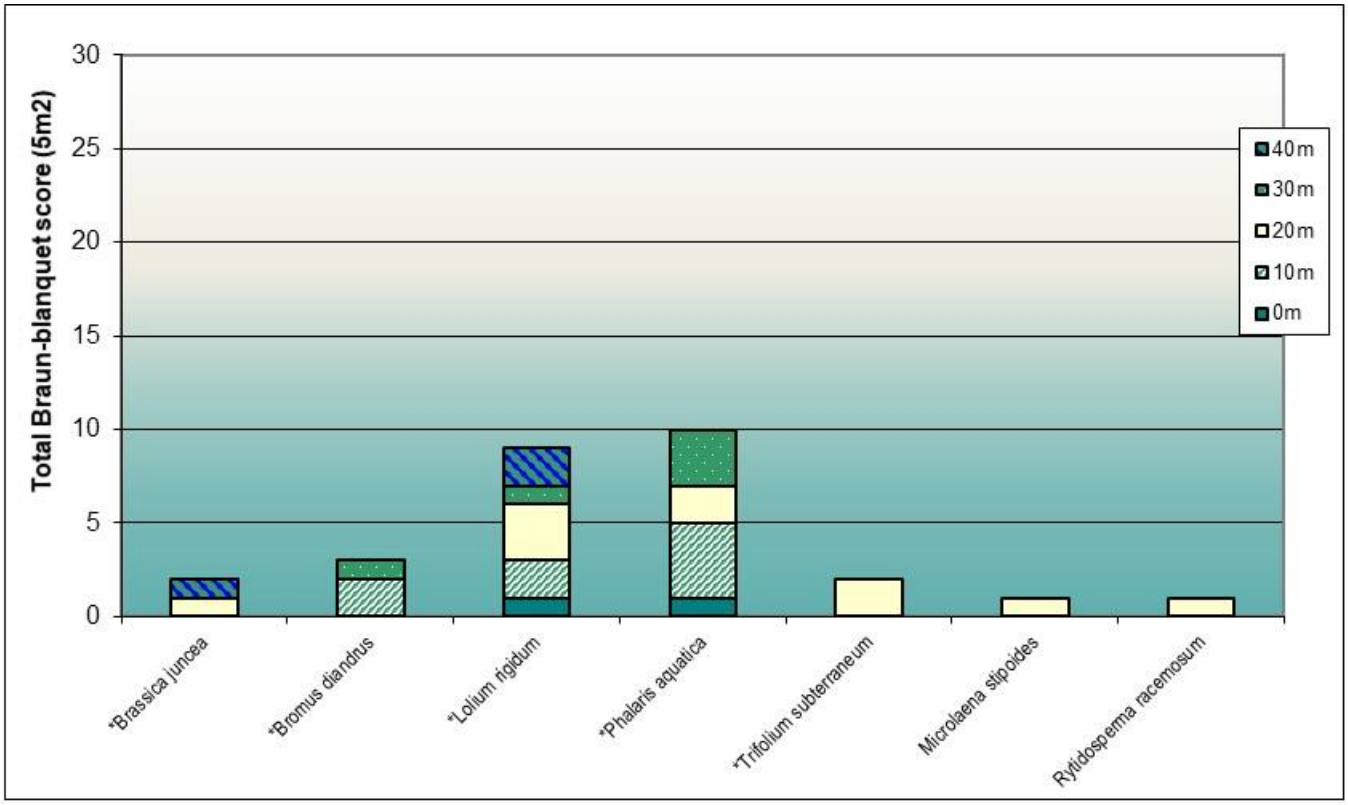


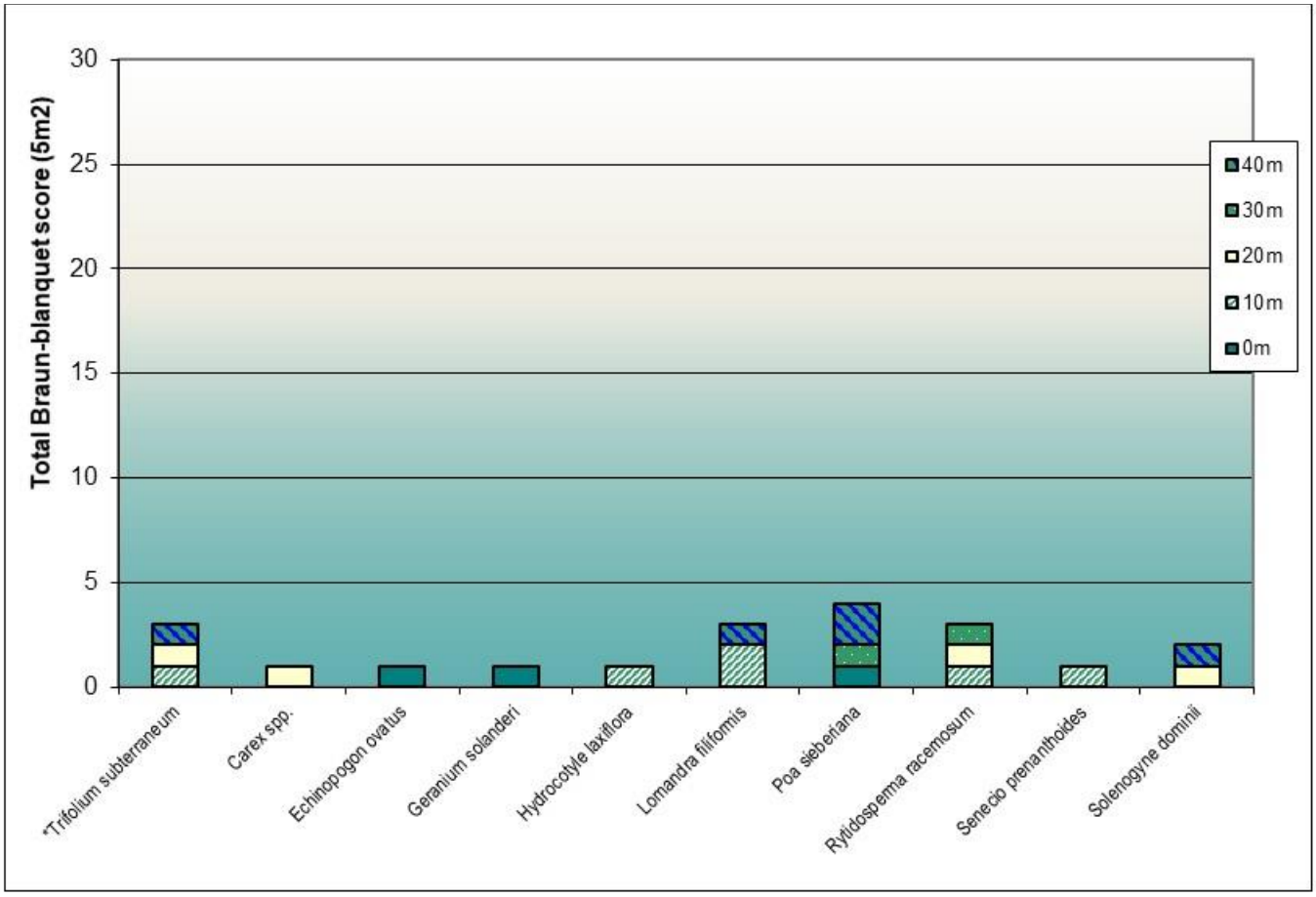
RfWood01



RfWood02



RWood05



Appendix 7: 2020 Woodland reference site data.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	RfWood01 2020	RfWood02 2020	RWood05 2020
Performance indicators are quantified by the range of values obtained from replicated reference sites assessed in 2020							Ashleigh Park	Bundarra	Cadiangullong Dam
Phase 2: Landform establishment and stability	**Landform slope, gradient**	Landform suitable for final landuse and generally compatible with surrounding topography and final landform design	Slope	Landform is generally compatible within the context of the local topography and final landform design.		Degrees (<18°)	**10**	**14**	**12**
	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.	**4**	**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	m^2	**0.09**	**0.00**	**0.00**
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**	**7.0**	**6.1**
			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)	**0.092**	**0.142**	**0.055**
			Organic Matter	Organic Matter levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	**7.9**	**10.2**	**7.6**
			Phosphorous	Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		mg/kg (50)	**36.7**	**20.7**	**15.4**
			Nitrate		Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	mg/kg (>12.5)	**19.2**	**37.7**	**2.1**
			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)	**13.7**	**29.9**	**13.2**
			ESP		Exchangeable Sodium Percentage (a measure of sodicity) is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	% (<5)	**0.5**	**0.3**	**0.6**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	RfWood01 2020	RfWood02 2020	RfWood05 2020
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		%	**61.8**	**67.3**	**67.5**
			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		%	**64**	**82**	**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**	**1**	**7**
				The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		% population	**0**	**100**	**77**
			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	**24**	**19**	**41**
			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	**13**	**7**	**31**
			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	**11**	**12**	**10**
			Ratio of native to exotic species		The ratio of live native species compared to live exotic plant species provides an indication of the relative native species richness of the site and that it is more than or comparable to the local remnant vegetation	>	**1.2**	**0.6**	**3.1**
