

2013 Rehabilitation Monitoring Report

for

Northparkes Mines

December 2013



Disclaimer

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Executive summary

The 2013 rehabilitation monitoring report is a result of work carried out by DnA Environmental on behalf of Northparkes Mine (NPM). The primary objective of this project 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.

The monitoring project was first established in 2009 and 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 this process included:

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

At Northparkes Mines, rehabilitation is not just limited to areas within the mining lease but has been undertaken across the entire NPM landholdings. Primary objectives include integrating rehabilitation areas into the surrounding landscape and maximising conservation outcomes across the farming properties which are managed to enhance the regional landscape and native habitat values. Subsequently NPM envisages a post-mining landscape that comprises a mixture of landforms and land uses, including:

- Voids that will primarily be managed to minimise safety exposures;
- Land capable of supporting agricultural cropping production;
- Land capable of supporting agricultural broad acre grazing; and
- Native vegetation conservation and management.

In 2009 DnA Environmental established a total of 21 monitoring sites which included four woodland and three native grassland reference sites. All reference sites have been subjected to some prior form of disturbance, in particular clearing, logging and grazing and some sites were likely to be older regrowth. Exotic annual grasses and a range of other agricultural weeds such as *Carthamus lanatus* (Saffron Thistle), *Echium plantagineum* (Paterson's Curse) and *Sisymbrium orientale* (Hedge Mustard) were also common. These sites however are typical of the local area and help set realistic rehabilitation targets and provide a benchmark for the transitional processes that can be expected or that are presently occurring in the rehabilitation areas.

The rehabilitation monitoring sites included a selection of six rehabilitated woodland areas planted within the cleared agricultural lands and eight rehabilitated pasture areas on mining disturbed lands such as the Tailings Storage Facilities and various waste emplacements. The sites were chosen based on their final landuse/vegetation community type and year of establishment and were considered to be representative of the rehabilitation area as a whole. In large rehabilitation areas multiple sites were established. The same selection of monitoring sites has been revisited annually and the monitoring methodology was consistent with that used in previous monitoring years.

The monitoring methodology used included a combination of Landscape Function Analyses, accredited soil analyses and various measurements of ecosystem diversity and habitat values based on and adapted from the Biometric methodology. Data obtained from within replicated reference sites were used to provide upper and lower ecological performance indicator limits. As not all key performance indicators are considered to be fundamental to completion, or in some cases achievable (eg. average

trunk diameter), key performance indicators have been further separated into "*Completion performance indicators*" and "*Desirable performance indicators*".

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 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 performance indicator are adapted annually to reflect seasonal conditions and local disturbance events. Rehabilitation monitoring has been undertaken during spring in all monitoring years and this year occurred from the 14th – 18th October.

Summary of results

Woodland rehabilitation sites

In most woodland rehabilitation sites there had been an increasing trend in ecological function between 2009 - 2011 due to improved seasonal conditions which stimulated perennial ground cover and provided an abundance of live annual vegetation. Despite periodic flood events which stimulated a lot of annual plant growth, prolonged dry conditions over the past twelve months and preceding the monitoring event have resulted in a reduction of active plant growth which has been compounded by increased levels of macropod activity and this was typically evident across the range of monitoring sites this year, especially the more sheltered older woodland rehabilitation sites including Estcourt, Beechmore, Altona and Kundibah.

Despite the dry conditions and subtle setbacks, the older woodland rehabilitation sites were establishing well and were ecologically very similar to the local woodlands with which they were being compared to, with Beechmore the only site which did not meet stability and infiltration capacity targets. The two younger Limestone Forest rehabilitation areas continued to maintain high patch area and stability due largely to the high levels of cryptogams and annual plants which provided very high stability, however due to the very hard setting soils and low soil surface roughness infiltration (and nutrient recycling in LFO-02) capacities remained low.

This year all woodland rehabilitation sites contained a population of maturing trees and shrubs (>5cm dbh) and in the young Limestone Forest sites these populations were small but provide an indication of good growth and development of the planted tubestock. In the older rehabilitation sites Beechmore, Altona, Kundibah and Estcourt, the density of trees and shrubs (>5cm dbh) continued to exceed the range values provided by the reference sites and these were increasing in structural diversity and complexity. In most sites the minimum trunk diameters were 5 – 6cm however the maximum dbh was an *E. melliodora* recorded in Estcourt which had a dbh of 36cm. In all sites, including the two new rehabilitation sites in the LFO area there was an appropriate diversity of tree species. While all species were endemic some may not strictly be associated with the particular habitat type being rehabilitated. A large percentage of trees and mature shrubs in the older rehabilitation sites continued to provide reproductive structures such as buds, flowers and/or fruits.

This year many sites had a declining shrub and juvenile tree population with a small number having grown into "trees", however in most cases many smaller individuals had died. Exceptions included significant recruitment which was observed in LFO-02 and RWood04 both which contained a relatively recent regeneration event. While all sites contained an appropriate diversity of shrubs and juvenile trees, two rehabilitation sites LFO-01 and Estcourt 1997 did not contain an appropriate density, which may have implications in meeting longer-term ecological targets and may require replacement planting and/or grazing exclusion to enhance natural regeneration.

Total ground cover, which is a combination of leaf litter, annual plants, cryptogams, rocks, logs and live perennial plants (<0.5m in height) demonstrated a marginal decrease across all monitoring sites this year, with the exception of one of the woodland reference sites. Of the rehabilitation sites, Beechmore and Altona failed to meet total ground cover targets, while there was low perennial plant cover in LFO-01 and Beechmore. Interestingly the two youngest rehabilitation sites LFO-01 and LFO-02 had the highest level of total ground cover perhaps due to a low level of disturbance by animals and reduced competition levels due to the absence of the competitive mature overstorey.

Dead leaf litter continued to be a dominant ground cover component in the rehabilitation sites however annual plants continued to provide significant levels of ground cover within the two young Limestone Forest rehabilitation sites. In the older more established sites annual plants continued to be much less significant or were not present at all. While rocks were not an important habitat feature in the local woodlands, most sites contained some levels of log cover which provide additional ground cover protection and critical habitat diversity and except in Altona where a large acacia had died and fallen over, no log cover was yet recorded in the rehabilitation areas. All sites contained at least some vertical structure 0.5 – 2.0m in height and all but the two young Limestone Forest rehabilitation areas contained foliage cover within each of the 2.0m vertical height classes and all had some canopy cover exceeding 6.0m in height, indicating good growth and establishment and the development of mature tree canopies. Rehabilitation sites Estcourt and Beechmore had a mature canopy cover which now provided similar levels of projected foliage cover as the local remnant woodlands.

This year there were no consistent trends in the changes in plant diversity across the range of monitoring sites however in most cases there was a relatively large increase in exotic species richness. While conditions were particularly dry at the time of monitoring, above average rainfall in June had resulted in a flush of plant growth with exotic species tending to persist in lower depressions and in disturbed shady areas beneath tree canopies (i.e. old stockcamps). Other factors that are likely to have affected species diversity include selective browsing, degree of grazing pressure and extent of disturbance, combined with some degree of sampling variability. Nonetheless the results indicate there is typically a lack of native plant diversity within the younger Limestone Forest rehabilitation sites, and these sites were weedier than desired. The older rehabilitation areas Estcourt, Beechmore and Kundibah generally contained an adequate richness of native and exotics species, but there was often a low diversity of forbs and grasses.

The number of species recorded across the range of woodland rehabilitation sites has ranged between 97 – 151 species since 2009 with 24 – 45% of these being exotic species. In 2013, two species were common to all rehabilitation sites and these were a native perennial forb *Dichondra repens* (Kidney Weed) and the exotic annual grass *Lolium rigidum* (Wimmera Ryegrass) and these too were present in almost all of the woodland reference sites, indicating they are very common in the local area. Two species of endemic acacia including *Acacia deanei* (Deane's Wattle) and *A. hakeoides* (Hakea Wattle) and *Eucalyptus populnea* (Bimble Box) which were planted as part of the rehabilitation program were recorded in five of the six sites, while numerous other native tree and shrub species were also common.

The results of the soil analyses indicate that some sites have strongly acidic soil, may be low in organic matter and/or have a low Cation Exchange capacity but most other chemical characteristics were within or similar to those recorded in the local woodlands or were within agricultural industry standards. In 2013 however anomalies in the soil analyses indicated there were particularly high concentrations of a variety of elements and heavy metals in sites situated in the Limestone Forest (LFO-01, LFO-02 and RWood04) as well as Altona, an old gravel quarry. The high concentration of these combinations of these elements may have the potential to affect plant establishment and ecosystem development.

Grassland rehabilitation sites

The LFA data have shown strong associations with the rainfall data since 2009 and despite flooding rain during June 2013, minimal rainfall has been received since that time which has had an adverse impact of perennial plant growth and promoted very hard soil crusts. While there may have been an increase in grazing pressure during this period, the impacts of animal - macropods was less evident in the grassland sites compared to the woodland sites probably due to the absence of shade and protective shelter. In addition, there was no evidence of grazing by travelling stock on reference sites situated on the Travelling Stock Routes (TSRs) over the past twelve months.

Native grasslands are usually devoid of trees and shrubs but small populations of shrubs such as *Maireana brevifolia* (Yanga Bush) continued to be recorded in all grassland rehabilitation sites as a result of voluntary establishment from the soil seed bank however there tended to be a decline in numbers due to the prolonged dry conditions.

Total ground cover, continued to be high in the grassland reference sites however there was a consistent decrease recorded across these sites year due to the dry weather. In the rehabilitated grassland sites however, there tended to be an increase in total ground cover, perhaps due to lower levels of grazing pressures and all sites however continued to have a suitable level of protective ground cover. The most dominant form of ground cover continues to be dead leaf litter in most cases, however this year annual plants were more prolific and had become quite dominant in numerous rehabilitation sites, as well as in one of the reference sites. Perennial grasses and forbs continue to be an important ground cover component in the reference sites but rehabilitation sites that did not have suitable perennial plant cover included TSF1-01, E22-02 and E27-01. Other ground covers and habitat features such as cryptogam, rocks or logs were typically absent or provided very low cover values. Most sites had small amounts of projected foliage cover 0.5 – 2.0m in height due to patches of tall annual and perennial grasses.

This year there were no consistent trends in the changes in plant diversity across the range of grassland monitoring sites however in most cases there was a relatively large increase in total and exotic species richness in most but not all grassland sites. While conditions were particularly dry at the time of monitoring, above average rainfall in June had resulted in a flush of plant growth with exotic species tending to persist in lower depressions and in more open or disturbed areas where plant competition was lower, especially in sites such as RGrass01 which also contained a high number of native annual species. While grazing did not appear to be primary factor affecting species diversity and composition in these grassland areas this year, the degree of previous disturbances and current competition levels may be key influences. In areas with a high degree of plant cover, there is a higher chance that small plants may be undetected also thus increasing the degree of sampling error. Nonetheless the results indicate there is typically a lack of native plant diversity within the grassland rehabilitation sites with some sites containing a higher diversity of weeds than desired.

The number of species recorded across the range of grassland rehabilitation sites has ranged between 62 – 91 species since 2009 with 27 – 53% of these being exotic species. In 2013, three species were common to all rehabilitation sites and in at least two of the reference sites and these included the exotic annuals *Avena fatua* (Wild Oats) and *Echium plantagineum* Paterson's Curse) and the native perennial species *Walwhalleya proluta* (Rigid Panic).

Rilling continued to be recorded in sites TSF2-01 and E22-02 and these continued to exceed the minimum value of concern and may require amelioration. Investigation for further rilling across the larger TSF2 and E22 areas should also be undertaken with any actively eroding areas treated accordingly. There was also active tunnel erosion in the tree lots near site E22-01 which require amelioration.

Numerous rehabilitation sites continued to have moderately alkaline soils however in site TSF2-01 the soils were slightly acidic. Despite a significant reduction in Electrical Conductivity in TSF2-01, EC levels

continued to exceed acceptable levels and continued to be elevated in TSF1-02. The soils in the rehabilitation sites were often low in organic matter, phosphorous and nitrates but the data indicates local soils obtained from the grassland reference sites were often low in fertility, therefore amelioration is not considered necessary. The very high ESP in soils in some of the TSF sites however indicates the soils are highly sodic and may require treatment with gypsum. There continued to be unusually high levels of Sulfur in sites situated on the TSFs and these continued to be particularly high in TSF2-01. There were elevated levels of Copper in most rehabilitation sites but these were significantly high in E27. While the soil analyses have indicated a reduction in some adverse soil chemistry especially in the TSF sites, tailings material continues to seep onto the external walls and continues to have an adverse influence on plant growth and establishment in these seepage areas.

Conclusion

The extreme climate and seasonal conditions experienced over the past five years of monitoring have had a profound effect on not only the diversity of the monitoring sites, but also on the composition of the vegetation and resultant ecological function of the sites. Most woodland rehabilitation sites were stable and establishing well with many attributes similar to the relevant reference sites and in most sites, positive recovery trends were apparent and only require additional development time. The flush of annual plants during 2010 resulted in a significant improvement in total ground covers and there tended to be an increasing trend in total ground cover since then. Some exceptions however were due to disturbance associated with macropod activity or mobilisation of resources during the high summer rainfall activity, but the effects of these were comparatively minor. In 2012 however, the visible effects of seepage through the TSF walls was first encountered, with adverse soil conditions being expressed as large bare patches and white sulphate crystals on the soil surface, with these adverse conditions also being reflected in the soil analyses and other monitoring data, especially in site TSF2-01.

This year the prolonged dry conditions over the past twelve months, combined with localised flooding during winter has resulted in variable results across the range of monitoring sites. There appeared to be a high degree of association with the extent of grazing pressure and animal disturbance and declining total and perennial plant cover, with animal impacts being more pronounced within the sheltered woodland communities. This year there was also a reduction in the effects of the tailings seepage which may have been due to the flushing of salts which had accumulated on the soil surface during the winter floods. Overall however there tended to be a declining trend in ecological function, and this was largely due to the decline in perennial plant and cryptogam covers combined with increased soil surface hardness in numerous sites.

Many rehabilitated grassland sites lacked the diversity of native ground cover species and while these may improve naturally over time, enhanced diversity and other ecological targets could have been achieved via active rehabilitation methods such as seeding and/or planting when the sites were first established. While some sites contained an abundance of weedy species, these species are part of the successional process and will make a positive contribution in providing protective ground cover and assisting with the development of microbial and nutrient recycling processes and most species are likely to decline in abundance over time. Some species however are now naturalised components of the native grasslands and local agricultural lands and therefore some species are likely to persist in the longer-term and will be reflected in the reference sites.

There continued to be some undesirable spoil characteristics within the grassland rehabilitation sites situated on both of the TSFs and in E22-01 and investigation for further rilling across the larger TSF2 and E22 areas should also be undertaken with any actively eroding areas treated accordingly. The use of suitable topsoil material in rehabilitation areas should be a priority management action which should involve adhering to stockpiling protocols and testing of soil stockpiles and spoil material prior to use in rehabilitation in any future site rehabilitation. Improved design and construction of the tailings dam walls is also warranted.

The older woodland rehabilitation sites Estcourt, Beechmore, Altona, Kundibah and E26-01 a grassland rehabilitation site within the E26 Subsidence Zone contain many ecological attributes which are comparable to their reference sites and have typically demonstrated they are stable and functional communities, despite some minor shortfalls in some years and often these have been in response to local seasonal conditions and disturbance events.

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1 2013 Rehabilitation Monitoring Report

1.1 Introduction

The 2013 rehabilitation monitoring report is a result of work carried out by DnA Environmental on behalf of Northparkes Mines (NPM). The primary objective of this project was to establish an annual rehabilitation monitoring program and compare the progress of rehabilitated landforms against a set of completion criteria. The monitoring program aims to comply and be consistent with a range of conditions specified within approval documents, management systems and associated Management Plans and government regulations and best practice guidelines (NSW I&I 2010, NSW T&I 2012).

This report describes the annual rehabilitation monitoring program first established in 2009 at NPM and provides quantified data from representative reference sites as a benchmark for rehabilitation outcomes to assist with the compliance process. The full process associated with establishing the completion criteria relevant to rehabilitated native ecosystems can be found in "Rehabilitation monitoring methodology and determination of completion criteria" (DnA Environmental 2010a). Rehabilitation monitoring has been undertaken during spring in all monitoring years and this year was completed 14th – 18th October. The monitoring methodology has been consistent in all monitoring years and included a combination of Landscape Function Analyses (LFA), accredited soil analyses and an assessment of ecosystem characteristics using an adaptation of methodologies derived by CSIRO Grassy woodland Benchmarking project.

The same monitoring sites were revisited and these included four woodland and three native grassland reference sites and six woodland and eight grassland rehabilitation sites. Data obtained from within replicated reference sites were used to provide upper and lower performance indicator limits. As not all key performance indicators are considered to be fundamental to completion, or in some cases achievable, key performance indicators have been further separated into "*Completion performance indicators*" and "*Desirable performance indicators*". 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 completion performance indicators have been met, or trending in the right direction, the sites should therefore theoretically be eligible for closure sign off. The range values of each performance indicator are adapted annually to reflect seasonal conditions and disturbance events.

Results of the rehabilitation monitoring are first presented in a comparative summary against their corresponding reference sites since monitoring began in 2009. The remainder of the report includes detailed descriptions of the individual rehabilitation monitoring sites, indicating the changes that have occurred and how they compare to the KPI's and ecological completion targets.

1.2 Current NPM environmental management and monitoring requirements

Northparkes Mine (NPM) currently operates under numerous Management Plans (MPs) and all activities are conducted in accordance with the Environment, Safety and Health Policy and are aligned with Rio Tinto's Environment Standards (NPM 2008). These plans address a range of issues associated with mining and mine closure but include numerous protocols for the best practice

management of rehabilitation of mine disturbed area and areas of remnant vegetation and surrounding agricultural lands.

Relevant plans include:

- Landscape Management Plan Site wide (A480466);
- Land use Management Plan (A340845);
- Flora and Fauna Management Plan (A216136);
- Topsoil Management Plan (A213262);
- Three year rehabilitation Plan ((A173026);
- Rio Tinto Environment Standard Land Use Stewardship;
- Erosion and Sediment Control Management Plan (A480459);
- Rehabilitation Monitoring SOP (A498904);
- Site Disturbance Standard Operating Procedure (A164522);
- Government Reporting of Environmental Incidents SOP (A189982); and
- Injury, Illness and Incident Reporting and Recording Standard (A139552).

The Landscape Management Plan was prepared in accordance with Schedule 3, Conditions 7 and 14 of Department of Planning Project Approval 06-0026 and was prepared in consultation with the Department of Water and Energy (DWE, formerly Department of Natural Resources), Department of Environment and Climate Change (DECC, formerly Department of Environment and Conservation) and Parkes Shire Council (PSC).

In addition, NPM have a range of Standard Operating Procedures (SOPs) which clearly define the appropriate manner of conduct and management required in a range of areas. Some of these SOPs include (NPM 2008):

- Hot Work Permit SOP (A239612)
- Risk Assessment Standard (A238190)
- Geochemical Assessment, Acid Rock Drainage and Mineral Waste (A307295)
- Tailings Storage Facility Operations Manual
- Australian Standard AS/NZ 4360:1998 Risk Management
- Australian Standard AS/NZS 5667 – Water Quality - Sampling
- Site Disturbance Form

1.3 *Rehabilitation objectives at NPM*

The following is an extract from the LMP (NPM 2010) which states that “Rehabilitation programmes are intrinsically linked to the mine closure planning process in which post-mining landforms and land uses are identified. Accordingly, rehabilitation completion criteria need to assess whether planned post-mining landforms and land uses have been achieved. Presently, NPM envisages a post-mining landscape that comprises a mixture of landforms and land uses, including:

- Voids that will primarily be managed to minimise Safety exposures;
- Land capable of supporting agricultural cropping production;
- Land capable of supporting agricultural broad acre grazing; and
- Native vegetation conservation and management.

The post-mining landuse is a fundamental aspect to consider in developing completion criteria as will dictate the vegetation community that will need to be established and the type of management regime that it will be subjected to. At Northparkes Mines, the Landscape Management Plan (NPM 2008) specifies that rehabilitation incorporates the entire landholding and not just the area covered by the

mining leases. Progressive rehabilitation conducted onsite is integrated with the surrounding NPM owned land and is managed with a view to enhancing the regional landscape and native habitat values.

1.4 NPM Management areas

1.4.1 Restricted Areas

Damage by vehicles can result in the compaction of soil, the spread of weeds and disturbance to vegetation. To restrict access and reduce disturbance, rehabilitated areas (within the mine lease) will be signposted and fenced, as deemed appropriate by the Environment Section.

1.4.2 Sustainable Agriculture

NPM own and manage approximately 4,370ha of surrounding agricultural land that acts as a buffer zone for the operations. Since acquiring the various landholdings, considerable emphasis has been placed upon sustainable agricultural practices to minimise off-site impacts.

Cropping is undertaken within large paddocks, divided by tree lines acting as connected wildlife corridors. All stock has been removed from the area to reduce erosion, compaction and improve regeneration of tree lines. The farming practices implemented such as soil conservation works, conservation tillage practices, stubble retention and an absence of livestock grazing, has contributed to the absence of visible land degradation through erosion and has improved soil quality. Additionally, large areas of remnant forest areas within the agricultural land, particularly along Bogan River, Goonumbla Creek and the ridgelines on the "Rosedale" and "Rocklands" properties, are progressively rehabilitated.

1.4.3 Conservation

1.4.3.1 Native Habitat Enhancement

The cumulative effects of agriculture, forestry and mining have resulted in significant clearing of native vegetation and the removal of habitat for native fauna. NPM has, wherever possible, been able to maintain large sections of remnant vegetation within its landholding. An important component of the rehabilitation strategy is the development and implementation of rehabilitation plans that link the significant areas of remnant vegetation with wildlife corridors and enhance ecological value. The linking of remnant vegetation aims to produce sustainable native ecosystems within the agricultural landscape thereby assisting to conserve biodiversity and maintain evolutionary potential.

1.4.3.2 Revegetation

Revegetation activities are designed for erosion control, aesthetic improvement and ecosystem regeneration and are undertaken on constructed landforms such as waste rock dumps, tailings storage facilities, topsoil stockpiles and other disturbed areas. Revegetation is also undertaken to create wildlife corridors and for screening and landscaping purposes.

Revegetation is undertaken as soon as practical after completion of surface preparation. Topsoil conditioning involving the addition of gypsum or fertiliser may be used where required. Depending on the proposed land use, this will involve direct seeding or planting of selected shrub, grass and tree

species. Sowing and planting is dependent on seasonal factors and will be scheduled, where possible, in autumn or early winter.

Species utilised are dependent on the type of area to be revegetated with:

- Introduced grasses and legumes selected for erosion control on embankments and topsoil stockpiles (i.e. temporary landforms or rehabilitation); and
- Local provenance native tree and shrub species for infill planting, wildlife corridors and screening of disturbed areas (i.e. long term rehabilitation).

1.5 Management of potential threats on NPM property

As part of the normal operating procedures at NPM, there are a range of threats to areas of non mining lands or areas of conservation significance and these have been identified in the Landscape Management Plan (NPM 2008). Some of these are threats and management protocols undertaken by NPM are listed below.

1.5.1 Site Disturbance

Prior to the disturbance of any areas, a site disturbance form must be completed and approved by the Environment Section in accordance with the Site Disturbance SOP (A164522). The form identifies any potential environmental issues associated with the disturbance and control measures to be undertaken. The boundaries of the disturbance areas will be clearly identified to minimise the extent of clearing. No clearing will occur outside these boundaries without additional consultation with the Environment Section.

1.5.2 Pest and Weed Control

Control of feral animals is undertaken on an as needs basis and is achieved by trapping or baiting. Feral animal control is conducted in consultation with the Molong Rural Lands Protection Board (now the Livestock Health and Pest Authority). Weed control is undertaken to limit the spread and colonisation of noxious and environmental weeds. Weed control methods include:

- Ongoing surveillance and reporting
- Management of topsoil stockpiles to limit weed proliferation and spread
- Strategic crop rotation, fallow, slashing and controlled burning (where necessary) on agricultural lands
- Limiting vehicle access to rehabilitated areas
- Chemical spraying with approved herbicides
- Physical removal by manual chipping

Any observations of noxious weeds or feral animals are reported internally and actioned as outlined above.

1.5.3 Bushfire Management

Bushfire prevention and control measures implemented include:

- Fire fighting training and awareness provided to relevant personnel, including an onsite Emergency Response Team;
- Provision and maintenance of onsite fire fighting equipment;

- Permits for hot work are issued before commencement of works in accordance with the Hot Work Permit SOP (A239612);
- Appropriate management of hazardous materials;
- Maintenance of designated firebreaks by a combination of grading and spraying;
- Consultation with the NSW Fire Brigade and Rural Fire Service, as required.

In the event that bushfire management requires the clearance of vegetation the Site Disturbance SOP (A164522) will be implemented.

1.6 Monitoring Performance and Completion Criteria

Rehabilitation completion criteria set benchmarks for a suite of parameters that need to be met to demonstrate that rehabilitation has been successful, or is considered sustainable. NPM is committed to meeting legislative requirements and industry policies for the decommissioning of sites and closure practices" (NPM 2008). NPM have also committed to undertaking an annual rehabilitation monitoring program. It states that:

- Rehabilitation performance will be monitored to ensure vegetation is establishing and to determine the need for any maintenance and/or contingency measures;
- Rehabilitation will be monitored in existing remnant vegetation, agricultural land and temporary rehabilitated areas;
- Monitoring will be undertaken after the first year and at intervals thereafter depending on the type of rehabilitation in accordance with the Rehabilitation Monitoring SOP (A498904); and
- Results of monitoring will be reviewed to identify where improvements are required in design works, annual rehabilitation plans or where maintenance is required to existing rehabilitation.

2 Rehabilitation monitoring methodology

The primary objective of this project 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 Northparkes Mines Landscape Management Plan (NPM 2008), community expectations as well as relevant NSW legislation, policies and best practice guidelines (eg. NSW I&I 2010, NSW T&I 2012). 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.

To ensure many of the key issues identified by Nichols (2005) are addressed in the monitoring methodology and establishment of completion criteria at Northparkes, the methodologies used include a combination Landscape Function Analyses (LFA), soil analyses and an assessment of ecosystem characteristics using an adaptation of methodologies derived by CSIRO Grassly woodland Benchmarking project (Gibbons 2002). A detailed description of the rehabilitation monitoring

methodology can be found in the DnA Environmental (2010a), however a summarised description is provided below.

2.1 **Landscape Function Analyses**

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

The LFA methodology collects data at two “nested” spatial scales.

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

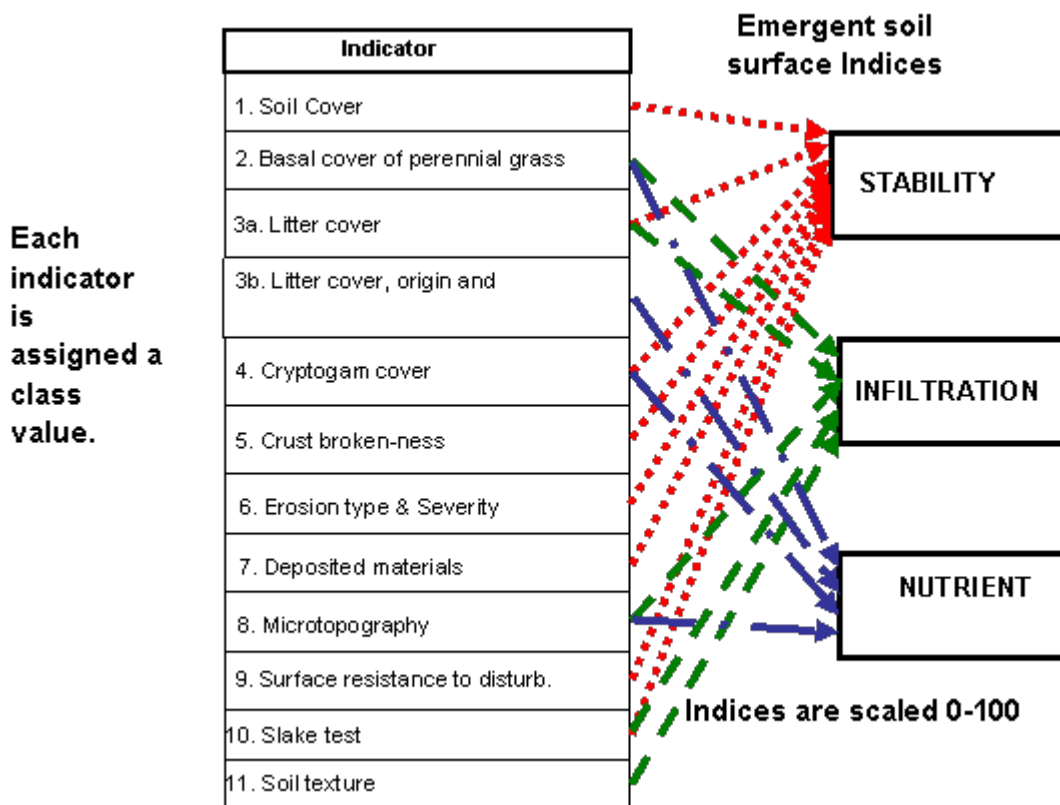
At each scale, parameters are calculated that reflect several aspects of landscape function. In the first stage, we identify and record the patches and interpatches along a line oriented directly down slope. Sometimes there are several different types of each patch/interpatch which provides a measure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

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

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

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

1. **Stability** (that is, resistance to accelerated erosion),
2. **Infiltration** (the rate soil absorbs water) and
3. **Nutrient Cycling** (the way plant litter and roots decompose and become available for use by other plants).



2.2 Soil analyses

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

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

2.3 Monitoring structural diversity, floristic and other biodiversity attributes

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

Some simple and rapid procedures for making these assessments were developed by CSIRO scientists (Gibbons 2002, Gibbons *et al* 2008), and were developed for assessment habitat quality across a range of vegetation types in the southern NSW Murray-Darling Basin. Some adaptations have been made to reduce monitoring effort where possible, and to incorporate aspects of newly formed revegetation sites

or sites in the early stages of recovery. For example some habitat features such as the detailed measuring and assessment of decomposition of the logs and branches has been omitted, whilst the understorey assessment included planted tubestock, direct seeding as well as natural recruitment and naturally occurring shrubs.

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

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

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

3 Selecting suitable reference sites at Northparkes Mines

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

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

- Mixed native woodland; and
- Native grassland.

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

Vegetation communities are seldom uniform and are comprised of a different suite of species according to variations in climate, geology, soils, topography, aspect as well as other influences such as seasonal conditions, disturbance events and management conditions. This makes it difficult to determine what exactly a “woodland community” or “native grassland” is, what features it should have, how to establish one and at what point is it considered to be one.

Therefore we selected four woodland sites and three native grassland sites as replicated examples of each community type to allow for these inherent variations, range of local conditions and ecological transition.

3.1 Woodland reference sites

Four vegetation communities have been identified across the NPM and surrounding properties (NPM 2008) and include:

- Tall *Eucalyptus microcarpa* (Grey Box) Open Woodlands;
- Mid – High/Tall *Callitris glaucophylla* (White Cypress Pine) – *Eucalyptus populnea* (Poplar Box) open woodland to savannah grassland;
- Mid – High/Tall *Eucalyptus populnea* (Poplar Box) open woodland to woodland; and
- Mid – High/Tall *Eucalyptus albens* (White Box) – *Callitris glaucophylla* (White Cypress Pine) woodland.

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

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

These major vegetation communities have a patchy distribution across the local area and vary according to soil type and topography and often form ecotones. Species commonly associated with these communities include *Alectryon oleifolius* (Rosewood), *Allocasuarina luehmannii* (Bullock), *Brachychiton*

populneus (Kurrajong) and *Geijera parviflora* (Wilga). On the heavier soils, subjected to inundation, *Acacia pendula* (Weeping Myall) and *Casuarina cristata* (Belah) can also be common. There are also areas dominated by *Eucalyptus melliodora* (Yellow Box) woodland and native grasslands (or derived native grasslands).

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

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

3.2 Grassland reference sites

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

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

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

3.3 Amendments

In 2013 the Key Performance Indicators (KPI) Tables provided within the annual rehabilitation report has been restructured to more accurately align with the new REMP reporting guidelines. Please refer to NSW T&I: Resources and Energy (2012).

The application of the ecological performance data during the Decommissioning phase (Phase 1) is not considered applicable within the presentation of this ecological data. Subsequently the ecological performance criteria which are consolidated into Key Performance Indicator (KPI) tables are only represented within Rehabilitation Phase 2 (Landform Establishment and Stability), Phase 3 (Growth

Medium Development), Phase 4 (Ecosystem and Landuse Establishment) and Phase 5 (Ecosystem and Land Use Development).

In terms of restructuring the KPI table, the two previously separate phases Ecosystem Development (represented previously as Phase 4: Dark green) and Ecosystem Stability (represented previously as Phase 5: Dark Blue) have since been integrated and are now represented as Ecosystem and Land Use development (Phase 5: Dark Blue) only.

4 Rainfall

Total annual rainfalls recorded at the NPM compared to the long-term annual averages recorded at the Parkes Airport are shown in Figure 4-1. It should be noted that rainfall data for 2009 – 2011 was obtained from NPM weather station, however since then rainfall data has been taken from the automatic weather station at Parkes Airport (BoM 2013).

In 2009 the total rainfall was 250mm below average and with only 364mm was a particularly dry year and during the monitoring period the weather was very hot ($>40^{\circ}\text{C}$) and windy with dust storms being a frequent occurrence. Subsequently there was little active plant growth and species diversity was very low. In contrast, 2010 had a total rainfall of 1026mm with most months providing above average growing conditions and the temperatures were milder. The substantial increase in rainfall in 2010 resulted in significant changes occurring within the vegetation, in particular increases in total ground cover and species diversity and abundance across the range of sites.

Rainfall in 2011 continued to be above the long-term average with 676mm recorded, however 36% of this was experienced after the monitoring period in November and December with the above average rainfall continuing into March 2012, producing widespread floods. Apart from July, conditions become very dry with significantly low rainfall falling throughout most of 2012 and this extended into 2013, with practically no rain falling during April and generally there was below average monthly rainfall (Figure 4-2). The exceptions included March (81.6mm) and June (176.4mm) when 68mm was received within a 24 hour period causing localised flooding. Above average rain also occurred in July with 71.8mm. While rainfall in September was on average, August and October were very dry. Rainfall up until November 2013 was 513.6mm and this was 44.5mm below the 11month average.

Subsequently the drier conditions over summer as well as the latter part of the year has continued to influence the diversity, abundance and composition of the monitoring sites, and these have been compounded by the prolonged dry conditions which tended to result in increased levels of browsing and disturbances created by resident macropod populations, especially under the shelter of the tree canopies.

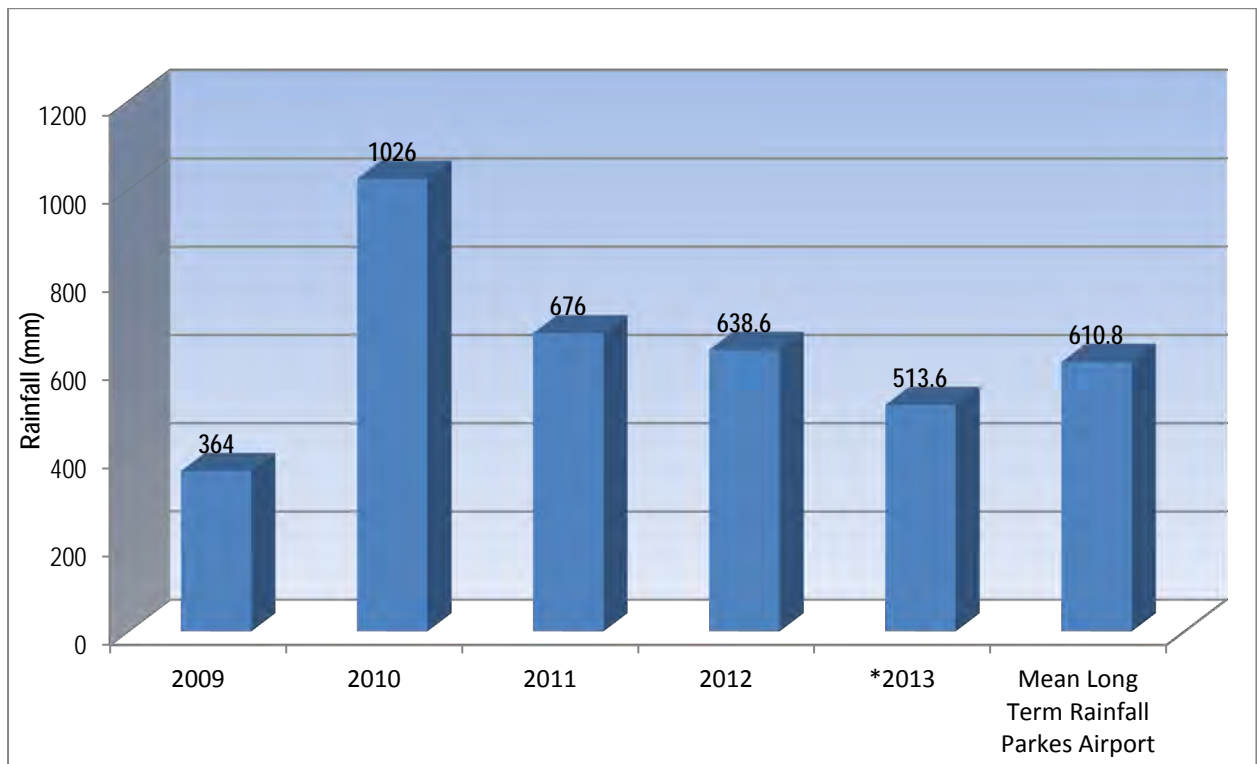


Figure 4-1. Annual rainfall recorded at NPM 2009-2013 compared to long-term mean annual rainfall for Parkes Airport AWS. (NB: All rainfall data from 2012 onwards from Parkes Airport AWS) *Jan-Nov 2013 only

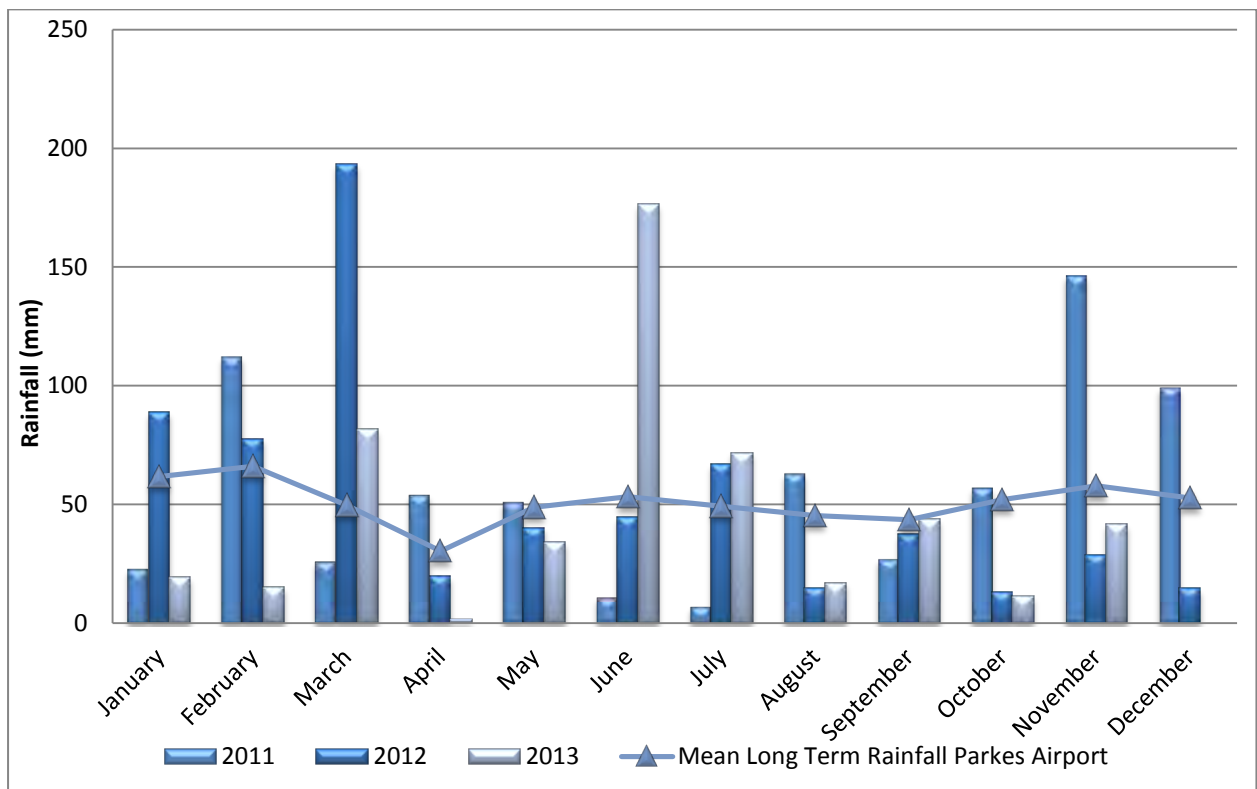


Figure 4-2. Monthly rainfall recorded at the Northparkes Mines from January 2011 to November 2013 compared to the long term monthly averages recorded at Parkes Airport AWS. (Nb: all rainfall data from 2012 onwards from Parkes Airport AWS [BoM 2013])

5 General site descriptions and permanent photo-points

A map of the monitoring sites in relation to the NPM is given in Figure 5-1.



Figure 5-1. Map showing the locations of the monitoring sites (Image November 2010 – Google Earth Pro).

5.1 Reference sites

General descriptions of the reference sites, including photographs taken in the permanent monitoring quadrats in 2009 – 2013 have been provided in Table 5-1. GPS coordinates and other site specific information is provided in Table 5-2.

Table 5-1. General site descriptions and permanent photo-points of the reference monitoring sites.














Photo 2009	Photo 2010	Photo 2011	Photo 2012	Photo 2013
<p>RWood01: Open grassy woodland dominated by <i>E. microcarpa</i> with some <i>Allocasuarina luehmannii</i> and <i>Alectryon oleifolius</i> sub dominants. There were some large old regrowth trees, scattered regrowth and some limited regeneration of the overstorey species. The site had small scattered patches of <i>Dodonaea viscosa</i> subsp. <i>cuneata</i>, <i>Acacia hakeoides</i> and <i>Maireana microphylla</i>. The ground cover included scattered tussocks of <i>Austrostipa</i> and <i>Austroanthonia</i> species as well as a variety of small chenopod sub-shrubs. There were some fallen branches. Leaf litter was abundant beneath tree canopies but there were numerous patches of bare ground particularly in the more open areas, which were commonly covered with cryptogams. In 2009 the wildflowers were flowering. In 2010, the area had been recently grazed by travelling stock with some shrubs damaged and some grass tussocks had been pulled out. In 2011, there was no evidence of recent livestock grazing however there was less plant diversity due to the drier conditions. In 2011 the <i>Austrostipas</i> were flowering and one large <i>E. microcarpa</i> had fallen down. In 2012 and 2013 the site continued to be very dry.</p>				
				
<p>RWood02: Open regrowth woodland dominated by <i>E. albens</i>, <i>E. populnea</i> and <i>Callitris glaucophylla</i> with some older <i>Callitris</i> and eucalypt regeneration. The site had small scattered patches of <i>Acacia deanei</i> with some limited regeneration of the overstorey species. The ground cover included sparsely scattered tussocks of <i>Bothriochloa macra</i>, <i>Austrostipa</i> and <i>Austroanthonia</i> species as well as a diverse range of herbs and forbs. Leaf litter was abundant beneath tree canopies but there were numerous patches of bare ground particularly in the more open areas, which were commonly covered in cryptogams. There were some fallen branches and an active presence of ants and ant nests. In 2010, the area had been recently grazed by travelling stock with numerous deep hoofprint depressions scattered across the site, but there was little grazing damage. In 2011, there was no evidence of recent livestock grazing however there was less plant diversity due to increased grass cover and drier conditions. In 2012 and 2013 the site continued to be very dry.</p>				
				

Photo 2009	Photo 2010	Photo 2011	Photo 2012	Photo 2013
<p>RWood03: Open grassy woodland dominated by <i>E. microcarpa</i> with an individual <i>Allocasuarina luehmannii</i>. There were some large old growth trees with hollows, scattered regrowth and some limited regeneration of the overstorey species. The site had small scattered patches of <i>Dodonaea viscosa</i> subsp. <i>cuneata</i>, <i>Acacia hakeoides</i> and <i>Senna artemisioides</i>. The ground cover included sparsely scattered tussocks of <i>Austrostipa</i> and <i>Austrodanthonia</i> species as well as a variety of small chenopod sub-shrubs. Leaf litter was abundant beneath tree canopies but there were numerous patches of bare ground particularly in the more open areas, which were commonly covered in cryptogams. There were some fallen branches. Grey Crowned Babblers were present at this site. In 2010, the area had been recently grazed by travelling stock with numerous deep hoofprint depressions scattered across the site, but there was little grazing damage. In 2011, there was no evidence of recent livestock grazing however there was less plant diversity due to increased grass cover and drier conditions. In 2012 and 2013 the site continued to be very dry.</p>				
				
<p>RWood04: Open woodland dominated by <i>E. populnea</i>, <i>E. melliodora</i> and <i>Callitris glaucophylla</i> which has some large old growth trees and numerous stumps but in 2009 there was no shrub or tree regeneration. The ground cover was patchy and contained sparsely scattered tussocks of <i>Austrostipa</i> and <i>Austrodanthonia</i> species. In 2009 there was a limited diversity of herbs and forbs, but generally total ground cover was good with large patches of <i>Xerochrysum bracteatum</i> (Golden everlasting) scattered across the forest area. In 2010, there was a high diversity of native understorey species, including significant patches of <i>Dichopogon</i> (Chocolate lily). There were also old stock camps beneath the trees which were dominated by weeds. The area is not subjected to livestock grazing but maintains a healthy macropod population. In 2011, there had been a significant increase in grass cover resulting in lower plant diversity and fewer weeds, especially beneath the tree canopies in the old stockcamps. The patch of <i>Dichopogon</i> was reduced to about one dozen individuals due to increased competition and drier conditions. In 2012 the site continued to be exceptionally dry but there was some <i>Callitris</i> regeneration. In 2013, it continued to be very dry, but significant regeneration of <i>Callitris</i> was evident across the larger Limestone Forest area, with seedlings having grown over the year.</p>				
				
<p>RGrass01: Large open natural grassland area on the TSR adjacent to the Wombin State Forest, on the Bogan Rd. In 2009, the site contained sparsely scattered tussocks of native grass tussocks, with <i>Austrostipa</i> and <i>Austrodanthonia</i> species being the most dominant. Most plants were very stressed and likely to have been recently grazed by travelling stock. Numerous small "puff banks" were characteristic across the site and often these maintained a higher diversity and sustained growth of the plants. There were extensive areas of hard pans which were often colonised by cryptogams, and in suitable seasons, <i>Hyalosperma semisterile</i> (Orange Sunray) would be prolific in these areas. In 2010, the site was covered in water after recent heavy rainfall and deep cattle hoofprints were extensive. There was a high diversity of native forbs. In 2011 the area remained ungrazed and there was an increase in cover provided by the perennial grasses. <i>Trifolium angustifolium</i> was abundant and there was a relatively high native species diversity. In 2012 and 2013 the site continued to be very dry, but green patches were maintained in lower depressions.</p>				



RGrass02: A derived grassland area on the TSR on the Bogan Rd east of TSF 2. It was a relatively dense sward of mixed native grasses dominated by *Austrostipa bigeniculata*, *Bothriochloa macra* and *Austrodanthonia* species. There were few areas of bare soil as cryptogams were in significant abundance across the area. In 2009, the grasses were particularly stressed due to the extreme hot and dry conditions and introduced annuals and weeds were dead. In 2010, the site contained an abundance of exotic annuals. Recent grazing and trampling by a large herd of cattle during/after heavy rainfall has caused extensive soil damage and large deep hoofprints across the site. In 2011 the area remained ungrazed and there was an increased cover of grasses. In 2012 and 2013 the site continued to be very dry.



RGrass03: A large derived grassland area opposite "Berra Lee" on the TSR adjacent to the Bogan Rd. It was a relatively dense sward of mixed native grasses dominated by *Austrostipa bigeniculata* and *Austrodanthonia eriantha* and in suitable conditions, *Avena fatua* (Wild Oats). The history of the site is largely unknown but there were a series of old contour banks transversing the slope which were usually low in ground cover, therefore creating patchiness. Apart from some of these contours, there were few areas of bare soil with the presence of some cryptogams. In 2009, the grasses were particularly stressed due to the extreme hot and dry conditions and overall plant diversity was low and introduced annuals and weeds were dead. In 2010, the site contained an abundance of exotic annuals, but ground cover was very good and appeared unaffected by livestock. In 2011 the area remained ungrazed and there was an increased cover of grasses and a reduction in annual exotics. In 2012 and 2013 the site continued to be very dry.



Table 5-2. GPS co-ordinates, aspects and slopes of the reference monitoring sites.











Site Reference	LFA Start	LFA Finish	LFA slope°	LFA bearing°	Veg transect start	Veg transect finish	Veg transect bearing °
RWood01	55599368 E 6361978 N	55599386 E 6361982 N	0	52 NE	55599378 E 6361978 N	55599399 E 6361934 N	142 SE
RWood02	55604368 E 6350055N	55604386 E 6350060 N	5	56 NE	55604378 E 6350058 N	55604394 E 6350012 N	158 SE
RWood03	55600792 E 6359342 N	55600772 E 6359350 N	1	269 W	55600781 E 6359348 N	55600794 E 6359393 N	0 N
RWood04	55597396 E 6356649 N	55597398 E 6356626 N	4	159 S	55597398 E 6356637 N	55597350 E 6356628 N	240 SW
RGrass01	55597120 E 6363077 N	55597102 E 6363088 N	1	287 NW	55597110 E 6363082 N	55597137 E 6363125 N	21 NE
RGrass02	55601382 E 6358380 N	55601379 E 6358397 N	2	350 N	55601378 E 6358389 N	55601431 E 6358387 N	80 E
RGrass03	55603432 E 6350661 N	55603425 E 6350682 N	3	325 NW	55603428 E 6350673 N	55603477 E 6350688 N	70 NE

5.2 Rehabilitation monitoring sites

The rehabilitation monitoring sites were chosen based on their final landuse/vegetation community type and year of establishment and were considered to be representative of the rehabilitation area as a whole. In large rehabilitation areas multiple sites were established. In total, there were six “woodland” and eight “grassland” monitoring sites established in 2009 and these same sites have been monitored annually.

The location of the rehabilitation monitoring sites is provided in Figure 5-1 (above). General descriptions of the rehabilitation sites, including photographs taken in the permanent monitoring quadrats in 2009 – 2013 have been provided in Table 5-3. GPS coordinates and site specific information is provided in Table 5-4.

Table 5-3. General site description and photo of the rehabilitation monitoring sites.

Photo 2009	Photo 2010	Photo 2011	Photo 2012	Photo 2013
<p>LFO-01: Mixed native woodland planted 2009. Limestone Forest Offset (LFO) planting situated at the southern end of the offset area. Variation: The vegetation transect aligned with the LFA transect to accommodate the row and inter-row sequence. This site has had a long cropping history and was graded several years in preparation for planting. Tubestock were planted in July 2009. In 2009 the site was predominantly bare within the inter-rows but weeds have begun to colonise the rip line and in some of the area spraying around the tubestock was recently undertaken. There appears to have been moderate wind erosion within the bare inter-rows but due to the flat topography the site is generally stable. In 2010, this site had been sprayed and dead tubestock had recently been replaced. In 2011 the site had become very weedy with weeds colonising the bare areas and the tubestock had grown considerably. Parts of the area had been slashed. The troughs and banks had become redundant with the entire area now described as a "weak" woodland rehab patch. In 2012, the tubestock has further grown and the plants had become better established. <i>Xerochrysum bracteatum</i> has become well colonised within the site but the site continued to be weedy. In 2013 the tubestock had grown and <i>Xerochrysum</i> were prolific but the site remained weedy.</p>				
				
<p>LFO-02: Mixed native woodland planted 2009. Limestone Forest Offset (LFO) planting situated at the northern end of the offset area. Variation: The vegetation transect aligned with the LFA transect to accommodate the row and inter-row sequence. This site has had a long agricultural history but has not been cropped. It has been a native grassland area which was direct drilled with Lucerne several years ago. Tubestock were planted in July 2009. The site contained adequate ground cover and leaf litter. There were relatively few weeds within the rip lines. In 2010, this site had been sprayed and dead tubestock had recently been replaced. In 2011 the site was weedy with weeds colonising the bare areas and the tubestock had grown considerably and was similar to LFO-01. Termites were abundant. The entire area is now described as a "weak" woodland rehab patch. In 2012 and 2013, the tubestock has further grown and the plants had become better established but the site remained weedy.</p>				
				
<p>Estcourt 1997: Mixed native woodland planted 1997. Situated at the south-east corner of TSF 2 adjacent to the main NPM access Road. This site was one of the oldest rehabilitation areas planted with mixed native tubestock in 1997. The site maintains an open woodland structure, scattered shrubs and a mosaic of grassy clearings and bare patches. Vegetation cover was limited beneath the tree canopies but there was generally good leaf litter cover. In 2009, ground cover species were particularly stressed with little active green growth. The site contains kangaroo camps and would be subjected to kangaroo grazing. There has been excellent establishment and growth with some trees exceeding 6m in height, generally healthy and setting seed. In 2011, the site had reduced plant diversity due to the dry seasonal conditions. In 2012 and 2013 the site continued to be very dry.</p>				













Beechmore 1999: Mixed native woodland planted 1999. Within a fenced off area around a drainage line on "Beechmore" situated SW of the NPM. Due to patchiness of the site, the vegetation transect fell within a particularly bare area and may under represent certain characteristics of the site. This site was planted in 1999 and maintains an open woodland structure, scattered shrubs and a mosaic of grassy clearings and bare patches. Vegetation cover was limited beneath the tree canopies but there was generally good leaf litter cover. In 2009, ground cover species were particularly stressed with little active green growth. There has been excellent establishment and growth with some trees exceeded 6m in height, were generally healthy and setting seed. Grey Crowned Babblers were observed within the site in 2009, 2010. In 2011, there was a slight improvement in ground cover and the site retains its patchiness. In 2012 and 2013 the site continued to be very dry.