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees		The total density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation	No./area	**0**	**1**	**75**
				The density of endemic shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation		No./area	**0**	**1**	**58**
	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	**2**	**1**	**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**	**0**	**6**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	RfWood01 2020	RfWood02 2020	RWood05 2020
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0
			Herbs		The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	15	13	24
			Grasses	The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	6	5	7
			Reeds		The number of reed, sedge or rush species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	1	0	1
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0
			Ferns		The number of ferns comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0
			Aquatic		The number of aquatic plants comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	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		%	55.8	52.9	62.2
			LFA Nutrient recycling	LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and is comparable to or trending towards that of the local remnant vegetation		%	51.7	48.5	61.5
	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	%	86.0	65.0	94.5
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	4.5	5.5	0.0
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0.0	0.0	0.0
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0.0	7.0	1.0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	1.0	4.5	1.0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	RfWood01 2020	RfWood02 2020	RWood05 2020
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	**7.5**	**3.0**	**2.0**
			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		%	**1.0**	**15.0**	**1.5**
			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		%	**92.5**	**97.0**	**98.0**
	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	**1.2**	**0.4**	**3.0**
			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	**2.2**	**2.8**	**0.4**
	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) compared to exotic species is comparable to that of the local remnant vegetation		%	**30.0**	**7.1**	**85.0**