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



Kundibah 2001: Mixed native woodland 2001. A small tree planting area north of TSF 1 and north of Adavale Lane. The site was planted in 2001 and maintains an open woodland structure, scattered shrubs and a mosaic of grassy clearings and bare patches. Vegetation cover was limited beneath the tree canopies but there was generally good leaf litter cover. In 2009, ground cover species were

Photo 2009	Photo 2010	Photo 2011	Photo 2012	Photo 2013
<p>particularly stressed with little active green growth. There has been good establishment and growth with some trees exceeded 6m in height, were mostly healthy and setting seed. Some trees however were showing signs of stress and some insect attack by lerps. Some species (eg. <i>E. melliodora</i>) appeared to be stunted. In 2009, Grey Crowned Babbler were observed within the site. In 2011 there was a significant reduction in cover provided by exotic annual species. In 2012 and 2013 the site continued to be very dry.</p>				
				
<p>TSF1-01: Native grassland. Rehabilitation area on the mid-lower slope of the north-eastern facing slope of TSF 1. A grassy slope with tussocks of native perennial grasses dominated by <i>Walwhalleya prolata</i> (Rigid Panic) with scattered <i>Avena</i> (Wild Oats) and <i>Lolium</i> (Ryegrass). In 2009, grasses and annual species were particularly stressed with little active green growth and the various weed species were dead due to the hot dry seasonal conditions. The upper parts of the slope had less ground cover and more erosion than the lower parts, with some slight sheet erosion occurring between the grass tussocks. In 2010, there was a significant increase in annual plant cover and the perennial grasses were actively growing, with a significant reduction in the amount of bare ground. The upper slope appears almost stable. Cryptogams had become extensive and spiders and ants were common. In 2011, there has been a significant increase in perennial plant cover largely due to the native grasses and there were fewer weeds. In 2012 and 2013 the site continued to be very dry.</p>				
				
<p>TSF1-02: Native grassland . A grassy slope dominated by annual grasses and medics with few native perennial grasses. <i>Sonchus oleraceus</i> was common. There was significant establishment of <i>Maireana brevifolia</i> (Yanga Bush) and <i>Atriplex</i> species were common. The Yanga Bush was particularly important for the overall function of the site and was important for trapping seeds, soil and litter material. In 2010 however, the Yanga Bush appeared to be very stressed. There was some active erosion in less vegetated areas, but these sediments were trapped within the plant patches. The bare areas had a light cover of annual plants. In 2011 the Yanga Bush has recovered slightly and there has been an increased in litter and perennial plant cover. In 2012 and 2013 the site continued to be very dry.</p>				



TSF2-01: Native grassland. Rehabilitation area on the mid slope, southern end of the south facing slope of TSF 2. A grassy slope with scattered tussocks of native perennial grasses (*Walwhalleya proluta*) and a heavy cover of *Medicago polymorpha*. There was a small pocket of *Maireana brevifolia* (Yanga Bush) establishing in the table drain, and scattered individuals of *Atriplex* species. In 2009, the grasses and annual plants were particularly stressed with little active green growth or were dead. In 2010, there was evidence of extensive soil erosion from the bare upper slope which contained numerous rills, but the eroded materials were captured within the plant patches down slope. The bare areas now had a light cover of annual plants. In 2011, there has been a significant increase in perennial plant cover largely due to the native grasses and there were fewer weeds but *Medicago polymorpha* retains its dominance. Some of the older rills on the upper slope were becoming well vegetated and were more stable. In 2012 the site continued to be very dry. There were numerous areas where seepage of the tailings materials was being expressed as bare and scalded with white salt crystals and require amelioration. In 2013 the site continued to be very dry.



TSF2-02: Native grassland. Rehabilitation area on the northeast wall of TSF 2. A grassy slope similar to TSF2-01 with scattered tussocks of native perennial grasses (*Walwhalleya proluta*) and a heavy cover of *Medicago polymorpha*. A single *Acacia hakeoides* and *M. brevifolia* were noted further along the slope. In 2009, the grasses and annual plants were particularly stressed with little active green growth or were dead. In 2010, there was evidence of extensive soil erosion from the bare upper slope which contained numerous rills, but the eroded materials were captured within the plant patches down slope. The bare areas now had a light cover of annual plants. In 2011, there has been a significant increase in perennial plant cover largely due to the native grasses and there were fewer weeds. The top of the slope continues to be bare and eroding. In 2012 and 2013 the site continued to be very dry.







Photo 2009	Photo 2010	Photo 2011	Photo 2012	Photo 2013
<p>E22-01: Native grassland. Rehabilitation area the western batters of the waste emplacement surrounding the E22 open cut. An open grassy area on the upper slope of the waste emplacement batter. The upper half of the monitoring plot contains less vegetation cover with scattered tussocks of <i>Walwhalleya proluta</i> and exotic annuals. The lower part of the slope is more densely vegetated and in 2010 it was dominated by <i>Vicia</i>, <i>Rapistrum rugosum</i> and various other weeds. Spiny Orb weavers were abundant. Below the site there are some small planted tree lots with little to no ground cover with severe tunnel erosion observed nearby. Some Grey Crowned Babbler were observed in these trees during the monitoring. In 2011, there has been a significant increase in perennial plant cover largely due to the native grasses and there were fewer weeds. In 2012 and 2013 the site continued to be very dry.</p>				
				
<p>E22-02: Native grassland. Rehabilitation area located on the northern face of the waste rock emplacement that surrounds E22 open cut. A rocky north facing slope that appears to have been deep ripped after shaping. There are sparse tussocks of <i>Walwhalleya proluta</i> scattered over the site and in 2010 there was a significant increase in ground cover dominated by <i>Medicago polymorpha</i>, <i>Echium plantagineum</i> and <i>Rapistrum rugosum</i>. In 2009 active sheet erosion was observed across the site with one active rill of concern. In 2010 the rills had become vegetated and appeared to have stabilised. In 2011, there has been a significant increase in perennial plant cover largely due to the native grasses and there were fewer weeds but there were still patches of weeds including <i>Carthamus lanatus</i> (Saffron thistle). <i>Vittadinia</i> (Fuzzweed) was becoming very abundant. There were echidna scratching at the end of the veg transect. In 2012 and 2013 the site continued to be very dry.</p>				
				
<p>E26-01: Native grassland. Rehabilitation area located on the north eastern slope of the waste emplacement surrounding the E26 subsidence zone. This site had generally good ground cover with scattered tussocks of <i>Walwhalleya proluta</i> and had a range of exotic annuals such as <i>Avena</i> and <i>Lolium</i>. In 2009, the vegetation was particularly stressed with very little active growth and the floristic diversity was significantly low. In 2010, there was a significant increase in diversity of native and exotic plants and the site was particularly stable. In 2011 the site was dominated by a dense sward of <i>Walwhalleya proluta</i> with occasional scattered weeds. The site was green and the grasses were actively growing and seeding. In 2012 and 2013 the site continued to be very dry.</p>				

Photo 2009	Photo 2010	Photo 2011	Photo 2012	Photo 2013
				

E27-01: Native grassland. Rehabilitation area located on the western side of the E27 open cut waste rock emplacement. The site had generally good ground cover with scattered native perennial grasses and scattered establishment of *Maireana brevifolia* (Yanga Bush), *Senna artemisioides* (Silver Cassia) and *Acacia brachystachya* (Umbrella Mulga). In 2009, there was little green growth with all the annual species being dead. In 2010, there was a significant increase in cover provided a range of annual plants especially *Vicia villosa* and *Medicago polymorpha* which may have compromised the floristic diversity of the site (it was particularly difficult to detect plants beneath the dense cover of *Vicia* and *Medicago*). Well used Kangaroo camps exist under the larger shrubs within the site. In 2011 there was significant reduction in the abundance of exotic annuals (especially *Vicia* and *Medicago*) and there has been an increase in native perennial plant cover. Kangaroo camps continue to exist under the larger shrubs within the site. In 2012 and 2013 the site continued to be very dry.



Table 5-4. GPS co-ordinates and other site specific information related to the rehabilitation monitoring sites.

Site Reference	LFA Start	LFA Finish	LFA slope°	LFA bearing °	Veg transect start	Veg transect finish	Veg transect bearing °
LFO-01	55597197E 6356500 N	55597178E 6356491 N	4	230 SW	55597197 E 6356500 N	55597153E 6356479 N	230 SW
LFO-02	55597032E 6356936N	55597013E 6356929N	1	241 SW	55597032 E 6356936N	55596985E 6356921N	241 SW
Estcourt 1997	55600759E 6357771N	55600763E 6357785N	2	340 NE	55600764E 6357776N	55600807E 6357783N	70 NE
Beechmore 1999	55595911E 6354638N	55595930E 6354635N	2	85 E	55595921E 6354636N	55595913E 6354590N	174 S
Altona 1999	55598827E 6354733N	55598836E 6354753N	3	9 N	55598833E 6354742N	55598879E 6354726N	99 E
Kundibah 2001	55597059E 6359558N	55597055E 6359580N	0	338 NW	55597057E 6359568N	55597106E 6359580N	68 NE
TSF1-01	55599592E 6369478N	55599609E 6359484E	14	50 NE	55599599E 6359481N	55599625E 6359439N	141 SE
TSF1-02	55598848E 6360055N	55598837E 6360073N	10	31 NW	55598844E 6360062N	55598886E 6360088N	45 NE
TSF2-01	55599339E 6358043N	55599335E 6358026N	11	178 S	55599338E 6358036N	55599285E 6358034N	268 W
TSF2-02	55600293E 6358536N	55600309E 6358946N	13	48 NE	55600301E 6358541N	55600330E 6358502N	135 SE
E22-01	55596444E 6358102N	55596425E 55596413N	14	244 SE	55596434E 6358101N	55596421E 6358150N	332 NW
E22-02	55597201E 6358694N	55597204E 6358713N	12	358 N	55597204E 6358704N	55597252E 6358694N	87 E
E26-01	55598279E 6355148N	55598297E 6355150N	15	70 NE	55598286E 6355149N	55598302E 6355103N	162 SSE
E27-01	55598601E 6358343N	55598619E 6358341N	15	83 E	55598609E 6358343N	55598618E 6358295N	171 S

6 Woodland rehabilitation sites: Ecological trends and performance against a selection of primary ecological performance indicators

6.1 *Landscape Function Analyses*

6.1.1 Landscape Organisation

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

All four reference sites continued to be functional woodland ecosystems which each scored Landscape Organisation Index (LOI) of 100% (Figure 6-1) indicating there were high levels of ground cover and no leakage of resources. The younger rehabilitation sites in the Limestone Forest Offset (LFO) which were planted in 2009 have demonstrated the most significant changes with both sites maintaining 100% patch area since 2011. In 2009 there were significant areas of bare ground due to ground preparation techniques but these rapidly became colonised by a variety of weeds and cryptogams. While perennial vegetation cover remained low, the annual plants, cryptogams and dead leaf litter created important and functional patch areas.

The older remaining rehabilitated woodlands all demonstrated a decline in patch area this year. The lowest LOI continued to be recorded in Estcourt 1997 which had an LOI of 72%, while this year Kundibah 2001 had slightly declined but continued to have a high LOI of 95%. The lower LOIs in Estcourt 1997 and Beechmore 1999 have previously been attributed to competition effects from the more mature trees and shrubs and heavier clay soils which tend to limit vegetative cover to sparsely scattered perennial ground covers, particularly within the tree root zones. This year however these have been compounded by the prolonged dry conditions which tended to result in increased levels of browsing and disturbances created by resident macropod populations, especially under the shelter of the tree canopies.

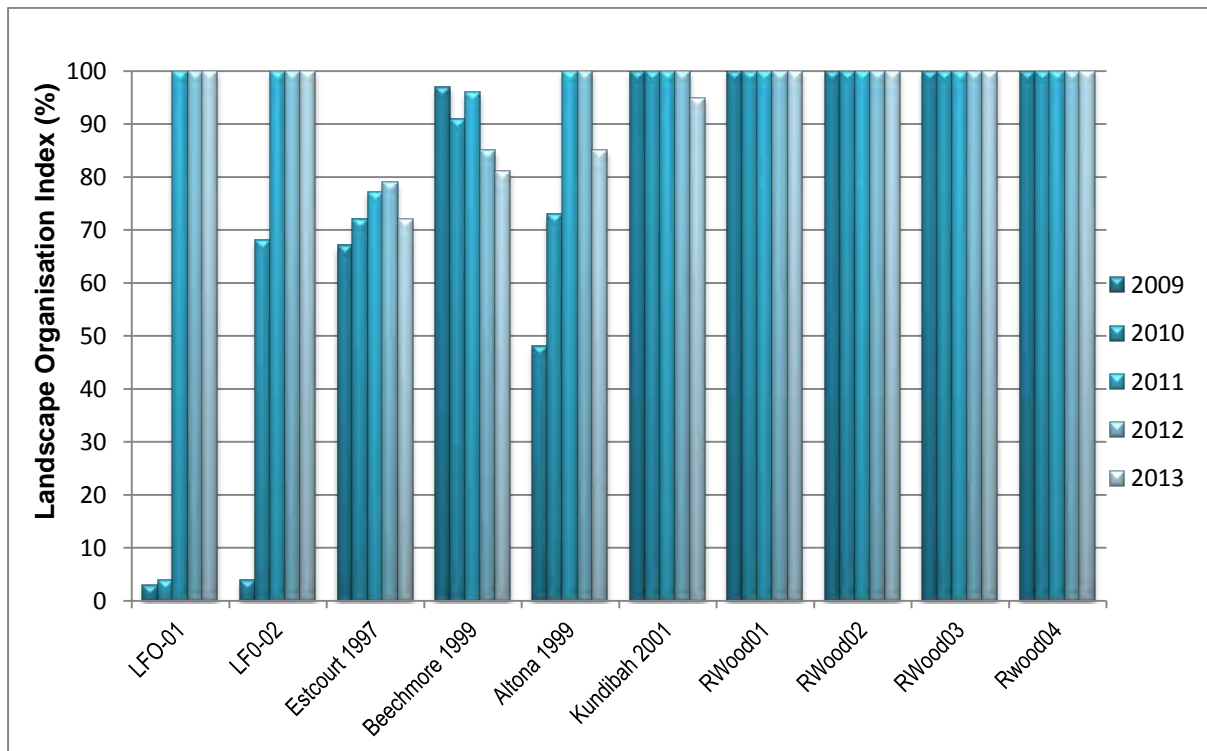


Figure 6-1. Landscape organisation indices recorded in the woodland rehabilitation sites compared to the woodland reference sites.

6.1.2 Soil surface assessments

6.1.2.1 Stability

Up until 2012 there has been an increasing trend in stability in most rehabilitation sites largely due to improved seasonal conditions since the peak of the drought which stimulated active perennial ground cover and provided an abundance of live annual vegetation. The exceptions in 2012 were recorded in Beechmore and Kundibah. In these two sites the effects of extended dry periods, which resulted in a reduction in active growth of the perennial ground cover plants, were also compounded with the existing high competition levels from the mature trees and shrubs which have always been pronounced in these heavier soil floodplain sites. Minor decreases were also observed in three of the four woodland reference sites in that year for similar reasons.

Despite above average rainfall in June 2013, monthly rainfall since that time has largely been well below average resulting in a further decline in live plant cover due to the dry conditions which has also resulted in increasing macropod predation and disturbance levels. This effect appeared to be consistent across all monitoring sites, including the four woodland reference sites.

Subsequently the LFA stability indices for the woodland reference sites were lower this year and these ranged between 62.9 – 69.0 and all rehabilitation sites exceeded this stability range, with the exception of Beechmore which was negligibly lower with a stability index of 62.8 (Figure 6-2). Interestingly, the youngest and previously most disturbed site LFO-01 had become the most stable of the rehabilitation sites with an index of 72.0 and this was due to the high levels of cryptogams, annual plants and very hard setting soils. There was also much lower evidence of macropod activity in the LFO sites.

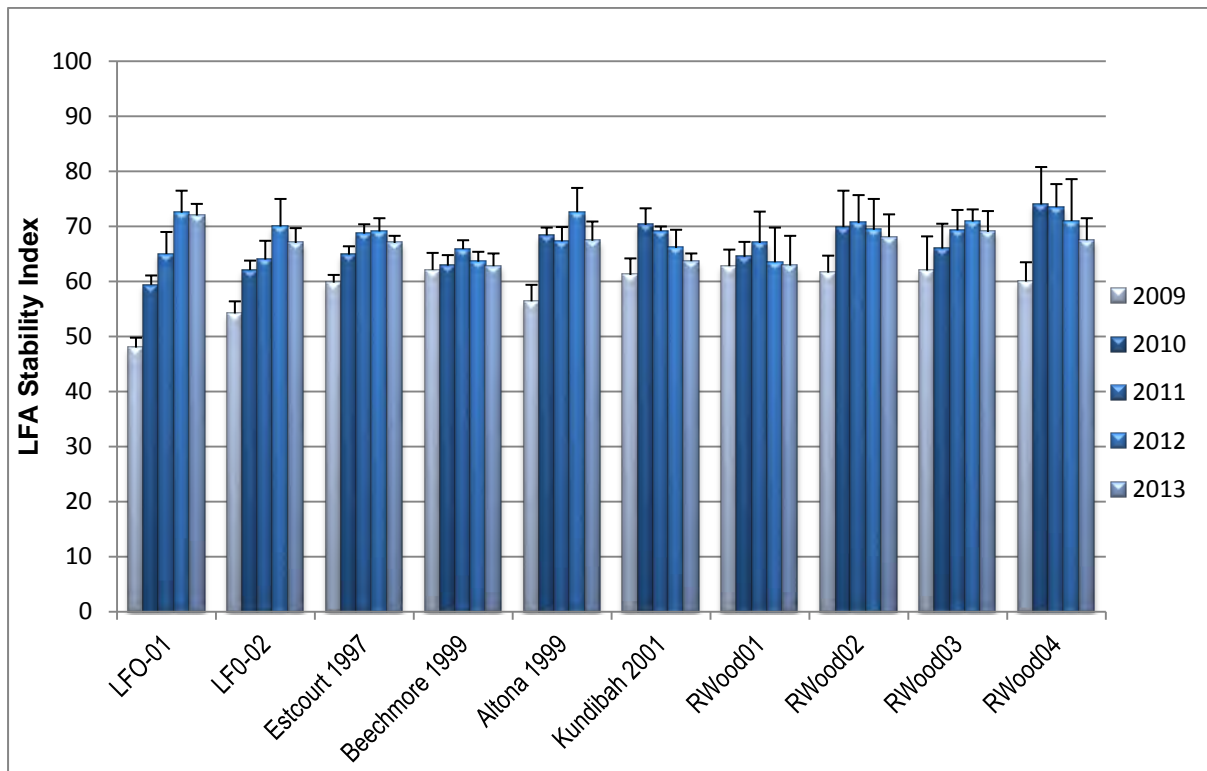


Figure 6-2. Comparisons of LFA stability indices recorded in the woodland rehabilitation monitoring sites and the woodland reference sites.

6.1.2.2 Infiltration

There has been no consistent change in infiltration indices across the range of woodland reference sites over the past year with RWood01 and RWood02 demonstrating a relatively large improvement, while RWood03 and RWood04 had declined but there was a high levels of variation within the sites. The resultant target range was slightly wider with indices of 41.1 – 55.7. Kundibah (and Altona) also demonstrated an increase in infiltration index and this was largely due to a slight improvement in litter cover and a reduction on soil hardness as the soils could be being quite crumbly and loose in patches.

The remaining rehabilitation sites however had declining infiltration capacity and in most cases these decreases were typically minor. While there was also variability across the sites, most sites tended to have less perennial vegetation and cryptogam cover and often there was an increase in interpatch areas due to disturbance by macropods.

Altona, Kundibah and Estcourt had infiltration indices that fell within the target range, but the remaining sites did not, with the lowest index of 34.3 being recorded in LFO-01 which continued to have little perennial vegetation, low soil surface roughness and very hard setting soils (Figure 6-3).

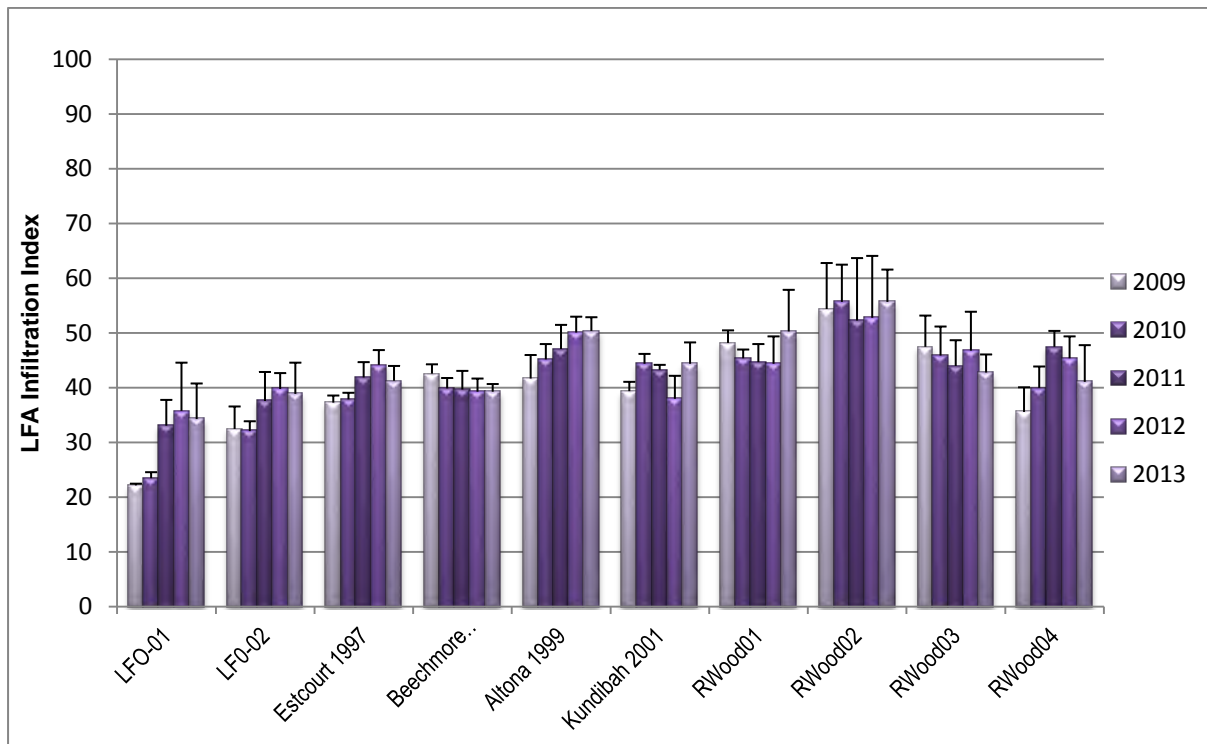


Figure 6-3. Comparisons of LFA infiltration indices recorded in the woodland rehabilitation monitoring sites and the woodland reference sites.

6.1.2.3 Nutrient recycling

Similar and inconsistent trends in LFA nutrient recycling indices were also observed across the range of woodland monitoring sites and these appeared to be strongly influenced by the level of animal - macropod activity and this year the reference sites provided a larger range of 36.2 – 53.0, with the site being very 'patchy' which provided large variations across the sites (Figure 6-4).

Kundibah demonstrated an increase in nutrient recycling index and this was largely due to a slight improvement in litter cover and a reduction in soil hardness as the soils could be being quite crumbly and loose in patches. The remaining rehabilitation sites demonstrated a lower nutrient recycling capacity largely due to a reduction in perennial vegetation and cryptogam cover combined with a decrease in functional patch area in the older rehabilitation sites.

Despite these changes all rehabilitation sites fell within the target range with the only exception being LFO-02 which was marginally lower with an index of 35.8. The highest nutrient recycling index was recorded in Altona which had an index of 46.2.

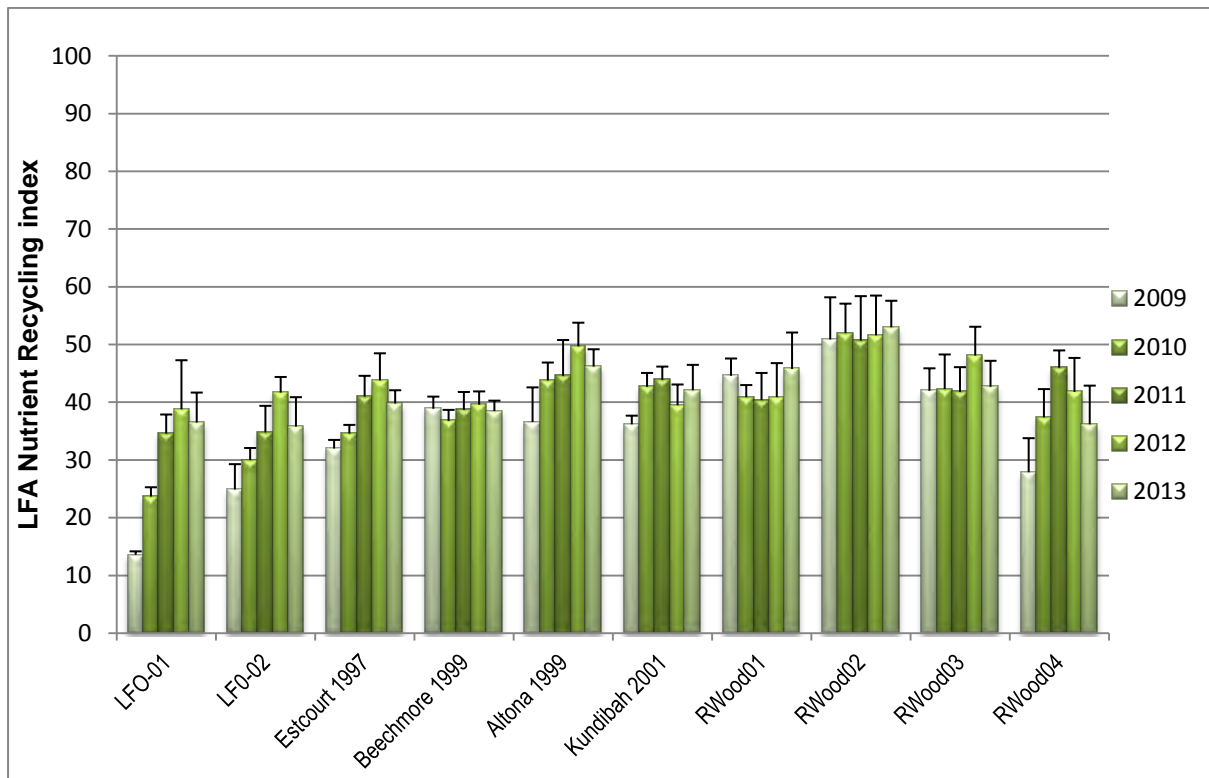


Figure 6-4. Comparisons of LFA nutrient recycling indices recorded in the woodland rehabilitation monitoring sites and the woodland reference sites.

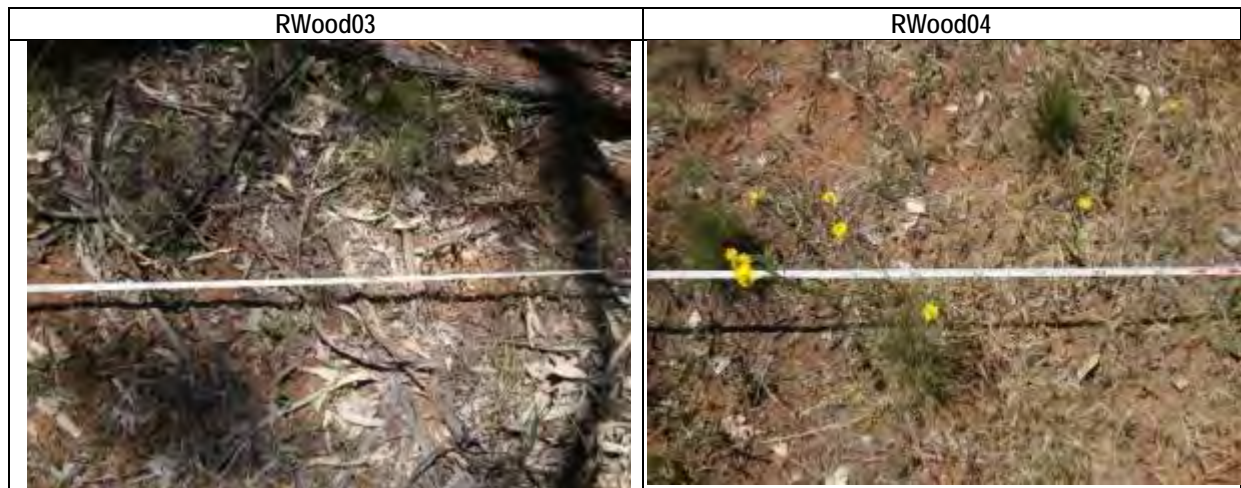
6.1.3 LFA Summary

The prolonged dry conditions have resulted in a reduction of active plant growth which has been compounded by increased levels of macropod activity and this was typically evident across the range of monitoring sites. Despite the dry conditions all woodland rehabilitation sites appear to be establishing well and in the older rehabilitation areas ecological function was very similar to those recorded in the reference sites with the exception of Beechmore which had negligibly lower stability and infiltration this year.

The two younger Limestone Forest rehabilitation areas have continued to maintain high patch areas and this was largely due to the high levels of cryptogams and annual plants providing very high stability, however due to the low levels of perennial plant cover, very hard setting soils and low soil surface roughness infiltration and nutrient recycling capacities remained low. Table 6-1 demonstrates the varying levels of ground covers within the monitoring sites and that active perennial plant growth was low due to the dry conditions.

Table 6-1. Examples of the different ground covers in the woodland monitoring sites.

LFO-01	LFO-02
	
Estcourt	Beechmore
	
Altona	Kundibah
	
RWood01	RWood02
	



6.2 Tree density

This year all rehabilitation sites contained a population of maturing trees and shrubs and in the young Limestone Forest Offset sites these populations were small but provide an indication of good growth and development of the planted tubestock which were starting to have a trunk diameter which was 5cm or greater.

Tree densities recorded in the local woodlands ranged from 5 – 19 individuals or 50 – 190 individuals per hectare (Figure 6-5) and the older rehabilitation sites continued to have densities which were similar or higher, with Kundibah and Beechmore having densities of 30 and 26 stems per monitoring plot respectively. There were four and two individuals recorded in LFO-01 and LFO-02 respectively. One large acacia had died in Altona however there was also one less tree in RWood01 as it had died and fallen over.

The average dbh recorded in the reference sites ranged from 18 – 54cm but ranged from 5 – 82cm, whilst the average trunk diameters in the rehabilitation sites were much lower with an average of 6 – 19cm. In most sites the minimum dbh were 5 – 6cm however the maximum dbh was an *E. melliodora* recorded in Estcourt which had a dbh of 36cm.

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

In the rehabilitation sites the most common species recorded were *E. microcarpa*, *E. melliodora*, *E. camaldulensis*, *E. populnea*, *E. largiflorens* (Black Box), *Casuarina cristata* (Belah), *Acacia pendula* (Myall) and mature *Acacia deanei* (Deane's Wattle). Other less common species were *E. dwyeri* (Dwyer's Red Gum), *E. viridis* (Green Mallee), *Acacia leucoclada* (Northern Silver Wattle), *A. spectabilis* (Mudgee Wattle), *A. trineura* (Three-nerved Wattle) and *Casuarina cunninghamiana* (River Sheoak).

While all species were endemic some may not strictly be associated with the particular habitat type being rehabilitated. Alternatively sites such as Beechmore and Altona were situated on the heavier soil types and were suitably rehabilitated with a selection of species which dominated the floodplain areas and these naturally varied from the drier woodland communities used as the target reference sites.

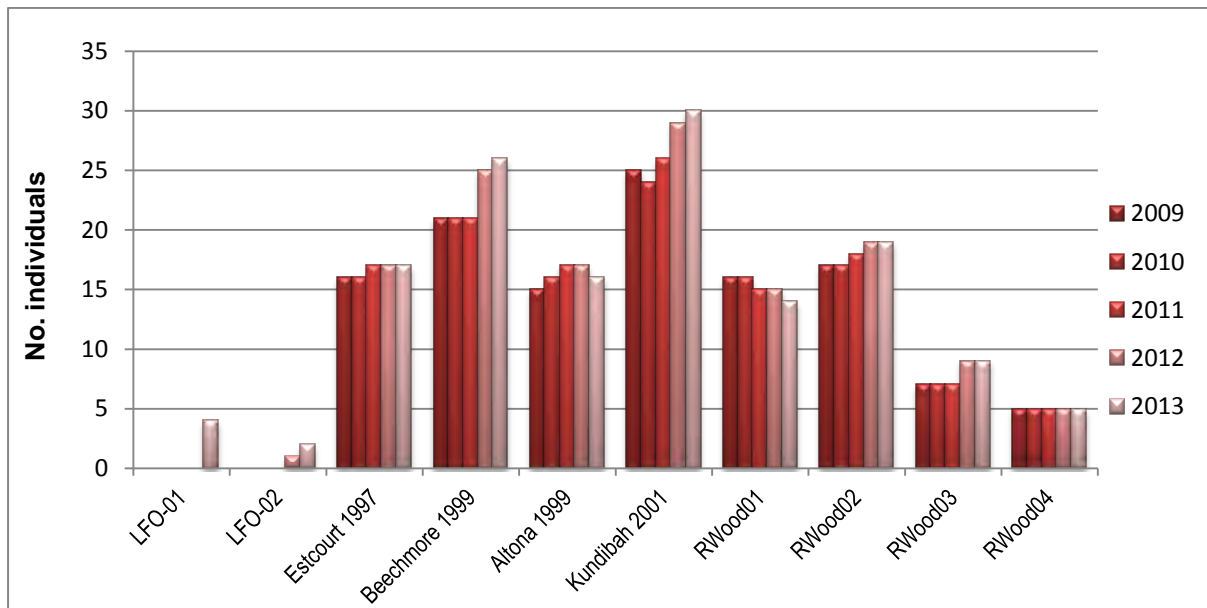


Figure 6-5. Tree densities (>5cm dbh) in the rehabilitation sites compared to the woodland reference sites.

6.3 Shrubs and recruitment

RWood04, a reference site situated in the Limestone Forest initially lacked shrubs and juvenile trees, probably due to a long history of continuous grazing and all rehabilitation sites therefore fell within the performance indicator range. In 2012 however a recruitment event was initiated with 48 *Callitris glaucophylla* seedlings being recorded, increasing the target shrub and juvenile tree density target to 48 – 134 individuals per 0.1 ha (Figure 6-6). In 2012, natural regeneration was also recorded in all of the older rehabilitation sites with Beechmore and Altona falling within the target range.

This year many sites had a declining shrub and juvenile tree population with a small number having grown into “trees”, while many smaller seedlings were thought to have been heavily predated and later died. Exceptions included significant recruitment in LFO-02 and RWood04 both of which contained a relatively recent regeneration event. In LFO-02 there were 82 very small (~3cm) *A. deanei* seedlings establishing around a mature *A. deanei* towards the end of the vegetation transect. In RWood04, there were 43 additional *Callitris glaucophylla* seedlings which may have been so small in 2012 they went undetected.

The density of juvenile trees and shrub recorded in the remnant woodlands in 2013 ranged from 29 - 110 per 0.1 ha monitoring plot. Two rehabilitation sites did not fall within this range and these were LFO-01 and Estcourt 1997.

The most common shrubs recorded in the reference sites were *Acacia deanei*, *A. hakeoides*, *Dodonaea viscosa subsp. cuneata* (Wedge-leaved Hopbush), *Senna artemisioides subsp. filifolia* (Sliver Cassia) and juvenile *Callitris glaucophylla*. There were also a small number of the dominant tree species in several plots. The diversity of shrubs and juvenile trees recorded in the rehabilitation sites were often greater than this and while most species were typically local, some species may not be strictly considered locally endemic woodland species.

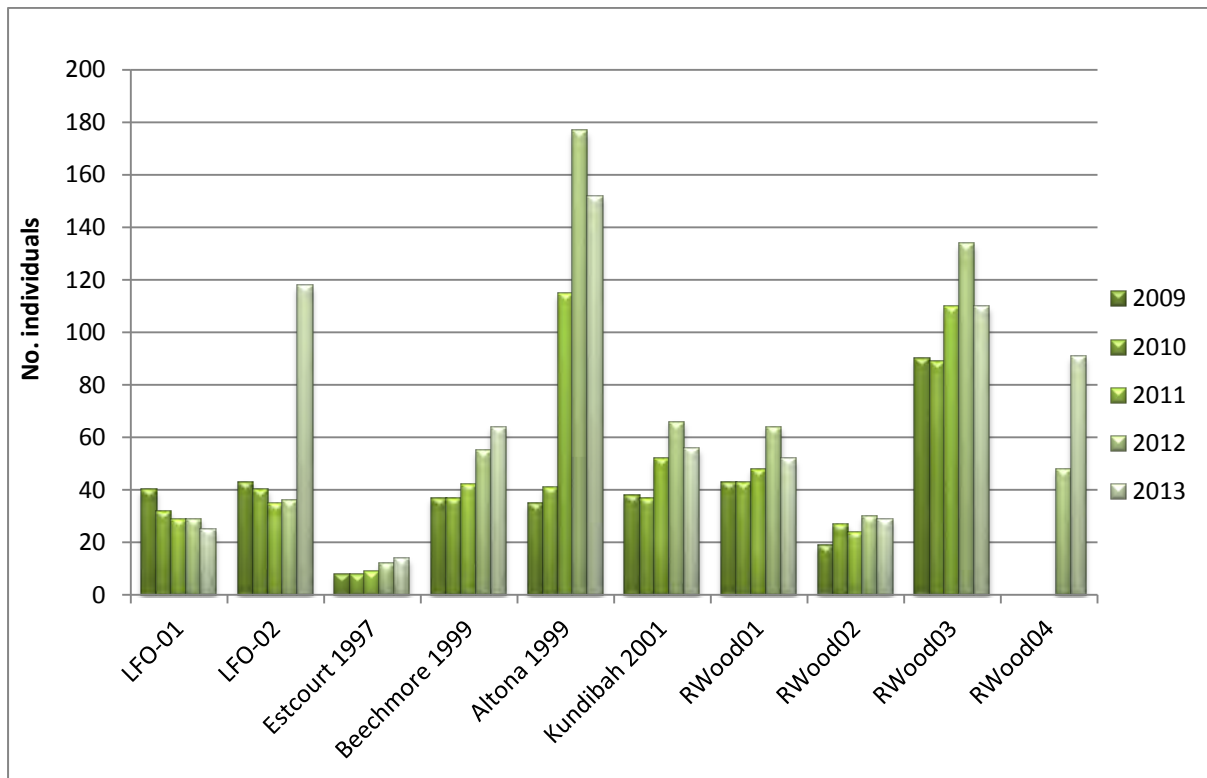


Figure 6-6. Total live shrubs recorded in the woodland rehabilitation sites compared to the woodland reference sites.

6.4 Total ground cover

Total ground cover, which is a combination of leaf litter, annual plants, cryptogams, rocks, logs and live perennial plants (<0.5m in height) demonstrated a marginal decrease across all monitoring sites this year, with the exception of RWood01. The target range for total ground cover levels was therefore slightly narrower and this year provided a total ground cover target ranging from 89 – 93.5% (Figure 6-7).

Last year all sites except Beechmore contained appropriate levels of ground cover however this year, there was a significant reduction recorded in Altona, and along with Beechmore remained low in protective ground cover. Despite having less cover the remaining rehabilitation sites ranged from a low of 89.5% in Estcourt and Kundibah, to a high of 93% in LFO-02. Interestingly the two youngest rehabilitation sites LFO-01 and LFO-02 had the highest level of cover this year.

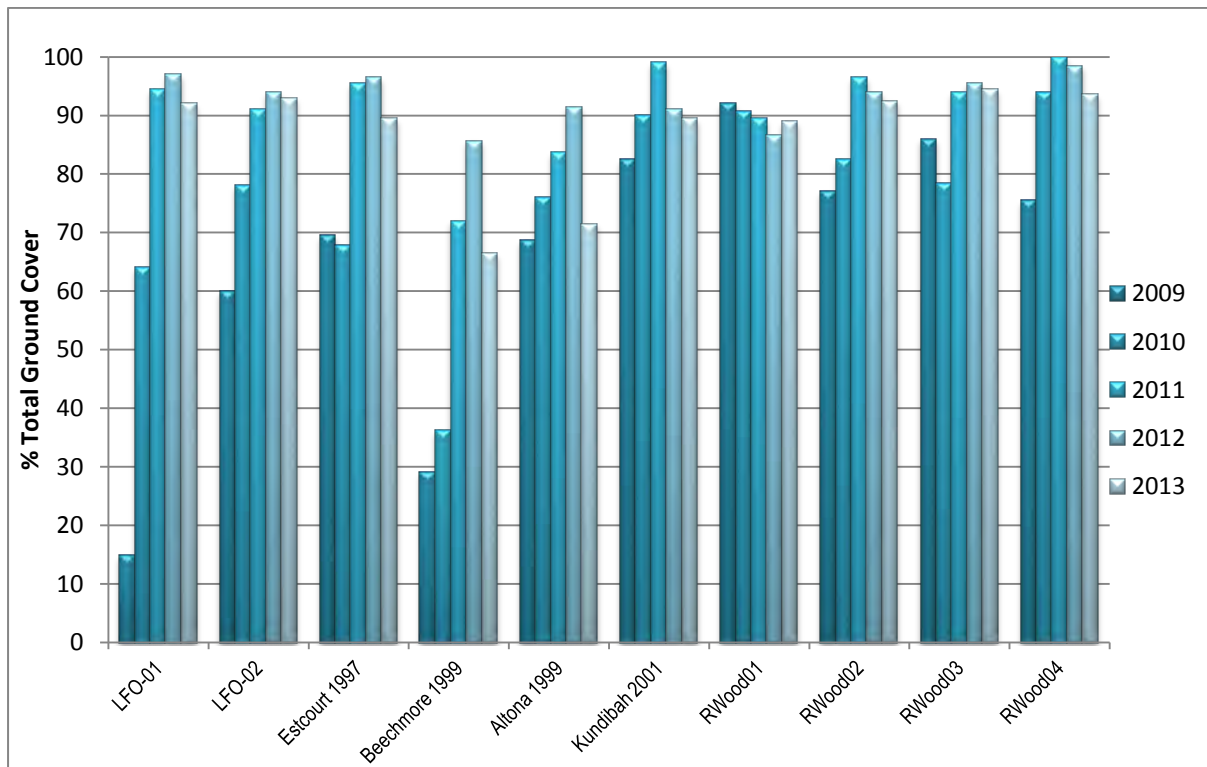


Figure 6-7. Total ground cover recorded in the woodland rehabilitation sites compared to the woodland reference sites.

6.5 Structural composition

The structural composition of the woodland sites is provided in Figure 6-8 which indicates the most dominant form of ground cover continues to be provided by dead leaf litter in all woodland sites. Low growing scattered perennial grasses and forbs are also an important component in the woodland reference sites but have provided comparatively low levels of ground cover especially during the last two years due to the dry conditions. The perennial ground cover targets have declined from a range of 9 – 35.5% last year to 6.8 – 25.0% this year. LFO-01, Estcourt and Beechmore did not meet these targets this year with very low covers of 1.0%, 6.5% and 5.0% perennial ground cover respectively.

Cryptogams also continued to be a small but very important ground cover component as these were colonising areas of otherwise bare and very hard setting soils. While no cryptogams were recorded in RWood04, up to 8.5% on average were recorded in all other monitoring sites.

Annual plants continued to provide significant levels of ground cover within the two young Limestone Forest rehabilitation sites, but in the older more established sites annual plants continued to be much less significant or were not present at all. This year however, there was a significant increase in annual plant cover in RWood04 which reached 21.5% cover, however the level of annual plant cover in both LFO rehabilitation exceeded this with 45.5% and 22.5% annual plant cover respectively.

Rocks were typically not encountered but there were low levels of log cover in the three of the four reference sites which provide additional ground cover protection and critical habitat diversity. Due to a fallen dead shrub, a small amount of log cover was now recorded in Altona 1999.

All sites contained at least some vertical structure 0.5 – 2.0m in height and all but the two young Limestone Forest rehabilitation areas contained foliage cover within each of the 2.0m height classes and all had some canopy cover exceeding 6.0m in height, indicating good growth and establishment and the development of a mature canopy layer. Rehabilitation sites Estcourt and Beechmore had a

mature canopy cover which now provided similar levels of projected foliage cover as the naturally occurring woodland communities. The structural compositions of the different woodland monitoring sites are provided in Table 6-2.

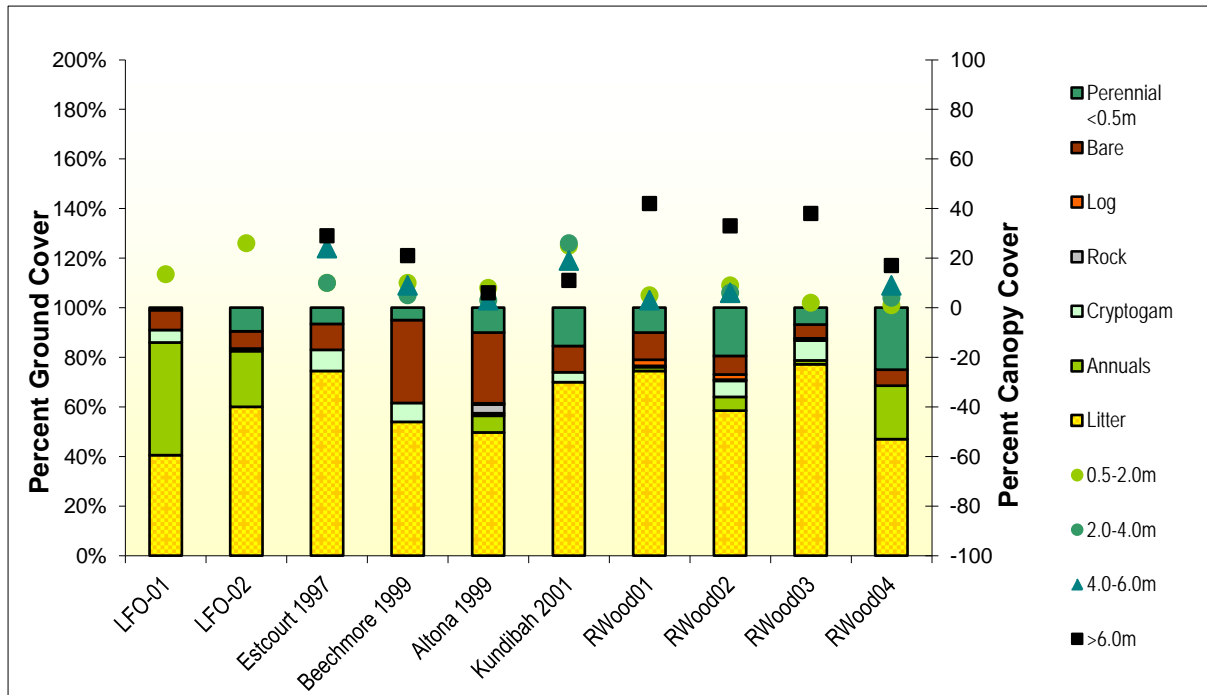
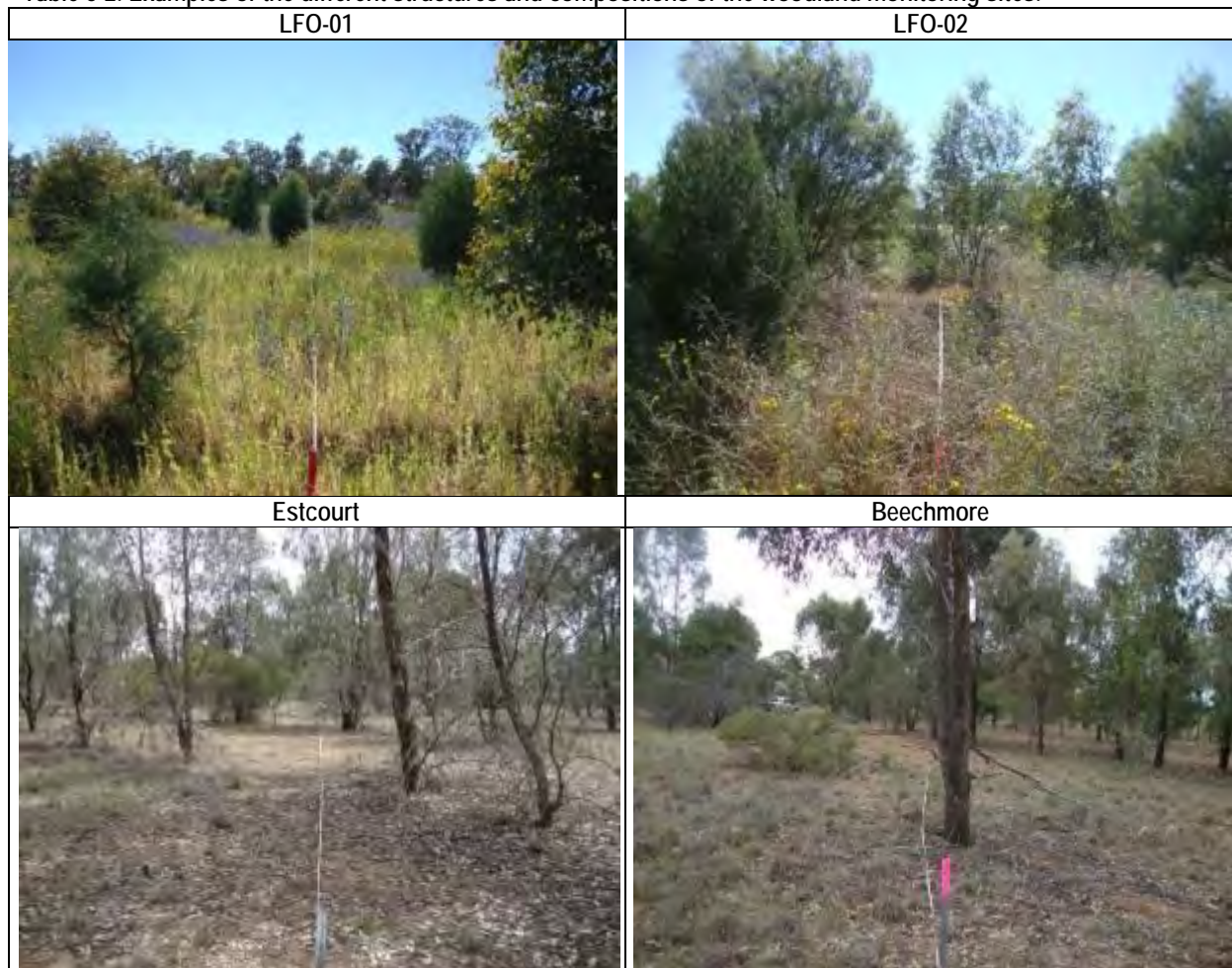


Figure 6-8. Average percent ground cover and projected foliage cover recorded in the woodland monitoring sites in 2013.

Table 6-2. Examples of the different structures and compositions of the woodland monitoring sites.





6.6 *Species Diversity*

6.6.1 Total species diversity

In 2010 there was a significant increase in total species diversity in all sites due to improved seasonal conditions after a long drought period. Since then there has been no consistent trend in the changes in species diversity across the range of sites however then tended to a higher diversity recorded in the reference sites this year with a total of 53 – 76 different plant species (Figure 6-9).

Rehabilitation sites which also had an increase in species diversity included Estcourt, Altona and Kundibah. Rehabilitation sites that did not contain an adequate level of plant diversity included LFO-01, Estcourt and Beechmore which had 46, 42 and 47 different species respectively.

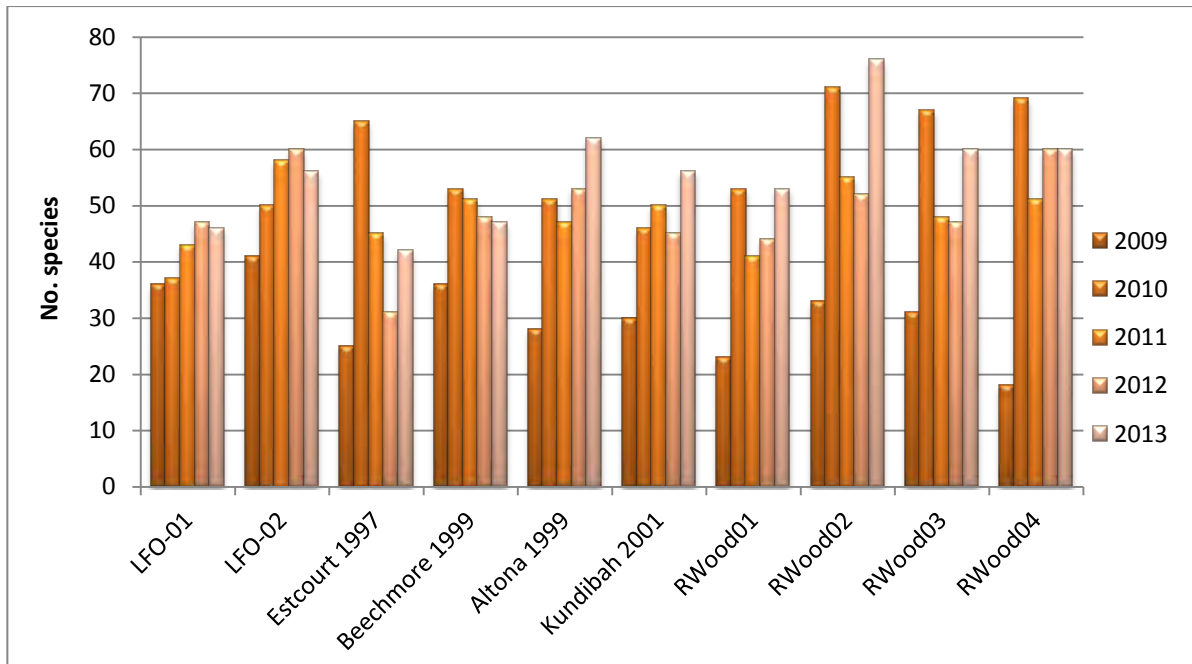


Figure 6-9. Total species recorded in the rehabilitation sites compared to the woodland reference sites.

6.6.2 Native species diversity

In the woodland reference sites there was an increase in the number of native species in three of the four sites but there were nine species less in RWood03, resulting in a lower minimum but higher maximum native diversity target of 33 – 53 species (Figure 6-10). A minor increase in the number of native species was also recorded in Estcourt, Altona and Kundibah, while the remaining sites contained slightly fewer.

This year sites which met this diversity target included Estcourt, Beechmore and Kundibah which had 33, 42 and 46 native species respectively. The lowest native species diversity continued to be recorded in LFO-01 with 19 species.

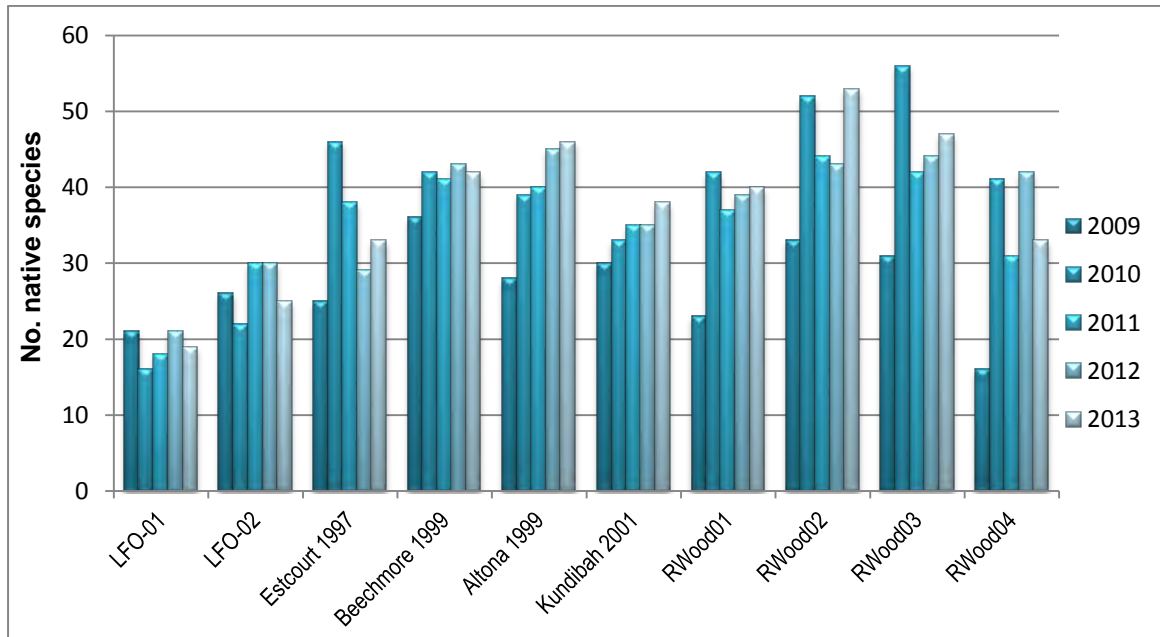


Figure 6-10. Native species recorded in the rehabilitation sites compared to the woodland reference sites.

6.6.3 Exotic species diversity

There was a consistent increase in the number of exotic species recorded across all woodland monitoring sites this year except in Beechmore which remained unchanged. There were relatively large increases in the reference sites increasing the minimum acceptable level to 27 exotic species, most of which were annual weeds associated with an old stockcamp (Figure 6-11). As a result all rehabilitation sites except LFO-02 which had 31 exotics could be said to have an acceptable level of exotics species.

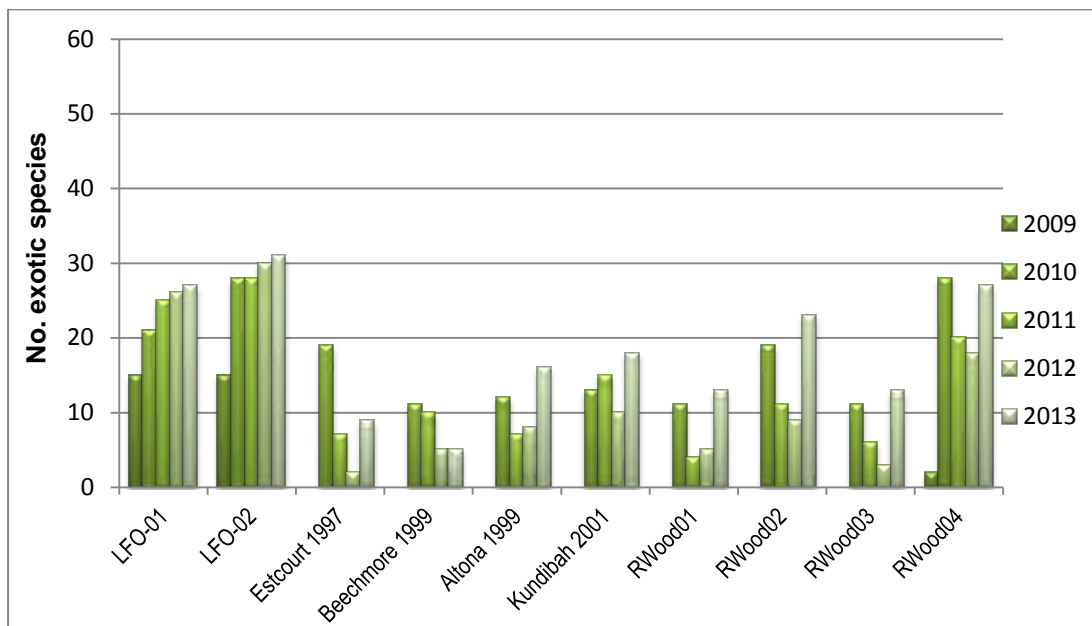


Figure 6-11. Exotic species recorded in the rehabilitation sites compared to the woodland reference sites.

6.6.4 Summary

This year there were no consistent trends in the changes in plant diversity across the range of monitoring sites however in most cases there was a relatively large increase in exotic species richness. While conditions were particularly dry at the time of monitoring, above average rainfall in June had resulted in a flush of plant growth with exotic species tending to persist in lower depressions and in disturbed shady areas beneath tree canopies (i.e. old stockcamps). Other factors that are likely to have affected species diversity include selective browsing, degree of grazing pressure and extent of disturbance, combined with some degree of sampling variability.

Nonetheless the results however indicate there is typically a lack of native plant diversity within the younger Limestone Forest rehabilitation sites, and these sites were weedier than desired. The older rehabilitation areas Estcourt, Beechmore and Kundibah generally contained an adequate richness of native and exotics species.

6.7 *Percent endemic ground cover*

In 2012, the percent endemic ground cover was included as an additional ecological indicator to provide some measure of the cover abundance of the native vegetation and an indication of its weediness (Figure 6-12). In the woodland rehabilitation sites cover provided by native species was demonstrating an increasing trend up until this year where all sites had a reduction in native plant cover. This year native species in the reference sites provided a much lower range of 63.4 – 87.1% of the total live plant cover.

The older rehabilitation sites Estcourt, Beechmore and Kundibah met this ecological target this year with endemic plant covers providing 92.6%, 86.8% and 72.2% respectively while the remaining sites did not and were presently more weedy than desired. Sites LFO-01 and LFO-02 had comparatively low native plant ground cover which ranged from 38.6% and 17.8% respectively but these are expected to improve over time as the native perennial ground covers begin to establish.

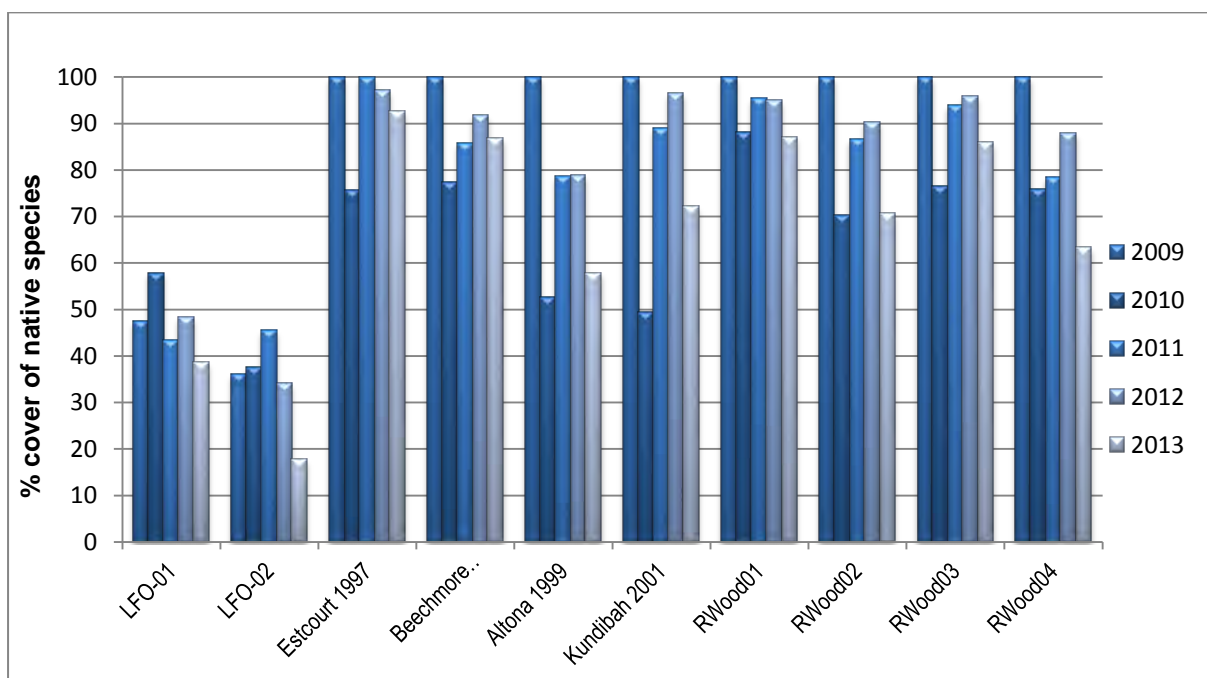


Figure 6-12. Percent endemic ground cover recorded in the woodland monitoring sites.

6.8 Most common species

The number of species recorded across the range of woodland rehabilitation sites has ranged between 97 – 151 species since 2009 with 24 – 45% of these being exotic species (Table 6-4).

Table 6-3. Summary of the number of species recorded in the rehabilitation monitoring sites since 2009.

Year	No. sites	Total species	% Exotic species
2009	6	97	24
2010	6	151	39
2011	6	141	35
2012	6	136	31
2013	6	139	45

In 2013, two species were common to all rehabilitation sites and these were a native perennial forb *Dichondra repens* (Kidney Weed) and the exotic annual grass *Lolium rigidum* (Wimmera Ryegrass) and these too were present in almost all of the woodland reference sites, indicating they are very common in the local area.

Two species of endemic acacia including *Acacia deanei* (Deane's Wattle) and *A. hakeoides* (Hakea Wattle) and *Eucalyptus populnea* (Bimble Box) which were planted as part of the rehabilitation were recorded in five of the six sites, while numerous other native tree and shrubs species were also common in the planted sites.

Other common volunteer species included the natives *Carex inversa* (Knob Sedge), *Walwhalleya proluta* (Rigid Panic), *Oxalis perennans* (Yellow Wood-sorrel) and *Convolvulus erubescens* (Australian Bindweed). Common exotic species included *Avena fatua* (Wild Oats), *Echium plantagineum* (Paterson's Curse) and *Trifolium glomeratum* (Clustered Clover).

A range of other annual species especially *Medicago* and *Trifolium* species may also have been common and abundant but most of these had since died and therefore were not included in the live species diversity data. A comprehensive list of species recorded in all monitoring sites in 2013 has been included in Appendix 1.

Table 6-4. Species that were recorded in at least four of the six woodland rehabilitation monitoring sites in 2013.

Family	exotic	Scientific Name	Common Name	Habit	LFO-01	LFO-02	Beechmoore	Estcourt	Altona	Kundibah	Total	RWood01	RWood02	RWood03	RWood04
Convolvulaceae		<i>Dichondra repens</i>	Kidney Weed	h	1	1	1	1	1	1	6		1	1	1
Poaceae	*	<i>Lolium rigidum</i>	Wimmera Ryegrass	g	1	1	1	1	1	1	6	1	1	1	1
Fabaceae (Mimosoideae)		<i>Acacia deanei</i>	Green Wattle	s		1	1	1	1	1	5		1		
Cyperaceae		<i>Carex inversa</i>	Knob Sedge	r		1	1	1	1	1	5		1		
Poaceae		<i>Walwhalleya proluta</i>	Rigid Panic	g		1	1	1	1	1	5			1	
Fabaceae (Mimosoideae)		<i>Acacia hakeoides</i>	Hakea Wattle	s		1	1	1	1	1	5	1		1	
Poaceae	*	<i>Avena fatua</i>	Wild Oats	g	1	1		1	1	1	5		1	1	
Myrtaceae		<i>Eucalyptus populnea</i>	Bimble Box	t	1	1	1	1		1	5		1		1
Plantaginaceae	*	<i>Echium plantagineum</i>	Paterson's Curse	h	1	1	1		1	1	5	1	1		1
Oxalidaceae		<i>Oxalis perennans</i>	Yellow Wood-sorrel	h		1	1	1	1	1	5	1	1	1	
Convolvulaceae		<i>Convolvulus erubescens</i>	Australian Bindweed	h		1	1	1	1	1	5	1	1	1	1
Fabaceae (Faboideae)	*	<i>Trifolium glomeratum</i>	Clustered Clover	h	1	1		1	1	1	5	1	1	1	1
Fabaceae (Faboideae)	*	<i>Trifolium tomentosum</i>	Woolly Clover	h	1	1			1	1	4				
Myrtaceae		<i>Eucalyptus melliodora</i>	Yellow Box	t			1	1	1	1	4				1
Sapindaceae		<i>Dodonaea viscosa subsp. cuneata</i>	Wedge-leaf Hopbush	s	1		1	1		1	4	1		1	
Chenopodiaceae		<i>Einadia nutans subsp. linifolia</i>	Climbing Saltbush	h			1	1	1	1	4	1		1	
Myrtaceae		<i>Eucalyptus microcarpa</i>	Grey Box	t	1	1	1			1	4	1		1	
Asteraceae		<i>Euchiton sphaericus</i>	Japanese Cudweed	h	1	1			1	1	4			1	1
Poaceae	*	<i>Hordeum leporinum</i>	Barley Grass	g	1	1		1	1		4	1			1
Chenopodiaceae		<i>Salsola kali</i>	Buckbush	ss	1	1	1		1		4	1		1	
Asteraceae	*	<i>Carthamus lanatus</i>	Saffron Thistle	h	1	1		1		1	4	1	1		1
Asteraceae	*	<i>Lactuca serriola</i>	Prickly Lettuce	h	1	1			1	1	4	1	1	1	1
Asteraceae	*	<i>Sonchus oleraceus</i>	Milk Thistle	h	1	1			1	1	4	1	1	1	1

6.9 Vegetation composition

The composition of the vegetation as categorised by seven different growth forms is given in Figure 6-13. In the reference sites herbs were the most dominant growth form with 33 - 46 different species followed by grasses which had 9 - 22 species. There were 2 - 4 tree species, 1 - 3 shrub species and 1 - 5 different sub-shrubs. There was one reed and one fern species in RWood02.

The woodland rehabilitation sites appear to be imitating that of the reference sites but notable differences include the higher number of tree species and low diversity of herbs and forbs in the four older rehabilitation sites. In the Limestone Forest Offset planting areas there was a lack of grass species. Subsequently no site yet contains an adequate composition of species.

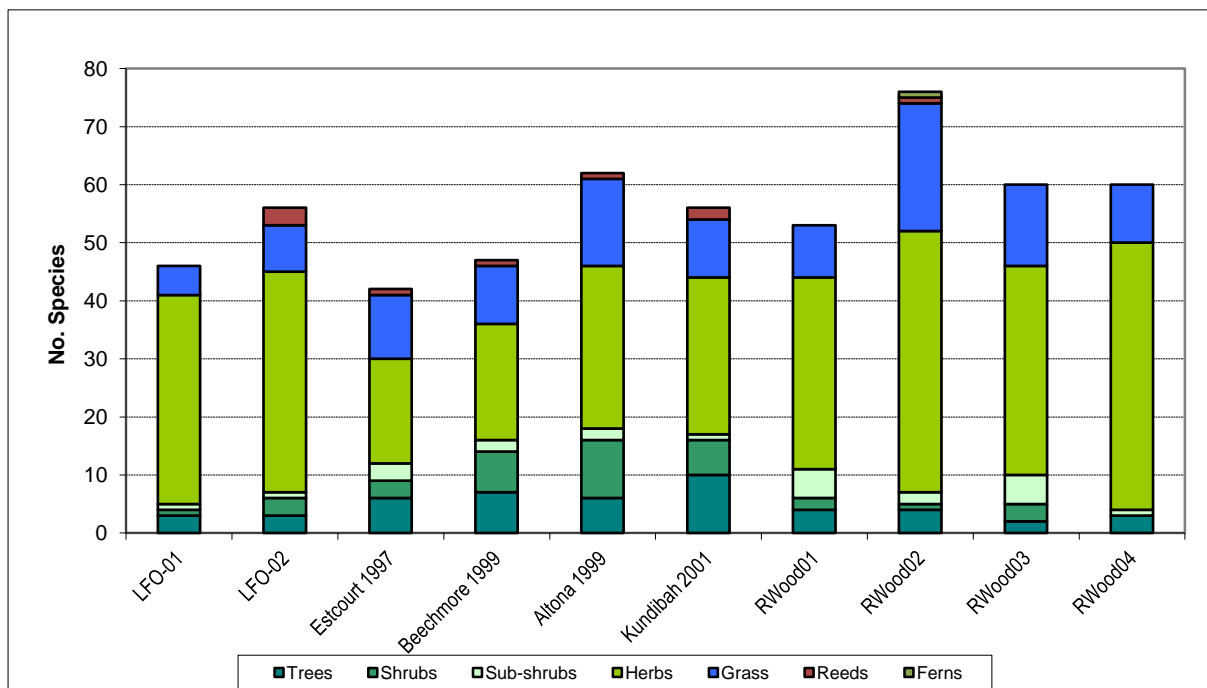


Figure 6-13. Composition of the vegetation recorded in the woodland rehabilitation sites compared to the woodland reference sites.

6.10 Rill assessment

No rills were recorded in any woodland rehabilitation site.

6.11 Soil analyses

6.11.1 pH

Figure 6-14 shows the pH recorded in the woodland rehabilitation sites compared to the upper and lower pH values recorded in the woodland reference sites and prescribed "desirable" levels in medium soils. The pH range recorded in the remnant woodlands had slightly expanded this year to provide a target range of 5.99 – 7.10, with these soils being moderately acidic to neutral.

There has been no consistent trend in the change in pH recorded across any site since 2009 but this year there was a noticeable reduction in the younger Limestone Forest sites as well as in Altona with the soil in these sites now falling in the strongly acidic soil class (Bruce & Rayment 1982). While a lower pH range was also recorded in the reference sites, these rehabilitation sites fell below the target range and desirable levels and were more acidic than desired. Conversely, increased soil pH was recorded in Estcourt and Beechmore, while no change was observed in Kundibah and these sites continued to fall within acceptable pH ranges.

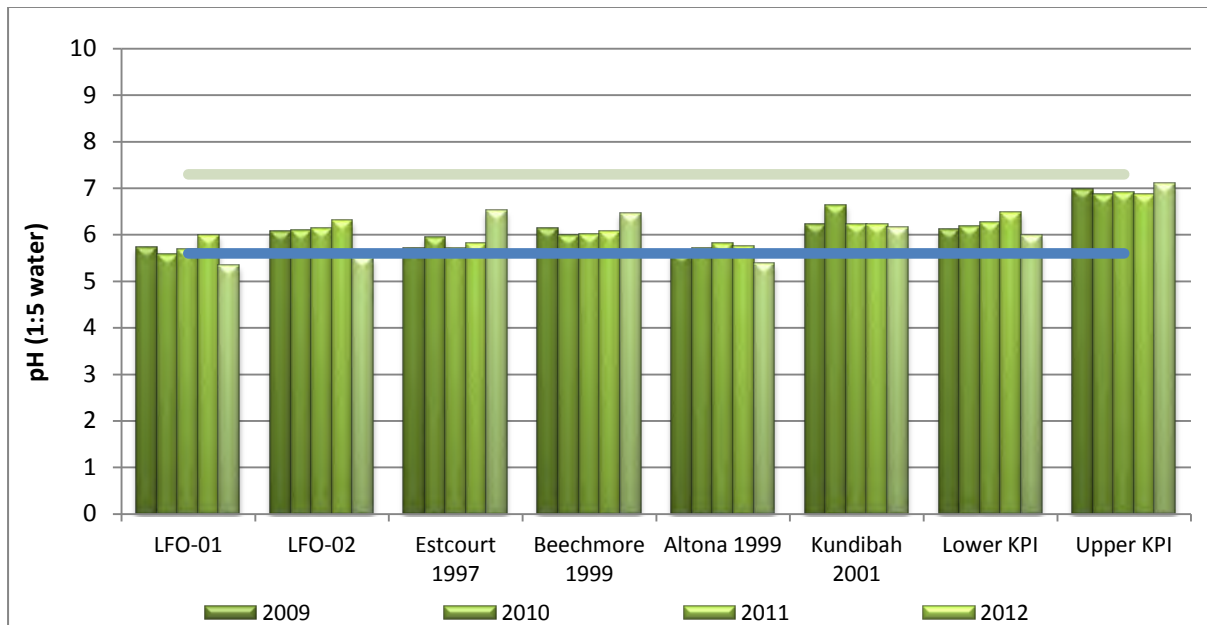


Figure 6-14. Comparison of pH values recorded in the woodland rehabilitation sites, upper and lower values from the woodland reference sites and desirable levels.

6.11.2 Conductivity

Figure 6-15 shows the Electrical Conductivity (EC) recorded in the rehabilitation sites, the lower and upper values of the woodland reference sites as well as the “desirable” level provided by the laboratory in medium soils. Since 2009 there has typically been a declining trend in EC across the range of monitoring sites. This year however, there continued to be a declining trend in the minimum EC target range, but there was also a large increase in the upper EC target range which provided a target range of 0.038 – 0.191 dS/m but these remained within non saline levels (Slavich & Petterson 1993).

The Limestone Forest rehabilitation sites LFO-01 and LFO-02 and Kundibah have continued to demonstrate a declining trend, while increased EC was recorded in Estcourt, Beechmore and Altona but all rehabilitation sites were within the local EC levels. EC levels in the rehabilitation sites ranged from a low of 0.039 dS/m (LFO-02) to a high of 0.113 dS/m (Estcourt).

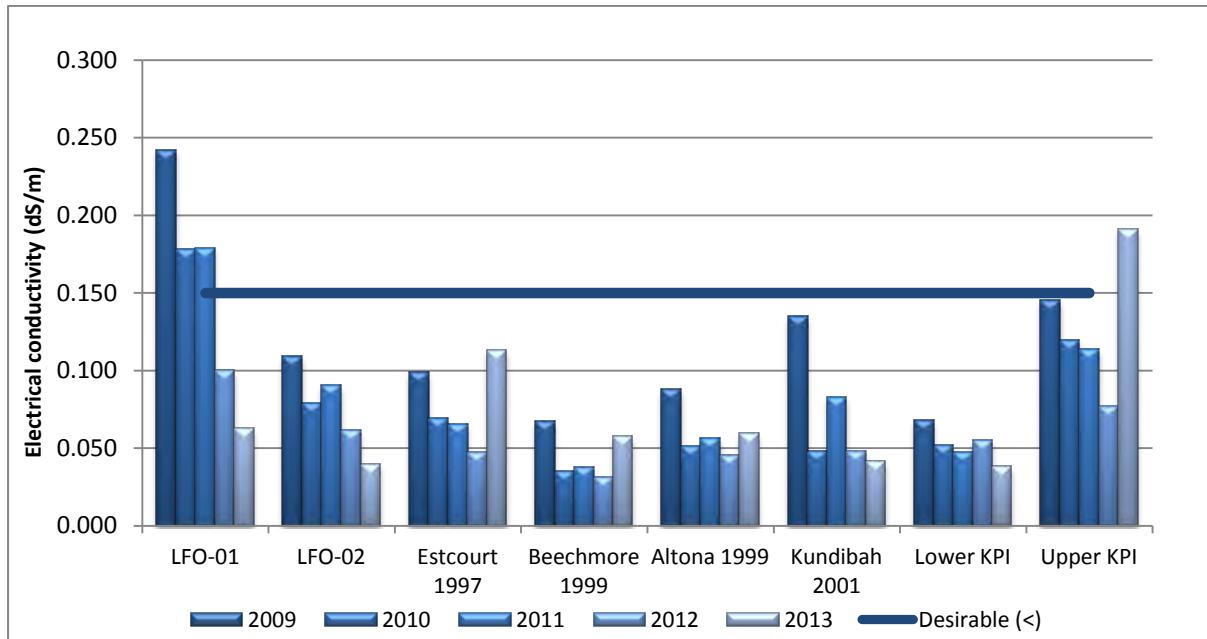


Figure 6-15. Comparison of conductivity values recorded in the woodland rehabilitation sites compared to the upper and lower values from the woodland reference sites and desirable levels.

6.11.3 Organic Matter

There has been no consistent trend in the changes in the percentage Organic Matter (OM) recorded in the rehabilitation sites since monitoring began except that the highest levels were recorded in 2009 and there may be a declining trend across most of the monitoring sites. This year the KPI range has continued to decrease to provide a target range of 3.0 – 4.35% OM (Figure 6-16).

OM recorded in the rehabilitation sites had also tended to demonstrate a declining trend across all sites except Beechmore, but Beechmore and Altona fell within the local levels with OM levels of 4.6% and 4.2% respectively. The lowest OM was recorded in LFO-02 which had OM of 1.9%.

The low OM percentages in the rehabilitation sites are not unusual as many of the sites are immature and under normal circumstances organic matter levels would be expected to increase with time as the vegetation and dead leaf litter accumulate and decompose as a result of increased fungal and microbial activities which result in the development of a humus profile which is rich in organic material. The prolonged dry conditions however have tended to increase predation and disturbance levels within many of the sites, creating bare patches with the potential for topsoil and the developing soil profile to deteriorate and erode. In addition, the rehabilitation sites were already inherently patchy. Despite this apparently declining trend, most changes were relatively minor (<1%).

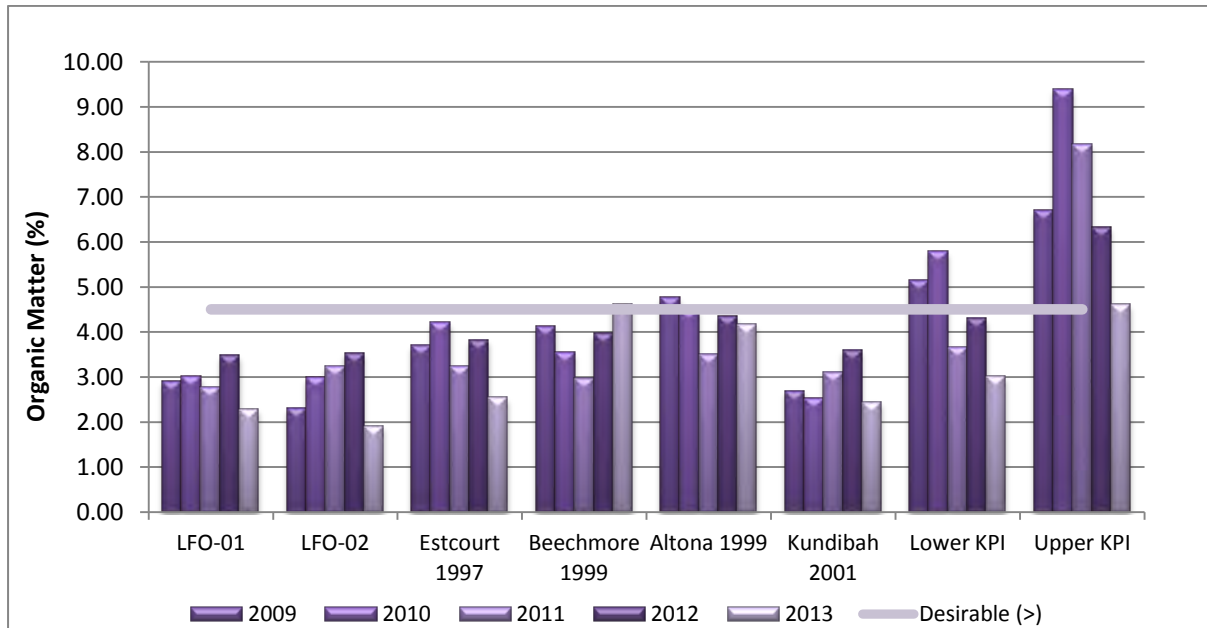


Figure 6-16. Comparison of percent organic matter recorded in the woodland rehabilitation sites compared to the upper and lower values from the woodland reference sites and desirable levels.

6.11.4 Phosphorous

Phosphorous levels continued to be lower than the desirable level in the woodland reference sites reflecting the naturally low soil fertility in the local area these had further declined providing a target range of 6 – 17 mg/kg (Figure 6-17). Phosphorous levels in the woodland rehabilitation sites also showed a consistent decline this year however LFO-01 continued to far exceed the local range as well as concentrations prescribed by the agricultural which is likely to be related to the long cropping and fertilising history.

While some sites including LFO-02 and Altona were slightly higher than the target range, all sites except LFO-01 fell within acceptable levels. High phosphorous concentrations in LFO-01 are expected to continue to decline over time provided additional fertiliser is not applied. While phosphorous levels are typically very low in the other sites, the addition of artificial fertilisers is generally not encouraged as unnatural increases in fertility levels are more likely to promote growth of undesirable weeds rather than invigorate growth of desirable species which are adapted to naturally low fertility soils.

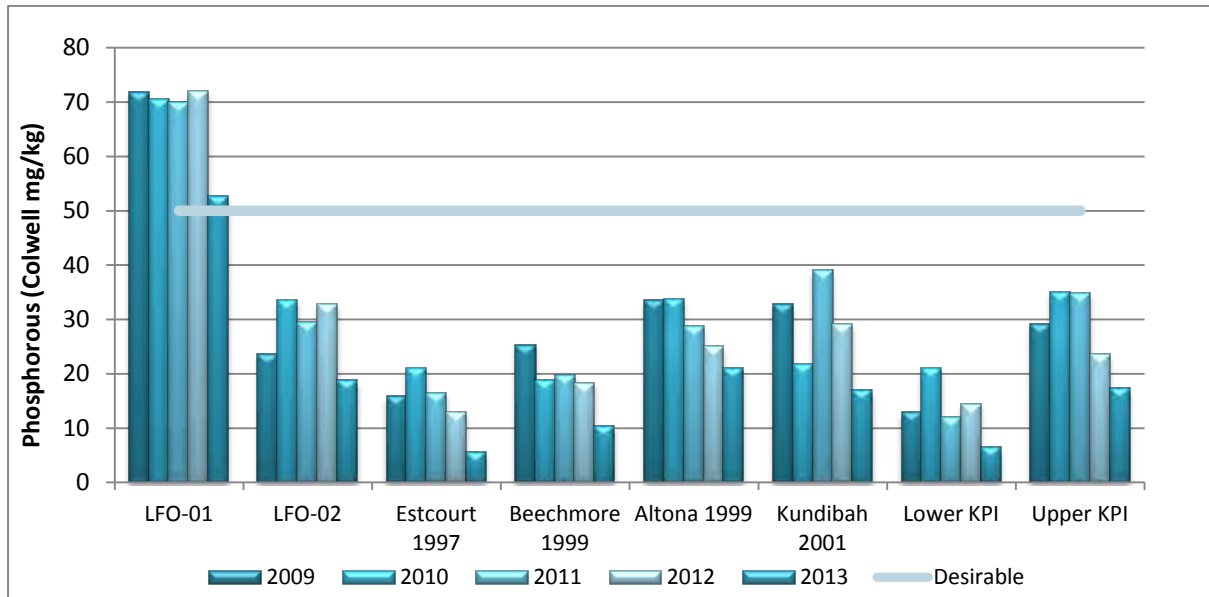


Figure 6-17. Comparison of phosphorous levels recorded in the woodland rehabilitation sites compared to the upper and lower values from the woodland reference sites and desirable levels.

6.11.5 Nitrate

The concentration of nitrates recorded in the woodland reference sites have also declined this year and now provided a very low target of 1.2 – 1.9 mg/kg (Figure 6-18), which is also a reflection of the naturally low soil fertility around NPM. These concentrations are significantly lower than that prescribed by the agricultural industry.

A declining trend was also consistent across the woodland rehabilitation sites. While LFO-02 and Altona had concentrations which were slightly higher than the reference target, they remained significantly lower than the agricultural standards. Nitrate levels in LFO-01 and Kundibah had fallen considerably low and with a concentration of 1.0 mg/kg recorded this year were marginally lower than the local levels. The remaining sites had acceptable nitrate levels.

Nitrate levels are often unpredictable with high rainfall stimulating microbial growth and fungal activity within the soil profile often resulting in a peak in nitrate levels. The prolonged dry conditions have probably resulted in the continued utilisation of nitrates. While nitrate levels are typically very low, the addition of nitrate fertilisers is generally not encouraged as unnatural increases in fertility levels are more likely to promote growth of undesirable weeds rather than invigorate growth of desirable species which are adapted to naturally low fertility soils.

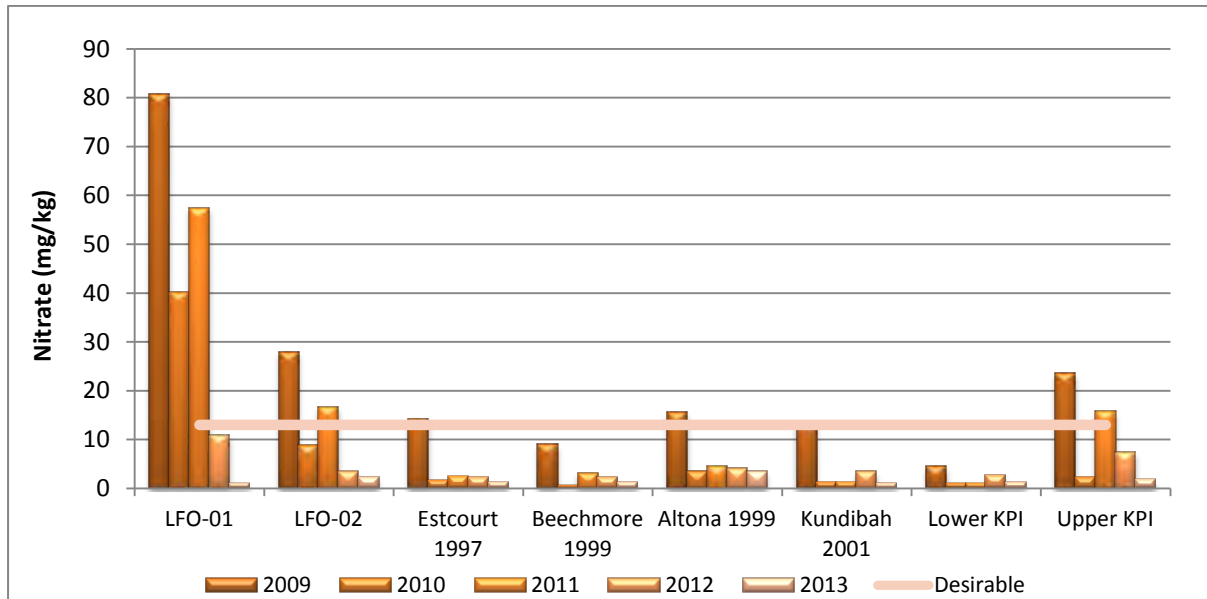


Figure 6-18. Comparison of Nitrate levels recorded in the woodland rehabilitation sites compared to the upper and lower values from the woodland reference sites and desirable levels.

6.11.6 Cation Exchange Capacity

Cation Exchange Capacity (CEC) is the capacity of the soil to hold the major cations (Calcium, Magnesium, Sodium and Potassium) and is also a measure of the potential fertility of the soil. This year the CEC target had widened to provide a range of 12.0 – 22.9 cmol/kg (Figure 6-19). In the rehabilitation sites, there was no consistent change with LFO-01, LFO-02 and Altona demonstrating a small decrease, while the remaining sites had a slightly higher CEC. Sites which contained an adequate CEC this year included Estcourt, Beechmore and Kundibah.

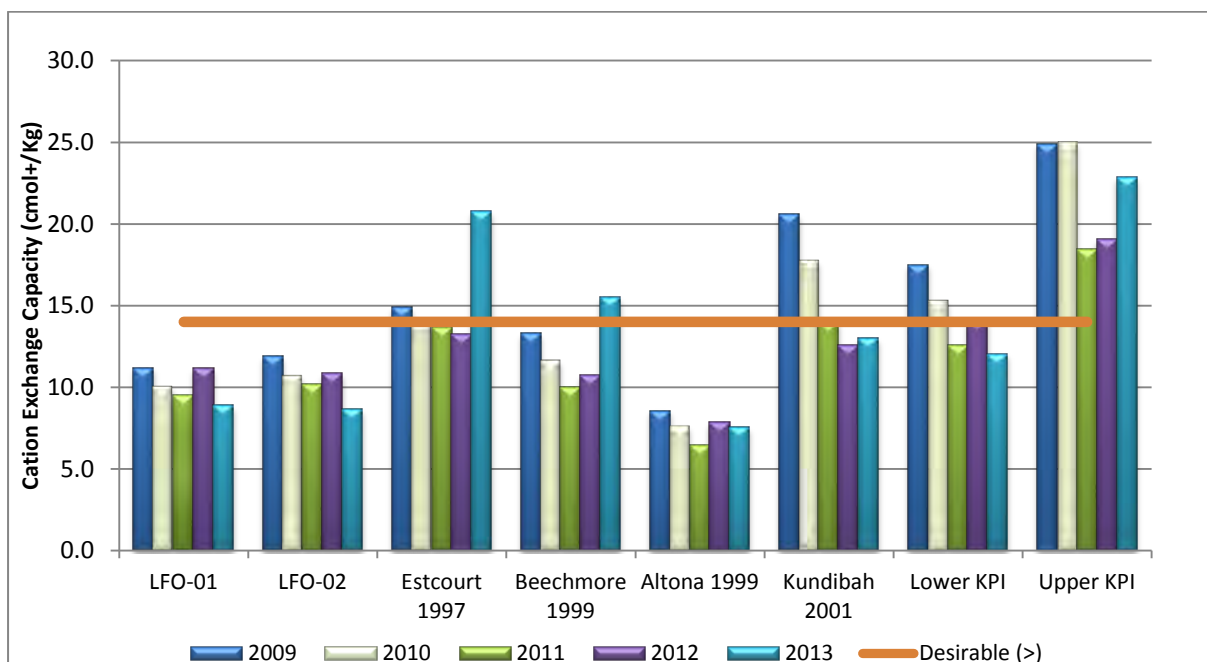


Figure 6-19. Comparison of Cation Exchange Capacity recorded in the woodland rehabilitation sites compared to the upper and lower values from the woodland reference sites and desirable levels.

6.11.7 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.

This year significant increase in ESP were recorded in the older rehabilitation sites, with Estcourt now having an ESP of 8.94% which far exceeded the desirable levels and exhibiting concentration which indicate the soils were sodic (Isbell 1996), while in Beechmore ESP levels were just below the desirable threshold (Figure 6-20). Small increases in ESP were also recorded in the woodland reference sites which provided a natural target range of 0.29 – 2.42% this year. While LFO-01, LFO-02 and Altona fell within these local levels, Kundibah remained well below the threshold with an ESP of 3.76%.

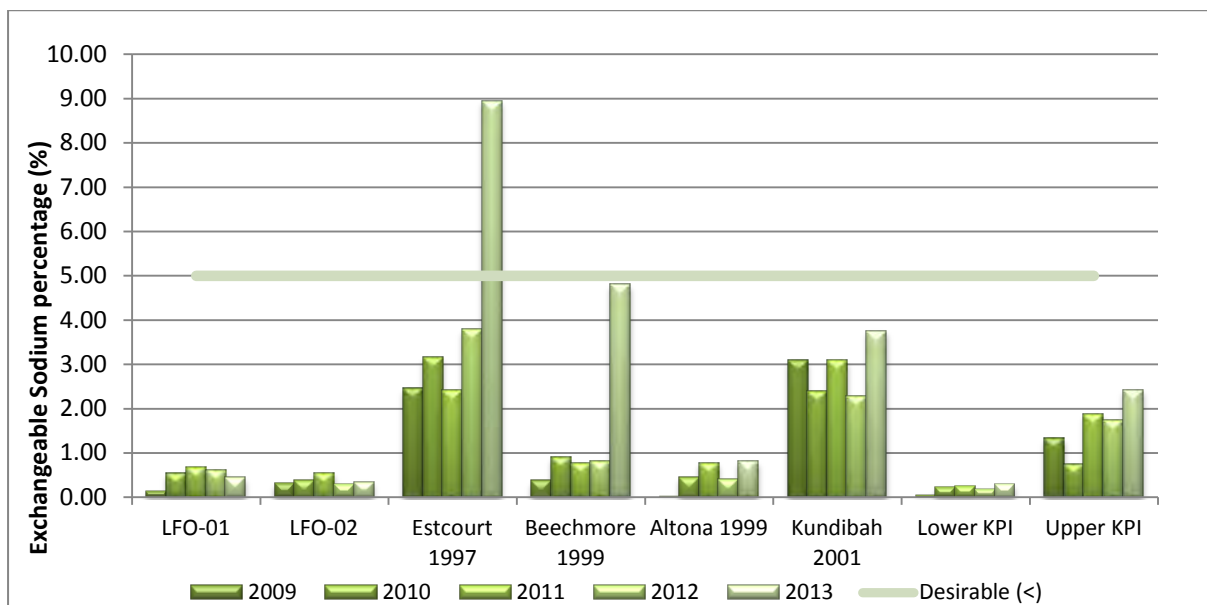


Figure 6-20. Comparison of ESP recorded in the woodland rehabilitation sites compared to the upper and lower values from woodland reference sites and desirable levels.

6.11.8 Other soil test results

The full results of the soil analysis are provided in Appendix 3 and 4 but a summarised version highlighting abnormal results is provided in Table 6-5. The results indicate there are numerous elements which occur at elevated levels in the rehabilitation sites, however in most cases these are also found to be elevated within the woodland reference sites. As these woodland rehabilitation areas are essentially tree planting enhancement projects (rather than rehabilitation of mine disturbed areas), the results tend to indicate that various elements may occur at naturally high levels within soils surrounding the Northparkes Mines which may be implicated with landscape clearing, as well as a long agricultural and mining history.

In 2013 there were very high levels of Magnesium, Potassium, Manganese, Iron, Copper and Silicon in numerous sites. Sites with particularly high concentrations of a variety of elements and heavy metal include those situated in the Limestone Forest (LFO-01, LFO-02 and RWood04) as well as Altona, an old gravel quarry site. The high concentration of these combinations of these elements may have the potential to affect plant establishment and ecosystem development.

Table 6-5. Summarised soil analyses highlighting abnormal test results in the woodland monitoring sites in 2013.

Method		Nutrient	Site		LF0-01	LF0-02	Estcourt	Beechmore	Altona	Kundibah	RWood01	RWood02	RWood03	RWood04	Medium Soil e.g Clay Loam
	Morgan 1	Calcium	Ca	mg/kg	617	571	841	815	426	604	1508	1183	2118	796	750
		Magnesium	Mg		115	143	604	396	121	413	458	520	682	228	105
		Potassium	K		252	255	115	155	285	114	256	181	134	242	75
	KCl	Sulfur	S	mg/kg	18.4	9.4	7.0	2.7	12.9	4.9	7.1	4.3	8.0	10.1	8.0
	DTPA	Zinc	Zn	mg/kg	1.3	1.1	0.3	0.9	1.4	0.6	1.4	0.7	0.5	6.9	5.0
		Manganese	Mn		93	78	78	75	120	61	108	37	46	92	22
		Iron	Fe		111	80	83	56	205	102	40	30	36	61	22
		Copper	Cu		8.0	10.5	4.2	3.3	15.0	4.0	3.5	5.5	3.0	15.8	2.0
	CaCl ₂	Silicon	Si	mg/kg	80	66	104	92	57	98	32	108	34	66	45
	Total Acid Extractable	Chromium	Cr	mg/kg	30	27	21	19	19	18	21	73	21	20	<25 Cr

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

6.12 Woodland rehabilitation site performance towards meeting completion criteria targets

Table 6-6 indicates the performance of the rehabilitation monitoring sites against a selection of proposed Completion Performance Indicators developed for woodland communities during the 2013 monitoring period. The selection of criteria has been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have been identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 6-6. Performance of the rehabilitation monitoring sites against a selection of proposed Completion Performance Indicators or completion criteria.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-01	LFO-02	Estcourt 1997	Beechmore 1999	Altona 1999	Kundibah 2001
Performance indicators are quantified by the range of values obtained from replicated reference sites						Lower	Upper	2013	2013	2013	2013	2013	2013
Phase 2: Landform establishment and stability	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation	%	62.9	69.0	72.0	67.0	67.0	62.8	67.4	63.7
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation	%	41.1	55.7	34.3	38.9	41.3	39.3	50.4	44.4
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation	%	36.2	53.0	36.5	35.8	39.8	38.5	46.2	42.1
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation	%	100	100	100	100	72	81	85	95
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising	No.	0	0	0	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-01	LFO-02	Estcourt 1997	Beechmore 1999	Altona 1999	Kundibah 2001
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)	6.0	7.1	5.34	5.51	6.5	6.5	5.37	6.2
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry	% (>4.5)	3.0	4.6	2.3	1.9	2.6	4.6	4.2	2.4
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (>12.5)	1.2	1.9	1.0	2.4	1.4	1.3	3.5	1.0
Phase 4: Ecosystem& Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees	The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.	species/area	1	6	4	6	4	12	7	6
				The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation	% population	100	100	100	100	100	100	100	98
			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	13	27	27	31	9	5	16	18
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees	The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation	No./area	29	110	25	118	14	64	152	56
	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	4	3	3	6	7	6	10
			Shrubs	The number of shrub species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	3	1	3	3	7	10	6
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	33	46	36	38	18	20	28	27
	Phase 5: Ecosystem & Landuse Development	Protective ground cover	Ground layer contains protective ground cover and habitat structure comparable with the local remnant vegetation	Perennial plant cover (< 0.5m)	Percent ground cover provided by live perennial vegetation (< 0.5m in height) is comparable to that of the local remnant vegetation	%	7	25	1	9.5	6.5	5.0	10.1	15.5
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	%	89	95	92	93	89.5	66.5	71.5	89.5
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 height) compared to exotic species is comparable to that of the local remnant vegetation	%	63	87	38.6	17.8	92.6	86.8	57.9	72.2

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-01	LFO-02	Estcourt 1997	Beechmore 1999	Altona 1999	Kundibah 2001
	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	7	89	0	82	2	32	21	3
			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	18	7	8	3	4	43	8
	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	1	9	13.5	26	10	10	8	25
			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	17	42	0	0	29	21	6	11
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity	The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation	%	100	100	100	100	100	100	100	100
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees	The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation	% population	83	100	100	100	100	100	94.1	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	7	47	100	100	52.9	38.5	47.1	53
			Flowers/fruit: Trees	The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation	% population	50	83	25	50	41.2	30.8	58.8	33.3

7 Grassland rehabilitation sites: Ecological trends and performance against a selection of primary ecological performance indicators

7.1 Landscape Function Analyses

7.1.1 Landscape Organisation

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

All three grassland reference sites continued to be characterised as functional “grassland” patches which subsequently resulted in a Landscape Organisation Index (LOI) of 100% (Figure 7-1) indicating there was little to no leakage of resources. In 2012 TSF1-01 and E22-02 contained some bare and eroding areas but these have improved and this year all sites were considered to be 100% functional patch areas.

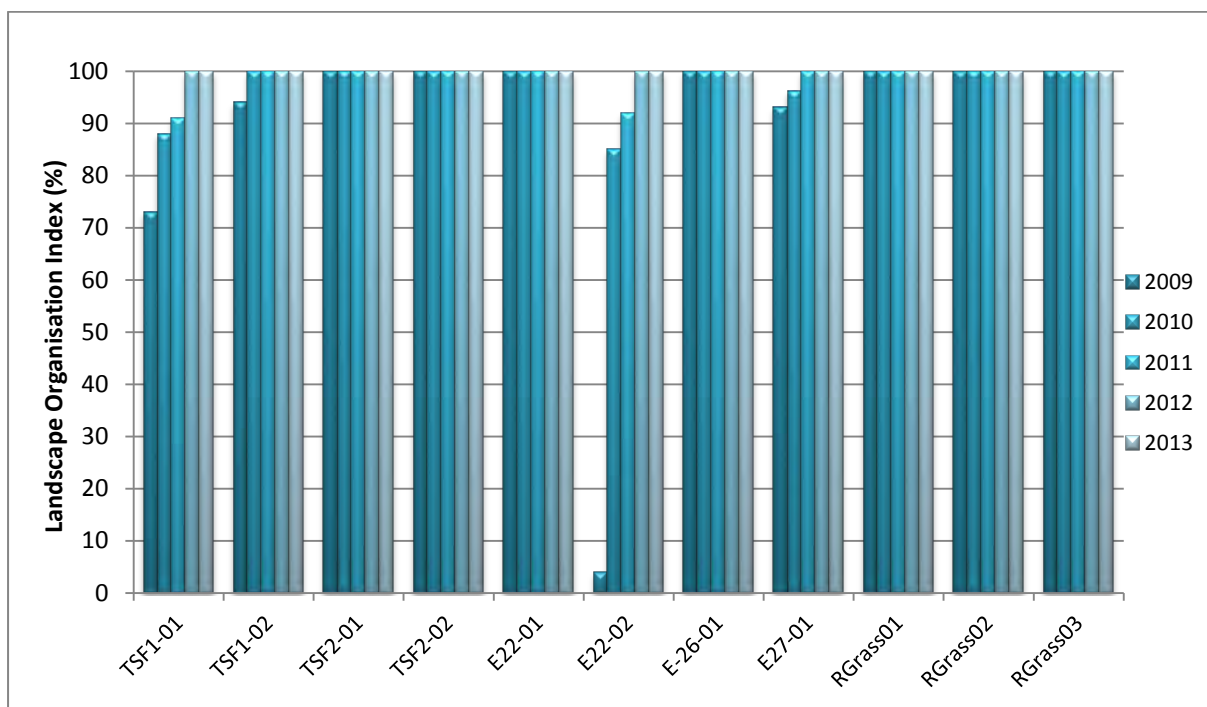


Figure 7-1. Landscape organisation indices recorded in the rehabilitation sites compared to the grassland reference sites.

7.1.2 Soil surface assessments

7.1.2.1 Stability

The LFA stability indices in the grassland reference sites have typically shown an improvement between 2009 – 2011 due to the improved seasonal conditions after the extended drought and absence of grazing pressure however prolonged dry conditions since then have resulted in slightly less stable

environments largely due to less active perennial plant covers. Nonetheless the grassland reference sites continued to provide a relatively high stability range of 64.5 – 73.0 (Figure 7-2).

Similar trends were also apparent within the grassland rehabilitation sites which have generally continued to show an improvement in stability due to increased litter and cryptogam cover and decomposition and in some sites there appeared to be increased soil coherency up until 2012. This year a slight reduction in stability was recorded in all rehabilitation sites with the exception of TSF2-01 and TSF2-02. While no change was observed in TSF2-01, a relatively large improvement was observed in TSF2-02 due in part from the exposure of a more stable but very hard setting clay soil which also provided large cracks and increased soil surface roughness.

Despite these changes all rehabilitation sites fell within the target range, with the exception of E22-02 which had a stability index 60.5. Site TSF2-02 exceeded the target ranges with a stability index of 76.0.