	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**	**1**	**68**
			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**	**5**
			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**
			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		No./area	**0**	**0**	**0**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	RfWood01 2020	RfWood02 2020	RWood05 2020
				comparable to that of the local remnant vegetation					
			shrubs and juvenile trees >2m in height		The number of shrubs or juvenile trees >2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	**0**	**0**	**2**
	Ecosystem structure	The vegetation is developing in structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5 - 2 m	Projected foliage cover provided by perennial plants in the 0.5 - 2m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover	**0.0**	**0.0**	**0.0**
			Foliage cover 2 - 4m	Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover	**0.0**	**0.0**	**2.0**
			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	**3.0**	**3.0**	**6.0**
			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	**41**	**42**	**37**
	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/area	**2**	**1**	**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		% endemic	**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	**24.0**	**9.0**	**48.0**
			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	**32.0**	**68.0**	**25.0**
	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	**95.8**	**88.9**	**85.4**
			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	**8.3**	**11.1**	**10.4**

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Primary Performance Indicators	Secondary Performance Indicators	Unit of measure	RfWood01 2020	RfWood02 2020	RWood05 2020
			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	**79.2**	**77.8**	**56.3**
			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	**8.3**	**0.0**	**18.8**
			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**	**11.1**	**14.6**
			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**
			Flowers/fruit: Trees	The presence of 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	**16.7**	**88.9**	**37.5**
			Hollows		The presence of hollows provides evidence that the ecosystem is maturing, and can provide habitat resources comparable to that of the local remnant vegetation	% population	**0.0**	**44.4**	**6.3**