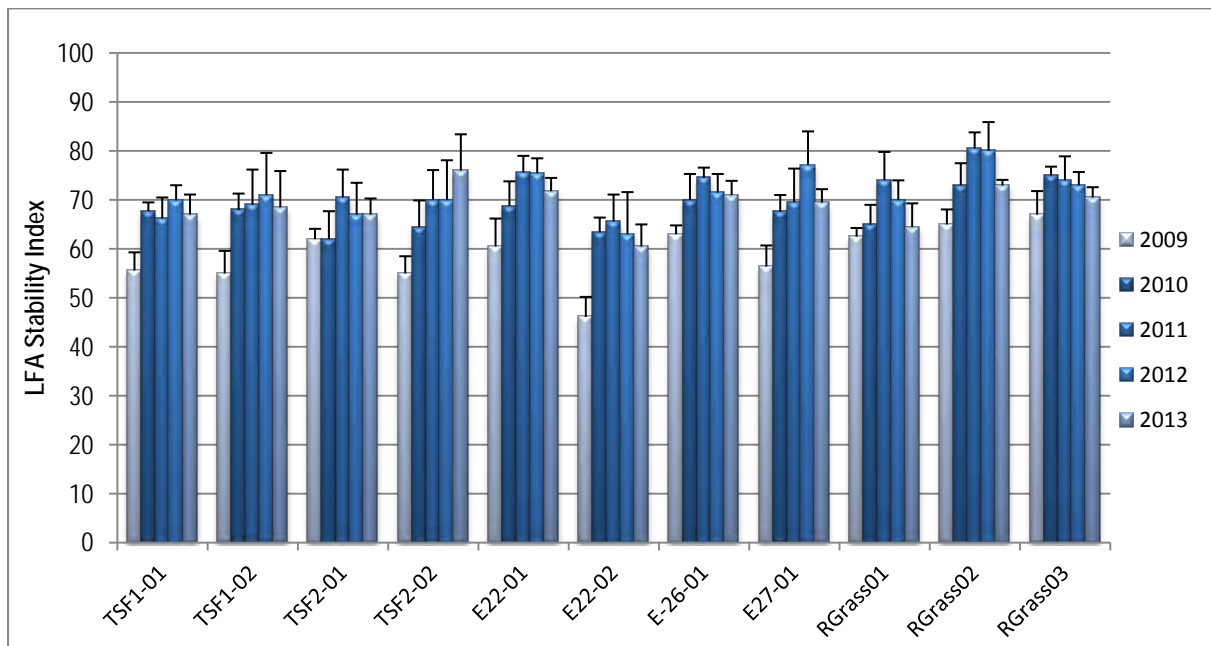


Figure 7-2. Comparison of LFA stability indices recorded in the grassland rehabilitation sites and the grassland reference sites.

7.1.2.2 Infiltration

Marginal decreases in infiltration capacity were also recorded within the grassland reference sites this year due to lower levels of perennial plant covers and maintenance of hard soil crusts and they provided a target range of 29.3 – 46.3. All grassland rehabilitation sites, except E26-01 which remained the same, also demonstrated a marginal decline in infiltration capacity however all rehabilitation sites continued to fall within the target ranges. Site E27-01 continued to exceed the maximum target with an infiltration index of 47.8 (Figure 7-3).

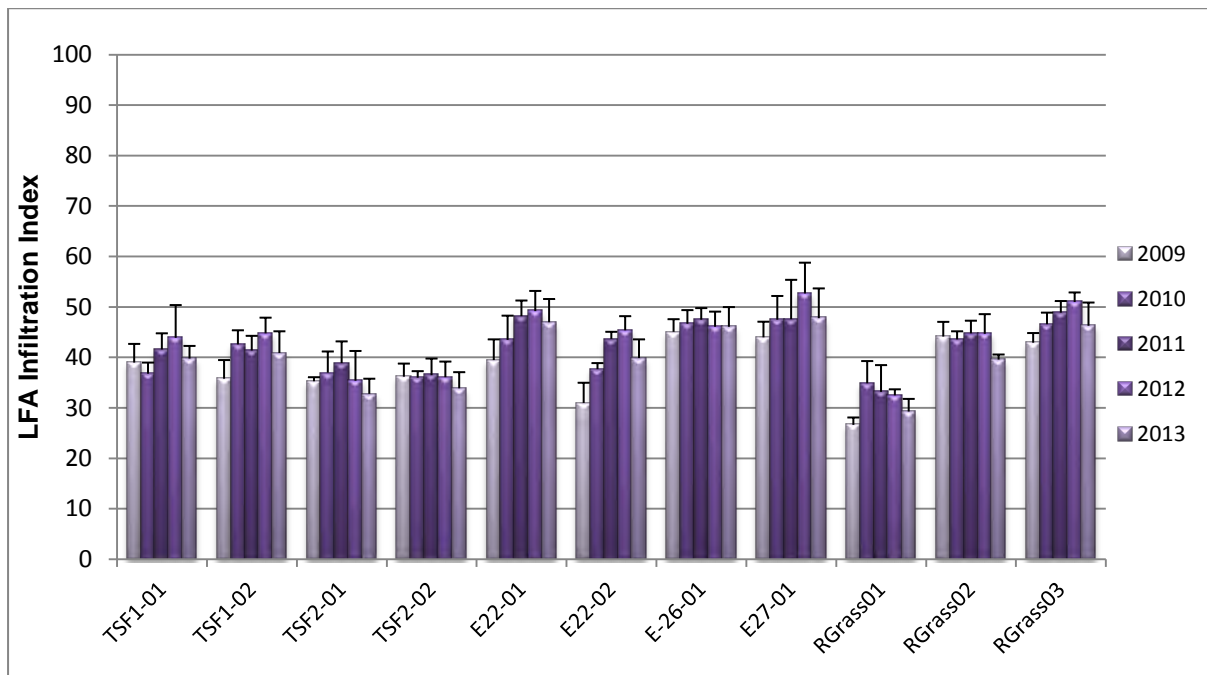


Figure 7-3. Comparison of LFA infiltration indices recorded in the grassland rehabilitation sites and the grassland reference sites.

7.1.2.3 Nutrient recycling

Similar trends in nutrient recycling indices were also recorded this year with the grassland reference sites providing a lower target range of 28.1 – 43.2. All rehabilitation sites with the exception of TSF2-01 have also demonstrated this decline however all rehabilitation sites continued to fall within the target range (Figure 7-4).

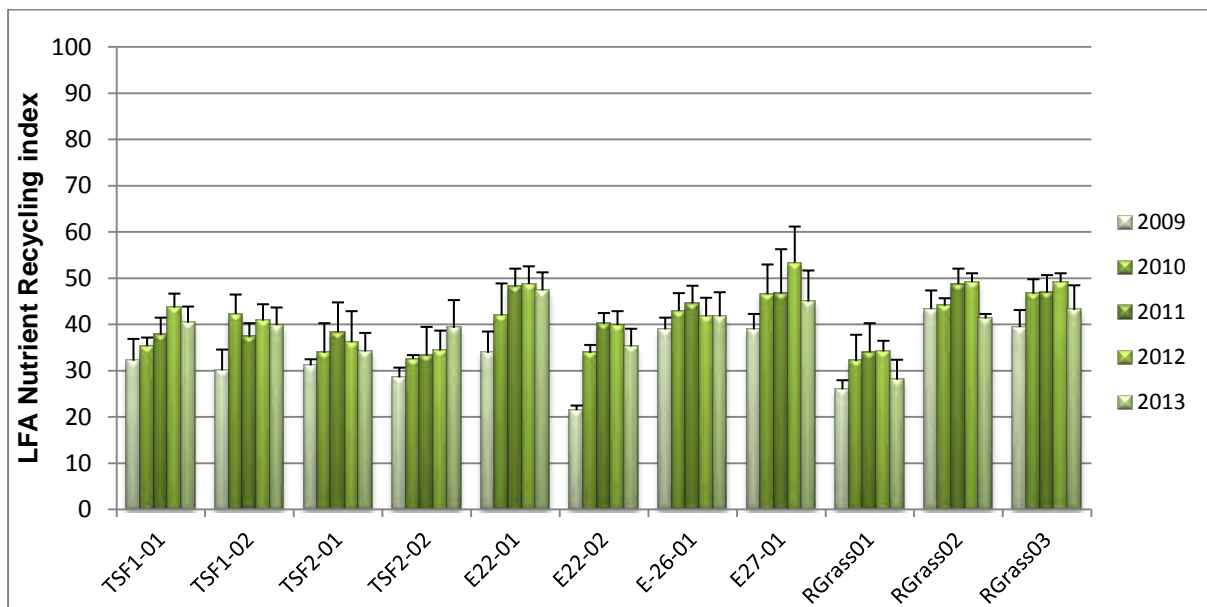








Figure 7-4. Comparison of LFA nutrient recycling indices recorded in the grassland rehabilitation sites and the grassland reference sites.

7.1.3 LFA summary

The LFA data have shown strong associations with the rainfall data since 2009 and despite flooding rain during June 2013, minimal rainfall has been received since that time which has had an adverse impact of plant growth and maintained very hard soil crusts. While there may have been an increase in grazing pressure during this period, the impacts of animal - macropods was less evident in the grassland sites compared to the woodland sites probably due to the absence of shade and protective shelter. In addition, there was no evidence of grazing by travelling stock over the past twelve months. Table 7-1 demonstrates the varying levels of ground covers within the grassland monitoring sites and that active perennial plant growth was minimal this year due to the dry conditions.

Table 7-1. Examples of the ground covers in the grassland monitoring sites.

TSF1-01	TSF1-02
	
TSF2-01	TSF2-02
	
E22-01	E22-02
	



7.2 *Tree density*

No mature trees and shrubs were present in any grassland site.

7.3 *Shrubs and juvenile trees*

Native grasslands are usually devoid of shrubs and this was the case within the grassland reference sites (with the exception of RGrass03 which had one shrub in 2011), and therefore all rehabilitation sites met or exceeded target ranges provided by the reference sites (Figure 7-5).

Shrubs were however recorded in all rehabilitation sites and are likely to be volunteer species establishing from the soil seed bank (except in E27-01 which contained some scattered planted tubestock) and they were showing an increasing density up until 2011 but since then the dry conditions and increased predation have reduced population numbers.

Most sites continued to have less than three individuals however in site TSF1-02 and E27-01 shrubs were quite abundant with 136 and 110 individuals recorded this year respectively. All shrubs recorded in the grassland rehabilitation areas were young chenopod *Maireana brevifolia* (Yanga Bush) individuals with the exception of site E27-01 where most were young *Senna artemisioides*. The regeneration was probably initiated by the high rainfall activity occurring over the summer period during 2012. No exotics species or juvenile trees were recorded.

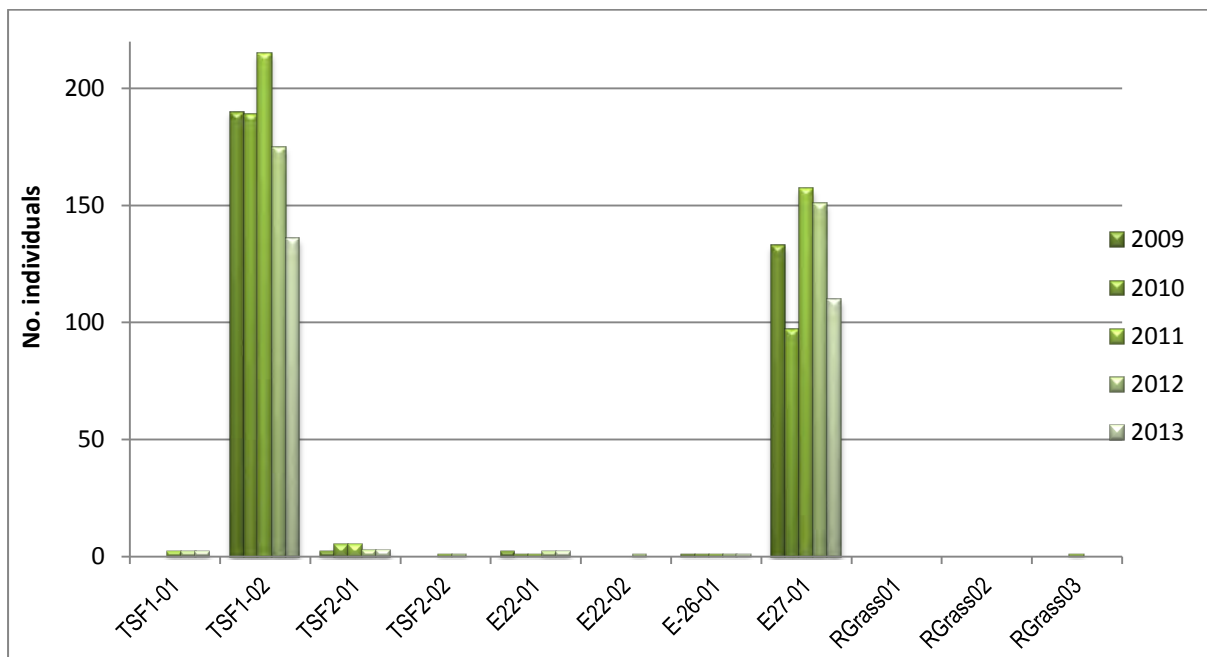


Figure 7-5. Total live shrubs recorded in the rehabilitation sites compared to the grassland reference sites.

7.4 Total ground cover

Total ground cover, which is a combination of leaf litter, annual plants, cryptogams, rocks, logs and live perennial plants (<0.5m in height) continued to be high in the grassland reference sites however there was a consistent decrease recorded across the reference sites due to the dry weather. The resultant total ground cover targets this year were 85.5 – 97.0% (Figure 7-6).

In the rehabilitated grassland sites however, there tended to be an increase in total ground cover, perhaps due to lower levels of grazing pressures except in TSF1-02 which was negligibly lower. All sites however continued to have a suitable level of protective ground cover.

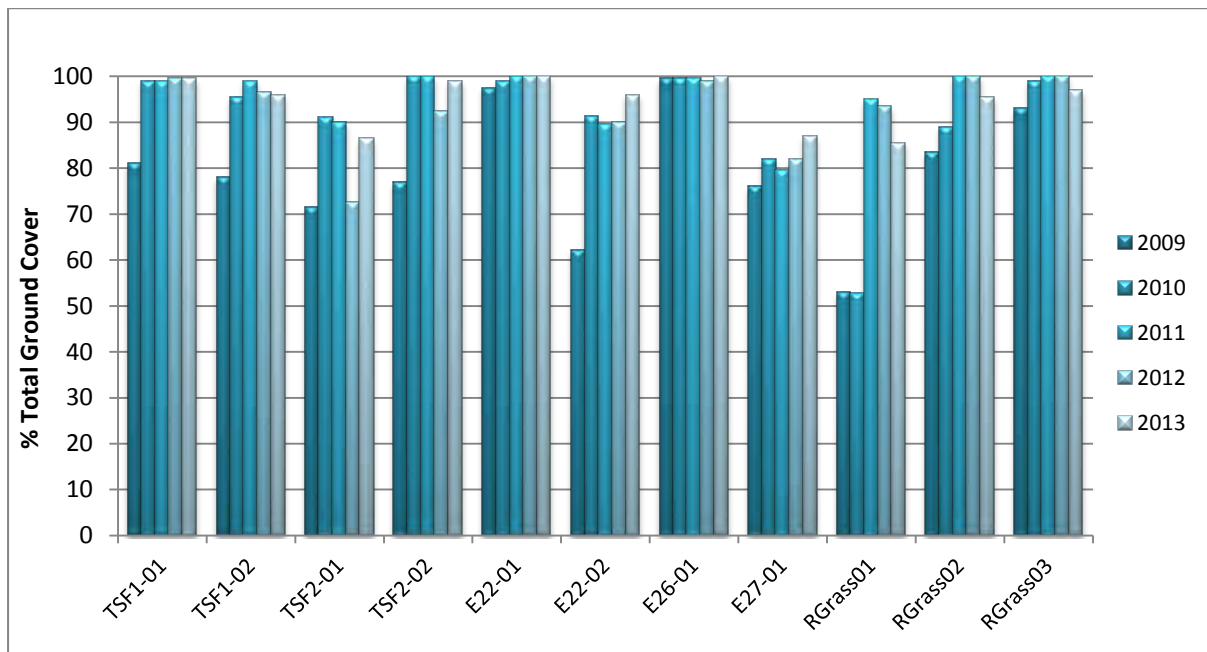


Figure 7-6. Total ground cover recorded in the rehabilitation sites compared to the grassland reference sites.

7.5 Structural composition

The structural composition of the grassland sites is provided in Figure 7-7 which indicates the most dominant form of ground cover continues to be dead leaf litter in most cases, however this year annual plants were more prolific and had become quite dominant in numerous rehabilitation sites, as well as in the reference site RGrass03. The level of annual plants in the reference sites ranged from 3.5 – 38.5% and all sites except E22-02 had annual grasses within or lower than this target range.

Perennial grasses and forbs continue to be an important ground cover component and in the reference sites there was 16.0 – 30.0% perennial plant cover. Rehabilitation sites which did not have suitable perennial plant cover included TSF1-01, E22-02 and E27-01.

Cryptogams were not present in one of the reference sites but in RGrass01 cryptogams were also an important form of ground cover and provided 16.5% cover on otherwise bare hard setting soils. While cryptogams were also present in low abundance, they were not in sufficient quantities along the vegetation transect of any of the rehabilitation sites. There were no other habitat features such as rocks or logs, with the exception of 5% rock cover being recorded in E22-02.

Most sites had small amounts of projected foliage cover 0.5 – 2.0m in height tall due to the tall annual and perennial grasses but sites which retained a low form of ground cover included TSF2-01, E22-02, E26-01 and the reference sites RGrass01 and RGrass03. Examples of the different structural composition within the grassland sites are provided in Table 6-2.

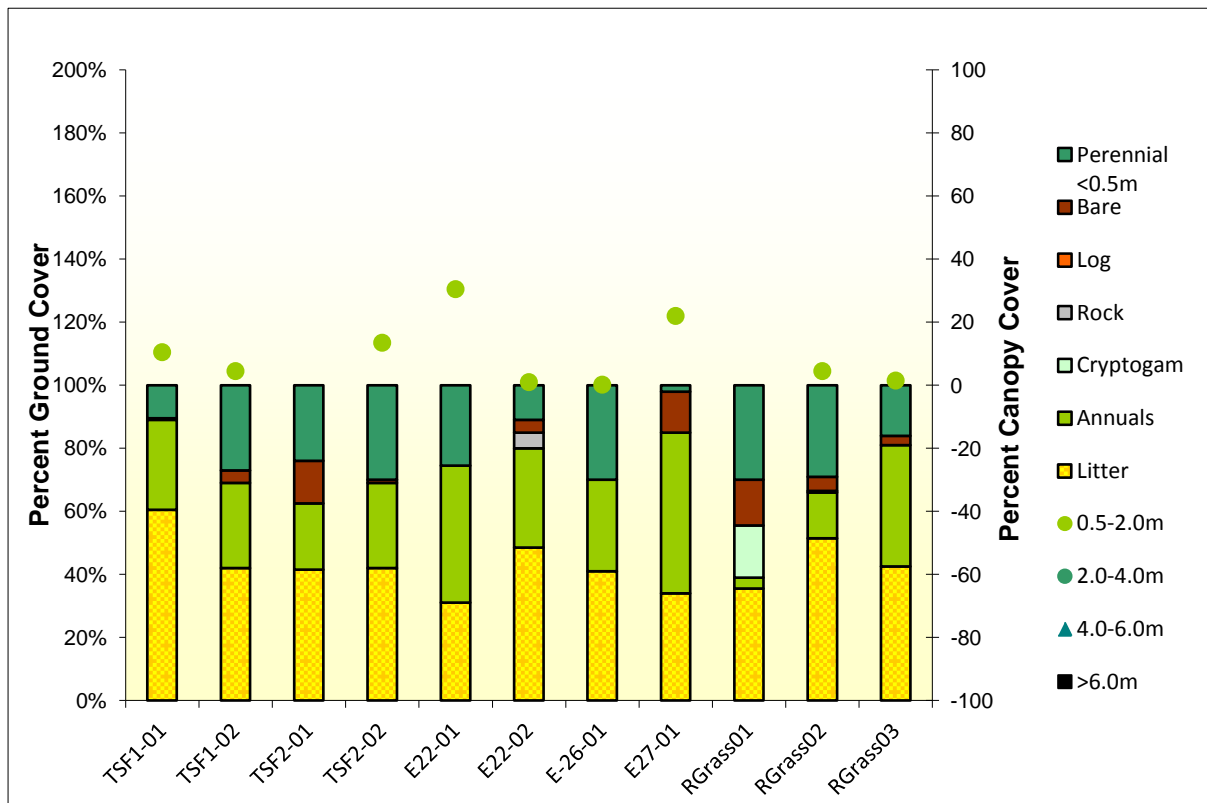
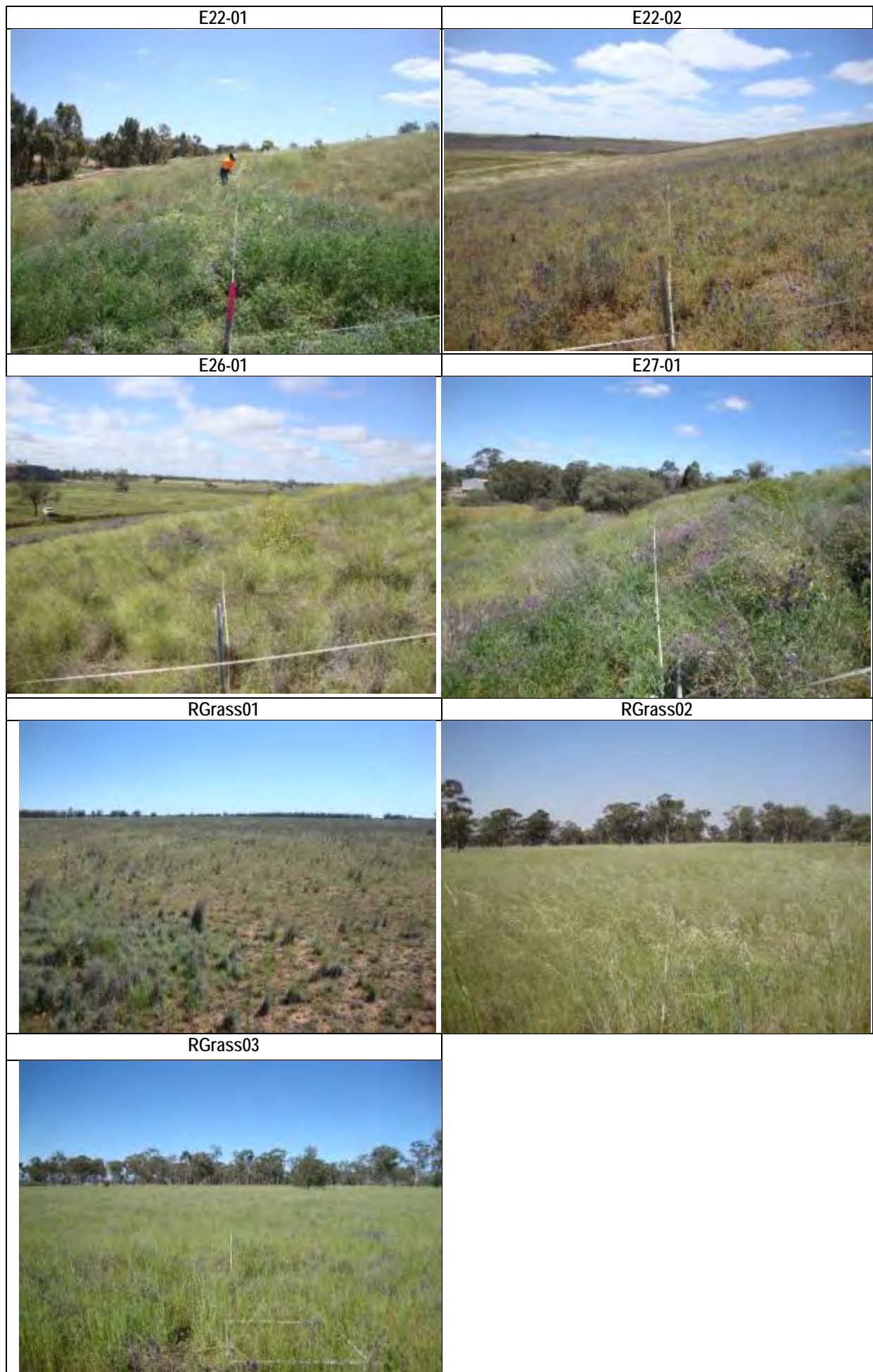


Figure 7-7. Average percent ground cover and projected foliage cover recorded in the grassland monitoring sites in 2013.

Table 7-2. Examples of the different structures and compositions of the grassland monitoring sites.





7.6 Species Diversity

7.6.1 Total species diversity

Floristic diversity was particularly low in 2009 due to the prolonged drought conditions which extended across most of eastern Australia with a total of 20-29 species recorded in the derived grassland areas. 2010 marked the end of the drought and with above average rainfall, floristic diversity significantly increased. Since then however extended dry periods have tended to precede the monitoring events and in the reference sites, the diversity of live plants has been somewhat variable with a total of 37 – 52 species being recorded this year (Figure 7-8).

While all rehabilitation sites had more plant diversity than recorded in 2009, there was no consistent trend developing across the sites, but rather these also probably fluctuated with seasonal conditions. In the grassland rehabilitation sites, E27-01 was the only site to fall within diversity targets, but in this site, planted shrubs were also present elevating the plant diversity. Of the remaining rehabilitation sites TSF1-01 contained the lowest diversity with 24 species, while the highest was recorded in E26-01 which had 36 species and just fell below this KPI target.

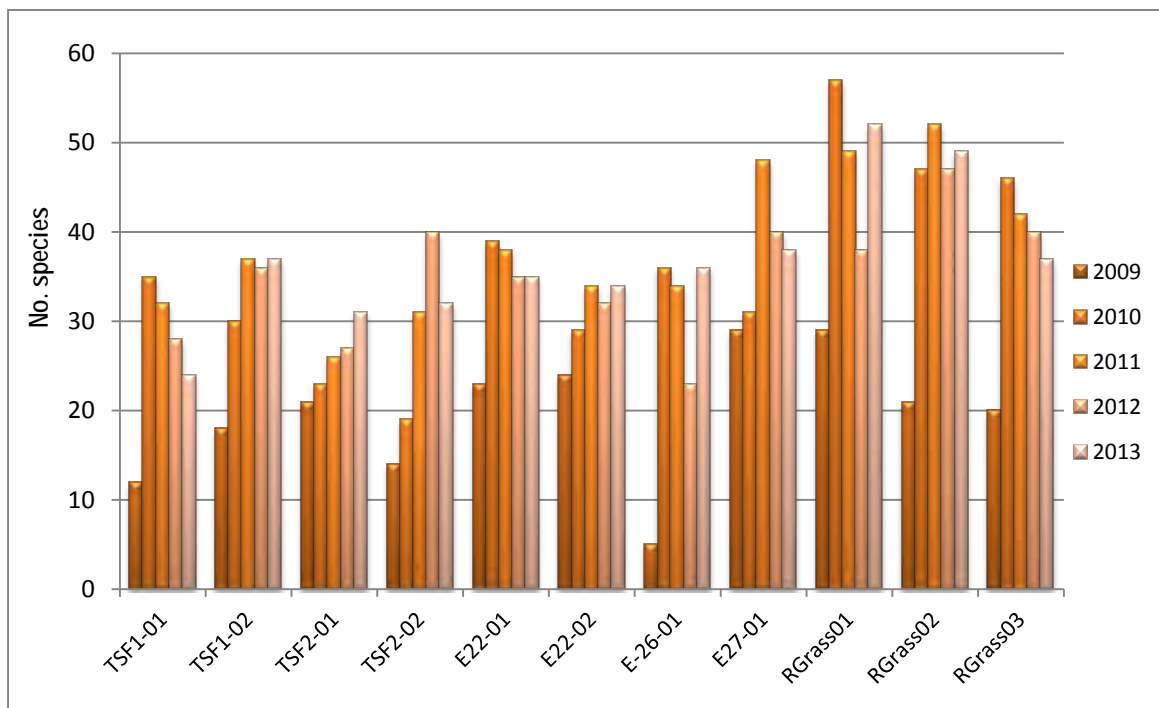


Figure 7-8. Total live plant species recorded the rehabilitation sites compared to the grassland reference sites.

7.6.2 Native species diversity

In the reference sites there was an increase in native species in two of the three sites, especially in RGrass01 which contained a higher number of annual native and exotic species, while a decrease in native species was recorded in RGrass03, due to an apparent increase in competition levels from the more robust native grasses. This year there were 19 – 38 native species recorded in the reference sites (Figure 7-9). Similarly there was no consistent trend in changes in native species diversity in the rehabilitation sites but this year no site contained the desired diversity of native species. The lowest number of native species was recorded in TSF1-01 which had 8 native species, while the highest was recorded in TSF1-02 with 17 species.

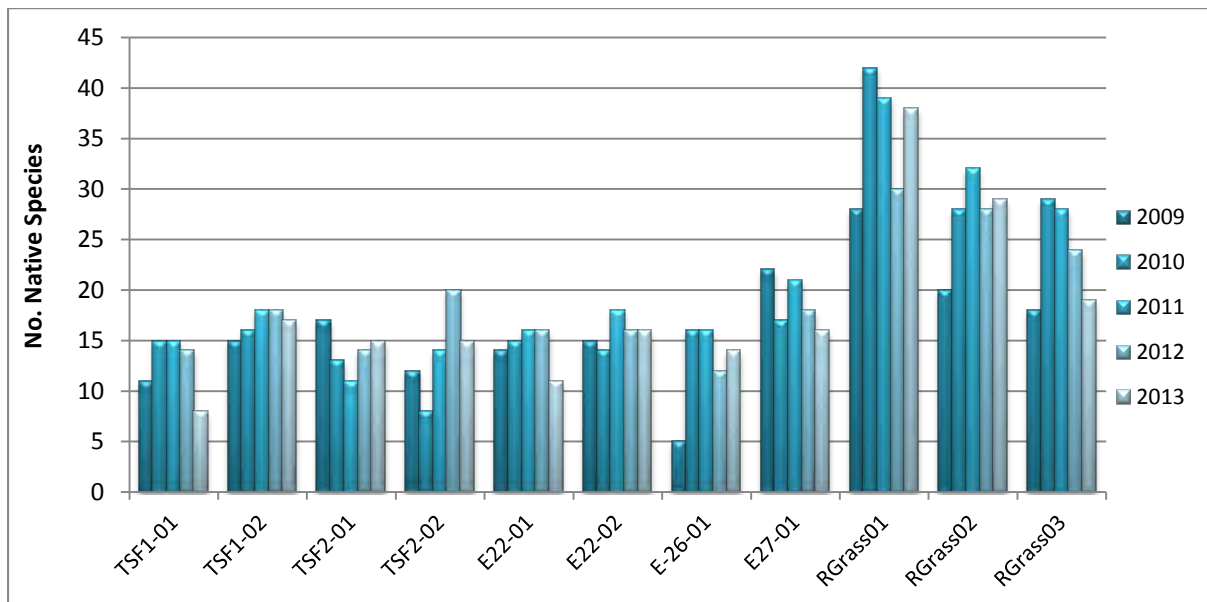


Figure 7-9. Native species recorded the rehabilitation sites compared to the grassland reference sites.

7.6.3 Exotic species diversity

There was typically an increase in exotic species in all monitoring sites over the past year except in TSF2-02. In the reference sites there were 14 – 20 different exotic species (Figure 7-10). Sites E22-01 (24 species), E26-01 and E27-01 (22 exotic species) had more exotic species than the reference sites and were therefore more weedy than desired. In the remaining sites the numbers of exotic species were similar to or lower than those recorded in the reference sites and therefore met this completion KPI target this year.

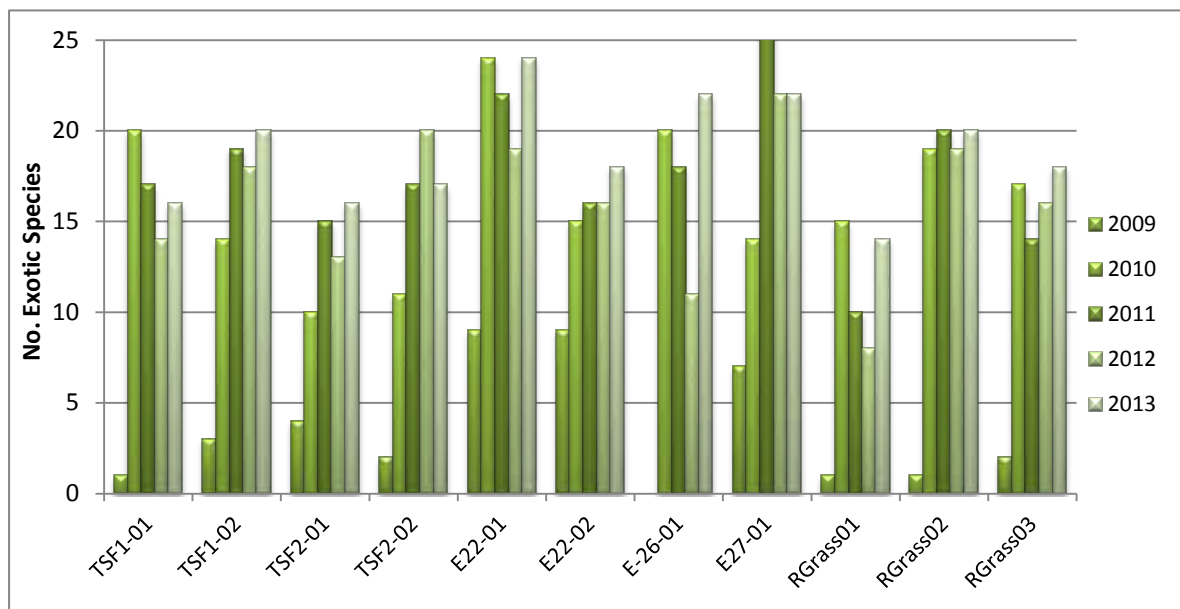


Figure 7-10. Exotic species recorded the rehabilitation sites compared to the grassland reference sites 2009 - 2013.

7.6.4 Summary

This year there were no consistent trends in the changes in plant diversity across the range of monitoring sites however in most cases there was a relatively large increase in total and exotic species

richness in most but not all grassland sites. While conditions were particularly dry at the time of monitoring, above average rainfall in June had resulted in a flush of plant growth with exotic species tending to persist in lower depressions and in more open or disturbed areas where plant competition was lower, especially in sites such as RGrass01 which also contained a high number of native annual species. While grazing did not appear to be primary factor affecting species diversity and composition in these grassland areas this year, the degree of previous disturbances and current competition levels may be key influences. In areas with a high degree of plant cover, there is a higher chance that small plants may be undetected also thus increasing the degree of sampling error.

Nonetheless the results however indicate there is typically a lack of native plant diversity within the grassland rehabilitation sites with some sites containing a higher diversity of weeds than desired.

7.7 *Percent endemic ground cover*

The percent endemic ground cover provides some measure of the cover abundance of the native vegetation and a better indication of the extent of weeds across the sites. In 2009, the prolonged drought ensured all but the hardiest of species were able to exist and in numerous sites the only live plants were native species thus providing 100% endemic plant cover. The break of the drought resulted in an increase in exotic species, however drier conditions in 2011 and 2012 led to an increasing trend in cover provided by native species in the grassland reference sites. This year however a substantial decline in native plant cover was recorded as exotic plant cover had increased as a result of good rainfall earlier in the year and this year there was only 28.6% - 76.8% endemic plant cover.

A similar trend was also recorded across the rehabilitation areas with all sites demonstrating a significant reduction in native plant cover this year. Due to the particularly low minimum KPI set by RGrass03, all sites except TSF1-01 (which was negligibly lower), E22-02 and E27-01 did not fall within the desired target and had 28.3%, 23.6% and only 16.7% native plant cover respectively. The highest endemic cover continued to be provided by E26-01 with 52.5%.

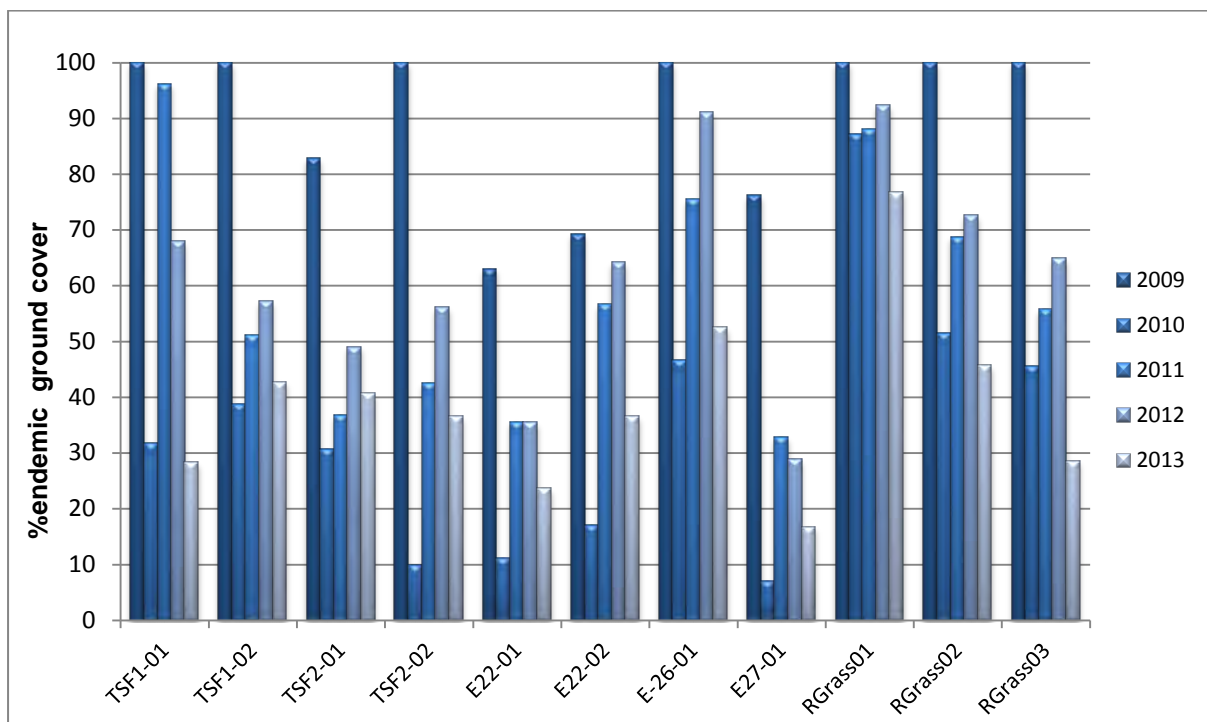


Figure 7-11. Percent endemic ground cover recorded in the grassland monitoring sites.

7.8 Most common species

The number of species recorded across the range of grassland rehabilitation sites has ranged between 62 – 91 species since 2009 with 27 – 53% of these being exotic species (Table 7-3).

Table 7-3. Summary of the number of species recorded in the rehabilitation monitoring sites since 2009.

Year	No. sites	Total species	% Exotic species
2009	8	62	27
2010	8	89	53
2011	8	91	47
2012	8	80	50
2013	8	84	51

The most common species (those that were recorded in at least five of the eight monitoring plots) in 2013 is given in Table 7-4 and there were 25 of these. In 2013, three species were common to all rehabilitation sites and in at least two of the reference sites and these included the exotic annuals *Avena fatua* (Wild Oats) and *Echium plantagineum* Paterson's Curse) and the native perennial species *Walwhalleya proluta* (Rigid Panic).

Other common exotic species were the annual species were *Lactuca saligna* (Wild Lettuce), *Rapistrum rugosum* (Turnip Weed), *Vicia villosa* (Vetch), *Medicago polymorpha* (Burr Medic), *Carthamus lanatus* (Saffron Thistle) and *Lolium rigidum* (Wimmera Ryegrass) which were present in seven of the eight rehabilitation sites. *Austrodanthonia setacea* (Small-flowered Wallaby Grass) and *Enteropogon acicularis* (Curly Windmill Grass) both native perennial grasses were also very common. A comprehensive list of species recorded in all monitoring sites in 2013 has been included in Appendix 1.

Table 7-4. Species that were recorded in at least five of the eight pasture rehabilitation monitoring sites in 2013.

Group	Family	exotic	Scientific Name	Common Name	Habit	TSF1-01	TSF1-02	TSF2-01	TSF2-02	E22-01	E22-02	E26-01	E27-01	Total	RGrass01	RGrass02	RGrass03
Monocotyledon	Poaceae	*	<i>Avena fatua</i>	Wild Oats	g	1	1	1	1	1	1	1	1	8		1	1
Dicotyledon	Plantaginaceae	*	<i>Echium plantagineum</i>	Paterson's Curse	h	1	1	1	1	1	1	1	1	8		1	1
Monocotyledon	Poaceae		<i>Walwhalleya proluta</i>	Rigid Panic	g	1	1	1	1	1	1	1	1	8	1	1	1
Dicotyledon	Asteraceae	*	<i>Lactuca saligna</i>	Wild Lettuce	h	1	1	1	1		1	1	1	7			
Dicotyledon	Brassicaceae	*	<i>Rapistrum rugosum</i>	Turnip Weed	h	1	1		1	1	1	1	1	7			
Dicotyledon	Fabaceae (Faboideae)	*	<i>Vicia villosa</i>	Vetch	h	1	1		1	1	1	1	1	7			
Monocotyledon	Poaceae		<i>Austroanthonia setacea</i>	Small-flowered Wallaby Grass	g		1	1	1	1	1	1	1	7		1	1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Medicago polymorpha</i>	Burr Medic	h		1	1	1	1	1	1	1	7	1	1	
Dicotyledon	Asteraceae	*	<i>Carthamus lanatus</i>	Saffron Thistle	h	1	1		1	1	1	1	1	7	1	1	1
Monocotyledon	Poaceae		<i>Enteropogon acicularis</i>	Curly Windmill Grass	g		1	1	1	1	1	1	1	7	1	1	1
Monocotyledon	Poaceae	*	<i>Lolium rigidum</i>	Wimmera Ryegrass	g	1	1	1	1	1	1		1	7	1	1	1
Dicotyledon	Chenopodiaceae		<i>Maireana brevifolia</i>	Yanga Bush	s	1	1	1		1		1	1	6			
Dicotyledon	Asteraceae		<i>Vittadinia cuneata</i>	Fuzzweed	h			1	1	1	1	1	1	6			
Dicotyledon	Asteraceae		<i>Vittadinia pterochaeta</i>	Rough Fuzzweed	h	1	1	1	1		1		1	6			
Dicotyledon	Oxalidaceae		<i>Oxalis perennans</i>	Yellow Wood-sorrel	h	1		1	1	1		1	1	6		1	1
Monocotyledon	Poaceae		<i>Dichanthium sericeum</i>	Queensland Bluegrass	g	1	1	1	1		1	1		6	1	1	1
Dicotyledon	Asteraceae	*	<i>Sonchus oleraceus</i>	Milk Thistle	h		1	1	1	1	1	1		6	1	1	1
Monocotyledon	Poaceae	*	<i>Bromus diandrus</i>	Great Brome	g		1	1		1		1	1	5			
Monocotyledon	Poaceae	*	<i>Phalaris minor</i>	Lesser Canary Grass	g	1	1		1			1	1	5			
Dicotyledon	Asteraceae	*	<i>Scorzonera laciniata</i>		h	1	1	1	1			1		5			
Dicotyledon	Asteraceae	*	<i>Lactuca serriola</i>	Prickly Lettuce	h	1	1		1			1	1	5			1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Medicago truncatula</i>	Barrel Medic	h	1	1	1			1		1	5		1	
Dicotyledon	Asteraceae	*	<i>Cirsium vulgare</i>	Spear Thistle	h	1		1	1	1		1		5		1	1
Dicotyledon	Convolvulaceae		<i>Convolvulus erubescens</i>	Australian Bindweed	h	1	1		1		1		1	5	1		1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium angustifolium</i>	Narrow-leaf Clover	h	1	1			1	1		1	5	1	1	1

7.9 Vegetation composition

The composition of the vegetation as categorised by seven different growth forms is given in Figure 7-12. The grassland reference sites continued to be dominated by 26 – 34 different herbs and 11 – 15 grasses. There were up to 4 sub-shrubs. While recorded in some sites in previous years there were no reed or fern species.

The rehabilitation sites were also dominated by herbs and grasses but the diversity of these continue to be lower. Sites such as TSF1-02, TSF2-02 and E22-02 were close having an appropriate composition of species and last year TSF2-02 met all growth form requirements.

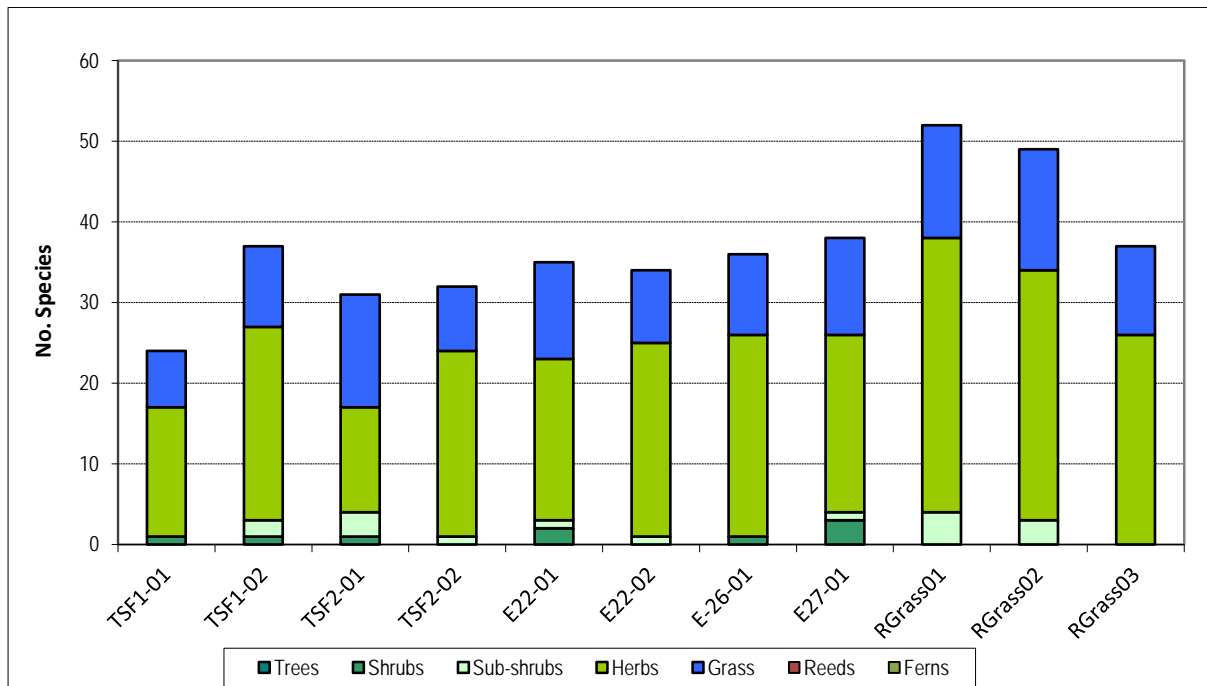


Figure 7-12. Composition of the vegetation recorded at the rehabilitation sites compared to the grassland reference sites.

7.10 Rill assessment

A rill assessment was undertaken despite most rills being much smaller (< 30cm in width or depth) than warranted to be recorded as prescribed by Nichols (2005). To identify potential rills of concern we have selected the dimensions of 10cm x 30cm (0.03m²) as the minimum value of concern. The sum of the cross-sectional areas of some rills recorded in the grassland rehabilitation areas are provided in Figure 7-13.

Rilling continued to be recorded in sites TSF2-01 and E22-02. Last year there were seven rills recorded in TSF2-01 with two rills exceeding the minimum value of concern. This year there were six rills, but the total cross-sectional area had increased to 0.215m². One rill in particular was recorded at 14.8m along the vegetation transect and with the dimensions of 28 x 50cm, greatly exceeded the minimum value of concern. Only one rill continued to be recorded in E22-02 and this year the rill had slightly decreased in size however with a total cross-sectional area of 0.113m² continued to exceed the minimum value of concern (Figure 7-13).

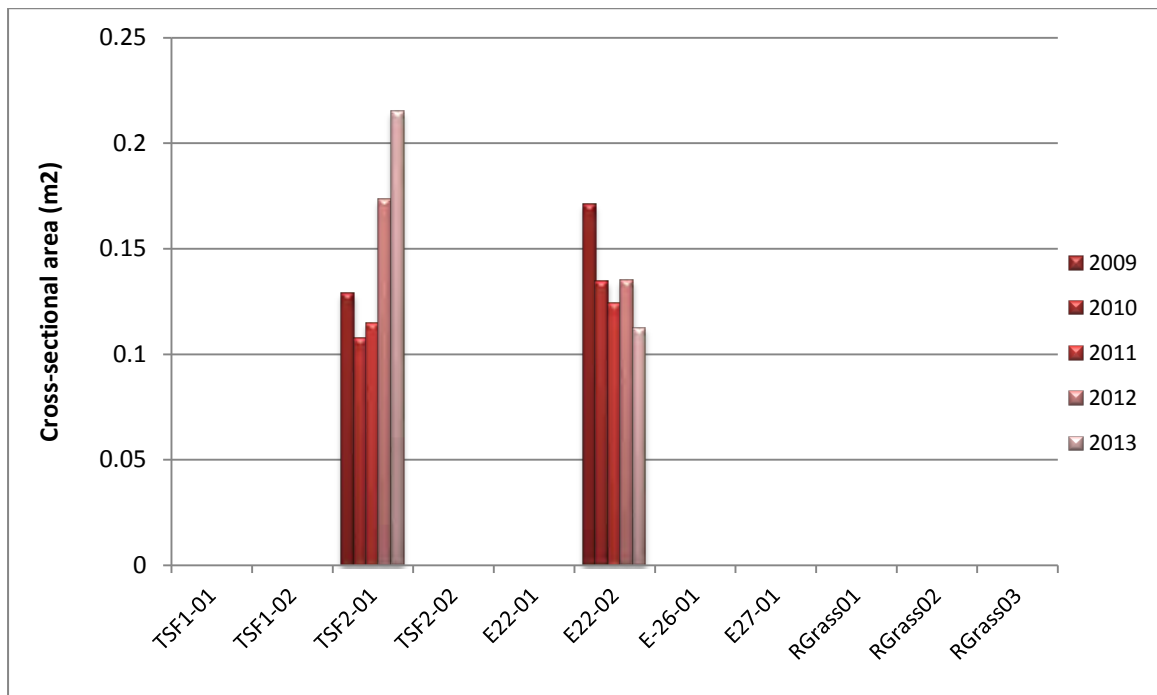


Figure 7-13. Sum of the cross-sectional area of some rills recorded in the grassland rehabilitation sites.

7.11 Soil analyses

7.11.1 pH

Figure 7-14 shows the pH recorded in the grassland rehabilitation sites compared to the upper and lower pH values recorded in the grassland reference sites and prescribed “desirable” levels in medium soils. There has been no consistent trend in the changes in pH across the sites but there was an increase observed in the three reference sites which provided a new pH target range of 6.73 – 7.97. The soils in the local grasslands were neutral to moderately alkaline and the maximum KPI remained slightly higher than the desirable range of 7.3 (Bruce and Rayment 1982).

All grassland rehabilitation sites fell within this range with the exception of TSF2-01 which was slightly acidic with a pH of 6.15 and E22-02 which had moderately alkaline soils and a pH of 8.24. In 2012 there was a significant reduction in pH as a result of some tailings seepage but soil pH just remained within the low end of desirable with a pH of 5.96.

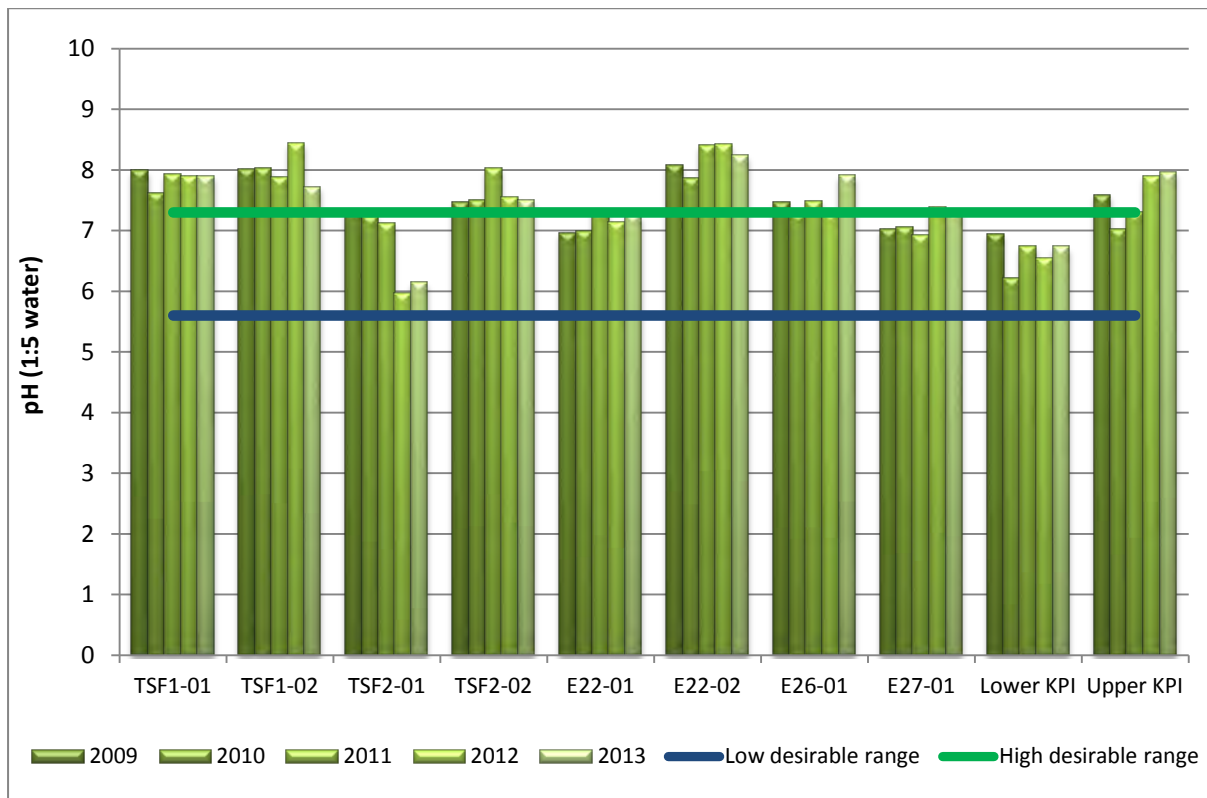


Figure 7-14. Comparison of pH values recorded in the grassland rehabilitation sites compared to the upper and lower values from grassland reference sites and desirable levels.

7.11.2 Conductivity

Figure 7-15 shows the Electrical Conductivity (EC) recorded in the grassland rehabilitation sites, the lower and upper levels for the grassland reference sites as well as the “desirable” levels. There was a slight reduction recorded in the reference sites which provided a new EC range of 0.043– 0.198 dS/m. While the upper EC target continued to exceed the agricultural standard, it remained non-saline (Slavich and Petterson 1993).

There was no consistent trend in changes in EC across the rehabilitation sites however most rehabilitation sites tended to have lower EC readings and continued to fall within the local ranges and most changes were relatively minor. The exception included site TSF2-01 which had demonstrated a significant increase in EC in 2011 and 2012 and last year had soils which were ‘extremely saline’ as a result of some tailings seepage which may have implications for plant growth and establishment (Slavich and Petterson 1993).

This year a significant decrease in EC was apparent at this site however with an EC of 0.275 dS/m it continued to be high in soluble salts but these were now in the lesser ‘saline’ classification. While the unvegetated salt scalds remained the white sulphate crystals were less visible on the soil surface than were witnessed last year.

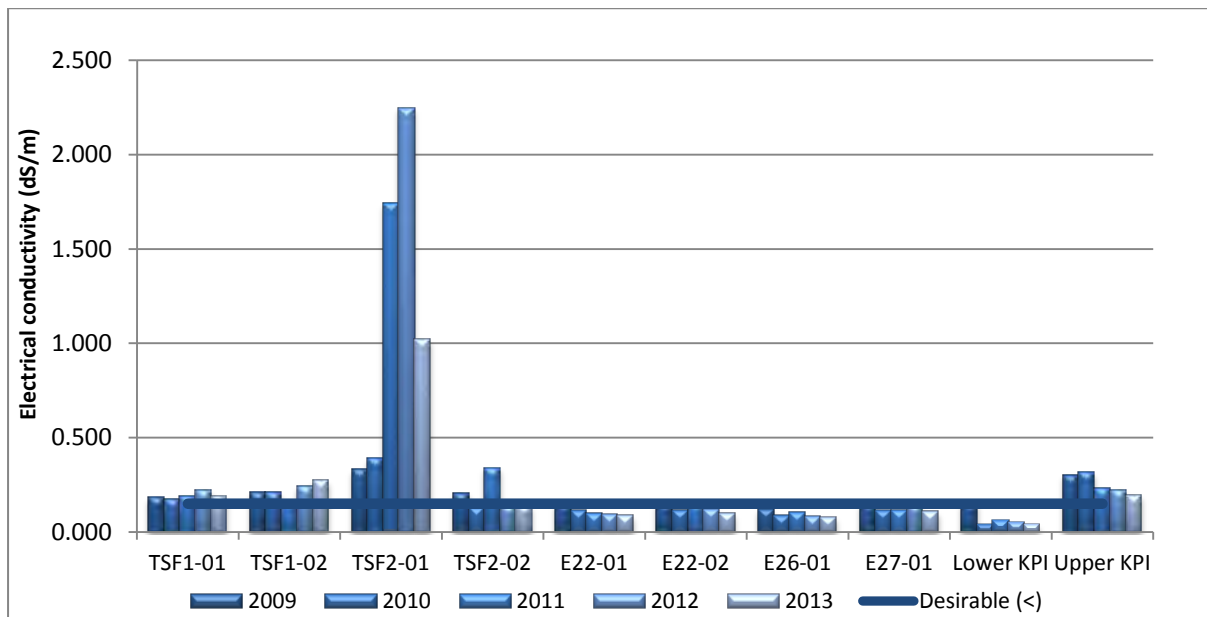


Figure 7-15. Comparison of conductivity values recorded in the grassland rehabilitation sites compared to the upper and lower values from grassland reference sites and desirable levels.

7.11.3 Organic Matter

The range of Organic Matter (%) present in the grassland reference sites has shown a further increase this year and ranged between 1.60 – 4.1% indicating low rates of nutrient recycling within the local grasslands especially in the past twelve months (Figure 7-16). There was no consistent trend in the changes in OM levels across the rehabilitation sites but small increases were recorded in TSF1-01, TSF1-02, TSF2-01 and E22-01, while small declines were recorded in the remaining sites.

Sites which have met the OM target this year included TSF1-01, E22-01, E22-02, E26-01 and E27-01. The low OM percentages in the rehabilitation sites are not unusual as many of the sites are immature and organic matter levels are expected to increase as the sites mature. As with most of the rehabilitation sites, the sites were very patchy and there have been no consistent trends across the range of sites over the five years of monitoring, indicating that in most cases OM levels are not likely to be consistent across the sites and most changes were relatively minor (<1%).

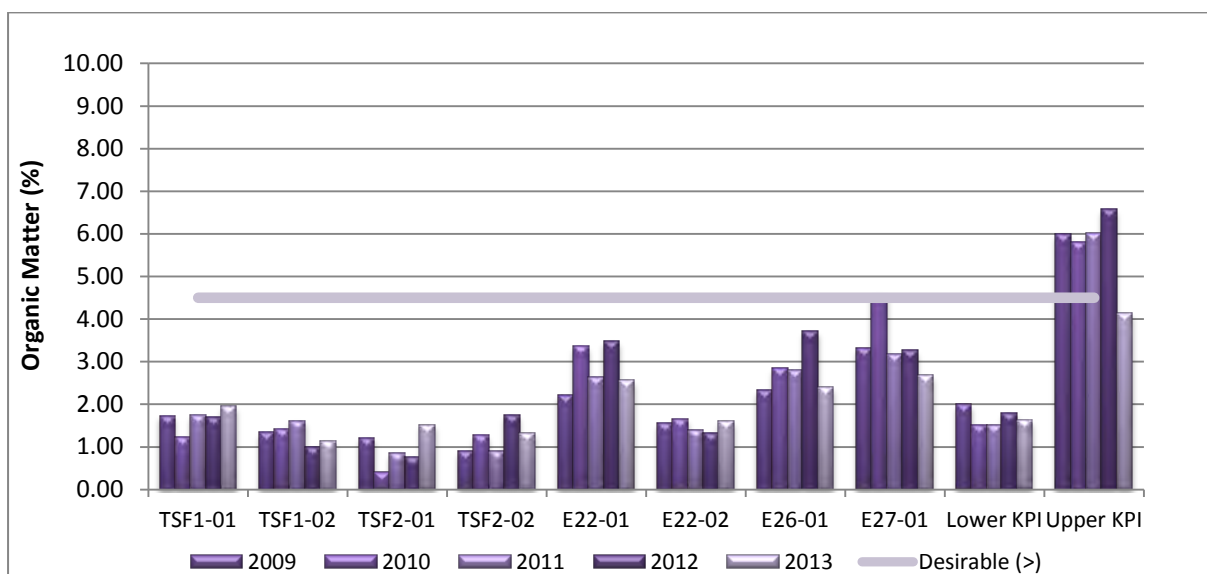


Figure 7-16. Comparison of organic matter recorded in the grassland rehabilitation sites compared to the upper and lower values from pasture reference sites and desirable levels.

7.11.4 Phosphorous

Phosphorous levels in the reference sites continued to be significantly lower than the prescribed desirable level and in 2013 the range has further constricted to provide a range of 5.0 – 9.0 mg/kg (Figure 7-17) reflecting the naturally low soil fertility in the local area. In the rehabilitation sites most sites also demonstrated a declining trend and all were well below the agricultural standard of 50 mg/kg. All grassland rehabilitation sites however have phosphorous levels which are within the local concentration ranges.

While phosphorous levels are very low compared to agricultural standards, the addition of artificial fertilisers is generally not encouraged as unnatural increases in fertility levels are more likely to promote growth of undesirable weeds rather than invigorate growth of desirable species which are adapted to naturally low fertility soils.

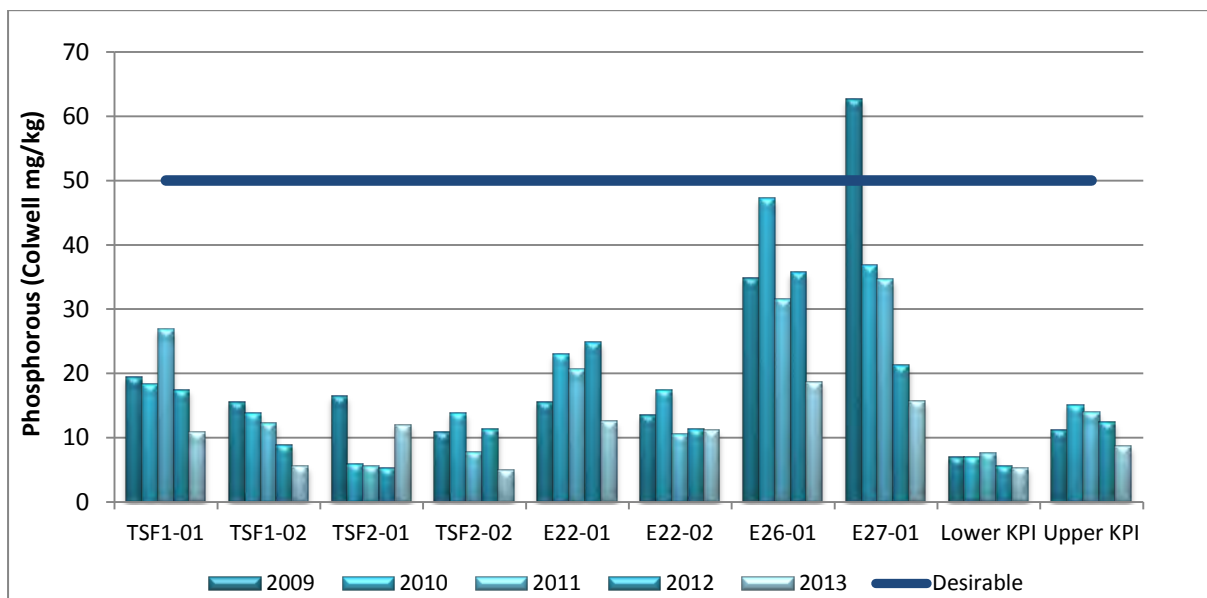


Figure 7-17. Comparison of Phosphorous levels recorded in the grassland rehabilitation sites compared to the upper and lower values from the grassland reference sites and desirable levels.

7.11.5 Nitrate

Nitrate levels in the reference sites also continued to be significantly lower than the prescribed desirable level and in 2013 the reference sites had a contracted range of 1.2 – 1.4 mg/kg (Figure 7-18) reflecting the naturally low soil fertility in the local grassland areas.

A decline in nitrate concentration was also consistently recorded in all grassland rehabilitation sites. Sites which did not fall within the target range included TSF2-01, E22-01 and E22-02 which had nitrate levels of 0.9, 0.3 and 0.8 mg/kg respectively. While nitrate levels are typically very low, the addition of artificial fertilisers is generally not encouraged as unnatural increases in fertility levels are more likely to promote growth of undesirable weeds rather than invigorate growth of desirable species which are adapted to naturally low fertility soils.

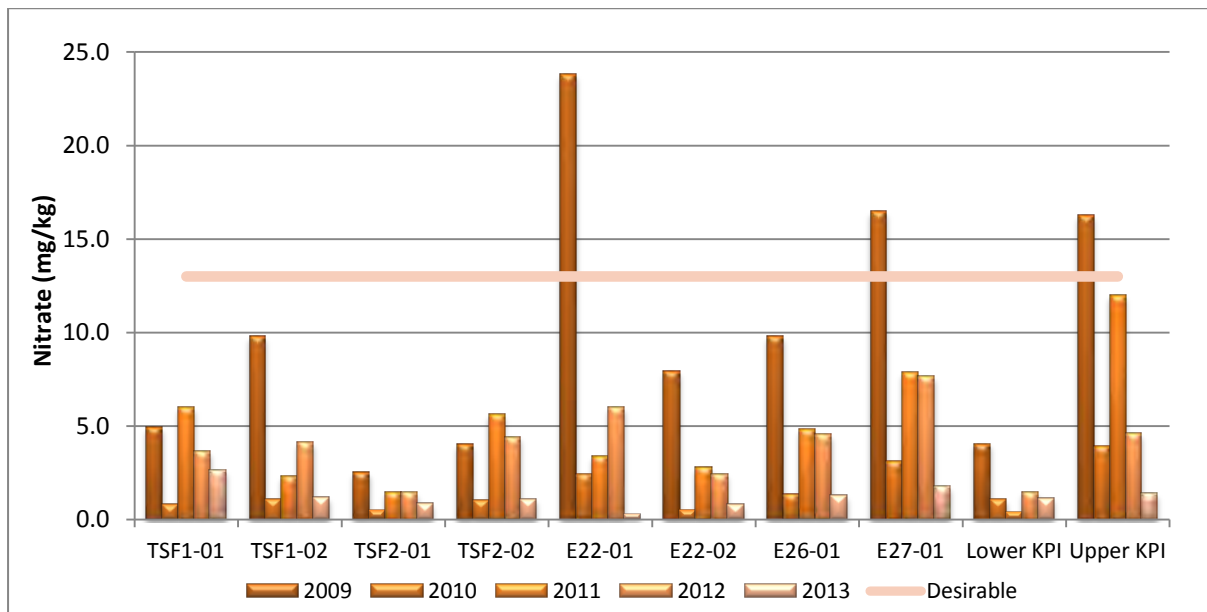


Figure 7-18. Comparison of Nitrate levels recorded in the grassland rehabilitation sites compared to the upper and lower values from the grassland reference sites and desirable levels.

7.11.6 Cation Exchange Capacity

Cation Exchange Capacity (CEC) is the capacity of the soil to hold the major cations (Calcium, Magnesium, Sodium and Potassium) and is also a measure of the potential fertility of the soil. The range of CEC recorded in the grassland reference sites has increased this year to provide a CEC target of 20.4 – 37.8 and these continued to be well above the desirable level indicating the soils may have a high soil retention capacity (Figure 7-19). There appeared however to be a minor decline in CEC within the rehabilitation site but all sites continued to far exceeded desirable levels and all except E22-01 were within the local limits.

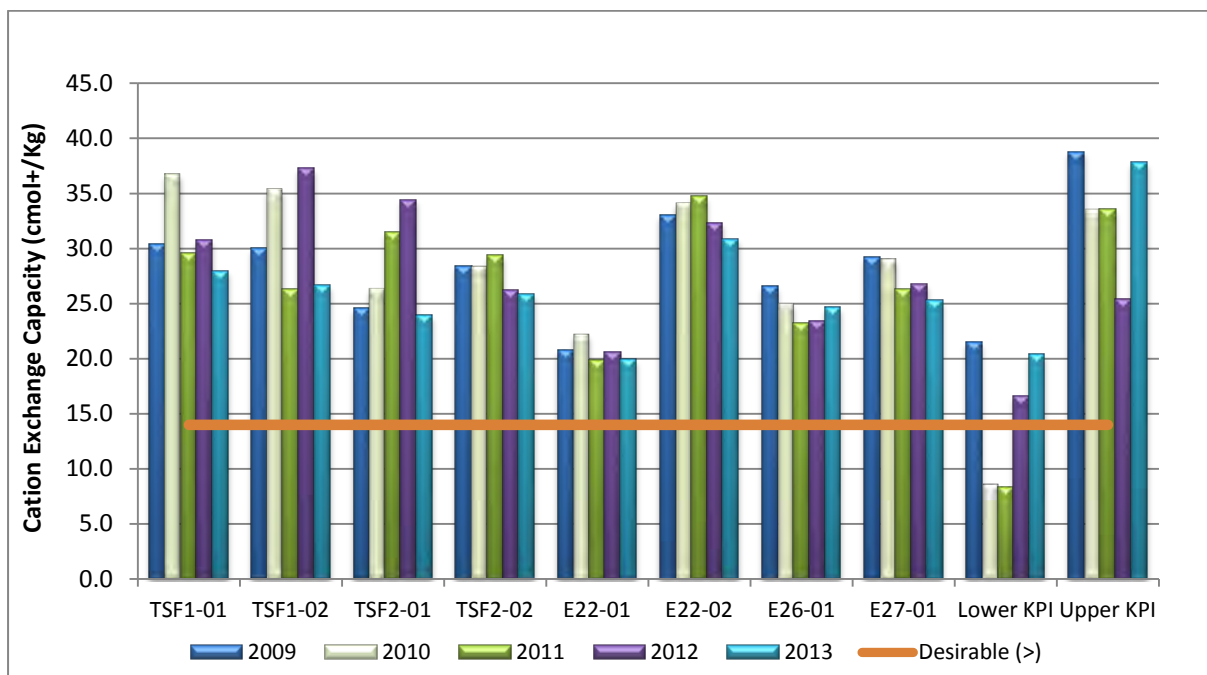


Figure 7-19. Comparison of Cation Exchange Capacity recorded in the grassland rehabilitation sites compared to the upper and lower values from the grassland reference sites and desirable levels.

7.11.7 Exchangeable Sodium Percentage

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

In 2013, the ESP target range has expanded to provide a range of 0.28 – 4.42% indicating the soils were well below the threshold of 5% and were non sodic (Figure 7-20). ESP recorded in the grassland rehabilitation sites had increased in all sites except TSF1-01 and TSF2-01 and those that exceeded the target range included TSF1-02, TSF2-01 and TSF2-02. Despite the decrease in ESP, site TSF2-01 continues to have highly sodic soil with an ESP of 19.15%. The significant increase in ESP was first recorded in 2011 and appeared to be related to the tailings seepage through the dam wall at this site. The remaining sites had ESPs which were well below the threshold of 5%.

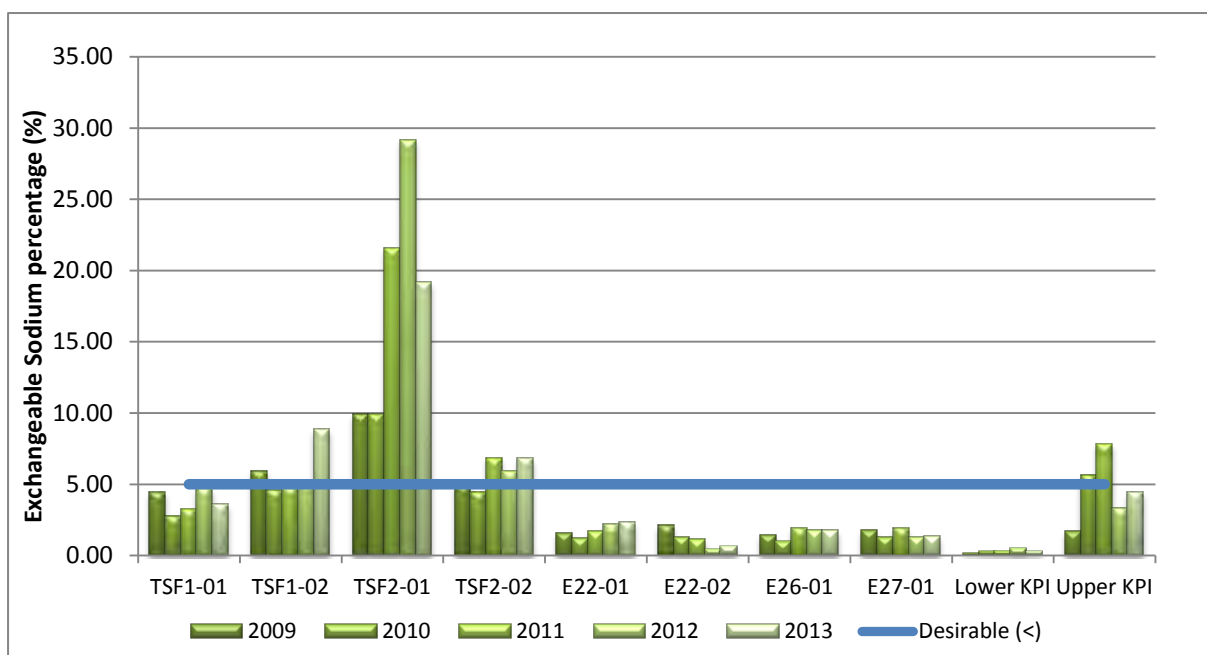


Figure 7-20. Comparison of ESP recorded in the grassland rehabilitation sites compared to the upper and lower values from the grassland reference sites and desirable levels.



Figure 7-21. The effects of the tailings seepage on the soil chemistry, vegetation and rill erosion within site TSF2-01 in 2013.

7.11.8 Other soil test results

The full results of the soil analysis are provided in Appendix 3 and 4 but a summarised version highlighting abnormal results in the grassland monitoring sites is provided in Table 7-5. The results indicate there are numerous elements which occur at elevated levels in the rehabilitation sites, however in most cases these are also found to be elevated within the grassland reference sites, indicating that various elements occur at naturally higher levels within soils surrounding the Northparkes Mine which may be implicated with landscape clearing, as well as a long agricultural and mining history. There were however unusually high levels of Sulfur in both of the Tailings Storage Facilities sites which may have long term implication for plant growth and establishment, especially in TSF2-01. There were also high levels of Copper in most sites and in particular TSF1-01, TSF2-01, both E22 sites as well as in E26. The levels of Copper in E27 were excessively high.

Table 7-5. Summarised soil analyses highlighting abnormal test results in the grassland monitoring sites in 2013.

Method		Nutrient	Site		TSF1-01	TSF1-02	TSF2-01	TSF2-02	E22-01	E22-02	E26	E27	RGrass01	RGrass02	RGrass03	Medium Soil e.g Clay Loam
	Morgan 1	Calcium	Ca	mg/kg	1924	1341	959	1185	1282	2492	1720	1491	3669	892	7329	750
		Magnesium	Mg		717	770	752	735	516	816	610	765	624	584	721	105
		Potassium	K		111	99	71	99	232	122	152	136	77	77	198	75
	KCl	Sulfur	S	mg/kg	26.7	78.1	384.9	31.5	6.4	3.6	5.7	6.5	2.3	3.5	6.4	8.0
	DTPA	Manganese	Mn	mg/kg	16	16	27	18	31	13	12	27	23	44	33	22
		Iron	Fe		29	27	57	31	21	12	15	27	18	63	23	22
		Copper	Cu		10.6	3.2	7.1	3.5	14.3	18.1	11.7	49.0	2.1	3.0	4.0	2.0
	CaCl ₂	Boron	B	mg/kg	1.43	1.96	1.50	1.61	1.16	1.10	1.17	0.84	0.65	1.18	0.68	1.7
		Silicon	Si		47	66	98	86	63	43	64	63	24	81	28	45
	Total Acid Extractable	Chromium	Cr	mg/kg	19	21	20	20	24	17	26	20	22	20	40	<25 Cr

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

7.12 Grassland rehabilitation site performance towards meeting completion criteria targets

Table 7-6 indicates the performance of the rehabilitation monitoring sites against a selection of proposed Completion Performance Indicators developed for grassland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 7-6. Performance of the grassland rehabilitation monitoring sites against a selection of proposed Completion Performance Indicators.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-01	TSF1-02	TSF2-01	TSF2-02	E22-01	E22-02	E26-01	E27-01
Performance indicators are quantified by the range of values obtained from replicated reference sites						Lower	Upper	2013	2013	2013	2013	2013	2013	2013	2013
Phase 2: Landform establishment and stability	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation	%	64.5	73.0	67.0	68.5	67.0	76.0	71.8	60.5	71.0	69.5
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation	%	29.3	46.3	39.8	40.9	32.8	33.9	47.0	39.9	46.1	47.8
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation	%	28.1	43.2	40.4	39.9	34.2	39.3	47.4	35.3	41.8	45.0
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation	%	100	100	100	100	100	100	100	100	100	100
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising	No.	0	0	0	0	6	0	0	1	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-01	TSF1-02	TSF2-01	TSF2-02	E22-01	E22-02	E26-01	E27-01
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)	6.73	7.97	7.90	7.72	8.15	7.50	7.26	8.24	7.91	7.34
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry	% (>4.5)	1.6	4.1	1.9	1.1	1.5	1.3	2.6	1.6	2.4	2.7
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (>12.5)	1.2	1.4	2.6	1.2	0.9	1.1	0.3	0.8	1.3	1.8
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	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	14	20	16	20	16	17	24	18	22	22
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	26	34	16	24	13	23	20	24	25	22
			Grasses	The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	11	15	7	10	14	8	12	9	10	12
Phase 5: Ecosystem & Landuse Development	Protective ground cover	Ground layer contains protective ground cover and habitat structure comparable with the local remnant vegetation	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	%	16	30	10.5	27	24	30	25.5	11.0	30	2.0
			Total Ground Cover	Total groundcover is the sum of protective ground cover components (as described above) and that it is comparable to that of the local remnant vegetation	%	86	97	99.5	96	86.5	99	100	96	100	87
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation	%	29	77	28.3	42.7	40.6	36.5	23.6	36.6	52.5	16.7
	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	5	11	4.5	0	13.5	30.5	1	0.2	22

8 Recommendations and management actions

The results of the 2013 monitoring program have been summarised in Table 8-1 which aims to identify any shortfalls associated with the individual rehabilitation areas and provide some management recommendations that will assist in improving long-term rehabilitation outcomes to ensure completion targets will be met.

Table 8-1. Sites summary and management recommendation

Site	Site summary and issues associated with long-term management outcomes	Management requirements	Priority
Rehabilitated Mining areas			
All new mining rehabilitation areas	Unsuitable spoil characteristics which may affect plant establishment and site development	The use of suitable topsoil material in rehabilitation areas should be a priority management action which should involve adhering to stockpiling protocols and testing of soil stockpiles and spoil material prior to use in rehabilitation. Suitable topsoil material should contain similar physical and chemical attributes as those within the woodland and pasture reference sites or within desirable levels prescribed by the agricultural industry.	High
	Increase physical patch area of newly established rehabilitation areas and reduce soil sodicity if required.	Create a sequence of troughs and banks to increase the "patch" of the slope and to act as a physical erosion prevention measure, at least until the vegetation can become established. The troughs and banks can be created by cross ripping using a dozer with three tynes to 600mm, after gypsum is spread over the prepared topsoil at the appropriate rate if required. Any rocks brought to the surface will provide additional erosion protection and micro-sites for plant establishment	High
	Provide immediate soil surface protection and increased diversity of native ground cover species	New mining rehabilitation areas should be treated with a sterile cover crop and an application of native pasture hay containing mature seeds where possible. These methods will improve rehabilitation outcomes, accelerate ecosystem recovery and assist in meeting many ecological completion targets, including those associated with native ground cover diversity. Management of local native pastures for the purpose of native grass harvesting should be incorporated into the NPM rehabilitation Management Plan.	High
Woodland rehabilitation sites			
Future woodland rehabilitation sites	Retain existing ecological integrity of native grasslands and enhance rehabilitation objectives. Grading and blanket spraying can severely compromise the integrity of otherwise intact and functional ecosystems with increased risks of further degradation such as erosion, weed invasion and unbeneficial substrate characteristics.	Future rehabilitation projects should aim to limit ground disturbances especially in areas of native grassland to retain relatively high levels of ecological function, diversity and composition of the existing native ecosystems. Rather deep ripping and strip spraying in narrow rows (~1m wide) prior to tubestock planting will more rapidly achieve ecological outcomes and completion targets.	High
LFO-01	A woodland offset area planted in 2009 with a long cropping history. This site has shown a significant transformation since 2009 with the bare inter-rows now well colonised with vegetation and cryptogams. While the LOI and LFA stability and nutrient recycling targets were met, it remained short of meeting LFA ecological targets for infiltration, largely due to	Limit site disturbances (such as spraying and grading) and allow the colonising vegetation to become well established. The site weediness is expected to decline as more desirable perennial species become more dominant. Continue to monitor macropod predation.	Low

Site	Site summary and issues associated with long-term management outcomes	Management requirements	Priority
	the lack of perennial ground covers and very hard soil crusts. The soils were deficient in organic matter and nitrates and had a low CEC but most other soil attributes were within local levels. There was an appropriate diversity of tree and shrub species but had a low shrub and potentially a low tree density. The site was low in total and native species diversity and there was a high diversity of exotic species. The site was dominated by exotic plants and was more weedy than desired. While there was good total ground cover, the site and lacked suitable proportions of perennial ground cover. There were no active rills. The soils contained elevated levels of Iron.		
LFO-02	A woodland offset area planted in 2009 with a long agricultural history but has not been cropped. This site has also shown a significant transformation since 2009 with the sprayed inter-rows now well colonised with vegetation and cryptogams. This year the LOI and LFA stability indices were met, but it remained short of meeting LFA ecological targets for infiltration and nutrient recycling. The soils were strongly acidic and deficient in organic matter with low CEC but most other soil attributes were within local levels. There was an appropriate density and diversity of tree and shrub species. The site met total floristic targets however the majority of species were exotic annuals and was more weedy than desired. There was a high proportion of annual species and there were no active rills. The soils contained elevated levels of Iron.	Limit site disturbances (such as spraying and grading) and allow the colonising vegetation to become well established. The site weediness is expected to decline as more desirable perennial species become more dominant. Continue to monitor macropod predation.	Low
Estcourt 1997	This site was one of the oldest rehabilitation areas planted with mixed native tubestock in 1997. The site maintains an open woodland structure, scattered shrubs and a mosaic of grassy clearings and bare patches. While the LOI remained short of the KPI targets, this site is typical of vegetation growing in low lying drainage depressions may never meet the LOI of the selected reference sites. It did however meet LFA indices for stability, infiltration and nutrient recycling this year. The soils were deficient in organic matter and phosphorous and this year the ESP indicated the soils were sodic. There was an appropriate diversity of tree and shrub species but these were in low density. The site had increased levels of ground cover and appropriate proportions of the various ground cover components but was low in native herbs. Many other site attributes were typical of the surrounding woodlands. The soils contained elevated levels of Silicon and Iron.	Continue to limit site disturbances. Continue to monitor macropod predation.	Low
Beechmore	This site was planted in 1999 and maintains an open woodland structure, scattered shrubs and a mosaic of grassy clearings and bare patches. There has been excellent establishment and growth with some trees exceeding 6m in height, and they were generally healthy and setting seed. This site continued to fall short of meeting LOI, stability and infiltration targets. This site is more typical of vegetation growing in low lying drainage depressions may never meet the LOI of the selected reference sites. The soils were typical of the surrounding woodlands. Despite increased levels of ground cover it fell short of meeting total and perennial ground cover targets. The ground cover was dominated by native species but there was a low diversity of native herb species. Most other ecological attributes were similar to the surrounding woodland communities. The soils contained	Continue to limit site disturbances.	Low

Site	Site summary and issues associated with long-term management outcomes	Management requirements	Priority
	elevated levels of Silicon.		
Altona 1999	Altona 1999 is an old council quarry that was rehabilitated by Northparkes Mines in 1999. It maintains an open woodland structure (although these are in obvious rows), scattered shrubs and a mosaic of grassy clearings with some bare patches. Heavy grazing pressure by Kangaroos was particularly evident at this site as ground cover vegetation cover was limited across the site but there was generally good leaf litter cover beneath tree canopies. The site has shown improved ecological function over the last three years and continued to meet all LFA targets except LOI was low this year. The soils were strongly acidic and had a low CEC but other characteristics were within local levels. There has been a significant reduction in annual weeds which were dominant in 2010 however there continued to be low native species and the site was weedier than desired. The ground cover composition was similar to surrounding woodland but there was a low diversity of herbs. A small percentage of the tree population were not considered to be local endemic species. The soils contained elevated levels of Manganese, Iron and Copper.	Continue to limit site disturbances. Continue to monitor macropod predation.	Low
Kundibah 2001	Kundibah 2001 is a small tree planting area planted in 2001 and maintains an open woodland structure, scattered shrubs and a mosaic of grassy clearings with some bare patches. Vegetation cover was limited beneath the tree canopies but there was generally good leaf litter cover. The site has demonstrated a slight reduction in ecological function however this year all LFA targets except LOI were met. The soils were deficient in organic matter and nitrates but other chemical characteristics were similar to the surrounding woodland areas. While native species provided the most ground cover there continued to be a low diversity of native forbs. A small percentage of the shrub population were not considered to be local endemic species. The soils contained elevated levels of Iron and Silicon.	Continue to limit site disturbances.	Low
Grassland rehabilitation sites			
TSF1-01	This site was a grassy slope with tussocks of native perennial grasses dominated by <i>Walwhalleya proluta</i> (Rigid Panic) with scattered weeds located on the north-eastern wall of TSF 1. This site continues to improve over time and this year met all LFA related targets. The soils were chemically characteristic of the surrounding grassland area. The site was dominated by exotic species this year and was low in native herb and grass diversity. It had good total ground cover and but this year was low in perennial plant cover. There were unusually elevated levels of Sulfur (and Copper).	Continue to limit site disturbances. Further investigation for tailings seepage across the larger TSF1 area should also be undertaken as a priority and treated appropriately.	High
TSF1-02	Site TSF1-02 is located on the north-western wall of TSF 1. It was a grassy slope dominated by annual grasses and medics with few native perennial grasses. <i>Sonchus oleraceus</i> was common. There was significant establishment of <i>Maireana brevifolia</i> (Yanga Bush) and <i>Atriplex</i> species were common however there has been significant decline in shrubs due to prolonged dry conditions. The site has met all LFA associated targets this year. The soils were slightly alkaline, slightly saline, sodic and deficient in organic matter. The site was low in native species diversity and was weedier than desired. There was an	Continue to limit site disturbances. Further investigation for tailings seepage across the larger TSF1 area should also be undertaken as a priority and treated appropriately.	High

Site	Site summary and issues associated with long-term management outcomes	Management requirements	Priority
	appropriate composition of ground cover components. There were unusually elevated levels of Sulfur.		
TSF2-01	Grassland rehabilitation monitoring site TSF2-01 is located on the southern wall of TSF 2. It is a grassy slope with scattered tussocks of native perennial grasses (<i>Walwhalleya proluta</i>) and in 2009 a heavy cover of <i>Medicago polymorpha</i> . There was evidence of extensive soil erosion from the bare upper slope which contained numerous rills, but the eroded materials were captured within the plant patches down slope. There were six rills recorded this year, within the monitoring site with one exceeding the minimum value of concern. The site has shown a decline in ecological function over the last years but continued to meet all LFA targets. While EC has declined the soils were highly saline, highly sodic and deficient in organic matter and nitrate. There was a lack of native forbs and grasses and the site was dominated by exotic plants. There was an appropriate composition of ground cover components. There were excessively high levels of Sulfur and elevated concentrations Copper and Silicon.	Ameliorate tailings seepages. There continued to be some active rills one of which exceeded the minimum value of concern which should be ameliorated via the application of native pasture hay (or weed free hay). Further investigation for active rilling and tailings seepage across the larger TSF2 area should also be undertaken as a priority and treated appropriately. In the bare rows which extend along the contour above the site, there continues to be active rilling which could be ameliorated via the application of more suitable topsoil materials and/or the application of rock mulch, sterile cover crop and native pasture hay. Application of native pasture hay would provide immediate benefits and would be encouraged. The use of suitable topsoil material should be a priority management action which should involve testing of soil stockpiles and spoil material prior to use in rehabilitation.	High
TSF2-02	This grassland rehabilitation site is located on the north-east wall of TSF 2. It is a grassy slope similar to TSF2-01 with scattered tussocks of native perennial grasses (<i>Walwhalleya proluta</i>) and in 2009 a heavy cover of <i>Medicago polymorpha</i> . In 2010, there was evidence of extensive soil erosion from the bare upper slope which contained numerous rills, but the eroded materials were captured within the plant patches down slope. There was no active rilling within the monitoring site. The site continued to meet all LFA targets. The soils were deficient in organic matter, phosphorous and nitrate and sodic. The site was low in native herb and grass diversity and was dominated by exotic species. There was an appropriate composition of ground cover components. There were elevated levels of Sulfur.	Further investigation for active rilling and tailings seepage across the larger TSF2 area should also be undertaken as a priority and treated appropriately. In the bare rows which extend along the contour above the site, there continues to be active rilling which could be ameliorated via the application of more suitable topsoil materials and/or the application of rock mulch, sterile cover crop and native pasture hay. However due to the relatively small size of these bare rows combined with increasing trends in many ecological attributes of the TSF2 sites, it is likely the area will begin to naturally stabilise over time. Application of native pasture hay would however provide immediate benefits and would be encouraged. The use of suitable topsoil material should be a priority management action which should involve testing of soil stockpiles and spoil material prior to use in rehabilitation.	High
E22-01	E22-01 is located on the western batter of the waste emplacement surrounding the E22 open cut and is an open grassy area on the upper slope of the batter. Below the site there are some small planted tree lots with little to no ground cover with severe tunnel erosion observed nearby. The ecological function within the monitoring site has slightly declined but continued to all LFA related KPI completion targets. The soil characteristics were similar to the surrounding grassland areas but it was low in nitrates. The site was low native species diversity and was weedier than desired due to the relatively high cover of annual plants. The cover provided by annual species was too high but retained an appropriate cover of perennial plants. There were elevated levels of Copper.	Active tunnel erosion in the vicinity of the tree lots require amelioration and revegetated using an application of more suitable topsoil materials and/or the application of rock mulch, sterile cover crop and native pasture hay.	High
E22-02	Site E22-02 is located on the northern batter of the waste rock emplacement that surrounds E22 open cut. It is a rocky north facing slope that appears to have been deep ripped after shaping. There was little change in ecological function over the last year and it continued to be less stable than the reference sites, with a large active rill which continues to exceed the	The undesirable spoil characteristics of this site have influenced the establishment and composition of the vegetation. While it continued to be dominated by exotic annual species, there is an increasing cover of native perennials.	Medium

Site	Site summary and issues associated with long-term management outcomes	Management requirements	Priority
	minimum value of concern. The soils were moderately alkaline and deficient in nitrates. The site was low in native species diversity, had a low diversity of herbs and grasses. While total ground cover targets remained low in perennial plant covers. The vegetation was dominated by exotic species and was more weedy than desired. There were elevated levels of Copper.	There continued to be some active rills one of which exceeded the minimum value of concern which should be ameliorated via the application of native pasture hay (or weed free hay). Further investigation for active rilling across the larger E22 area should also be undertaken and if required treated appropriately. The use of suitable topsoil material should be a priority management action which should involve testing of soil stockpiles and spoil material prior to use in rehabilitation.	
E26-01	E26-01 is located on the north eastern slope of the waste emplacement surrounding the E26 subsidence zone. This site has continued to be ecologically functional and has met all LFA KPI targets since monitoring began in 2009 and the soils were characteristically similar to the surrounding grassland areas. The site was low in native species diversity and had slightly fewer herb and grass species compared to the surrounding grassland sites. There continued to be good total and perennial ground cover. There were elevated levels of Copper.	Limit site disturbances.	Low
E27-01	E27-01 is located on the western side of the E27 open cut waste rock emplacement. The site had generally good ground cover with scattered native perennial grasses and scattered establishment of native shrubs. This year there were lower levels of perennial plant cover and increasing annual plant cover but the site continued to meet LFA targets. The soil chemical characteristics were similar to the surrounding grassland areas. The site was low in native herb diversity, contained more exotic annual species than desired and exotic species dominated the ground cover. There were excessively high levels of Copper.	Limit site disturbances.	Low - Medium

9 LFO-01 site description

LFO-01 is situated in the southern section of the Limestone Forest Offset (LFO) area. This site has had a long cropping history and was graded in 2007 in preparation for planting. Tubestock were planted in July 2009 and in some of the area, spraying around the tubestock had recently been undertaken in the 2009 survey period. In 2009 the site was predominantly bare within the inter-rows but weeds have begun to colonise the rip lines. There was moderate wind erosion within the bare inter-rows but due to the flat topography the site is generally stable. In 2010, this site had been sprayed and dead tubestock had recently been replaced. In 2011 the site had become very weedy with weeds colonising the bare inter-row areas and the tubestock had grown considerably. Parts of the area had been slashed. The troughs and banks had become redundant with the entire area now described as a “weak” woodland rehab patch. In 2012, the tubestock has further grown and the plants had become better established. *Xerochrysum bracteatum* has become well colonised within the site but the site continued to be weedy. In 2013 the tubestock had grown and *Xerochrysum* were prolific but the site remained weedy.

As for previous years, *the vegetation transect aligned with the LFA transect to accommodate the row and inter-row sequence.*

9.1 Landscape Function Analysis

9.1.1 Landscape organisation

In 2009 and 2010 LFO-01 was characterised into trough and bank sequences due to the deep ripping with flat graded inter-rows (Figure 9-1, Table 9-1). In 2010 there had been little change and the banks occupied 19.69% of the site and the flat inter-rows dominated 76.7% of the site resulting in a very low Landscape Organisation Index of 4.0%. There were however improvements in the functional capacity in all patch types, largely due to the establishment of the annual vegetation and cryptogams within the bank and troughs. In the flat inter-patches there were scattered plants and extensive colonisation of cryptogams which also increased the stability and nutrient recycling capacity within this patch type.

In 2011, there has been a significant increase in ground cover with the physical features such as the banks and troughs becoming redundant in terms of ecological function and subsequently the site was re-characterised as a woodland rehabilitation patch, although it was relatively “weak”. In 2012 the site continued to be a complete functional patch with increasing trends in stability, infiltration and nutrient recycling indices. In 2013 there was a marginal decrease in ecological function and with indices of 72.0, 34.3 and 36.5, this site met LFA stability and nutrient recycling targets but was 6.8 LFA units lower in infiltration capacity.



Figure 9-1. Permanent photo point taken from the top of the LFA transect in 2011 (left), 2012 (centre) and 2013 (right).

Table 9-1. Summary of landscape organisation and LFA indices since 2009.

LFO-01		7/12/2009				23/09/2010				19/10/2011		16/10/2012		18/10/2013	
Number of Patches/10m		2				2				0.5		0.5		0.5	
Total Patch Area (m2)		8				9.5				200		200		200.00	
Patch Area Index		0.03				0.04				1		1		1.00	
Landscape Organisation Index		0.03				0.04				1		1		1.00	
Average Interpatch Length (m)		1.75				1.75				NA		NA		NA	
Range Interpatch length (m)		0.35 to 5.4				0.35 to 5.25				NA		NA		NA	
Patch or Interpatch Type		Bank Interpatch	Trough Patch	Flat Interpatch		Bank Interpatch	Trough Patch	Flat Interpatch		Woodland Rehab Patch		Woodland Rehab Patch		Woodland Rehab Patch	
Patch or Interpatch Proportion (%)		18.9	3.2	77.9	100	19.6	3.7	76.7	100	100	100	100	100	100.0	100
Soil Surface Assessment															
Within Individual Zones	Stability	44.5	49.5	48.8		56.5	62.5	60		65		72.5		72.0	
	Infiltration	37.4	32.5	18.1		35	40	19.7		33.1		35.8		34.3	
	Nutrients	25.6	33	9.9		29.1	39.7	21.5		34.6		38.8		36.5	
		Total				Total				Total		Total		Total	
Individual zones contribution to the whole of Landscape	Stability	8.4	1.6	38	48	11.1	2.3	46	59.4	65	65	72.5	72.5	72.0	72.0
	Infiltration	7.1	1	14.1	22.2	6.9	1.5	15.1	23.5	33.1	33.1	35.8	35.8	34.3	34.3
	Nutrients	4.8	1	7.7	13.6	5.7	1.5	16.5	23.7	34.6	34.6	38.8	38.8	36.5	36.5

9.1.2 Soil Surface Assessment

This rehabilitation sites has undergone a significant transformation and was re-characterised as a woodland rehabilitation patch in 2011, two years after planting as there was no apparent leakage of resources. There continued to be low levels of protective ground cover in the form of perennial vegetation which was very sparse and scattered across the site, subsequently providing limited basal or canopy covers.

Annual plants continued to be very abundant across the site which provided increasing cover of dead litter with slight decomposition being observed on a couple of occasion, indicating increased levels of microbial and fungal activity. Cryptogams had colonised the otherwise bare soil crusts and continued to provide extensive ground covers throughout the site. With the increasing cover of litter and cryptogams there has been little evidence of erosion and deposition since 2013. The original flat inter-row areas remained very hard and continued to provide very low surface relief but remnant banks provided moderate surface relief on occasions and the soil crusts were often hard. The clay loam soils continued to have some slumping of the sub-crusts but some replicates had very stable soils indicating improved soil coherency probably due to the development of a humus layer (Table 9-2).

Table 9-2 . Results of the Soils Surface Assessment for the Woodland Rehab patch.

Features	Max score	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Soil Cover	5	1	2	1	1	2
Per. basal / canopy cover	4	1	1	1	1	3
Litter cover, orig & incorp.	10	5ln	5ln	5ln	5ls	5ls
Cryptogam cover	4	3	3	4	3	3
Crust broken-ness	4	4	4	4	4	4
Erosion type & severity	4	4	4	4	3	4
Deposited materials	4	4	4	4	4	4
Soil surface roughness	5	2	3	2	3	3
Surface resist. to disturb.	5	4	4	4	4	3
Slake test	4	3	4	3	4	4
Texture	4	2	2	2	2	2

9.2 Soil analyses

There was a marginal decrease in soil pH at LFO-01 and the soils were characterised as strongly acidic this year and they continued to fall below the reference KPI target of 5.99 and below the prescribed desirable level of 5.6 (Table 9-3). There was a further reduction in Electrical Conductivity and this year fell within the target ranges and these were non saline (Slavich and Petterson 1993). There was a slight reduction in Organic Matter and they remained lower than the local levels. There was a reduction in both phosphorus and nitrate levels but phosphorous levels remained elevated, while nitrates were exceptionally low. There was a slight decrease in CEC values and they continued to fall below the target range. There was also a reduction in ESP with the low values indicating that the soils are not sodic and unlikely to be dispersive.

Table 9-3. Results of the soil analysis for LFO-01 compared to the upper and lower values for the woodland reference sites and desirable levels.

Nutrient	Units	LFO-01					Lower KPI	Upper KPI	Desirable Level
		2009	2010	2011	2012	2013			
pH (1:5 water)	units	5.72	5.57	5.69	6.00	5.34	5.99	7.10	5.6 – 7.3
Conductivity (1:5 water)	dS/m	0.242	0.178	0.179	0.100	0.063	0.038	0.191	0.150
Organic Matter	%	2.90	3.0	2.8	3.5	2.3	3.0	4.6	>4.5
Phosphorus (Colwell)	mg/kg	72	71	70	72	53	6	17	50
Nitrate	mg/kg	81	40.1	57.4	10.9	1.0	1.2	1.9	13.0
Cation Exchange Capacity	cmol+/Kg	11.2	10.06	9.53	11.15	8.85	12.05	22.87	14.00
Exchangeable Sodium Percentage	%	0.12	0.54	0.67	0.62	0.44	0.29	2.42	<5

9.3 Rill assessment

No rills were observed within the monitoring quadrat.

9.4 Tree density and health condition

This site was planted with tubestock in mid 2009 and four individuals had grown significantly and this year had a diameter at breast height (dbh) greater than 5cm. Three individuals were *Eucalyptus microcarpa* and one was a *Callitris glaucophylla*. All individuals were healthy and the *C. glaucophylla* was already bearing fruit.

Table 9-4. Summary of tree health and density.

Dominant species	<i>Eucalyptus microcarpa</i> (3), <i>Callitris glaucophylla</i> (1)
Average dbh (Cm)	6
Max dbh (cm)	7
Min dbh (cm)	5
Total trees	4
No. with multiple limbs	2
No. Live trees	4
No. Healthy	4
No. Medium Health	0
No. Advanced Dieback	0
No. Dead	0
Mistletoe	0
Flowers / fruit	1

9.5 Shrubs and juvenile trees

In 2013 there was a net loss of four individuals as these were now included within the tree population data due to excellent growth and development.

The juvenile tree and shrub population was now 25 and was represented by four endemic species. *Callitris glaucophylla* continued to be the most dominant species with 16 individuals followed by *Eucalyptus microcarpa* (7) and *E. populnea* (1). There has been significant growth of the tubestock with most of the population (16 or 64%) now exceeding 2.0 m in height indicating excellent growth and development (Figure 9-2). There has been no new recruitment or replacement planting during the past year and therefore there continued to be no individuals less than 1.0m in height (Table 9-5).

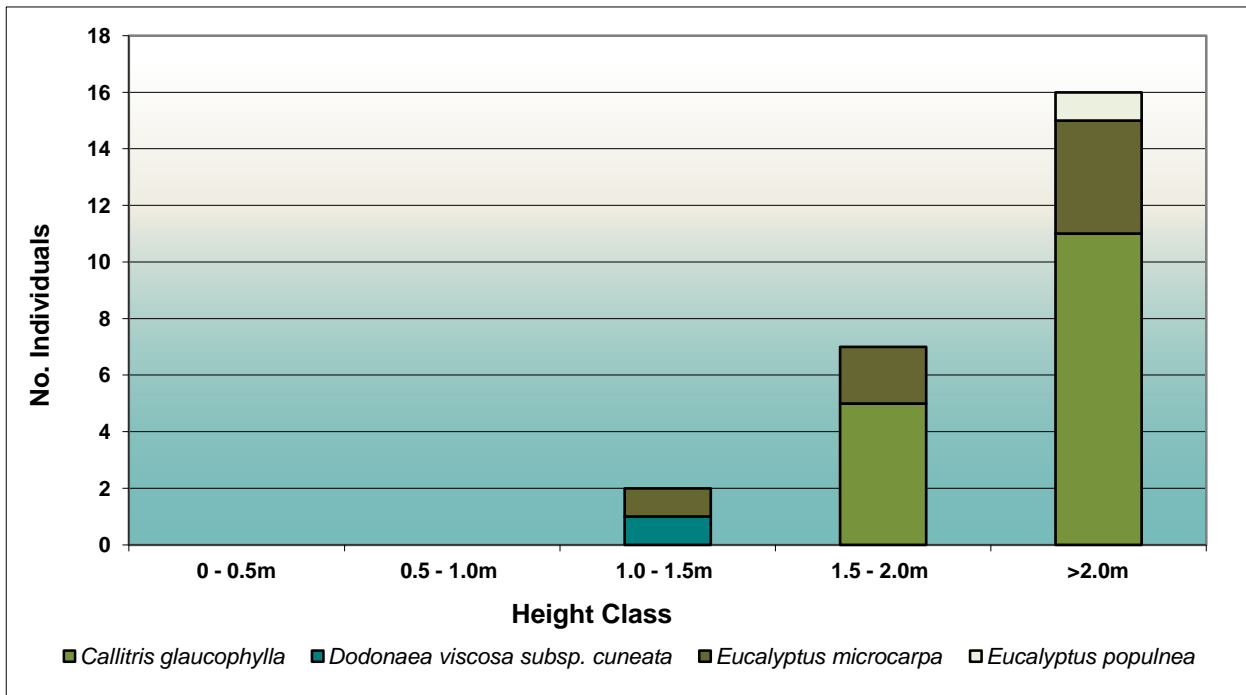


Figure 9-2 Shrubs and juvenile trees occurring within the monitoring site.

Table 9-5. Shrubs and young trees occurring within the monitoring site.

Species	0 - 0.5m	0.5 - 1.0m	1.0 - 1.5m	1.5 - 2.0m	>2.0m	Total	endemic	not endemic
<i>Callitris glaucophylla</i>				5	11	16	16	
<i>Dodonaea viscosa subsp. cuneata</i>			1			1	1	
<i>Eucalyptus microcarpa</i>			1	2	4	7	7	
<i>Eucalyptus populnea</i>					1	1	1	
Total	0	0	2	7	16	25	25	0
% endemic species							100	0

9.6 Structural diversity and habitat complexity

This area was an old cropping paddock and in 2009 the entire area was graded and sprayed out to control annual weeds prior to tubestock planting. As can be seen in Figure 9-3, there has been a continued improvement in total ground cover up until this year where a slight reduction resulted in a total ground cover of 92% on average across the site. There have been significant increases in annual plant and litter covers since 2009 and these now account for 45.5% and 40.5% of total ground cover respectively. While cryptogams provided a relatively large proportion (17.5%) of ground cover last year there was only 5% on average this year largely due to the increase in annual plant and litter covers. Perennial plants continued to be sparse and provided only occasional and very limited perennial plant cover of 1% (Figure 9-4, Table 9-6).

There continued to be limited occurrences of vertical plant cover in the 0.5 – 2.0m height category due to the large ground cover plants or establishing tubestock. Although there has been significant growth of the tubestock throughout the monitoring plot no vertical structure greater than 2.0m high was yet recorded along the vegetation transect.

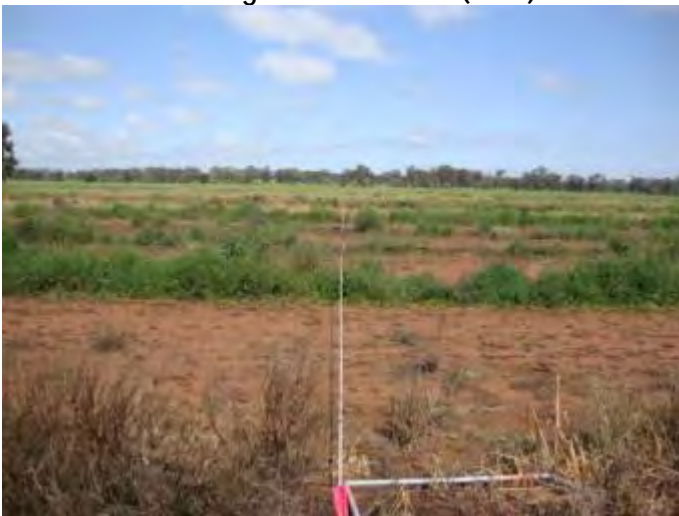
2009 Vegetation transect (front)



2009 Vegetation transect (rear)



2010 Vegetation transect (front)



2010 Vegetation transect (rear)



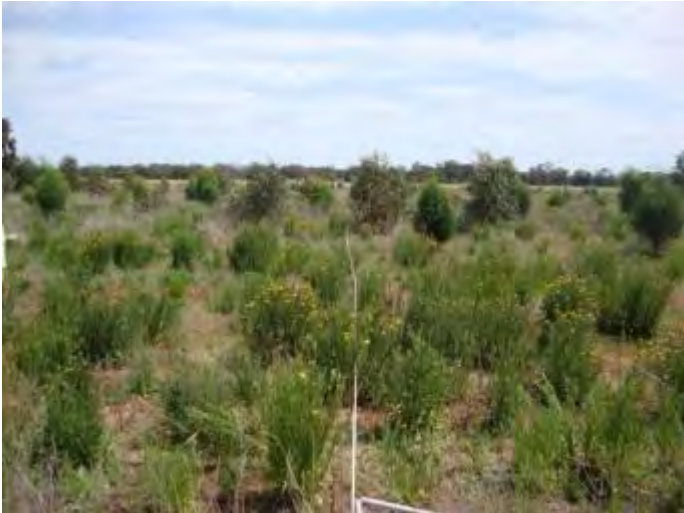
2011 Vegetation transect (front)



2011 Vegetation transect (rear)



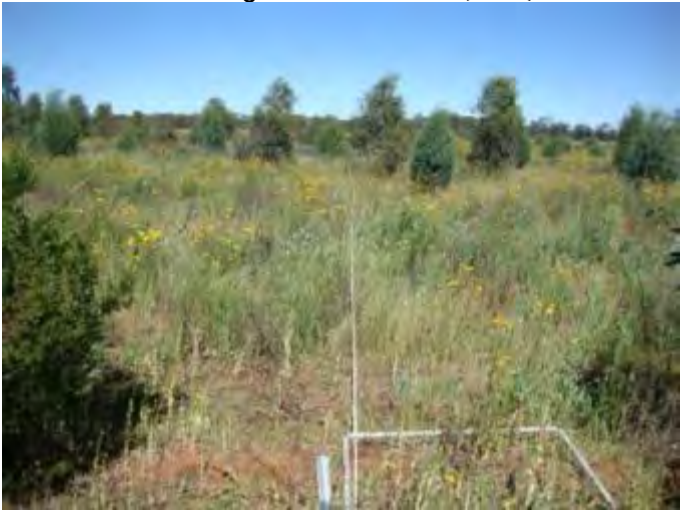
2012 Vegetation transect (front)



2012 Vegetation transect (rear)



2013 Vegetation transect (front)



2013 Vegetation transect (rear)



Figure 9-3. Permanent photo points taken from the front (left) and rear (right) of the vegetation transect.

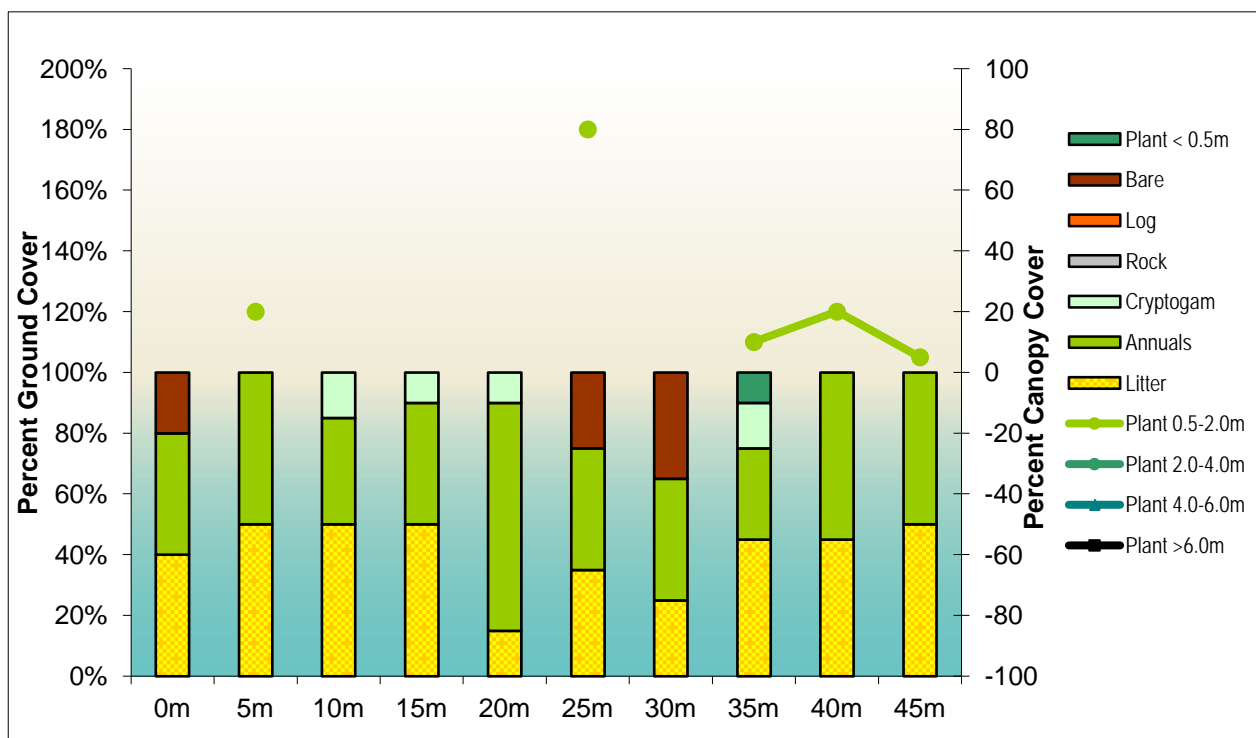


Figure 9-4. Graph illustrating the structural diversity and habitat complexity of the monitoring site in 2013.

Table 9-6. Average and minimum and maximum values of the structural diversity of the monitoring site.

Vegetation structure	0m	5m	10m	15m	20m	25m	30m	35m	40m	45m	Average	Min	Max
Litter	40	50	50	50	15	35	25	45	45	50	40.5	15	50
Annuals	40	50	35	40	75	40	40	30	55	50	45.5	30	75
Cryptogam	0	0	15	10	10	0	0	15	0	0	5	0	15
Rock	0	0	0	0	0	0	0	0	0	0	0	0	0
Log	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare	20	0	0	0	0	25	35	0	0	0	8	0	35
Perennial <0.5m	0	0	0	0	0	0	0	10	0	0	1	0	10
Total Ground Cover	80	100	100	100	100	75	65	100	100	100	92	65	100
0.5-2.0m	0	20	0	0	0	80	0	10	20	5	13.5	0	80
2.0-4.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0-6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
>6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0

9.7 Species cover abundance

There were 18 species recorded within the five 1m² quadrats on the permanent vegetation transect line and of these 11 were exotic species. Using the Braun-blauquet scale, the highest possible cover score that can be obtained is 30 and cover abundance is illustrated as a sum of scores (class values) obtained along the five 1m² quadrats.

Last year the annual weeds *Conyza bonariensis* and *Lactuca serriola* were very common and so were the annual natives *Crassula colorata* and *Xerochrysum bracteatum* and these were found in at least four of the five 1m² quadrats. This year however *Conyza bonariensis* was not recorded and the most common species were *Lactuca serriola*, *Papaver hybridum*, *Papaver somniferum*, *Euchiton involucratus*, *Wahlenbergia gracilentia* and *Xerochrysum bracteatum* and these were recorded in at least four of the five 1m² quadrats, but typically they provided low cover values (Figure 9-5, Table 9-7). There continued to be a low abundance of native perennial species and this year *Chloris truncata* was not recorded.

The remaining species were mainly weedy species commonly associated with areas of high disturbance and were recorded on only one occasion and/or provided low cover values. Of the live plant cover scores recorded 38.6% was provided by native species, a reduction from 48.3% recorded last year.

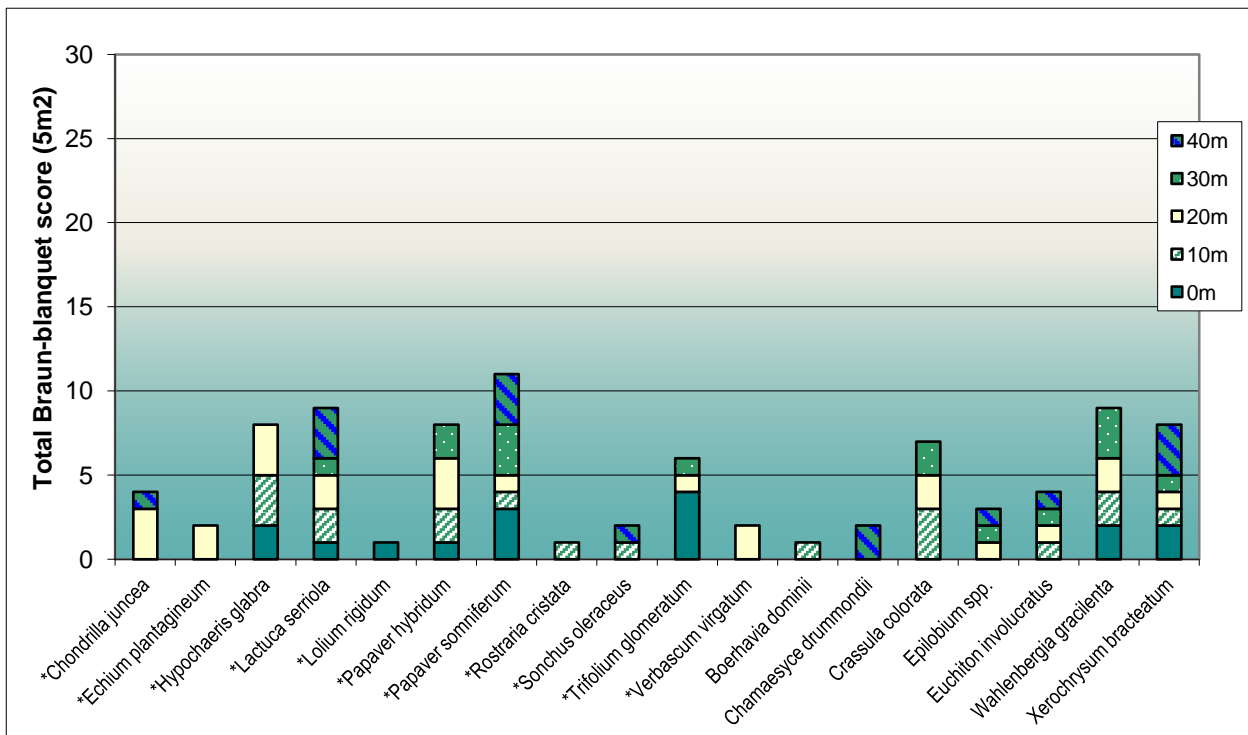


Figure 9-5. Total species recorded across the five, 1m² quadrats using the Braun-blanket scale (max possible score is 30) as a measure of cover abundance.

Table 9-7. List of species and their average cover abundance score across the five, 1m² monitoring quadrats.

Species	0m	10m	20m	30m	40m	Total
<i>*Chondrilla juncea</i>			3		1	4
<i>*Echium plantagineum</i>			2			2
<i>*Hypochaeris glabra</i>	2	3	3			8
<i>*Lactuca serriola</i>	1	2	2	1	3	9
<i>*Lolium rigidum</i>	1					1
<i>*Papaver hybridum</i>	1	2	3	2		8
<i>*Papaver somniferum</i>	3	1	1	3	3	11
<i>*Rostraria cristata</i>		1				1
<i>*Sonchus oleraceus</i>		1			1	2
<i>*Trifolium glomeratum</i>	4		1	1		6
<i>*Verbascum virgatum</i>			2			2
<i>Boerhavia dominii</i>		1				1
<i>Chamaesyce drummondii</i>					2	2
<i>Crassula colorata</i>		3	2	2		7
<i>Epilobium spp.</i>			1	1	1	3
<i>Euphorbia involucrata</i>		1	1	1	1	4
<i>Wahlenbergia gracilentia</i>	2	2	2	3		9
<i>Xerochrysum bracteatum</i>	2	1	1	1	3	8
Total cover						88
Sum of cover of native species						34
Percent endemic species cover						38.6

9.8 Floristic diversity

The floristic diversity of the sites was measured using two different methods. One provides an assessment of the average number of species within five, one square metre (m²) sub-quadrats along the vegetation transect, while the other provides the total number of species within the entire 50x20m monitoring plot.

9.8.1 Species diversity per m²

There has been a decline from 4.4 to 4.2 native species per m² this year. There were however an increased number of exotic species and there were 5.6 exotic species per m² this year (Table 9-8). The number of native species per m² ranged from 2 - 5, while there were 4 - 8 exotic species.

Table 9-8. Species diversity per 1m².

Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	2	5	5	5	4	4.2	1.3
Exotic	6	6	8	4	4	5.6	1.7
Total	8	11	13	9	8	9.8	2.2

9.8.2 Total species diversity

In 2009, there were 36 species including 21 native and 15 exotic species recorded in the 50 x 20m monitoring quadrat. In 2013, there was a total diversity of 46 species of which 19 were native and 27 were exotic species. (Figure 9-6, Table 9-9). The relatively flat line of the species area curves indicates that the site was relatively homogenous. A list of species recorded within the monitoring site is provided in Appendix 1.

Table 9-9. Cumulative species diversity.

Area (m2)	1	2	4	25	50	100	200	500	1000
Native	2	6	6	7	9	13	13	18	19
Exotic	6	7	10	12	15	17	22	26	27

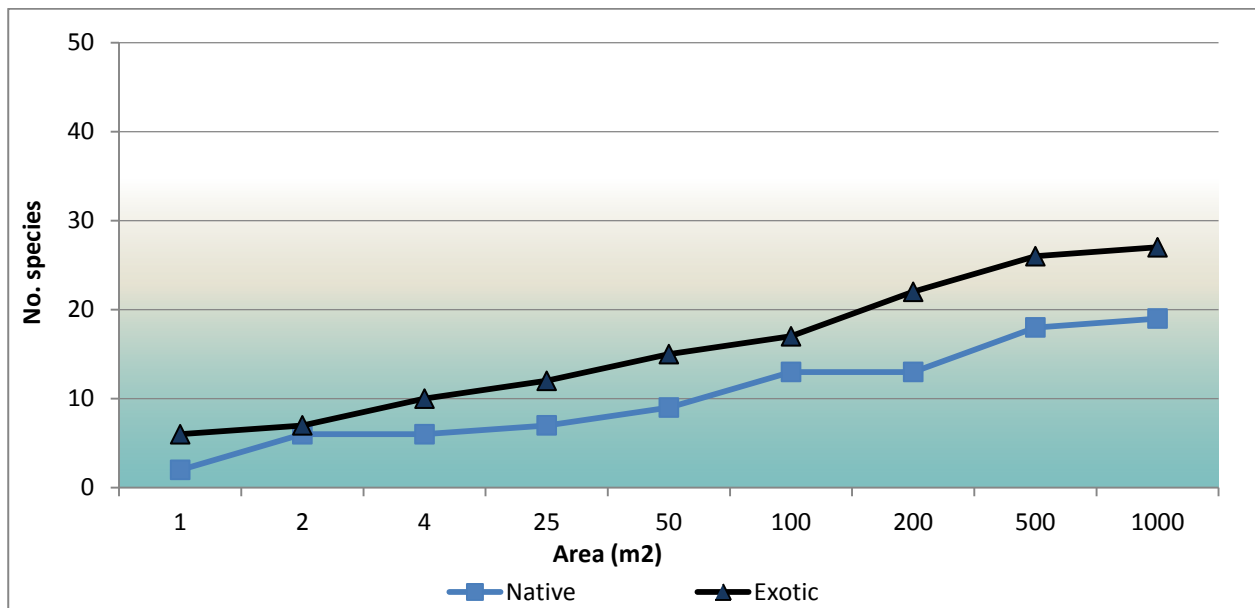


Figure 9-6. Cumulative species in the 50m x 20m (1000m²) monitoring quadrat in 2013.

9.9 Growth forms

Figure 9-7 is a summary of species in each growth form that were recorded in LFO-01. Herbs continued to be the most dominant plant type with 36 species including 22 exotic species, followed by grasses with five exotic species. There were also three tree, one shrub and one sub-shrub and these were all native species. No reed or fern representatives were present. Compared to the woodland reference there was an appropriate composition of most growth forms, however there was a lack of grass diversity.

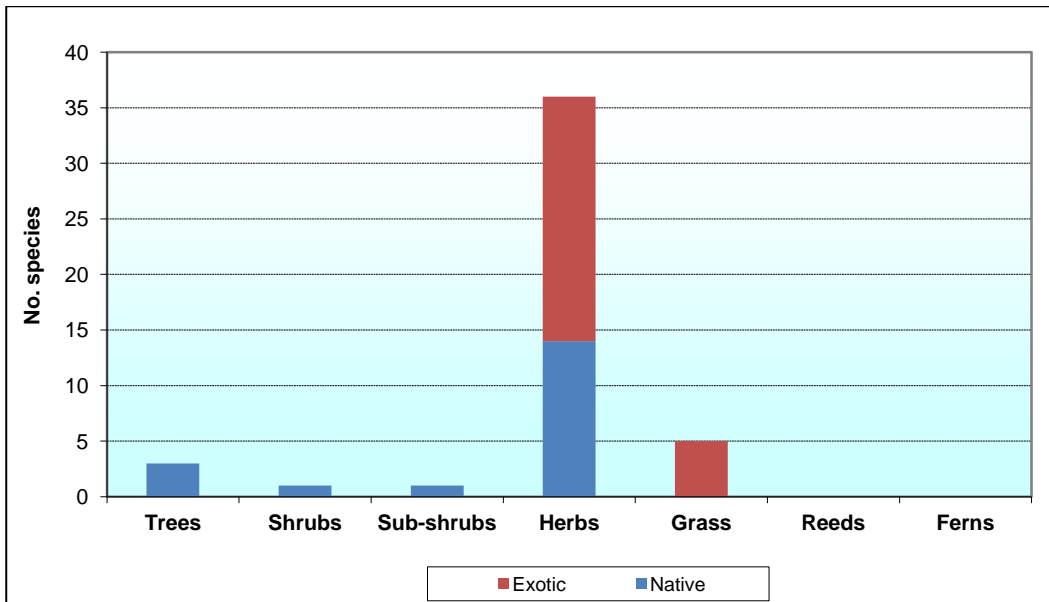


Figure 9-7. Graph illustrating the growth forms of species recorded in the 50m x 20m monitoring quadrat.

9.10 Comparison of rehabilitation data with key performance indicators

Table 9-10 indicates the performance of the rehabilitation monitoring site against the Completion and Desirable Performance Indicators developed for woodland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) for example and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 9-10. Comparison of key performance Indicators recorded in the rehabilitation site LFO-01 compared to lower and upper limits recorded in the woodland reference sites.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-01				
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2009	2010	2011	2012	2013
Phase2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	0	5	4	4	4	4	4
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%	62.9	69.0	48	59.4	65	72.5	72.0
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%	41.1	55.7	22.2	23.5	33.1	35.8	34.3
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%	36.2	53.0	13.6	23.7	34.6	38.8	36.5
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%	100	100	3	4	100	100	100

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-01				
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising		No.	0	0	0	0	0	0	0
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0	0	0	0	0
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)	6.0	7.1	5.72	5.57	5.89	6.00	5.34
			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)	0.038	0.191	0.242	0.178	0.179	0.100	0.063
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	3.0	4.6	2.9	3.0	2.8	3.5	2.3
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	6.4	17.3	71.8	70.5	70.0	72.0	52.7
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	1.2	1.9	80.8	40.1	57.4	10.9	1.0
			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)	12.0	22.9	11.18	10.06	9.53	11.15	8.85
			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	2.4	0.12	0.54	0.67	0.62	0.4
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees	The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.		species/area	1	6	6	5	5	5	4
				The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		% population	100	100	na	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	53	76	36	37	43	47	46

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-01				
			Native species richness		The total number of live native plant species provides an indication of the native plant diversity of the site and that it is greater than or comparable to the local remnant vegetation	>No./area	33	53	21	16	18	21	19
			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	13	27	15	21	25	26	27
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees	The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation		No./area	29	110	40	32	29	29	25
	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	4	4	4	4	4	3
			Shrubs	The number of shrub species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	0	3	2	1	1	1	1
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	1	5	2	0	1	0	1
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	33	46	26	26	28	35	36
			Grasses		The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	9	22	2	6	9	7	5
			Reeds		The number of reed, sedge or rush species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	1	0	0	0	0	0
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Ferns		The number of ferns comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	1	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-01				
Phase 5: Ecosystem & Landuse Development	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	%	47	77	3.2	19	37	31.5	40.5
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	2	22	11.7	14.3	39	45	45.5
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	8	0	30.7	17	17.5	5
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0	1	0	0	1	0.5	0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	3	0	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	6	11	85.1	36	5.5	3	8
			Perennial plant cover (< 0.5m)	Percent ground cover provided by live perennial vegetation (< 0.5m in height) is comparable to that of the local remnant vegetation		%	7	25	0	0	0.5	2.5	1
			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		%	89	95	14.9	64	94.5	97	92
	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	7	8	0.8	1.6	3.4	4.4	4.2
			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	1	4	1.0	1.4	4.6	5.0	5.6
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation		%	63	87	na	57.9	43.4	48.3	38.6

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-01				
	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	7	89	29	14	0	0	0
			shrubs and juvenile trees 0.5 - 1m in height		The number of shrubs or juvenile trees 0.5-1m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	2	15	11	18	12	1	0
			shrubs and juvenile trees 1 - 1.5m in height		The number of shrubs or juvenile trees 1-1.5m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	13	0	0	15	4	2
			shrubs and juvenile trees 1.5 - 2m in height	The number of shrubs or juvenile trees 1.5-2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation		No./area	0	18	0	0	1	13	7
			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	48	0	0	1	11	16
	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	1	9	0	0	0	2.5	13.5
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	6	0	0	0	0	0
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 - 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	9	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-01				
			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	17	42	0	0	0	0	0
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	3	3	0	0	0	0	2
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	100	100	na	na	0	0	100
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	6	19	0	0	0	0	4
			Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	18	54	0	0	0	0	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	83	100	0.0	0.0	0	0	100
			Healthy trees	The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation		% population	7	47	0.0	0.0	0	0	100
			Medium health		The percentage of the tree population which are in a medium health condition and that the percentage is comparable to the local remnant vegetation	% population	44	57	0.0	0.0	0	0	0
			Advanced dieback		The percentage of the tree population which are in a state of advanced dieback and that the percentage is comparable to the local remnant vegetation	<% population	0	36	0.0	0.0	0	0	0
			Dead Trees		The percentage of the tree population which are dead (snags) and that the percentage is comparable to the local remnant vegetation	% population	0	17	0.0	0.0	0	0	0
			Mistletoe		The percentage of the tree population which have mistletoe provides an indication of community health and habitat value and that the percentage is comparable to the local remnant vegetation	% population	0	7	0.0	0.0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-01				
			Flowers/fruit: Trees	The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation		% population	50	83	0.0	0.0	0	0	25

10 LFO-02 site description

LFO-02 is located in the northern section of the offset area created next to the Limestone Forest. This site has had a long agricultural history but has not been cropped. It has been a native grassland area which was direct drilled with Lucerne several years ago. Tubestock were planted in July 2009. The site contained adequate ground cover and leaf litter. There were relatively few weeds within the rip lines. In 2010, this site had been sprayed and dead tubestock had recently been replaced. In 2011 the site had become very weedy with weeds colonising the bare inter-row areas and the tubestock had grown considerably. The troughs and banks had become redundant with the entire area now described as a “weak” woodland rehab patch. Termites were abundant. In 2012 and 2013, the tubestock has further grown and the plants had become better established but the site remained weedy.

As for previous years, the vegetation transect aligned with the LFA transect to accommodate the row and inter-row sequence.

10.1 Landscape Function Analysis

10.1.1 Landscape organisation

In 2009 and 2010, LFO-02 was characterised into trough and bank sequences due to the deep ripping and there were large areas of flat inter-rows which in 2010 had become well colonised with annual vegetation and were referred to as grassy flat patches (Figure 10-1, Table 10-1).

In 2011, there was a significant increase in ground cover with the physical features such as the troughs and banks becoming redundant in terms of ecological function and subsequently the site was re-characterised as a woodland rehabilitation patch, although it was relatively “weak”. Since then the site had continued to develop and there has been a significant increase in Landscape Organisation Index which transformed from 4% in 2009 to 100% in 2011 with the overall LFA indices for stability, infiltration and nutrient recycling also increasing. This year there was a slight decrease in ecological function and while the stability targets continued to be met, infiltration and nutrient recycling remained 2.2 and 0.4 LFA units lower than the target KPI recorded in the woodland reference sites.



Figure 10-1. Permanent photo point taken from the top of the LFA transect in 2012 (left) and 2013 (right).

Table 10-1. Summary of landscape organisation and LFA indices in 2009, 2010, 2011, 2012 and 2013.

LFO-02		7/12/2009				23/09/2010					19/10/2011		16/10/2012		18/10/2013	
Number of Patches/10m		1.9				3.5					0.5		0.5		0.5	
Total Patch Area (m2)		9				134.85					200		200		200.00	
Patch Area Index		0.04				0.52					1		1		1.00	
Landscape Organisation Index		0.04				0.68					1		1		1.00	
Average Interpatch Length (m)		1.65				0.75					NA		NA		NA	
Range Interpatch length (m)		0.4 to 4.35				0.3 to 3.85					NA		NA		NA	
Patch or Interpatch Type		Bank Interpatch	Trough Patch	Flat Patch		Bank Interpatch	Trough Patch	Grassy Flat Patch	Bare Flat Interpatch		Woodland Rehab Patch		Woodland Rehab Patch		Woodland Rehab Patch	
Patch or Interpatch Proportion (%)		17.9	3.5	78.6	100	17.3	4.1	63.6	15	100	100	100	100	100	100.0	100
Soil Surface Assessment																
Within Individual Zones	Stability	46	43.5	56.5		58.5	49	65	57.5		64		70		67.0	
	Infiltration	38.8	26.1	31.3		28.8	26.5	36	21.1		37.6		39.8		38.9	
	Nutrients	22.8	20.7	25.6		24.9	22.3	33.7	22.1		34.8		41.7		35.8	
		Total				Total					Total		Total		Total	
Individual zones contribution to the whole of Landscape	Stability	8.2	1.5	44.4	54.2	10.1	2	41.4	8.6	62.1	64	64	70	70	67.0	67.0
	Infiltration	6.9	0.9	24.6	32.5	5	1.1	22.9	3.2	32.1	37.6	37.6	39.8	39.8	38.9	38.9
	Nutrients	4.1	0.7	20.1	24.9	4.3	0.9	21.4	3.3	30	34.8	34.8	41.7	41.7	35.8	35.8

10.1.2 Soil Surface Assessment

This rehabilitation sites has undergone a significant transformation and was re-characterised as a woodland rehabilitation patch in 2011, two years after planting as there was no apparent leakage of resources. There continued to be low levels of protective ground cover in the form of perennial vegetation which was very sparse and scattered across the site, subsequently providing limited basal or canopy covers.

Annual plants continued to be very abundant across the site which provided increasing cover of live and dead litter with slight decomposition being observed on a few occasions, indicating increased levels of microbial and fungal activity. Due to increasing levels of litter and vegetative cover there was a decline in cryptogam abundance but these continued to be observed in small quantities lower down the transect. With the increasing cover of annual plant, litter and cryptogams there has also been little evidence of erosion and deposition. With the colonising plants in the original flat inter-row areas and remnant troughs and banks the capacity of the soil surface to capture mobilised materials had generally improved and this year there was moderate surface roughness. The clay loam soils demonstrated some slumping of the sub-crusts in previous years however this year they appeared to be mostly stable, probably due to the development of a humus layer which has increased soil coherency. The soils varied between being moderately hard to very hard (Table 10-2).

Table 10-2 . Results of the Soils Surface Assessment for the Woodland Rehab patch.

Features	Max score	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Soil Cover	5	2	1	1	1	1
Per. basal / canopy cover	4	2	1	1	1	1
Litter cover, orig & incorp.	10	5ln	6ls	6ls	5ls	5ln
Cryptogam cover	4	1	1	1	3	1
Crust broken-ness	4	4	4	4	4	4
Erosion type & severity	4	4	4	4	3	3
Deposited materials	4	4	4	4	4	4
Soil surface roughness	5	3	3	3	3	3
Surface resist. to disturb.	5	3	3	3	4	4
Slake test	4	4	4	4	4	3
Texture	4	2	2	2	2	2

10.2 Soil analyses

There was a marginal decrease in soil pH at LFO-02 and the soils were characterised as strongly acidic this year and they continued to fall below the reference KPI target of 5.99 and below the prescribed desirable level of 5.6 (Table 9-3). There was a further reduction in Electrical Conductivity and this year fell within the target ranges and these were non saline (Slavich and Petterson 1993). There was a slight reduction in Organic Matter and they remained lower than the local levels. There was a reduction in both phosphorus and nitrate levels but phosphorous levels remained elevated, while nitrates were exceptionally low. There was a slight decrease in CEC values and they continued to fall below the target range. There was a slight increase in ESP however the low values indicate that the soils are not sodic and unlikely to be dispersive (Isbell 1996).

Table 10-3. Results of the soil analysis for LFO-02 compared to the upper and lower values for the woodland reference sites and desirable levels.

Nutrient	Units	LFO-02					Lower KPI	Upper KPI	Desirable Level
		2009	2010	2011	2012	2013			
pH (1:5 water)	units	6.07	6.09	6.14	6.31	5.51	5.99	7.10	5.6 – 7.6
Conductivity (1:5 water)	dS/m	0.109	0.079	0.090	0.061	0.039	0.038	0.191	0.150
Organic Matter	%	2.31	3.0	3.2	3.5	1.9	3.0	4.6	>4.5
Phosphorus (Colwell)	mg/kg	24	33	30	33	19	6	17	50
Nitrate	mg/kg	28	8.8	16.7	3.4	2.4	1.2	1.9	13.0
Cation Exchange Capacity	cmol+/Kg	11.9	10.72	10.18	10.85	8.63	12.05	22.87	14.00
Exchangeable Sodium Percentage	%	0.31	0.37	0.55	0.29	0.35	0.29	2.42	<5

10.3 Rill assessment

No rills were observed within the monitoring quadrat in any monitoring year.

10.4 Tree density and health condition

This site was planted with tubestock in mid 2009 and this year there were two individuals with a diameter at breast height (dbh) greater than 5cm. One individual was a *Eucalyptus microcarpa* and one was *Acacia deanei*. Both individuals were healthy and the *Acacia deanei* was already bearing fruit.

Table 10-4. Summary of tree health and density.

Dominant species	<i>Eucalyptus microcarpa</i> (1), <i>Acacia deanei</i> (1)
Average dbh (Cm)	6
Max dbh (cm)	6
Min dbh (cm)	5
Total trees	2
No. with multiple limbs	1
No. Live trees	2
No. Healthy	2
No. Medium Health	0
No. Advanced Dieback	0
No. Dead	0
Mistletoe	0
Flowers / fruit	1

10.5 Shrubs and juvenile trees

Tubestock were planted in mid 2009 along rip lines at approximately 4m spacing and due to the loss of a large percentage as a result of the prolonged drought many individuals were replaced in 2010. This year there was a significant recruitment with 82 very small (~3cm) *A. deanei* seedlings germinating around a mature *A. deanei* towards the end of the vegetation transect. The total density of shrubs was approximately 118 (it was difficult to accurately the small seedlings) and this was made up of six different species (Figure 10-2).

Apart from *A. deanei*, *Callitris glaucophylla* continued to be the most dominant species with 15 individuals, followed by *Acacia decora* (10) and *Eucalyptus microcarpa* (6). There were three *A. hakeoides* and two *E.*

populnea. While most of the original planted tubestock were now greater than 2.0m in height, 69.5% were new recruitments and less than 0.5m in height (Table 10-5). All species were considered to be local endemic woodland species.

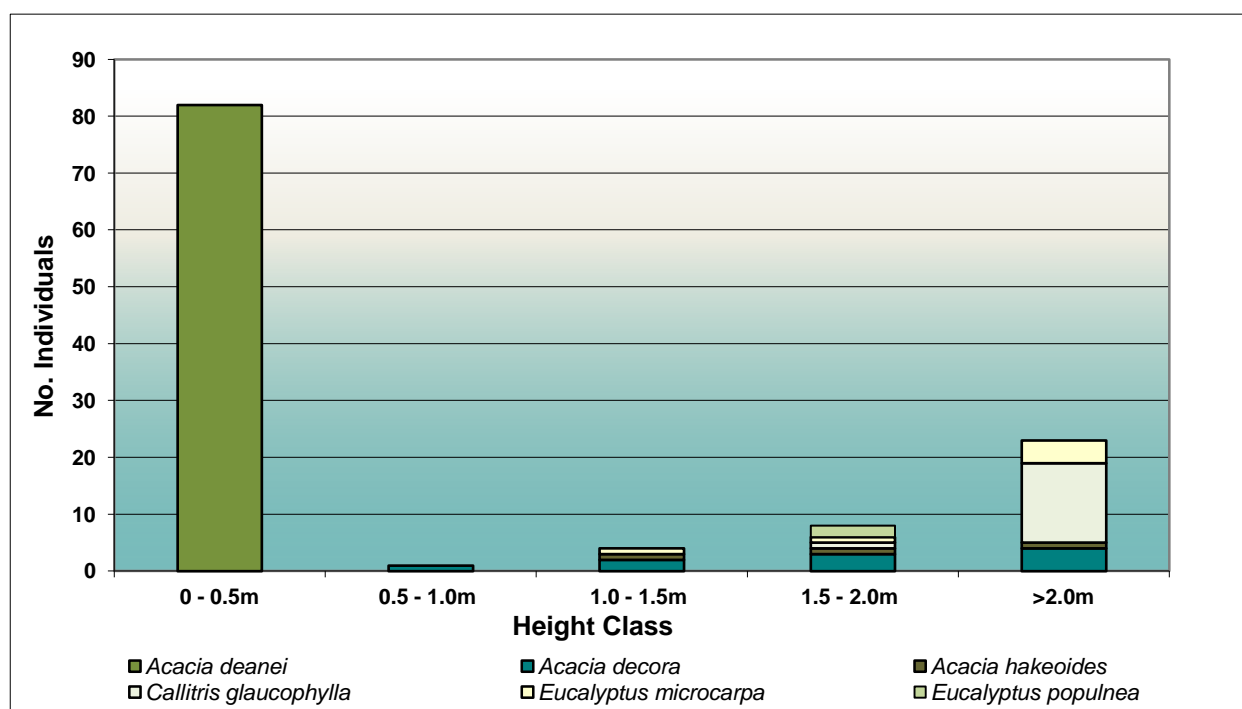


Figure 10-2 Shrubs and juvenile trees occurring within the monitoring site.

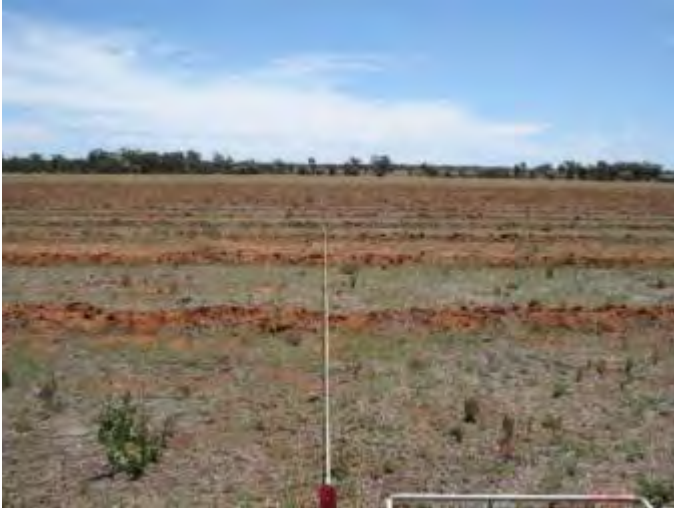
Table 10-5. Shrubs and young trees occurring within the monitoring site.

Species	0 - 0.5m	0.5 - 1.0m	1.0 - 1.5m	1.5 - 2.0m	>2.0m	Total	endemic	not endemic
<i>Acacia deanei</i>	82					82	82	
<i>Acacia decora</i>		1	2	3	4	10	10	
<i>Acacia hakeoides</i>			1	1	1	3	3	
<i>Callitris glaucophylla</i>				1	14	15	15	
<i>Eucalyptus microcarpa</i>			1	1	4	6	6	
<i>Eucalyptus populnea</i>				2		2	2	
Total	82	1	4	8	23	118	118	0
% endemic species							100	0

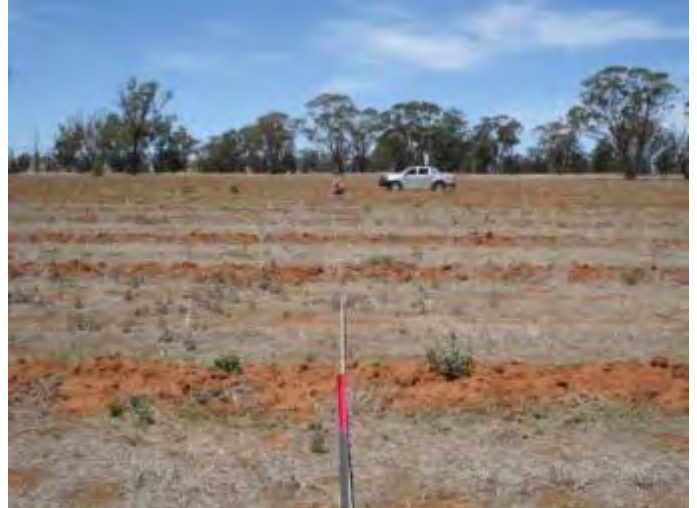
10.6 Structural diversity and habitat complexity

After a long agricultural history with little diversity in 2009 this site has continued to become increasingly more complex as the plants become more established. This year there was 93% total ground cover which was comprised of 60% dead leaf litter and there was a decline from 34 – 22.5% annual plant cover (Figure 10-3, Figure 10-4). Perennial plants continued to provide sparse ground over with only 9.5% recorded on average this year, with most cover being derived from the growing tubestock. There tended to be a reduction in the abundance of cryptogams with only one small patch being recorded. There continued to be some projected foliage cover 0.5 – 2.0m tall and this year it was due to the tall *Avena fatua* (Wild Oats), but at 15, 25 and 30m along the vegetation transect projected foliage cover was due to the presence of tubestock. Average and minimum and maximum values of the structural diversity are recorded in Table 10-6.

2009 Vegetation transect (front)



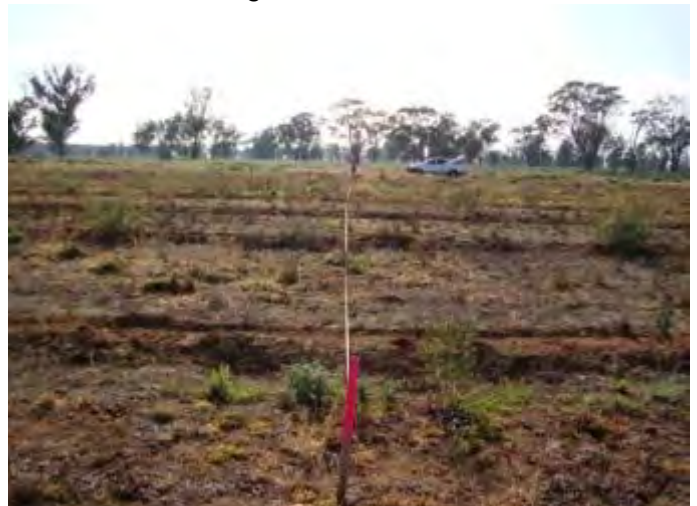
2009 Vegetation transect (rear)



2010 Vegetation transect (front)



2010 Vegetation transect (rear)



2011 Vegetation transect (front)



2011 Vegetation transect (rear)





Figure 10-3. Permanent photo points taken from the front (left) and rear (right) of the vegetation transect.

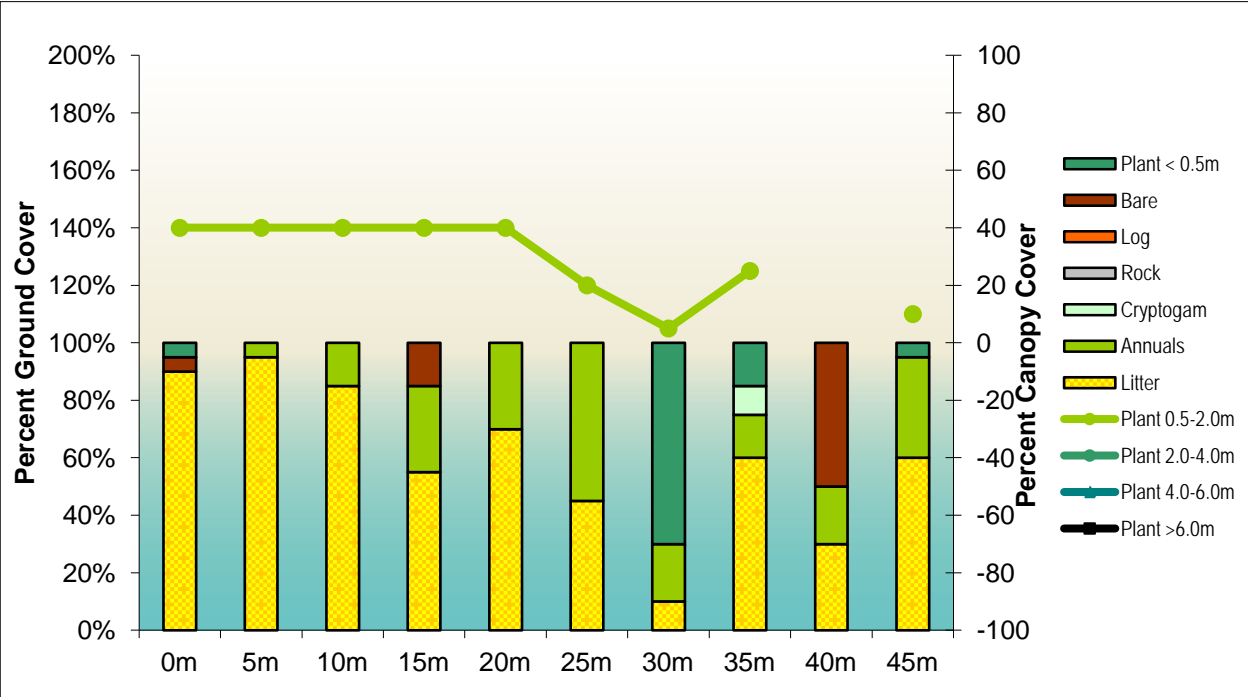


Figure 10-4. Graph illustrating the structural diversity and habitat complexity of the monitoring site.

Table 10-6. Average and minimum and maximum values of the structural diversity of the monitoring site.

Vegetation structure	0m	5m	10m	15m	20m	25m	30m	35m	40m	45m	Average	Min	Max
Litter	90	95	85	55	70	45	10	60	30	60	60	10	95
Annuals	0	5	15	30	30	55	20	15	20	35	22.5	0	55
Cryptogam	0	0	0	0	0	0	0	10	0	0	1	0	10
Rock	0	0	0	0	0	0	0	0	0	0	0	0	0
Log	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare	5	0	0	15	0	0	0	0	50	0	7	0	50
Perennial <0.5m	5	0	0	0	0	0	70	15	0	5	9.5	0	70
Total Ground Cover	95	100	100	85	100	100	100	100	50	100	93	50	100
0.5-2.0m	40	40	40	40	40	20	5	25	0	10	26	0	40
2.0-4.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0-6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
>6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0

10.7 Species cover abundance

There continued to be an increasing diversity of species recorded in the five 1m² quadrats on the permanent vegetation transect line and this year there were 27 species but 20 were exotic species. Using the Braun-blauquet scale, the highest possible cover score that can be obtained is 30 and cover abundance is illustrated as a sum of scores (class values) obtained along the five 1m² quadrats.

In 2009 *Panicum effusum*, *Heliotropium europaeum* and *Verbascum virgatum* were the most dominant and consistent species. While the species composition has tended to change over the years, species such as the exotic annuals species *Avena fatua*, *Lactuca serriola*, *Polycarpon tetraphyllum*, *Sisymbrium irio* and *Trifolium glomeratum* along with several other *Trifolium* species continue to be very common, with *Avena fatua* becoming very dominant this year, followed by *Polycarpon tetraphyllum* (Table 10-7).

Native species were comparatively low in abundance but some common native species continued to be *Crassula colorata*, *Euchiton involucratus*, *E. sphaericus*, *Oxalis perennans* and *Xerochrysum bracteatum*. While these species were low in abundance, there has been an increase in cover provided by *Xerochrysum bracteatum*. *Chloris truncata* a native grass recorded last year was not recorded this year. The remaining species were often annual weedy species commonly associated with areas of high disturbance and these were recorded on only one occasion and/or provided low cover values. There has continued to be a decline in endemic plant cover and this year it was only 17.8%, a reduction from 34.0% recorded last year

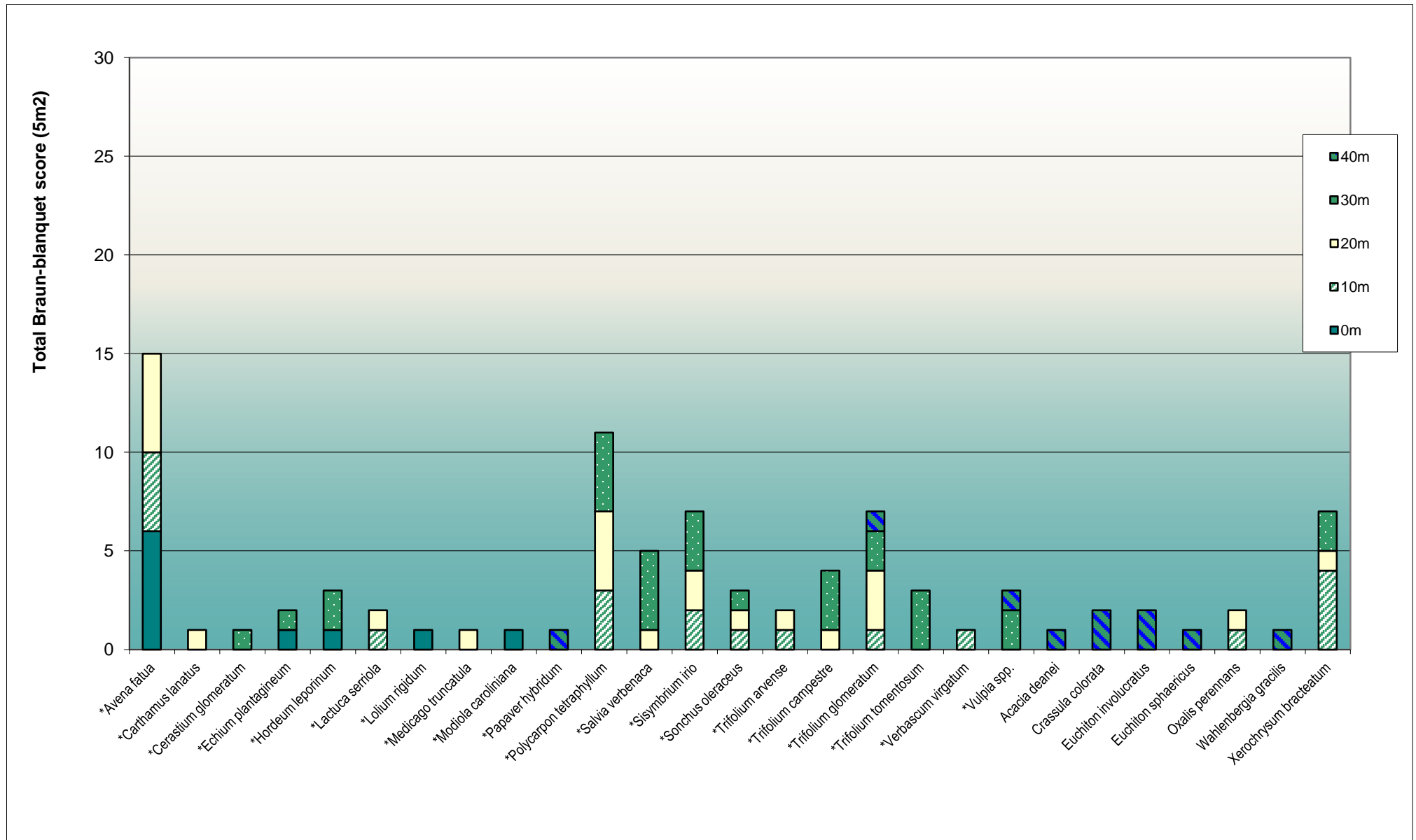


Figure 10-5. Total species recorded across the five, 1m² quadrats using the Braun-blauquet scale (max possible score is 30) as a measure of cover abundance

Table 10-7. List of species and their average cover abundance score across the five, 1m² monitoring quadrats.

Species	0m	10m	20m	30m	40m	Total
* <i>Avena fatua</i>	6	4	5			15
* <i>Carthamus lanatus</i>			1			1
* <i>Cerastium glomeratum</i>				1		1
* <i>Echium plantagineum</i>	1			1		2
* <i>Hordeum leporinum</i>	1			2		3
* <i>Lactuca serriola</i>		1	1			2
* <i>Lolium rigidum</i>	1					1
* <i>Medicago truncatula</i>			1			1
* <i>Modiola caroliniana</i>	1					1
* <i>Papaver hybridum</i>					1	1
* <i>Polycarpon tetraphyllum</i>		3	4	4		11
* <i>Salvia verbenaca</i>			1	4		5
* <i>Sisymbrium irio</i>		2	2	3		7
* <i>Sonchus oleraceus</i>		1	1	1		3
* <i>Trifolium arvense</i>		1	1			2
* <i>Trifolium campestre</i>			1	3		4
* <i>Trifolium glomeratum</i>		1	3	2	1	7
* <i>Trifolium tomentosum</i>				3		3
* <i>Verbascum virgatum</i>		1				1
* <i>Vulpia spp.</i>				2	1	3
<i>Acacia deanei</i>					1	1
<i>Crassula colorata</i>					2	2
<i>Euchiton involucratus</i>					2	2
<i>Euchiton sphaericus</i>					1	1
<i>Oxalis perennans</i>		1	1			2
<i>Wahlenbergia gracilis</i>					1	1
<i>Xerochrysum bracteatum</i>		4	1	2		7
Total cover						90
Sum of cover of native species						16
Percent endemic species cover						17.8

10.8 Floristic diversity

The floristic diversity of the sites was measured using two different methods. One provides an assessment of the average number of species within five, one square metre (m²) sub-quadrats along the vegetation transect, while the other provides the total number of species within the entire 50x20m monitoring plot.

10.8.1 Species diversity per m²

There has been a decline from 4.8 to 2.0 native species per m² this year. There were however an increased number of exotic species and there were 7.4 – 7.6 exotic species per m² this year (Table 10-8). The number of native species per m² ranged from 0 - 5, while the number of exotic species ranged from 5 – 13 indicating the floristic diversity was very patchy.

Table 10-8. Species diversity per 1m².

Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	0	2	2	1	5	2	1.9
Exotic	5	8	11	11	3	7.6	3.6
Total	5	10	13	12	8	9.6	3.2

10.8.2 Total species diversity

The total floristic diversity has marginally declined from 60 to 56 species over the past year but continued to be dominated by exotic species and there were 31 of these (Figure 10-6, Table 10-9). The sharp increase in the species diversity curve indicates the site was rather patchy beyond 50m². A list of species recorded within the monitoring site is provided in Appendix 1.

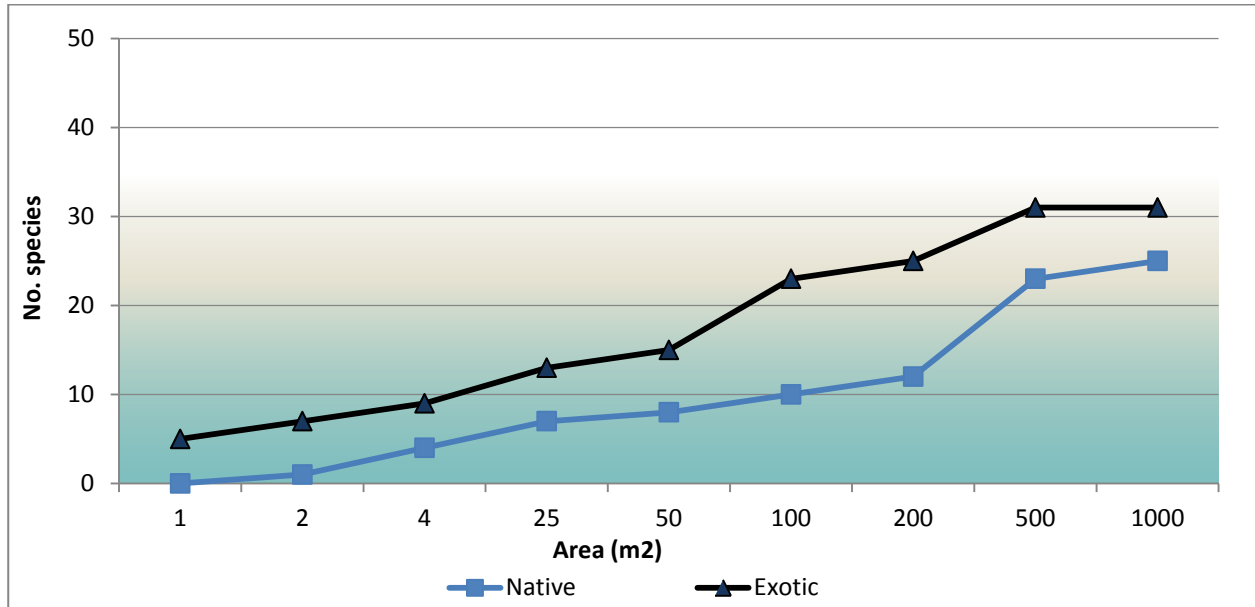


Figure 10-6. Cumulative species in the 50m x 20m (1000m²) monitoring quadrat.

Table 10-9. Cumulative species diversity.

Area (m ²)	1	2	4	25	50	100	200	500	1000
Native	0	1	4	7	8	10	12	23	25
Exotic	5	7	9	13	15	23	25	31	31

10.9 Growth forms

Figure 10-7 is a summary of species in each growth form that were recorded in LFO-02. Herbs remained the most dominant plant type with 38 species including 25 exotic species followed by grasses which had eight species including six exotics. There were three native tree and shrub species, one sub-shrub and three native reeds. There continued to be an absence of ferns. Compared to the woodland reference there was an appropriate composition of most growth forms, however there was a lack of grass diversity.

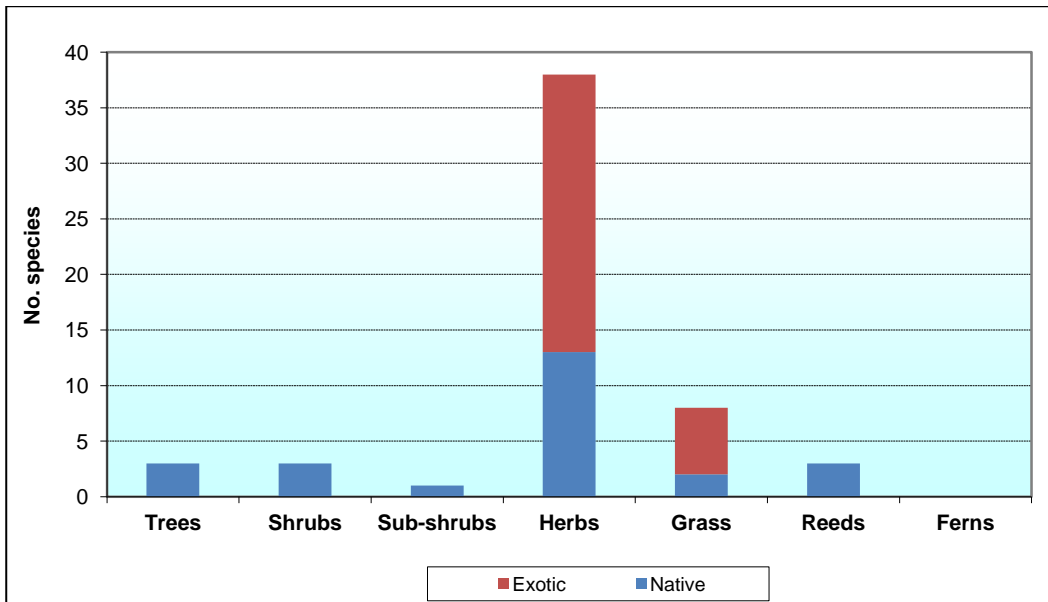


Figure 10-7. Graph illustrating the growth forms of species recorded in the 50m x 20m monitoring quadrat.

10.10 Comparison of rehabilitation data with key performance indicators

Table 10-10 indicates the performance of the rehabilitation monitoring site against the Completion and Desirable Performance Indicators developed for woodland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) for example and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 10-10. Comparison of key performance Indicators recorded in the rehabilitation site LFO-02 compared to lower and upper limits recorded in the woodland reference sites.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-02				
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2009	2010	2011	2012	2013
Phase2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	0	5	1	1	1	1	1
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%	62.9	69.0	54.2	62.1	64	70.0	67.0
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%	41.1	55.7	32.5	32.1	37.6	39.8	38.9
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%	36.2	53.0	24.9	30	34.8	41.7	35.8
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%	100	100	4	68	100	100	100

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-02				
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising		No.	0	0	0	0	0	0	0
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0	0	0	0	0
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)	6.0	7.1	6.07	6.09	6.14	6.31	5.51
			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)	0.038	0.191	0.109	0.079	0.090	0.061	0.039
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	3.0	4.6	2.3	3.0	3.2	3.5	1.9
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	6.4	17.3	23.6	33.5	29.6	32.8	18.7
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	1.2	1.9	27.9	8.8	16.7	3.4	2.4
			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)	12.0	22.9	11.87	10.72	10.18	10.85	8.63
			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	2.4	0.31	0.37	0.55	0.29	0.3
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees	The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.		species/area	1	6	7	7	7	7	6
				The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		% population	100	100	na	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	53	76	41	50	58	60	56

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-02				
			Native species richness		The total number of live native plant species provides an indication of the native plant diversity of the site and that it is greater than or comparable to the local remnant vegetation	>No./area	33	53	26	22	30	30	25
			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	13	27	15	28	28	30	31
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees	The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation		No./area	29	110	43	40	35	36	118
	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	4	4	3	3	3	3
			Shrubs	The number of shrub species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	0	3	4	4	4	4	3
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	1	5	0	0	0	0	1
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	33	46	30	35	39	42	38
			Grasses		The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	9	22	2	7	10	9	8
			Reeds		The number of reed, sedge or rush species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	1	0	1	2	2	3
			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	1	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	1	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-02				
Phase 5: Ecosystem & Landuse Development	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	%	47	77	52.7	50.5	49	43	60
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	2	22	7.3	11	30.5	34	22.5
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	8	0	16.5	8.5	4	1
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0	1	0	0	0	0	0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	3	0	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	6	11	40	22	9	6	7
			Perennial plant cover (< 0.5m)	Percent ground cover provided by live perennial vegetation (< 0.5m in height) is comparable to that of the local remnant vegetation		%	7	25	0	0	3	13	9.5
			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		%	89	95	60	78	91	94	93
	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	7	8	1.2	2.4	5.8	4.8	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	1	4	3.6	3.4	4.8	7.4	7.6
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation		%	63	87	na	37.5	45.5	34.0	17.8

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-02				
	Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	shrubs and juvenile trees 0 - 0.5m in height	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	7	89	32	18	0	0	82
			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	2	15	11	22	7	1	1
			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	13	0	0	18	5	4
			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	18	0	0	9	9	8
			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	48	0	0	1	21	23
	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	1	9	0	0	2	6.5	26
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	6	0	0	0	0	0
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 - 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	9	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-02				
			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	17	42	0	0	0	0	0
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	3	3	0	0	0	1	2
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	100	100	na	na	0	100	100
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	6	19	0	0	0	1	2
			Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	18	54	0	0	0	5	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	83	100	0	0	0	100	100
			Healthy trees	The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation		% population	7	47	0	0	0	100	100
			Medium health		The percentage of the tree population which are in a medium health condition and that the percentage is comparable to the local remnant vegetation	% population	44	57	0	0	0	0	0
			Advanced dieback		The percentage of the tree population which are in a state of advanced dieback and that the percentage is comparable to the local remnant vegetation	<% population	0	36	0	0	0	0	0
			Dead Trees		The percentage of the tree population which are dead (snags) and that the percentage is comparable to the local remnant vegetation	% population	0	17	0	0	0	0	0
			Mistletoe		The percentage of the tree population which have mistletoe provides an indication of community health and habitat value and that the percentage is comparable to the local remnant vegetation	% population	0	7	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		LFO-02				
			Flowers/fruit: Trees	The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation		% population	50	83	0	0	0	100	50

11 Estcourt 1997 site description

Estcourt 1997 is located south east of Tailings Storage Facility (TSF) two and adjacent to the mine access road. This site is one of the oldest rehabilitation areas, planted with mixed native tubestock in 1997. The site maintains an open woodland structure, scattered shrubs and a mosaic of grassy clearings and bare patches. Vegetation cover was limited beneath the tree canopies but there was generally good leaf litter cover. In 2009, ground cover species were particularly stressed with little active green growth. The site contains kangaroo camps and would be subjected to kangaroo grazing. There has been excellent establishment and growth with some trees exceeding 6m in height, generally healthy and setting seed. In 2011 - 2013 the site continued to be very dry and had low plant diversity.

11.1 *Landscape Function Analysis*

11.1.1 Landscape organisation

Estcourt 1997 remained organised into tree and grass patches with bare interpatches (Figure 11-1) and the tree and grass patches continued to dominate the site. Both patch types have been increasing in size however this year they were slightly lower and collectively provided an LOI of 72% (Table 11-1). Both patch types have also shown a decline in ecological function over the past year, but within the bare interpatch a slight improvement in infiltration and nutrient recycling was observed.

The tree and grass patches continued to have a higher functional capacity compared to the bare interpatches and these occupied 29.00% and 42.8% of the site respectively. The resultant LFA indices for stability, infiltration and nutrient recycling were therefore slightly lower this year and were 67.0, 41.3 and 39.8 respectively. Compared to the woodland reference sites, the Estcourt rehabilitation met stability, infiltration and nutrient recycling targets this year.



Figure 11-1. Permanent photo point taken from the top of the LFA transect in 2012 (left) and 2013 (right).

Table 11-1. Summary of landscape organisation and LFA indices in from 2009 to 2013.

Estcourt		8/12/2009				22/09/2010				19/10/2011				15/10/2012				17/10/2013			
Number of Patches/10m		3				2.5				2.5				2.5				2.0			
Total Patch Area (m2)		123.81				134.03				143.3				152.87				138.24			
Patch Area Index		0.62				0.67				0.72				0.76				0.69			
Landscape Organisation Index		0.67				0.72				0.77				0.79				0.72			
Average Interpatch Length (m)		1.32				1.39				1.18				1.04				1.88			
Range Interpatch length (m)		0.3 to 3.4				0.3 to 2.7				0.4 to 1.95				0.3 to 1.95				0.6 to 2.55			
Patch or Interpatch Type		Tree Patch	Bare	Grass Patch		Tree Patch	Bare	Grass Patch		Tree Patch	Bare	Grass Patch		Tree Patch	Bare	Grass Patch		Tree Patch	Grass Patch	Bare	
Patch or Interpatch Proportion (%)		25	33	42	100	28.5	27.8	43.8	100	32.5	23.5	44	100	34	20.8	45.3	100	29.0	42.8	28.3	100
Soil Surface Assessment																					
Within Individual Zones	Stability	57.7	52.5	66.9		60.8	56.3	73.1		64.4	60	76.7		64.8	63.3	75		65.6	72.5	60.0	
	Infiltration	40.1	22.9	47		37.7	26	45.7		52.8	22.8	44		54.9	24	45.5		51.9	43.8	26.7	
	Nutrients	35.3	15.7	43		32.3	19.2	45.9		53.4	21.7	42.2		54.9	24.8	44.1		51.2	41.8	25.1	
		Total				Total				Total				Total				Total			
Individual zones contribution to the whole of Landscape	Stability	14.4	17.3	28.1	59.8	17.3	15.6	32	64.9	20.9	14.1	33.7	68.7	22	13.1	33.9	69.1	19.0	31.0	17.0	67.0
	Infiltration	10	7.6	19.7	37.3	10.8	7.2	20	37.9	17.1	5.4	19.4	41.9	18.7	5	20.6	44.2	15.1	18.7	7.5	41.3
	Nutrients	8.8	5.2	18	32	9.2	5.3	20.1	34.6	17.3	5.1	18.6	41	18.7	5.1	20	43.8	14.9	17.9	7.1	39.8

11.1.2 Soil Surface Assessment

In the tree patches, there was still little ground cover and low protection from the impacts of rain splash but it continued to maintain high levels of canopy cover which was provided by the developing tree canopies. There continued to be high levels of litter cover which had developed to some depth in one case but these were not as high as recorded last year but there were slight to moderate levels of decomposition observed indicating good levels of microbial and fungal activity (Table 11-2). The soils remained crusted and due to the lower depth of litter cover, some cryptogams were present. There was minimal erosion but there were high levels of deposited materials especially beneath the trees where large quantities of leaf litter were accumulating around the base of the trees after the high rainfall activity during June. The clay loam soils continued to be moderately hard and very stable.

Table 11-2 . Results of the Soils Surface Assessment for the Tree patch.

Features	Max score	Rep 1	Rep 2	Rep 3
Soil Cover	5	1	2	2
Per. basal / canopy cover	4	4	4	4
Litter cover, orig & incorp.	10	5ls	6lm	6lm
Cryptogam cover	4	2	1	0
Crust broken-ness	4	4	4	4
Erosion type & severity	4	4	4	4
Deposited materials	4	4	1	1
Soil surface roughness	5	3	3	3
Surface resist. to disturb.	5	3	3	3
Slake test	4	4	4	4
Texture	4	2	2	2

The Soil Surface Assessment (SSA) for the grass patches show there were low to moderate levels of protective soil and basal cover provided by the scattered perennial grass tussocks (Table 11-3). There continued to be relatively high levels of litter cover derived from the dead annual and perennial vegetation growing within the patch and slight decomposition continued to be observed in all cases. Cryptogams continued to persist in low abundance and these helped to protect and stabilise the hard crusted soil surface. Combined with the scattered perennial grasses which provided moderate levels of soil surface roughness there continued to be little evidence of erosion or deposition. The clay loam soils continued to be moderately hard and very stable.

Table 11-3. Results of the Soils Surface Assessment for the Grass patches.

Features	Max score	Rep1	Rep 2	Rep 3
Soil Cover	5	3	3	2
Per. basal / canopy cover	4	3	3	2
Litter cover, orig & incorp.	10	5ls	5ls	5ls
Cryptogam cover	4	2	2	3
Crust broken-ness	4	4	4	4
Erosion type & severity	4	4	4	4
Deposited materials	4	4	4	4
Soil surface roughness	5	3	3	3
Surface resist. to disturb.	5	3	3	3
Slake test	4	4	4	4
Texture	4	2	2	2

In the bare areas, which have increased in extent this year, there have been improved levels of protection from rain splash due to increased grass cover and on one occasion there were also high levels of canopy cover due to an overhanging tree canopy (Table 11-4). The cover provided by dead leaf litter and annual plants was highly variable but beneath the tree, litter was quite abundant however

further away litter cover was very limited to absent. Cryptogams continued to provide extensive cover on the very hard soil surface crusts. There continued to be some slight sheet erosion but typically there was limited surface relief and therefore little capacity for capturing mobile resources however low levels of deposition was observed this year. The clay loam soils remained very stable.

Table 11-4. Results of the Soils Surface Assessment for the Bare interpatches.

Features	Max score	Rep1	Rep 2	Rep 3
Soil Cover	5	2	2	1
Per. basal / canopy cover	4	4	2	1
Litter cover, orig & incorp.	10	4ts	2tn	1
Cryptogam cover	4	2	4	4
Crust broken-ness	4	2	4	4
Erosion type & severity	4	3	3	3
Deposited materials	4	2	3	3
Soil surface roughness	5	3	2	2
Surface resist. to disturb.	5	3	4	4
Slake test	4	4	4	4
Texture	4	2	2	2

11.2 Soil analyses

The soil pH recorded in Estcourt 1997 had slightly increased and this year the soils can be considered to be slightly acidic and while these remained lower than target range provided by the reference sites they continued to be within desirable levels (Table 11-5). There was also an increased in Electrical Conductivity and these continued to fall within acceptable levels. The organic matter had slightly decreased but remained lower than the target KPI range.

There was little change recorded in phosphorous or nitrate levels and these remained lower than the target ranges. The CEC was remained moderate and fell within the target range. Exchangeable Sodium Percentage continued to far exceed the local ranges and this year also exceed the threshold of 5%, indicating the soils are likely to be sodic.

Table 11-5. Results of the soil analysis for Estcourt 1997 compared to the upper and lower values for the woodland reference sites and desirable levels from 2009 to 2013.

Nutrient	Units	Estcourt 1997					Lower KPI	Upper KPI	Desirable Level
		2009	2010	2011	2012	2013			
pH (1:5 water)	units	5.70	5.94	5.70	5.81	6.51	5.99	7.10	5.6 – 7.3
Conductivity (1:5 water)	dS/m	0.099	0.069	0.065	0.047	0.113	0.038	0.191	0.150
Organic Matter	%	3.69	4.2	3.2	3.8	2.6	3.0	4.6	>4.5
Phosphorus (Colwell)	mg/kg	16	21	16	13	6	6	17	50
Nitrate	mg/kg	14	1.5	2.5	2.3	1.4	1.2	1.9	13.0
Cation Exchange Capacity	cmol ⁺ /Kg	14.9	13.92	13.66	13.25	20.77	12.05	22.87	14.00
Exchangeable Sodium Percentage	%	2.46	3.16	2.42	3.77	8.94	0.29	2.42	<5

11.3 Rill assessment

No rills were observed within the monitoring quadrat in any monitoring year.

11.4 Tree density and health condition

As the oldest of the rehabilitation sites monitored, Estcourt 1997 continued to have a tree population of 17 trees with a dbh >5cm (Table 11-6). The tree population was a combination of four species of eucalypt, one species of acacia and *Casuarina cristata*. The trees were relatively young and have continued to demonstrate good growth rates with an average dbh of 19 cm dbh and these ranged from 6 – 36cm. In 2013 most trees were considered healthy and seven individuals had reproductive structures including buds, fruit and flowers.

Table 11-6. Summary of tree health and density.

Dominant species	<i>Eucalyptus melliodora</i> (9), <i>Acacia deanei</i> (2), <i>Casuarina cristata</i> (2), <i>Eucalyptus albens</i> (2), <i>Eucalyptus populnea</i> (1), <i>Eucalyptus viridis</i> (1)
Average dbh (Cm)	19
Max dbh (cm)	36
Min dbh (cm)	6
Total trees	17
No. with multiple limbs	12
No. Live trees	17
No. Healthy	9
No. Medium Health	6
No. Advanced Dieback	2
No. Dead	0
Mistletoe	0
Flowers / fruit	7

11.5 Shrubs and juvenile trees

There continued to be a low density of shrubs and juvenile trees (<5cm dbh) with a total of four different species but there were two additional shrubs this year providing a total population of 14 (Table 11-7, Figure 11-2). The shrubs have demonstrated increasing height with most individuals being greater than 2m in height. Individuals that remained in the lower height classes were suckers of *Acacia deanei*. All species were considered to be local endemic species.

Table 11-7. Shrubs and juvenile trees occurring within the monitoring site.

Species	0 - 0.5m	0.5 - 1.0m	1.0 - 1.5m	1.5 - 2.0m	>2.0m	Total	endemic	not endemic
<i>Acacia deanei</i>	2	1	1	3	2	9	9	
<i>Acacia hakeoides</i>			1		2	3	3	
<i>Brachychiton populneus</i>					1	1	1	
<i>Dodonaea viscosa</i> subsp. <i>cuneata</i>			1			1	1	
Total	2	1	3	3	5	14	14	0
% endemic species							100	0

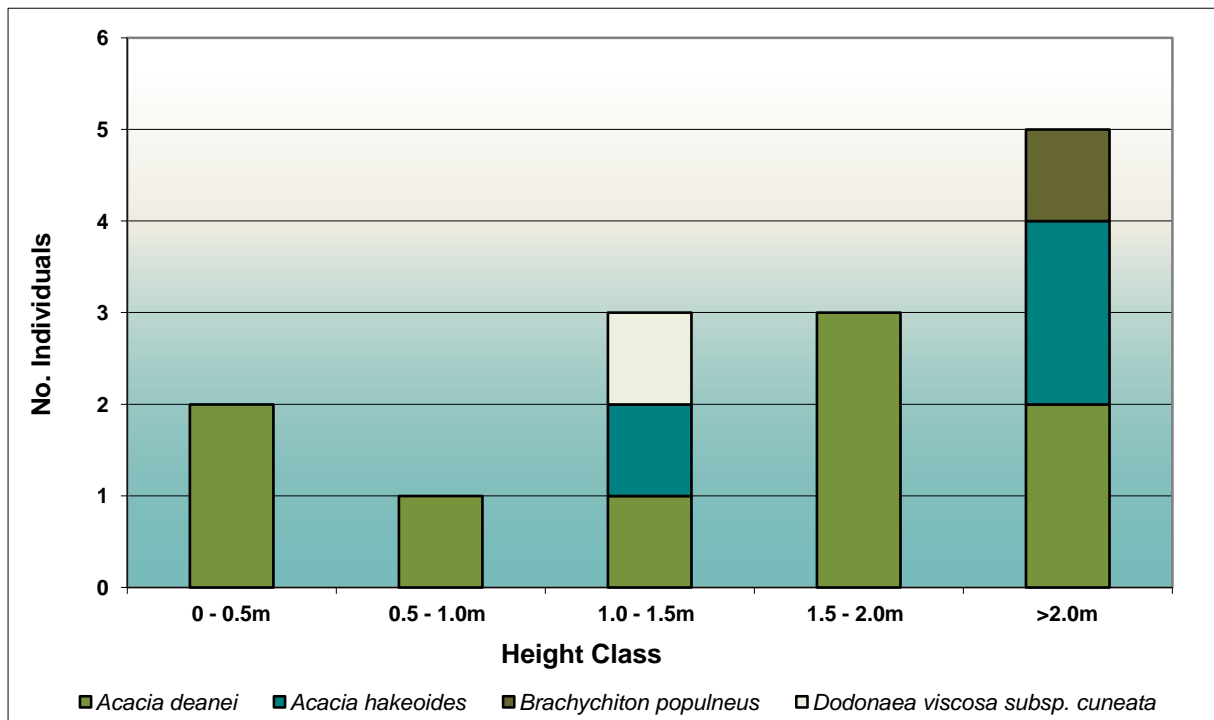


Figure 11-2 Shrubs and juvenile trees occurring within the monitoring site.

11.6 Structural diversity and habitat complexity

As this is one of the older woodland rehabilitation sites the establishing trees and shrubs and developing canopy cover has continued to have an influence on the composition of the ground cover (Figure 11-3, Figure 11-4). This year intense competition and increased disturbance has lead to a decline on total ground cover from 96.5 – 89.5% and these were lower than the acceptable levels this year. Dead leaf litter continued to be dominant and this has increased to 74.5% of the total ground cover and there was a marginal decline in cover provided by perennial plants which was now only 6.5%. Cryptogams were also an important ground cover component and while it was patchy and slightly lower than recorded last year cryptogams provided 8.5% cover on average across the site.

Canopy cover continued to be recorded in all height intervals and continued to have a patchy distribution along the transect. The canopy height continued to exceed 6m on four occasions indicating good growth and development of the site. Average and minimum and maximum values of the structural diversity are recorded in Table 11-8.

2009 Vegetation transect (front)



2009 Vegetation transect (rear)



2010 Vegetation transect (front)



2010 Vegetation transect (rear)



2011 Vegetation transect (front)



2011 Vegetation transect (rear)



2012 Vegetation transect (front)



2012 Vegetation transect (rear)



2013 Vegetation transect (front)



2013 Vegetation transect (rear)



Figure 11-3. Permanent photo points taken from the front (left) and rear (right) of the vegetation transect.

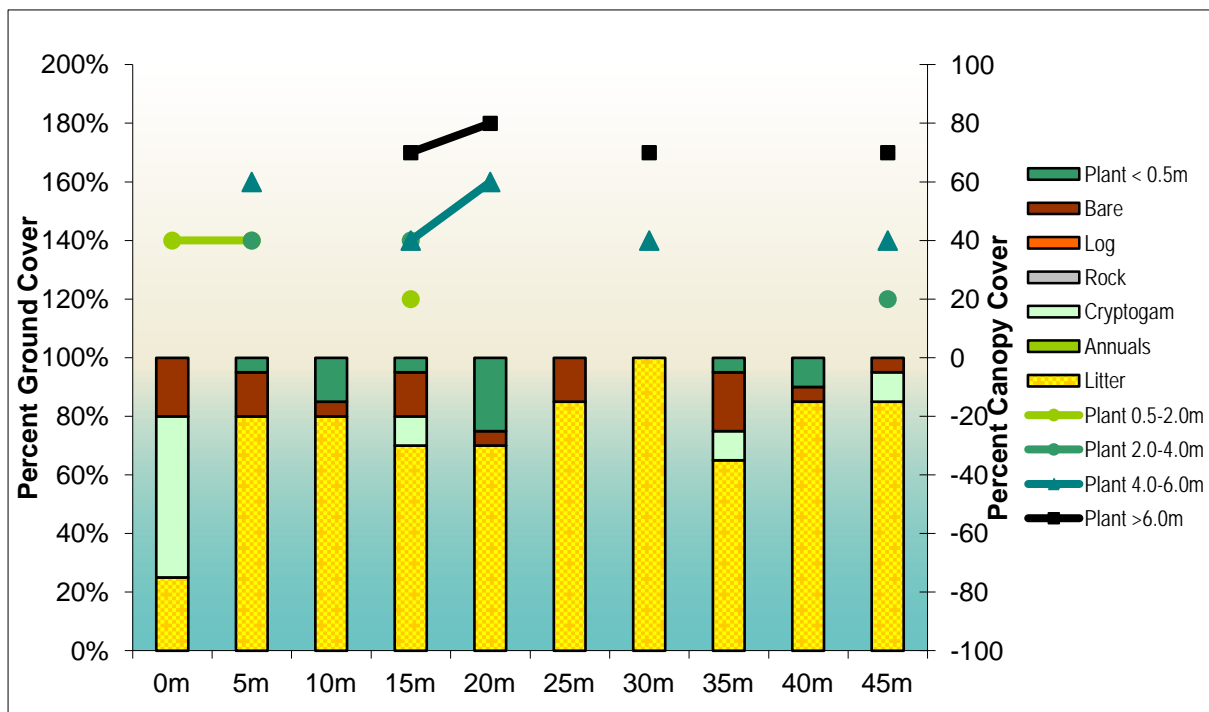


Figure 11-4. Graph illustrating the structural diversity and habitat complexity of the monitoring site.

Table 11-8. Average and minimum and maximum values of the structural diversity of the monitoring site.

Vegetation structure	0m	5m	10m	15m	20m	25m	30m	35m	40m	45m	Average	Min	Max
Litter	25	80	80	70	70	85	100	65	85	85	74.5	25	100
Annuals	0	0	0	0	0	0	0	0	0	0	0	0	0
Cryptogam	55	0	0	10	0	0	0	10	0	10	8.5	0	55
Rock	0	0	0	0	0	0	0	0	0	0	0	0	0
Log	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare	20	15	5	15	5	15	0	20	5	5	10.5	0	20
Perennial <0.5m	0	5	15	5	25	0	0	5	10	0	6.5	0	25
Total Ground Cover	80	85	95	85	95	85	100	80	95	95	89.5	80	100
0.5-2.0m	40	40	0	20	0	0	0	0	0	0	10	0	40
2.0-4.0m	0	40	0	40	0	0	0	0	0	20	10	0	40
4.0-6.0m	0	60	0	40	60	0	40	0	0	40	24	0	60
>6.0m	0	0	0	70	80	0	70	0	0	70	29	0	80

11.7 Species cover abundance

In 2009, only three native species were recorded in the five 1m² quadrats on the permanent vegetation transect line. This year there were ten species including two exotic species. Using the Braun-blanquet scale, the highest possible cover score that can be obtained is 30 and cover abundance is illustrated as a sum of scores (class values) obtained along the five 1m² quadrats.

Figure 11-5 and Table 11-9 illustrate that most common and abundant ground cover continues to be provided by *Austrodanthonia spp* but they provided only low cover values. *Einadia nutans subsp. linifolia*, *Sida spp.*, *Wahlenbergia gracilis* and *Walwhalleya proluta* were native species recorded in two of five replicates but these provided only low cover values. The remaining species were recorded less frequently and provided low cover values. Of the live plant cover scores recorded 92.6% was provided by native species.

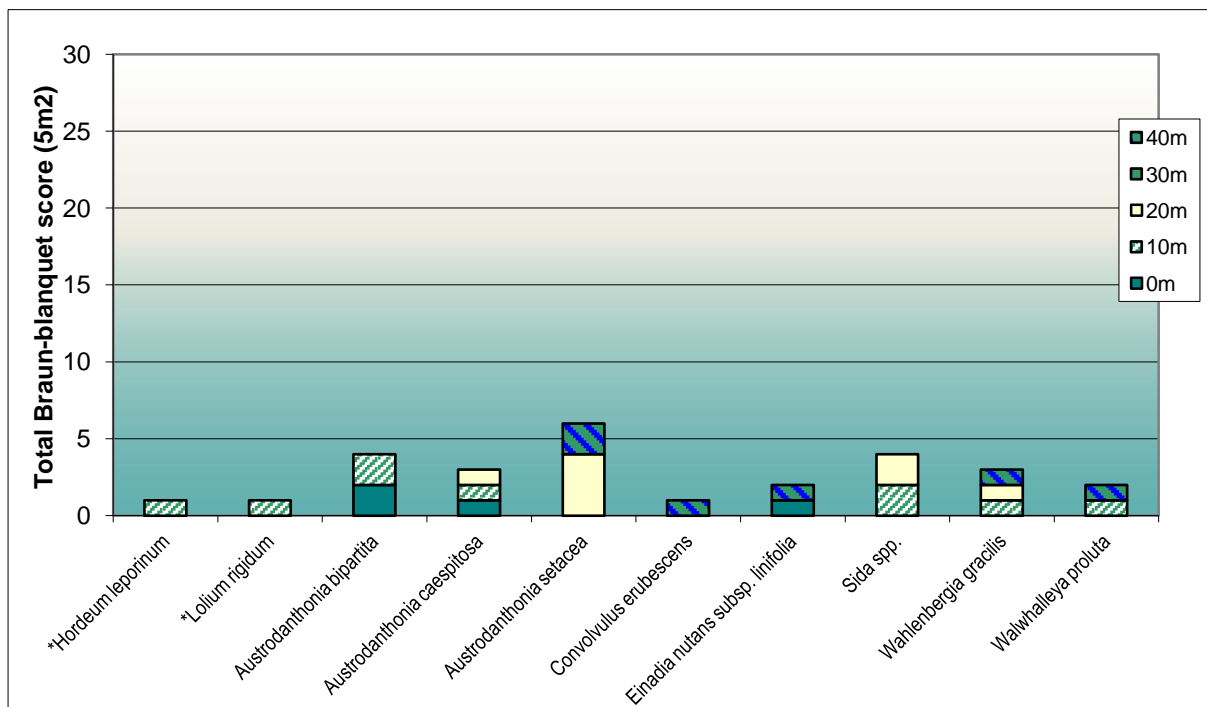


Figure 11-5. Total species recorded across the five, 1m² quadrats using the Braun-blanquet scale (max possible score is 30) as a measure of cover abundance.

Table 11-9. List of species and their average cover abundance score across the five, 1m² monitoring quadrats.

Species	0m	10m	20m	30m	40m	Total
* <i>Hordeum leporinum</i>		1				1
* <i>Lolium rigidum</i>		1				1
<i>Austrodanthonia bipartita</i>	2	2				4
<i>Austrodanthonia caespitosa</i>	1	1	1			3
<i>Austrodanthonia setacea</i>			4		2	6
<i>Convolvulus erubescens</i>					1	1
<i>Einadia nutans subsp. linifolia</i>	1				1	2
<i>Sida spp.</i>		2	2			4
<i>Wahlenbergia gracilis</i>		1	1		1	3
<i>Walwhalleya proluta</i>		1			1	2
Total cover						27
Sum of cover of native species						25
Percent endemic species cover						92.6

11.8 Floristic diversity

The floristic diversity of the sites was measured using two different methods. One provides an assessment of the average number of species within five, one square metre (m^2) sub-quadrats along the vegetation transect, while the other provides the total number of species within the entire 50x20m monitoring plot.

11.8.1 Species diversity per m^2

This year there were 3.4 native species per m^2 which was a slight reduction from 4.0 native species recorded per m^2 last year. While no exotic species were recorded in 2011 there continued to be on average 0.4 exotic species this year (Table 11-10). The number of native species ranged from 0 – 5 m^2 while there were 0 - 2 exotic species m^2 .

Table 11-10. Species diversity per 1m^2 .

Species / m^2	0m	10m	20m	30m	40m	Avg/ m^2	SD
Native	3	5	4	0	5	3.4	2.1
Exotic	0	2	0	0	0	0.4	0.9
Total	3	7	4	0	5	3.8	2.6

11.8.2 Total species diversity

In 2009, the total floristic diversity in the 50 x 20m monitoring quadrat was moderate with a total of 25 native species. This year there were 42 species, including 33 native species but this was lower than recorded last year (Figure 11-6, Table 11-11). A list of species recorded within the monitoring site is provided in Appendix 1.

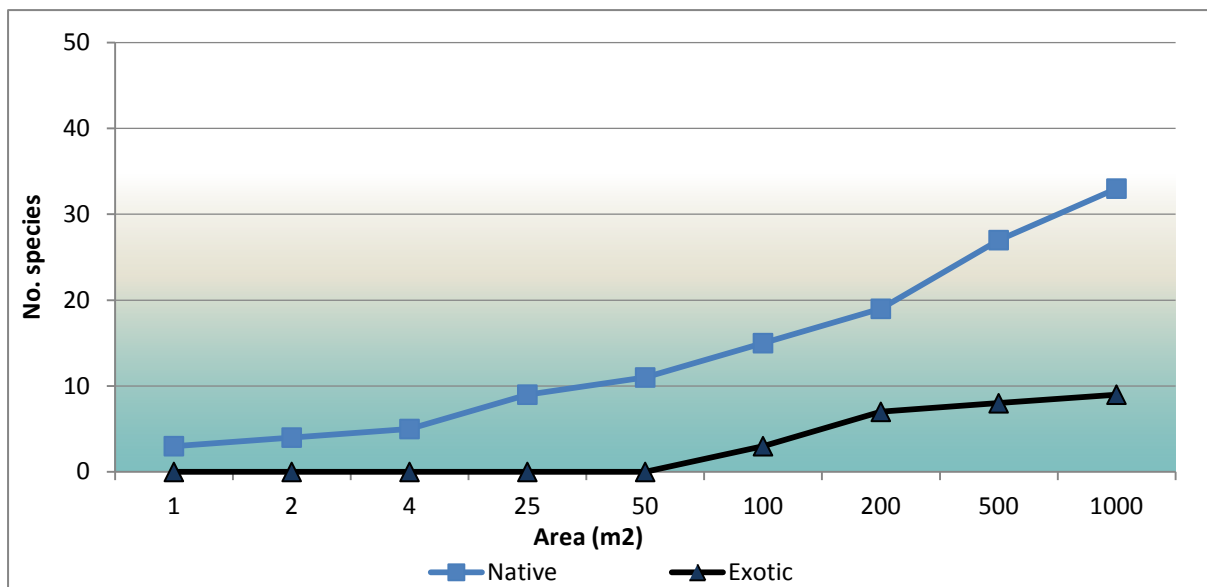


Figure 11-6. Cumulative species in the 50m x 20m (1000 m^2) monitoring quadrat.

Table 11-11. Cumulative species diversity.

Area (m^2)	1	2	4	25	50	100	200	500	1000
Native	3	4	5	9	11	15	19	27	33
Exotic	0	0	0	0	0	3	7	8	9

11.9 Growth forms

Figure 11-7 is a summary of species in each growth form that were recorded in Estcourt 1997. In 2009, grasses were the most dominant plant type followed by trees, herbs, shrubs, sub-shrubs and then reeds and no vines or fern representatives were found. Since then herbs were the most dominant plant group and this year there were 18 herb species including five exotic species. There were 11 grasses including four exotic species. There were six tree, three shrub and three native sub-shrubs. There continued to be one native reed species and no ferns. Compared to the woodland reference there was an appropriate composition of most growth forms, however there was a lack of herb diversity.

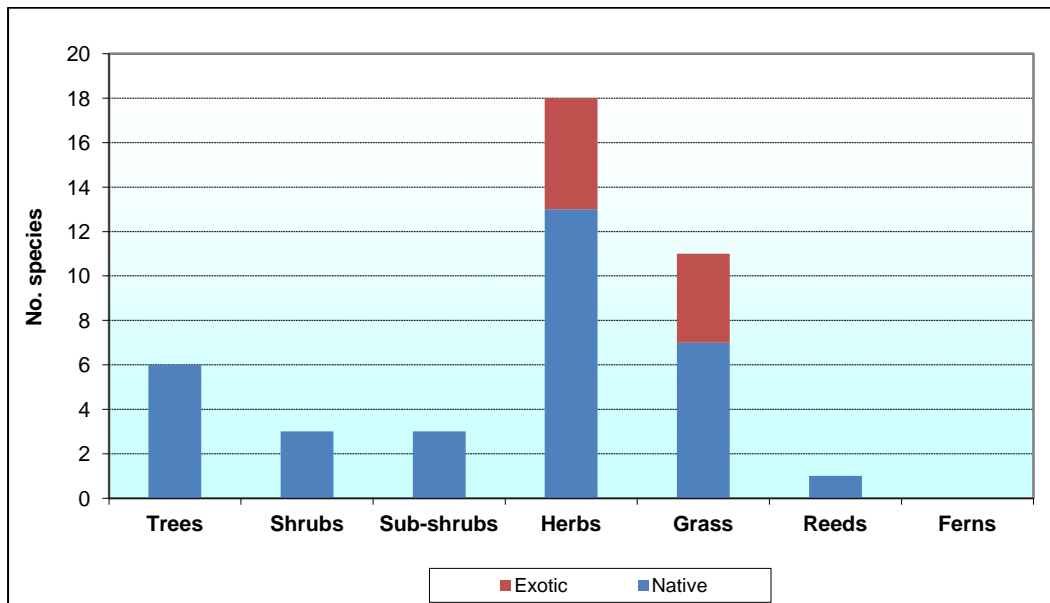


Figure 11-7. Graph illustrating the growth forms of species recorded in the 50m x 20m monitoring quadrat.

11.10 Comparison of rehabilitation data with key performance indicators

Table 11-12 indicates the performance of the rehabilitation monitoring site against the Completion and Desirable Performance Indicators developed for woodland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) for example and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 11-12. Comparison of key performance Indicators recorded in the rehabilitation site Estcourt 1997 compared to lower and upper limits recorded in the woodland reference sites.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Estcourt 1997				
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2009	2010	2011	2012	2013
Phase2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	0	5	2	2	2	2	2
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%	62.9	69.0	59.8	64.9	68.7	69.1	67.0
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%	41.1	55.7	37.3	37.9	41.9	44.2	41.3
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%	36.2	53.0	32	34.6	41.0	43.8	39.8
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%	100	100	67	72	77	79	72

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Estcourt 1997				
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising		No.	0	0	0	0	0	0	0
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0	0	0	0	0
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)	6.0	7.1	5.70	5.94	5.70	5.81	6.5
			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)	0.038	0.191	0.099	0.069	0.065	0.047	0.113
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	3.0	4.6	3.7	4.2	3.2	3.8	2.6
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	6.4	17.3	15.7	21.0	16.4	13.0	5.6
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	1.2	1.9	14.2	1.5	2.5	2.3	1.4
			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)	12.0	22.9	14.90	13.92	13.66	13.25	20.8
			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	2.4	2.46	3.16	2.42	2.77	8.94
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees	The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.		species/area	1	6	4	4	4	4	4
				The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		% population	100	100	na	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	53	76	25	65	45	31	42

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Estcourt 1997				
			Native species richness		The total number of live native plant species provides an indication of the native plant diversity of the site and that it is greater than or comparable to the local remnant vegetation	>No./area	33	53	25	46	38	29	33
			Exotic species richness	The total number of live exotic plant species provides an indication of the exotic plant diversity of the site and that it is less than or comparable to the local remnant vegetation		<No./area	13	27	0	19	7	2	9
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees	The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation		No./area	29	110	8	8	9	12	14
	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	4	6	7	7	6	6
			Shrubs	The number of shrub species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	0	3	3	3	3	3	3
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	1	5	3	3	2	2	3
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	33	46	4	36	18	12	18
			Grasses		The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	9	22	8	14	14	7	11
			Reeds		The number of reed, sedge or rush species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	1	1	2	1	1	1
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Ferns		The number of ferns comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	1	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Estcourt 1997				
Phase 5: Ecosystem & Landuse Development	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	%	47	77	68.5	57.2	69	70	74.5
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	2	22	0	1.5	0	0	0
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	8	0	1	15.7	14.5	8.5
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0	1	0	0	0	0	0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	3	0	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	6	11	30.5	32.3	4.5	3.5	10.5
			Perennial plant cover (< 0.5m)	Percent ground cover provided by live perennial vegetation (< 0.5m in height) is comparable to that of the local remnant vegetation		%	7	25	1	8	10.8	12	6.5
			Total Ground Cover	Total groundcover is the sum of protective ground cover components (as described above) and that it is comparable to that of the local remnant vegetation		%	89	95	69.5	67.7	95.5	96.5	89.5
	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	7	8	1.2	4.0	3.8	4	3.4
			Exotic understorey abundance		The abundance of exotic species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has less than or an equal number of exotic species as the local remnant vegetation	< species/m ²	1	4	0	1.6	0	0.2	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 height) compared to exotic species is comparable to that of the local remnant vegetation		%	63	87	na	75.6	100	97.1429	92.6

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Estcourt 1997				
	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	7	89	2	0	1	0	2
			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	2	15	1	3	0	1	1
			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	13	1	2	2	5	3
			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	18	0	0	2	1	3
			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	48	4	3	4	5	5
	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	1	9	11	14.5	15	9	10
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	6	5	7	6	13	10
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 - 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	9	9	13	19	25	24

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Estcourt 1997				
			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	17	42	16	20	19	27	29
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	3	3	0	6	7	6	6
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	100	100	na	94	94	100	100
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	6	19	16	16	17	17	17
			Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	18	54	15	15	18	19	19
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees	The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation		% population	83	100	100.0	100.0	100	100	100
			Healthy trees	The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation		% population	7	47	81.3	56.0	58.8	70.6	52.9
			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	44	57	6.3	31.0	29.4	17.6	35.3
			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	0	36	12.5	13.0	11.8	11.8	11.8
			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	17	0.0	0.0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Estcourt 1997				
			Mistletoe		The percentage of the tree population which have mistletoe provides an indication of community health and habitat value and that the percentage is comparable to the local remnant vegetation	% population	0	7	0.0	0.0	0	0	0
			Flowers/fruit: Trees	The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation		% population	50	83	43.8	44.0	47.1	52.9	41.2

12 Beechmore 1999 site description

Beechmore 1999 is located adjacent to the Bogan River on the Beechmore property, south west of the Northparkes Mines. This site was planted in 1999 and maintains an open woodland structure, scattered shrubs and a mosaic of grassy clearings and bare patches. Vegetation cover was limited beneath the tree canopies but there was generally good leaf litter cover. In 2009, ground cover species were particularly stressed with little active green growth. There has been excellent establishment and growth with some trees exceeding 6m in height, were generally healthy and setting seed. Grey Crowned Babblers were observed within the site in 2009 and 2010. In 2011, there was a slight improvement in ground cover and the site retains its patchiness. In 2012 and 2013 the site continued to be very dry.

12.1 *Landscape Function Analysis*

12.1.1 Landscape organisation

Beechmore 1999 continued to be organised into shrub and grass patches but the extent of the bare interpatches have increased in size and now ranged from 0.3 – 1.6m in length (Figure 12-1). Subsequently there has been a reduction in total patch area which provided a total patch area of 162.0m², but the extent of the shrub patch has increased to 60.5% while the grass patch has declined to 20.5%. As a result of the prolonged dry conditions and increased levels of disturbance the resultant LOI has therefore slightly declined from 85% to 81% (Table 12-1).

The shrub and grass patches continued to have a higher functional capacity compared to the bare interpatches. There was a slight decline in ecological function within the shrub and grass patches which in conjunction with the reduction in functional patch area have resulted in a marginal decline in ecological stability and nutrient recycling but no changes in infiltration capacity were apparent.

Overall the resultant LFA stability, infiltration and nutrient recycling indices were 62.8, 39.3 and 38.5 respectively and while LFA stability and infiltration was negligibly lower than recorded in the reference sites, nutrient recycling was 2.3 LFA units higher than the minimum KPI targets.



Figure 12-1. Permanent photo point taken from the top of the LFA transect in 2012 (left) and 2013 (right).

Table 12-1. Summary of landscape organisation and LFA indices from 2009 to 2013.

Beechmore		10/12/2009				23/09/2010				18/10/2011				17/10/2012				17/10/2013			
Number of Patches/10m		2				2.5				2.5				3				2.5			
Total Patch Area (m2)		159.08				164.29				192				167.18				162.00			
Patch Area Index		0.78				0.82				0.96				0.84				0.81			
Landscape Organisation Index		0.97				0.91				0.96				0.85				0.81			
Average Interpatch Length (m)		0.7				0.93				0.8				0.76				0.95			
Range Interpatch length (m)		0.7 to 0.7				0.7 to 1.15				0.8 to 0.8				0.5 to 1.25				0.3 to 1.6			
Patch or Interpatch Type		Shrub Patch	Grass Patch	Bare		Shrub patch	Grass Patch	Bare		Shrub Patch	Grass Patch	Bare		Shrub Patch	Grass Patch	Bare		Shrub Patch	Grass Patch	Bare	
Patch or Interpatch Proportion (%)		44.1	52.5	3.4	100	48	42.8	9.3	100	44.5	51.5	4	100	41	43.8	15.3	100	60.5	20.5	19.0	100
Soil Surface Assessment																					
Within Individual Zones	Stability	61.9	63.1	50		64.4	63.8	51.3		66.9	66.5	47.5		65.6	64.4	56.3		63.1	65.8	58.3	
	Infiltration	45.2	41.7	21.6		44.8	37.1	26.8		45.2	36.2	23.3		46.4	39	21.1		47.8	31.0	21.1	
	Nutrients	43	37.2	14		44.1	32.3	19.8		45.3	34.9	14		47.6	38.3	21.5		45.9	32.6	21.7	
		Total				Total				Total				Total				Total			
Individual zones contribution to the whole of Landscape	Stability	27.3	33.1	1.7	62.1	30.9	27.3	4.7	62.9	29.8	34.2	1.9	65.9	26.9	28.2	8.6	63.6	38.2	13.5	11.1	62.8
	Infiltration	20	21.9	0.7	42.6	21.5	15.9	2.5	39.9	20.1	18.6	0.9	39.7	19	17	3.2	39.3	28.9	6.4	4.0	39.3
	Nutrients	19	19.5	0.5	38.9	21.2	13.8	1.8	36.8	20.2	18	0.6	38.7	19.5	16.8	3.3	39.6	27.8	6.7	4.1	38.5

12.1.2 Soil Surface Assessment

In the shrub patches, there has previously been some limited cover provided by low hanging leaves which provided some protection from rain splash however this year there was an absence of lower leaves. The shrub thicket continued to provide high levels of canopy cover and while there was a good cover of fallen leaf litter it was not as thick as in previous years but slight states of decomposition continued to be observed in all replicates (Table 12-2).

The soil surface remained crusted and cryptogams were slightly abundant amongst the leaf litter in most but not all cases. Generally there was little erosion but there were often high levels of deposited litter after the high rainfall activity during June. The uneven ground provided moderate to high soil surface relief and the clay loam soils remained moderately hard and typically they were very stable.

Table 12-2 . Results of the Soils Surface Assessment for the Shrub patches.

Features	Max score	Rep 1	Rep 2	Rep 3	Rep 4
Soil Cover	5	1	1	1	1
Per. basal / canopy cover	4	4	4	4	4
Litter cover, orig & incorp.	10	5ls	5ls	5ls	6ls
Cryptogam cover	4	2	2	2	1
Crust broken-ness	4	4	4	4	4
Erosion type & severity	4	4	4	4	4
Deposited materials	4	2	2	4	1
Soil surface roughness	5	3	4	3	4
Surface resist. to disturb.	5	3	3	3	3
Slake test	4	4	4	4	4
Texture	4	2	2	2	2

In the grass patches there continued to be low to moderate levels of protective soil cover provided by the sparse perennial grass tussocks which also provided low basal cover (Table 12-3). There were relatively high levels of cover provided by dead leaf litter with most of the litter being derived from dead grass thatch however negligible decomposition was evident this year.

There was a moderate abundance of cryptogams which were colonising the soil crusts but they were absent on one occasion. There continued to be negligible to slight sheet erosion and with the grass tussocks providing moderate surface relief there were variable levels of deposition. The clay loam soils were very hard but continued to have some slumping of the sub-crusts when immersed in rain water.

Table 12-3. Results of the Soils Surface Assessment for the Grass patches.

Features	Max score	Rep1	Rep 2	Rep 3
Soil Cover	5	2	2	2
Per. basal / canopy cover	4	2	2	2
Litter cover, orig & incorp.	10	5tn	5ln	5ln
Cryptogam cover	4	1	3	3
Crust broken-ness	4	4	4	4
Erosion type & severity	4	4	3	3
Deposited materials	4	1	4	3
Soil surface roughness	5	3	3	3
Surface resist. to disturb.	5	4	4	4
Slake test	4	3	3	3
Texture	4	2	2	2

In the bare patches, there was some limited protection from rain splash due to some scattered grass tussock which also provided some perennial basal cover and limited litter cover. There were also some leaves which had been blown or washed into the bare area. Cryptogams were typically present but their abundance was highly variable but all were colonising the very hard soil crusts. There continued to be slight to moderate levels of sheet erosion and there was some slight deposition despite the low surface relief (Table 12-4). The clay loam soils were very hard but the sub crusts tended to become unstable when immersed in rain water.

Table 12-4. Results of the Soils Surface Assessment for the Bare interpatch.

Features	Max score	Rep1	Rep 2	Rep 3
Soil Cover	5	2	1	2
Per. basal / canopy cover	4	2	3	2
Litter cover, orig & incorp.	10	2tn	2tn	2tn
Cryptogam cover	4	4	3	2
Crust broken-ness	4	4	4	4
Erosion type & severity	4	3	2	2
Deposited materials	4	4	3	4
Soil surface roughness	5	2	2	2
Surface resist. to disturb.	5	4	4	4
Slake test	4	3	3	2
Texture	4	2	2	2

12.2 Soil analyses

The soil pH recorded at Beechmore 1999 had slightly increased this year and can now be considered to be slightly acidic and within the local KPI range (Table 12-5). There was a slight increase in Electrical Conductivity and Organic matter and these fell within local target ranges. Phosphorous and nitrate levels had slightly declined and both fell within local ranges this year, despite being very low. There was a large increase in CEC but this was well within local ranges. The ESP also demonstrated a significant increase and exceeded local ESP levels. However it just fell below the 5% threshold indicating the soils may be bordering sodic.

Table 12-5. Results of the soil analysis for Beechmore 1999 compared to the upper and lower values for the woodland reference sites and desirable levels from 2009 to 2013.

Nutrient	Units	Beechmore 1999					Lower KPI	Upper KPI	Desirable Level
		2009	2010	2011	2012	2013			
pH (1:5 water)	units	6.15	6.00	6.01	6.07	6.45	5.99	7.10	5.6 – 7.3
Conductivity (1:5 water)	dS/m	0.067	0.035	0.038	0.031	0.057	0.038	0.191	0.150
Organic Matter	%	4.13	3.5	3.0	4.0	4.6	3.0	4.6	>4.5
Phosphorus (Colwell)	mg/kg	25	19	20	18	10	6	17	50
Nitrate	mg/kg	9.1	0.6	3.2	2.3	1.3	1.2	1.9	13.0
Cation Exchange Capacity	cmol+/Kg	13.3	11.66	10.02	10.76	15.53	12.05	22.87	14.00
Exchangeable Sodium Percentage	%	0.36	0.89	0.78	0.81	4.80	0.29	2.42	<5

12.3 Rill assessment

No rills were observed within the monitoring quadrat in any monitoring year.

12.4 Tree density and health condition

There was one additional tree this year as a result of good growth and development of the planted trees and shrubs to provide a stem count of 26 trees (Table 12-6). The trees were relatively young and maintained an average dbh of 14cm and ranged between 5 – 25cm. All trees were alive and the majority were in moderate to healthy condition, with eight individuals bearing reproductive structures including buds, fruits and flowers. Two acacias continued to be in a state of advanced dieback and are probably at the end of their natural life span.

The tree population was comprised of four *Eucalyptus* species and three *Acacia* species. *Eucalyptus microcarpa* was the most dominant eucalypt species with ten individuals followed by *Eucalyptus populnea* with seven. All species were considered to local endemic species.

Table 12-6. Summary of tree health and density.

Dominant species	<i>Eucalyptus microcarpa</i> (10), <i>Eucalyptus populnea</i> (7), <i>Eucalyptus camaldulensis</i> (3), <i>Eucalyptus melliodora</i> (2), <i>Acacia pendula</i> (2), <i>Acacia stenophylla</i> (1), <i>Acacia trineura</i> (1)
Average dbh (Cm)	14
Max dbh (cm)	25
Min dbh (cm)	5
Total trees	26
No. with multiple limbs	13
No. Live trees	26
No. Healthy	10
No. Medium Health	14
No. Advanced Dieback	2
No. Dead	0
Mistletoe	0
Flowers / fruit	8

12.5 Shrubs and juvenile trees

Beechmore 1999 continued to have a healthy shrub and juvenile tree population and due to some new recruitment this year the resultant population was 64 this year. There were 12 different species, including two eucalypts and five acacias (Figure 12-2, Table 12-7). The most abundant species continued to be *A. deanei* which was increasing in numbers due to suckering and/or natural recruitment.

There were ten *Acacia hakeoides* and eight *Dodonaea viscosa subsp. cuneata*. The remaining species had three or less representatives. The majority of individuals continued to be less than 0.5m in height due to the recent recruitment of *Acacia deanei* and *Dodonaea viscosa subsp. cuneata* seedlings. The remaining individuals were usually greater than 2.0m in height. All individuals were considered to be local endemic species.

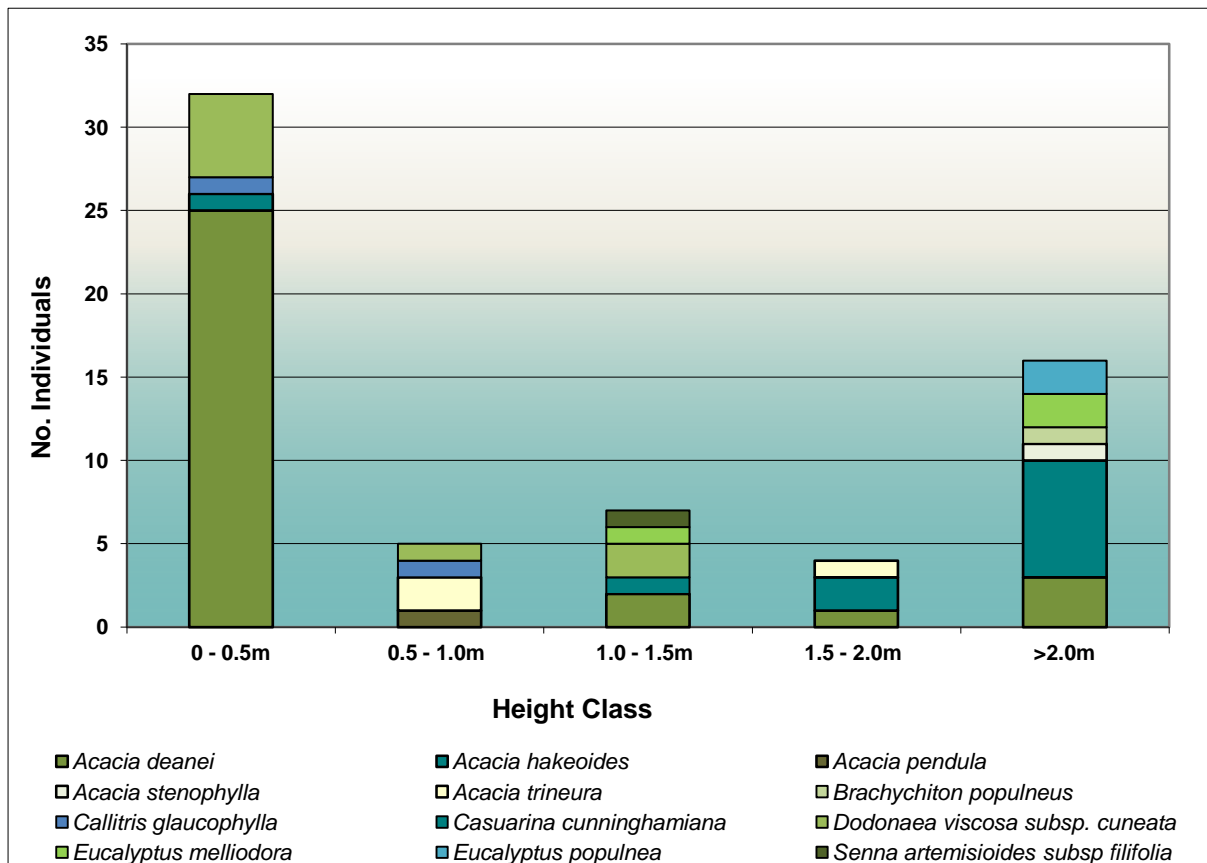


Figure 12-2 Shrubs and juvenile trees occurring within the monitoring site.

Table 12-7. Shrubs and young trees occurring within the monitoring site.

Species	0 - 0.5m	0.5 - 1.0m	1.0 - 1.5m	1.5 - 2.0m	>2.0m	Total	endemic	not endemic
<i>Acacia deanei</i>	25		2	1	3	31	31	
<i>Acacia hakeoides</i>	1			2	7	10	10	
<i>Acacia pendula</i>		1				1	1	
<i>Acacia stenophylla</i>					1	1	1	
<i>Acacia trineura</i>		2		1		3	3	
<i>Brachychiton populneus</i>					1	1	1	
<i>Callitris glaucophylla</i>	1	1				2	2	
<i>Casuarina cunninghamiana</i>			1			1	1	
<i>Dodonaea viscosa subsp. cuneata</i>	5	1	2			8	8	
<i>Eucalyptus melliodora</i>			1		2	3	3	
<i>Eucalyptus populnea</i>					2	2	2	
<i>Senna artemisioides subsp. filifolia</i>			1			1	1	
Total	32	5	7	4	16	64	64	0
% endemic species							100	0

12.6 Structural diversity and habitat complexity

Due to the nature of the rehabilitation works, row plantings and intensive competition from the advanced trees and shrubs there continued to be large patches of bare ground. While total ground had been improving in previous years, the prolonged dry period has resulted in a reduction from 85.7 – 66.5% over the past year (Figure 12-3). The majority of cover continued to be provided by dead leaf litter which provided 54% cover this year and cryptogams were patchy and less abundant but provided 7.5% cover on average. There was little change in the cover provided by the scattered grass tussocks which continued to provide 5% cover on average.

Due to the row and inter-row sequence, canopy cover continued to be variable but all vertical height increments continued to be represented. Projected foliage cover greater than 6m was recorded at 20, 25 and 45m along the transect. Average and minimum and maximum values of the structural diversity are recorded in Table 12-8.

2009 Vegetation transect (front)



2009 Vegetation transect (rear)



2010 Vegetation transect (front)



2010 Vegetation transect (rear)



2011 Vegetation transect (front)



2011 Vegetation transect (rear)



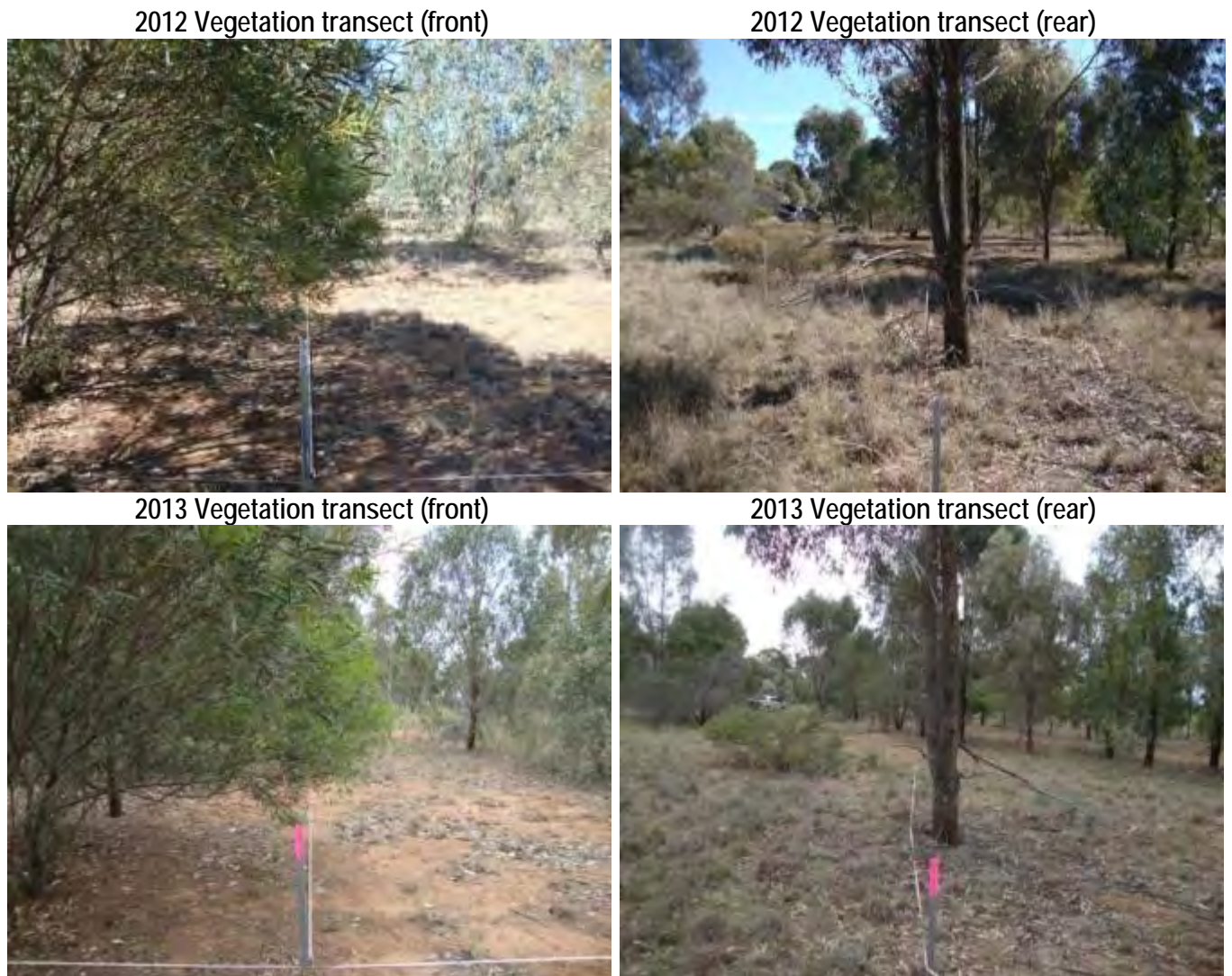


Figure 12-3. Permanent photo points taken from the front (left) and rear (right) of the vegetation transect.

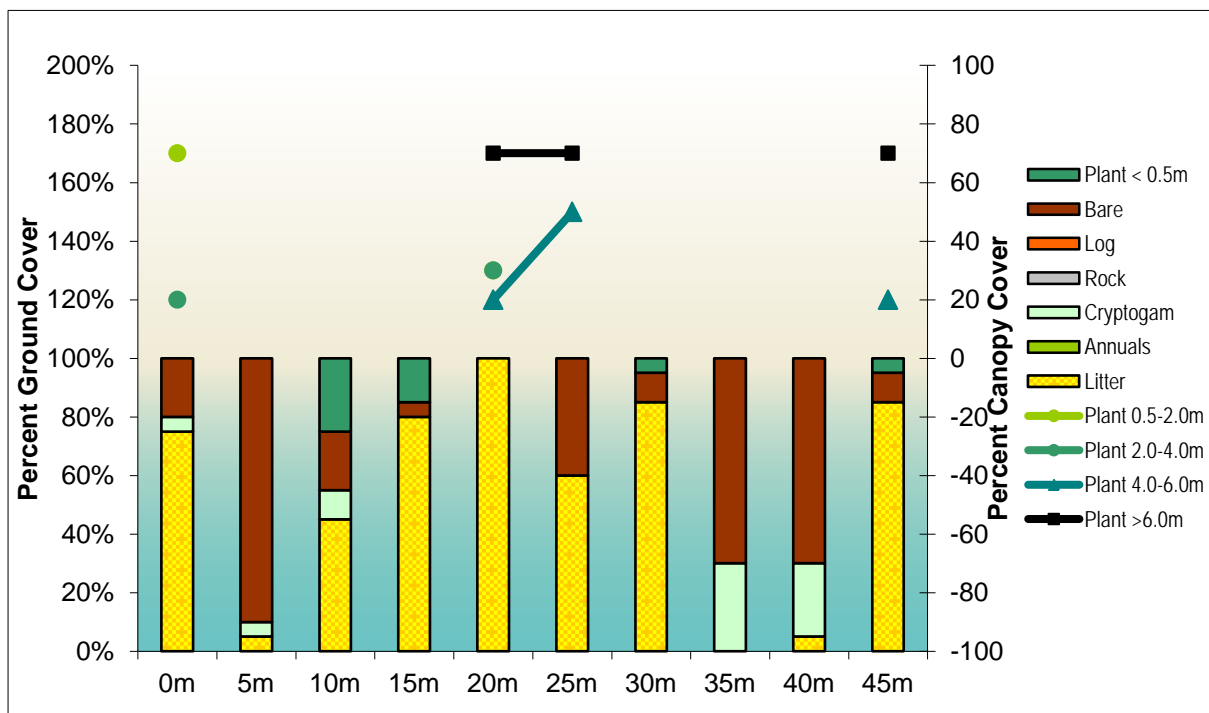


Figure 12-4. Graph illustrating the structural diversity and habitat complexity of the monitoring site.

Table 12-8. Average and minimum and maximum values of the structural diversity of the monitoring site.

Vegetation structure	0m	5m	10m	15m	20m	25m	30m	35m	40m	45m	Average	Min	Max
Litter	75	5	45	80	100	60	85	0	5	85	54	0	100
Annuals	0	0	0	0	0	0	0	0	0	0	0	0	0
Cryptogam	5	5	10	0	0	0	0	30	25	0	7.5	0	30
Rock	0	0	0	0	0	0	0	0	0	0	0	0	0
Log	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare	20	90	20	5	0	40	10	70	70	10	33.5	0	90
Perennial <0.5m	0	0	25	15	0	0	5	0	0	5	5	0	25
Total Ground Cover	80	10	80	95	100	60	90	30	30	90	66.5	10	100
0.5-2.0m	70	0	0	0	30	0	0	0	0	0	10	0	70
2.0-4.0m	20	0	0	0	30	0	0	0	0	0	5	0	30
4.0-6.0m	0	0	0	0	20	50	0	0	0	20	9	0	50
>6.0m	0	0	0	0	70	70	0	0	0	70	21	0	70

12.7 Species cover abundance

This year there were 14 species including only two exotic species recorded along the five 1x1m sub-plots placed at 10m intervals along the vegetation transect. Using the Braun-blanket scale, the highest possible cover score that can be obtained is 30 and cover abundance is illustrated as a sum of scores (class values) obtained along the five 1m² quadrats.

Austrodanthonia bipartita was recorded in three of the five sub-plots and despite providing limited ground cover overall, was the most common and abundant species recorded this year. Other natives including *Carex inversa*, *Einadia nutans* subsp. *linifolia*, *Enteropogon acicularis*, *Maireana enchylaenoides*, *Sida cunninghamii* and *Walwhalleya proluta* were all recorded twice but also provided limited cover. The exotic species were limited occurrences of *Arctotheca calendula* and *Lolium rigidum* (Figure 12-5, Table 12-9). Of the live plant cover scores recorded 86.8% was provided by native species.

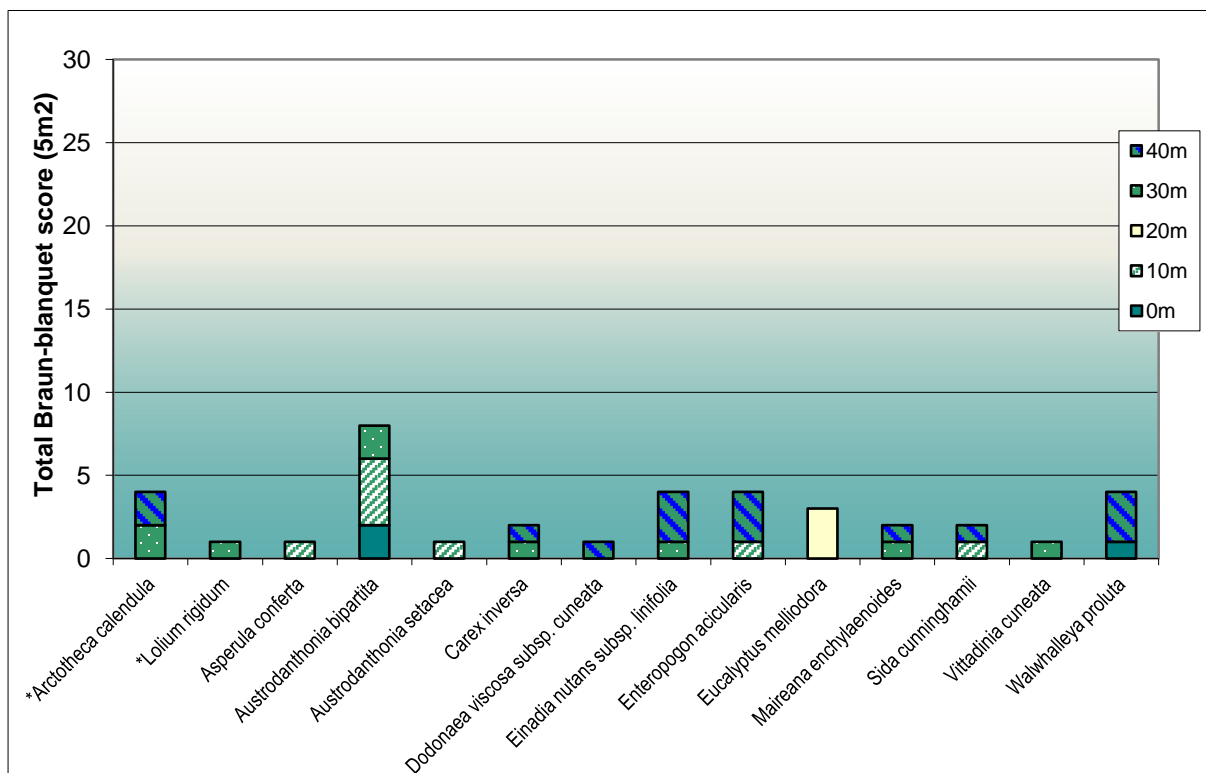


Figure 12-5. Total species recorded across the five, 1m² quadrats using the Braun-blanket scale (max possible score is 30) as a measure of cover abundance.

Table 12-9. List of species and their average cover abundance score across the five, 1m² monitoring quadrats.

Species	0m	10m	20m	30m	40m	Total
* <i>Arctotheca calendula</i>				2	2	4
* <i>Lolium rigidum</i>				1		1
<i>Asperula conferta</i>		1				1
<i>Austrodanthonia bipartita</i>	2	4		2		8
<i>Austrodanthonia setacea</i>		1				1
<i>Carex inversa</i>				1	1	2
<i>Dodonaea viscosa subsp. cuneata</i>					1	1
<i>Einadia nutans subsp. linifolia</i>				1	3	4
<i>Enteropogon acicularis</i>		1			3	4
<i>Eucalyptus melliodora</i>			3			3
<i>Maireana enchylaenoides</i>				1	1	2
<i>Sida cunninghamii</i>		1			1	2
<i>Vittadinia cuneata</i>				1		1
<i>Walwhalleya proluta</i>	1				3	4
Total cover						38
Sum of cover of native species						33
Percent endemic species cover						86.8

12.8 Floristic diversity

The floristic diversity of the sites was measured using two different methods. One provides an assessment of the average number of species within five, one square metre (m²) sub-quadrats along the vegetation transect, while the other provides the total number of species within the entire 50x20m monitoring plot.

12.8.1 Species diversity per m²

The average diversity of native species has not significantly changed since 2011 and this year was 4.0 species per m². The average number of exotic species has remained the same over the past year at 0.6 species per m² (Table 12-10). The number of native species ranged between 1 - 7 per m² while the number of exotic species ranged between 0 – 2 per m².

Table 12-10. Species diversity per 1m².

Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	2	5	1	5	7	4	2.4
Exotic	0	0	0	2	1	0.6	0.9
Total	2	5	1	7	8	4.6	3.0

12.8.2 Total species diversity

The overall the floristic diversity recorded in the 50 x 20m monitoring quadrat continued to be relatively high and this year there were 47 species and this included 42 native species (Figure 12-6, Table 12-11). The consistent and increasing trend in the species area curve indicates the site was relatively homogenous. A list of species recorded within the monitoring site is provided in Appendix 1.

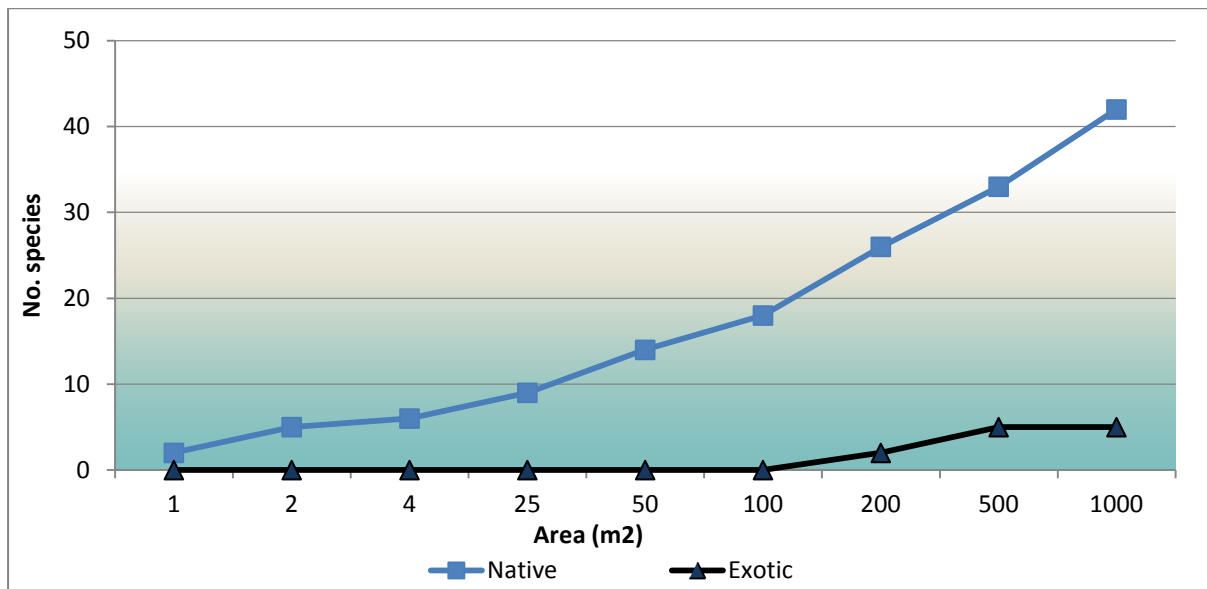


Figure 12-6. Cumulative species in the 50m x 20m (1000m²) monitoring quadrat.

Table 12-11. Cumulative species diversity.

Area (m2)	1	2	4	25	50	100	200	500	1000
Native	2	5	6	9	14	18	26	33	42
Exotic	0	0	0	0	0	0	2	5	5

12.9 Growth forms

Figure 12-7 is a summary of species in each growth form that were recorded in Beechmore. Herbs continued to be the most dominant plant type with 20 species, including four exotic species followed by grasses with 10 species including one exotic species. There were seven tree species, seven shrubs and two sub-shrubs and these were all native species. There continued to be one reed species and no ferns were yet recorded. Compared to the woodland reference there was an appropriate composition of most growth forms, however there was a lack of herb diversity.

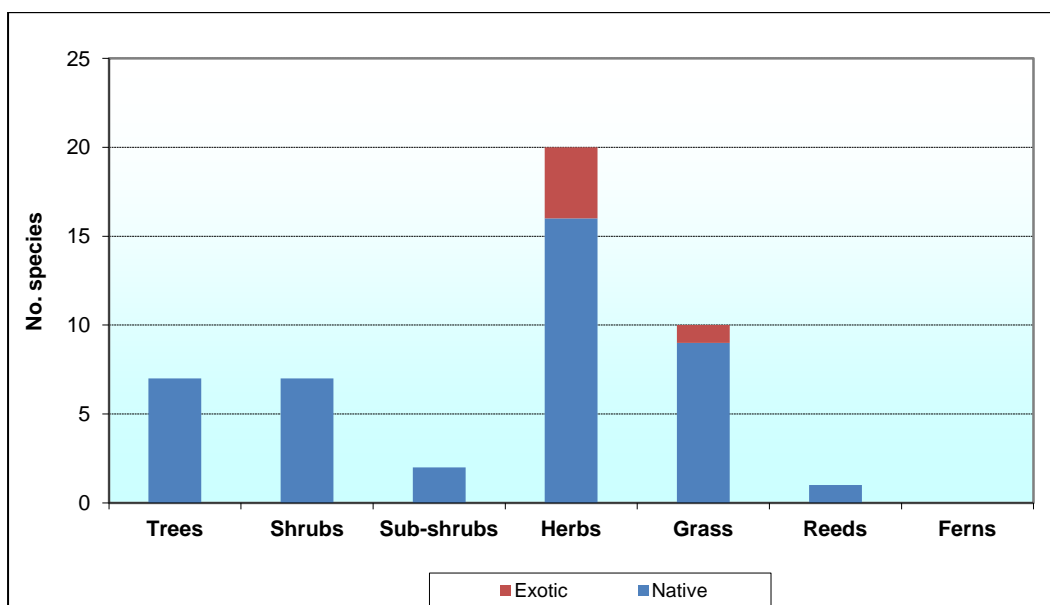


Figure 12-7. Graph illustrating the growth forms of species recorded in the 50m x 20m monitoring quadrat.

12.10 Comparison of rehabilitation data with key performance indicators

Table 12-12 indicates the performance of the rehabilitation monitoring site against the Completion and Desirable Performance Indicators developed for woodland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) for example and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 12-12. Comparison of key performance Indicators recorded in the rehabilitation site Beechmore 1999 compared to lower and upper limits recorded in the woodland reference sites.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Beechmore 1999				
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2009	2010	2011	2012	2013
Phase2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	0	5	2	2	2	2	2
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%	62.9	69.0	62.1	62.9	65.9	63.6	62.8
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%	41.1	55.7	42.6	39.9	39.7	39.3	39.3
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%	36.2	53.0	38.9	36.8	38.7	39.6	38.5

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Beechmore 1999				
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%	100	100	97	91	96	85	81
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising		No.	0	0	0	0	0	0	0
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0	0	0	0	0
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)	6.0	7.1	6.15	6.00	6.01	6.07	6.5
			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)	0.038	0.191	0.067	0.035	0.038	0.031	0.057
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	3.0	4.6	4.1	3.5	3.0	4.0	4.6
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	6.4	17.3	25.3	18.7	19.8	18.3	10.3
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	1.2	1.9	9.1	0.6	3.2	2.3	1.3
			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)	12.0	22.9	13.31	11.66	10.02	10.76	15.5
			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	2.4	0.36	0.89	0.78	0.81	4.8
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees	The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.		species/area	1	6	13	12	12	12	12
				The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		% population	100	100	na	100	100	100	100

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Beechmore 1999				
			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	53	76	36	53	51	48	47
			Native species richness		The total number of live native plant species provides an indication of the native plant diversity of the site and that it is greater than or comparable to the local remnant vegetation	>No./area	33	53	36	42	41	43	42
			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	13	27	0	11	10	5	5
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees	The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation		No./area	29	110	37	37	42	55	64
	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	4	7	7	8	7	7
			Shrubs	The number of shrub species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	0	3	8	7	7	7	7
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	1	5	1	2	1	2	2
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	33	46	12	26	22	17	20
			Grasses		The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	9	22	6	10	12	14	10
			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	2	1	1	1	1
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Ferns		The number of ferns comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	1	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Beechmore 1999				
Phase 5: Ecosystem & Landuse Development	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	%	47	77	27	22.2	41	61	54
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	2	22	0	2	0	0	0
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	8	0	6	20	20	7.5
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0	1	0	0	0	0	0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	3	0	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	6	11	70.9	63.8	28	14.3	33.5
			Perennial plant cover (< 0.5m)	Percent ground cover provided by live perennial vegetation (< 0.5m in height) is comparable to that of the local remnant vegetation		%	7	25	2.1	6.0	11.0	4.7	5.0
			Total Ground Cover	Total groundcover is the sum of protective ground cover components (as described above) and that it is comparable to that of the local remnant vegetation		%	89	95	29.1	36.2	72	85.7	66.5
	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	7	8	1.4	4.6	3.6	3.6	4.0
			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	1	4	0	1.2	1	0.6	0.6
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation		%	63	87	na	77.3	85.7	91.7	86.8

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Beechmore 1999				
	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	7	89	2	2	9	23	32
			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	2	15	1	2	3	5	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	13	5	6	4	2	7
			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	18	6	4	3	7	4
			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	48	23	23	23	18	16
	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	1	9	11	10	17	11	10
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	6	15	12	18	13	5
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 -6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	9	7	14	17	22.5	9
			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	17	42	0	8	7	34	21

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Beechmore 1999				
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	3	3	6	5	6	7	7
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	100	100	na	100	100	100	100
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	6	19	21	21	21	25	26
				Average dbh	Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	18	54	11	12	13	13	14
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees	The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation		% population	83	100	100.0	100.0	100	100	100
			Healthy trees	The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation		% population	7	47	81.0	90.0	66.7	72.0	38.5
			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	44	57	19.0	10.0	28.6	20.0	53.8
			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	36	0.0	0.0	4.8	8	7.7
			Dead Trees		The percentage of the tree population which are dead (snags) and that the percentage is comparable to the local remnant vegetation	% population	0	17	0.0	0.0	0	0	0
			Mistletoe		The percentage of the tree population which have mistletoe provides an indication of community health and habitat value and that the percentage is comparable to the local remnant vegetation	% population	0	7	0.0	0.0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Beechmore 1999				
			Flowers/fruit: Trees	The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation		% population	50	83	28.6	43.0	42.9	40.0	30.8

13 Altona 1999 site description

Altona 1999 is an old council quarry that was rehabilitated by Northparkes Mines in 1999. It is located on the Altona property, approximately 1km east of the E26 subsidence area. It maintains an open woodland structure (although these are in obvious rows), scattered shrubs and a mosaic of grassy clearings and bare patches. Heavy grazing pressure by Kangaroos was particularly evident at this site as ground cover vegetation cover was limited across the site but there was generally good leaf litter cover beneath tree canopies. In 2009, the ground cover species were particularly stressed with little active green growth. There has been excellent establishment and growth with some trees exceeded 6m in height, were generally healthy and setting seed. In 2010, there were large patches of weeds (*Echium* and *Lolium*), but was relatively bare beneath the shrubs due to Macropod camps. To the west of the site there were some large old growth *Callitris glaucophylla* and *E. populnea*, with some natural regeneration. Grey Crowned Babbler nests were observed within the tree planting areas in 2009. In 2011, there was a significant reduction in cover provided by exotic annual species and macropods continue to be evident. In 2012 and 2013 the site continued to be very dry.

13.1 Landscape Function Analysis

13.1.1 Landscape organisation

In 2009, Altona 1999 was characterised into shrub patches (rows) with a stony grass slope interpatch, but in 2010, significant growth of the annual weeds and other understory vegetation warranted the inclusion of a weedy patch (Figure 13-1, Table 13-1). In 2011, there was an absence of the “weedy” patch and good growing conditions over the summer period has resulted in the increased establishment of the perennial grasses and combined with the following dry conditions there was a high cover of litter within the previous stony grass slope interpatch. Subsequently the site had transformed into a complete functional patch area with two different patch types including shrub and grass patches. In 2012, there was little significant change within the site with the shrub and grass patches occupying 59% and 41% of the site respectively. In 2013, the bare interpatch had returned as a result of heavy grazing and disturbance and it occupied 15% of the slope and shrubs continued to dominate 55% of the slope while 30% was occupied by grass.

Interestingly there were some subtle improvements in ecological function recorded within the shrubby patches but the grass patches had deteriorated. Subsequently the resultant LFA indices for stability, infiltration and nutrient recycling were lower this year. However with indices of 67.4, 50.4 and 46.2 respectively these were 4.5, 9.3 and 10.0 LFA units higher than the minimum KPI target range.



Figure 13-1. Permanent photo point taken from the top of the LFA transect in 2011 (left), 2012 (centre) and 2013 (right).

Table 13-1. Summary of landscape organisation and LFA indices from 2009 to 2013.

Altona		10/12/2009			15/09/2010			18/10/2011			17/10/2012			18/10/2013			
Number of Patches/10m		1			1.6			1.5			1.5			1.5			
Total Patch Area (m2)		56.49			107.59			200			200			170.00			
Patch Area Index		0.3			0.56			1			1			0.85			
Landscape Organisation Index		0.48			0.73			1			1			0.85			
Average Interpatch Length (m)		10			2.65			NA			NA			3.00			
Range Interpatch length (m)		10	to 10		1.2	to 4.1		NA			NA			3	to 3		
Patch or Interpatch Type		Shrub Patch	Stony grass slope		Shrub Patch	Stony grass slope	Weedy Patch		Shrub Patch	Grass Patch		Shrub Patch	Grass Patch		Shrub Patch	Grass Patch	Bare
Patch or Interpatch Proportion (%)		47.6	52.4	100	49.9	27.4	22.7	100	59	41	100	59	41	100	55.0	30.0	15.0
Soil Surface Assessment																	
Within Individual Zones	Stability	56.6	56.3		69.5	64.2	71		66.4	68.8		70.9	75		71.3	65.9	56.5
	Infiltration	47	36.9		48.7	40.2	43.5		45.7	49		50.4	49.6		56.0	44.9	40.8
	Nutrients	44.4	29.6		48.3	36.4	43		42.4	47.7		50.4	48.6		52.6	40.2	34.8
		Total			Total			Total			Total			Total			
Individual zones contribution to the whole of Landscape	Stability	27	29.5	56.4	34.7	17.6	16.1	68.4	39.2	28.2	67.3	41.8	30.8	72.6	39.2	19.8	8.5
	Infiltration	22.4	19.3	41.7	24.3	11	9.9	45.2	27	20.1	47.1	29.8	20.3	50.1	30.8	13.5	6.1
	Nutrients	21.1	15.5	36.6	24.1	10	9.8	43.8	25	19.6	44.6	29.7	19.9	49.7	28.9	12.1	5.2

13.1.2 Soil Surface Assessment

In the shrub patches, there was moderate to high levels of protective ground cover largely due to the low hanging branches and there continued to high canopy cover provided by the maturing trees and shrubs. There was generally a high cover of fallen leaf litter which had accumulated to a depth of at least 20mm deep in three of the replicates with slight to moderate levels of decomposition in all replicates (Table 13-2). There was generally an absence of crusts due to a combination of increasing humus material. Typically there was no suitable cryptogam habitat due to the increasing litter layer and lack of soil crusts but cryptogams continued to be in low abundance in one replicate.

Generally there was negligible erosion or deposition but some deposition was noted in two replicates probably after heavy rainfall during June. There continued to be moderate to high soil surface relief with remnant rip lines providing some of this relief but many had previously filled with sediments. The clay loam soils were usually moderately hard but some areas which were rich with humus were quite friable and loose. The soils continued to be very stable.

Table 13-2 . Results of the Soils Surface Assessment for the Shrub patches.

Features	Max score	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Soil Cover	5	4	4	5	3	3
Per. basal / canopy cover	4	4	4	4	4	4
Litter cover, orig & incorp.	10	6lm	6lm	5lm	6lm	5ls
Cryptogam cover	4	0	0	0	0	1
Crust broken-ness	4	0	0	0	0	4
Erosion type & severity	4	4	4	4	4	4
Deposited materials	4	4	4	2	4	1
Soil surface roughness	5	3	3	3	4	3
Surface resist. to disturb.	5	2	2	2	3	3
Slake test	4	4	4	4	4	4
Texture	4	2	2	2	2	2

In the grass patches (Table 13-3) there was low to high protective ground cover largely provided by stones and scattered perennial grasses but this was highly variable. The scattered grasses also provided low levels of perennial basal in some cases.

The presence of annual weeds and dead leaf litter continue to provide relatively high levels of litter cover but these were not as thick as in 2013, but there continued to be slight to moderate levels of decomposition. Soil surface crusting was variable and was dependent on the retention of the thick litter layer and where it was present, soil crusts typically were not observed. Cryptogams were also not present despite the presence of some surface crusts. Due to the scattered grass tussocks and relatively good ground cover there continued to be moderate soil surface relief, and while these patches were usually stable, some erosion and deposition was recorded on one occasion. The clay loam soils continued to be moderately hard and stable.

Table 13-3. Results of the Soils Surface Assessment for the Grass patches.

Features	Max score	Rep1	Rep 2	Rep 3
Soil Cover	5	2	3	5
Per. basal / canopy cover	4	1	2	2
Litter cover, orig & incorp.	10	5lm	5lm	5ls
Cryptogam cover	4	1	1	1
Crust broken-ness	4	0	4	0
Erosion type & severity	4	3	4	4
Deposited materials	4	2	4	4
Soil surface roughness	5	3	3	3
Surface resist. to disturb.	5	3	3	3
Slake test	4	4	4	4
Texture	4	2	2	2

In the bare patches, there was some limited protection from rain splash due to some scattered perennial forbs with the overhanging branches providing some perennial canopy cover, but this was in only one of the two replicates. There were moderate to high levels of litter cover which had slightly decomposed. Cryptogams were not observed and soil crusting was variable. There continued to be slight to moderate levels of sheet erosion and deposition with there being low to moderate soil surface relief (Table 13-4). The clay loam soils were very moderately hard and very stable when immersed in rain water.

Table 13-4. Results of the Soils Surface Assessment for the Bare interpatches.

Features	Max score	Rep1	Rep 2
Soil Cover	5	2	1
Per. basal / canopy cover	4	4	1
Litter cover, orig & incorp.	10	4ls	5ls
Cryptogam cover	4	1	1
Crust broken-ness	4	4	0
Erosion type & severity	4	3	3
Deposited materials	4	2	3
Soil surface roughness	5	3	2
Surface resist. to disturb.	5	3	3
Slake test	4	4	4
Texture	4	2	2

13.2 Soil analyses

The soil pH recorded at Altona 1999 continued to decline and while it was lower than the local ranges it just fell within the desirable range (Table 13-5). There was a marginal increase in Electrical Conductivity and this year it fell within local levels and continued to meet this KPI target. There has been a minor decline in Organic Matter, phosphorous and nitrate levels and all continued to meet this KPI target. The Cation Exchange Capacity remained low and did not fall within the ranges provided by the reference sites indicating the soils may have a limited capacity to retain nutrients. The Exchangeable Sodium Percentage also remained low indicating that the soils are non sodic.

Table 13-5. Results of the soil analysis for Altona 1999 compared to the upper and lower values for the woodland reference sites and desirable levels from 2009 to 2013.

Nutrient	Units	Altona 1999					Lower KPI	Upper KPI	Desirable Level
		2009	2010	2011	2012	2013			
pH (1:5 water)	units	5.61	5.71	5.82	5.75	5.37	5.99	7.10	5.6 – 7.3
Conductivity (1:5 water)	dS/m	0.088	0.051	0.056	0.046	0.059	0.038	0.191	0.150
Organic Matter	%	4.77	4.5	3.5	4.4	4.2	3.0	4.6	>4.5
Phosphorus (Colwell)	mg/kg	33	34	29	25	21	6	17	50
Nitrate	mg/kg	16	3.6	4.5	4.1	3.5	1.2	1.9	13.0
Cation Exchange Capacity	cmol+/Kg	8.6	7.65	6.42	7.85	7.53	12.05	22.87	14.00
Exchangeable Sodium Percentage	%	0.02	0.44	0.77	0.39	0.80	0.29	2.42	<5

13.3 Rill assessment

No rills were observed within the monitoring quadrat in any monitoring year.

13.4 Tree density and health condition

This year there were 17 individuals with a dbh >5cm within the 50 x 20m Altona 1999 monitoring plot however one *Acacia* was dead and was probably at the end of its natural life span (Table 13-6).

The average trunk diameter was 15cm and they now ranged from 6 – 26cm which was a further 1cm increase since 2012. The tree population was comprised of ten different species including four *Acacia* species, four *Eucalyptus* species, *Brachychiton populneus* and *Casuarina cunninghamiana*. Most individuals were in healthy condition with 10 bearing reproductive such as buds, fruits or flowers. However six were in medium health and this year two acacias were in a state of advanced dieback.

Table 13-6. Summary of tree health and density.

Dominant species	<i>Eucalyptus camaldulensis</i> (3), <i>Eucalyptus dwyeri</i> (2), <i>Eucalyptus melliodora</i> (2), <i>Eucalyptus viridis</i> (2), <i>Casuarina cunninghamiana</i> (2), <i>Acacia deanei</i> (1), <i>Acacia pendula</i> (1), <i>Acacia spectabilis</i> (1), <i>Acacia trineura</i> (1), <i>Brachychiton populneus</i> (1)
Average dbh (Cm)	15
Max dbh (cm)	26
Min dbh (cm)	6
Total trees	17
No. with multiple limbs	8
No. Live trees	16
No. Healthy	8
No. Medium Health	6
No. Advanced Dieback	2
No. Dead	1
Mistletoe	0
Flowers / fruit	10

13.5 Shrubs and juvenile trees

In 2009, there were 35 shrubs and juvenile trees represented by nine different species and since then there have been continued recruitment of acacias and in 2012 there was a population of 177 individuals. This year there were less individuals probably due to dry conditions and increased browsing pressure and a population of 152 shrubs and juvenile trees were recorded (Figure 13-2, Table 13-7).

Acacia spectabilis continued to be the most common species with 73 individuals followed by *A. deanei* with 59 individuals. All height classes continued to be represented and while the majority were 1.5 – 2.0m in height, 40 individuals were greater than 2.0m in height. The volunteer species *Maireana brevifolia* has declined in numbers but 12 individuals persisted. All individuals were considered to be local endemic species.

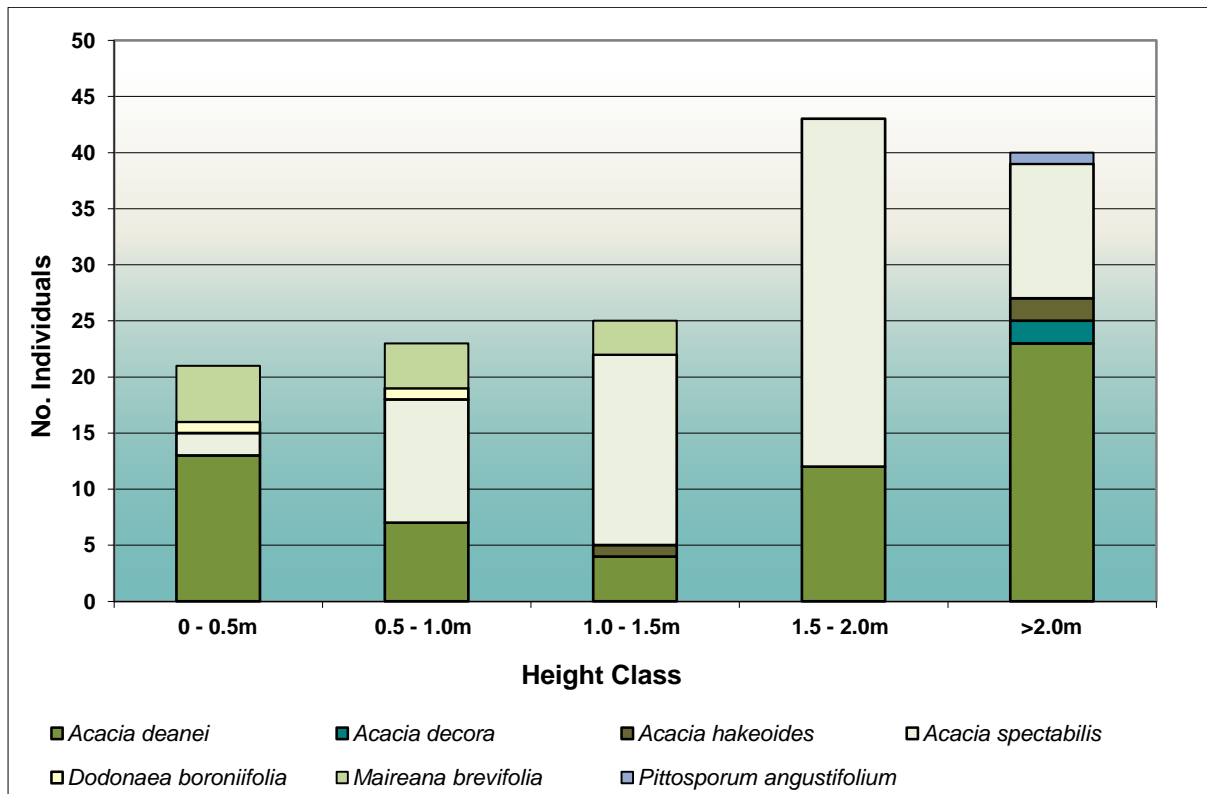


Figure 13-2 Shrubs and juvenile trees occurring within the monitoring site.

Table 13-7. Shrubs and young trees occurring within the monitoring site.

Species	0 - 0.5m	0.5 - 1.0m	1.0 - 1.5m	1.5 - 2.0m	>2.0m	Total	endemic	not endemic
<i>Acacia deanei</i>	13	7	4	12	23	59	59	
<i>Acacia decora</i>					2	2	2	
<i>Acacia hakeoides</i>			1		2	3	3	
<i>Acacia spectabilis</i>	2	11	17	31	12	73	73	
<i>Dodonaea boroniifolia</i>	1	1				2	2	
<i>Maireana brevifolia</i>	5	4	3			12	12	
<i>Pittosporum angustifolium</i>					1	1	1	
Total	21	23	25	43	40	152	152	0
% endemic species							100	0

13.6 Structural diversity and habitat complexity

The 50 m vegetation transect at this site crossed two planted rows of trees and shrubs with a 10m wide sparsely grassed open areas between them (Figure 13-3). Since 2009 the total average ground cover has continued to increase and the composition fluctuating with changes in the seasonal conditions. This year there was a dramatic reduction in total ground cover which declined from 91.5 - 71.5% as a result of prolonged dry and increased grazing and disturbance by animals. Dead leaf litter continued to provide 49.7% valuable ground cover while 10.1% of cover provided by perennial plants persisted. There was also limited cover provided by annual plants, cryptogams and rocks (Figure 13-4).

Due to the age of the site and row plantings, canopy cover was variable with projected foliage cover greater than 0.5m being recorded at only at two intervals (35, 40m) along the transect, but there has been overall good growth and development of the site. Canopy cover greater than 6m continued to be recorded at 40m along the transect. Average and minimum and maximum values of the structural diversity are recorded in Table 13-8.

2009 Vegetation transect (front)



2009 Vegetation transect (rear)



2010 Vegetation transect (front)



2010 Vegetation transect (rear)



2011 Vegetation transect (front)



2011 Vegetation transect (rear)



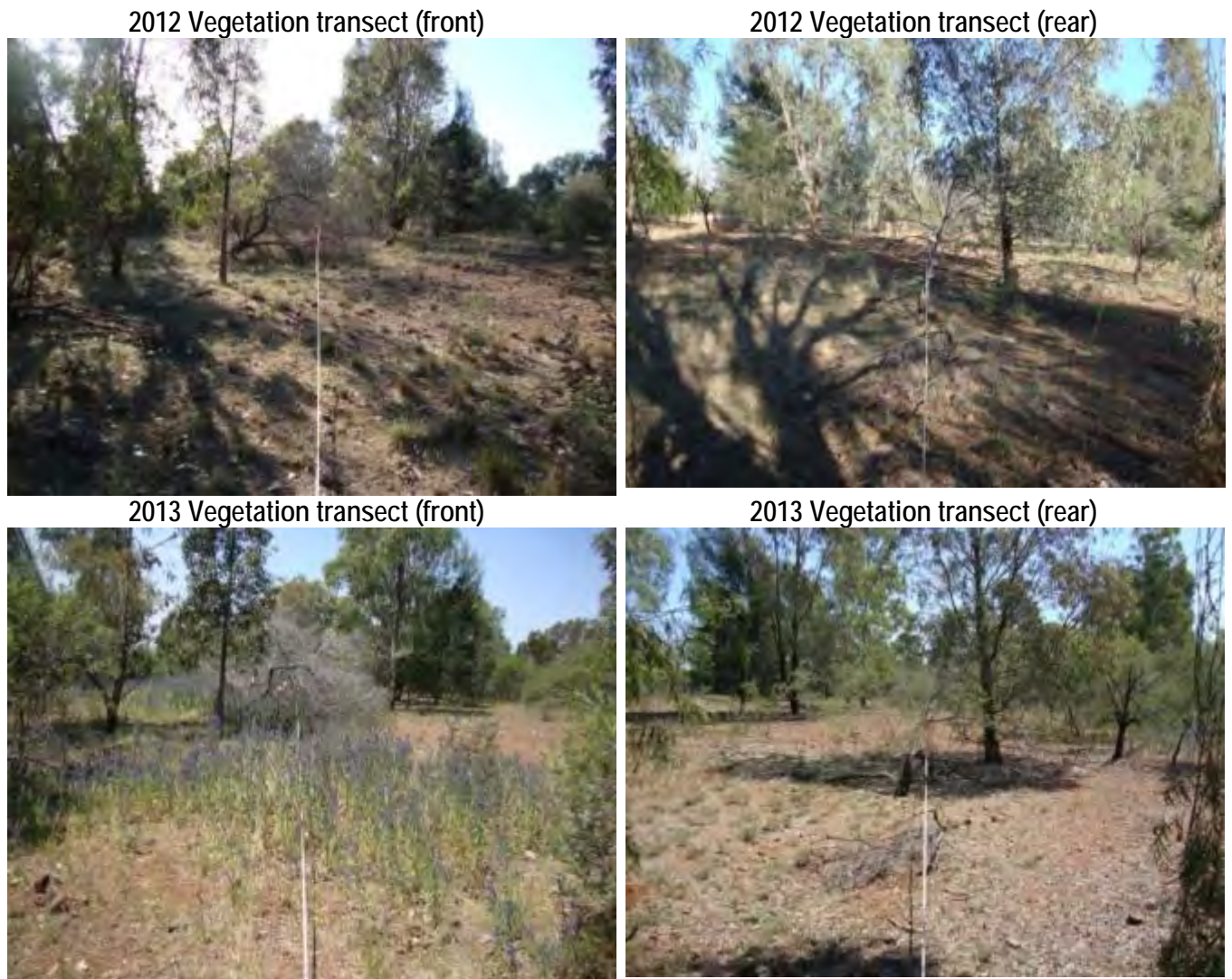


Figure 13-3. Permanent photo points taken from the front (left) and rear (right) of the vegetation transect.

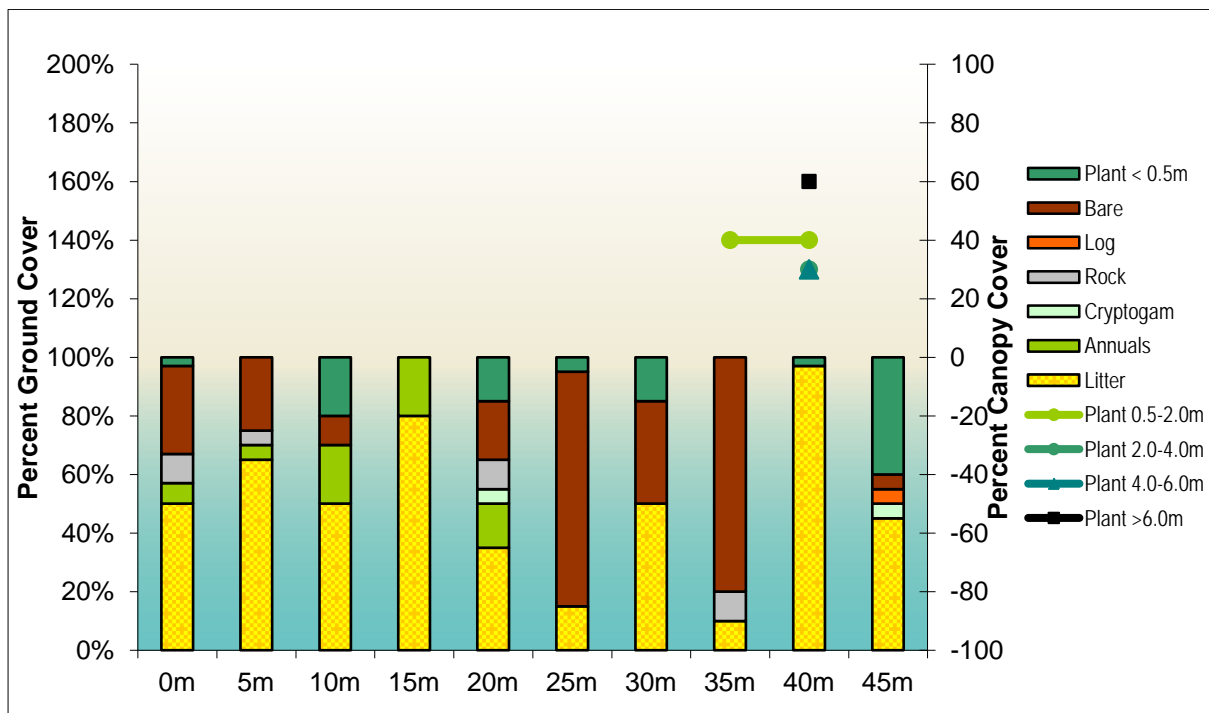


Figure 13-4. Graph illustrating the structural diversity and habitat complexity of the monitoring site.

Table 13-8. Average and minimum and maximum values of the structural diversity of the monitoring site.

Vegetation structure	0m	5m	10m	15m	20m	25m	30m	35m	40m	45m	Average	Min	Max
Litter	50	65	50	80	35	15	50	10	97	45	49.7	10	97
Annuals	7	5	20	20	15	0	0	0	0	0	6.7	0	20
Cryptogam	0	0	0	0	5	0	0	0	0	5	1	0	5
Rock	10	5	0	0	10	0	0	10	0	0	3.5	0	10
Log	0	0	0	0	0	0	0	0	0	5	0.5	0	5
Bare	30	25	10	0	20	80	35	80	0	5	28.5	0	80
Perennial <0.5m	3	0	20	0	15	5	15	0	3	40	10.1	0	40
Total Ground Cover	70	75	90	100	80	20	65	20	100	95	71.5	20	100
0.5-2.0m	0	0	0	0	0	0	0	40	40	0	8	0	40
2.0-4.0m	0	0	0	0	0	0	0	0	30	0	3	0	30
4.0-6.0m	0	0	0	0	0	0	0	0	30	0	3	0	30
>6.0m	0	0	0	0	0	0	0	0	60	0	6	0	60

13.7 Species cover abundance

In 2009, nine native species were recorded in the five 1m² quadrats on the permanent vegetation transect line. This year there were 18 including six exotic species. Using the Braun-blanket scale, the highest possible cover score that can be obtained is 30 and cover abundance is illustrated as a sum of scores (class values) obtained along the five 1m² quadrats.

In previous years *Dichondra repens* and *Austrostipa* species were the most abundant species but all species present provided only limited ground cover. This year the dominant native were *Austrostipa* species and *Einadia nutans* subsp. *nutans* while the exotic species *Echium plantagineum*, *Hordeum leporinum* and *Lolium rigidum* were also relatively dominant (Figure 13-5, Table 13-9). The remaining species were usually recorded only once and provided low cover scores. Of the live plant cover scores recorded 57.9% was provided by native species, a reduction from 78.8% last year.

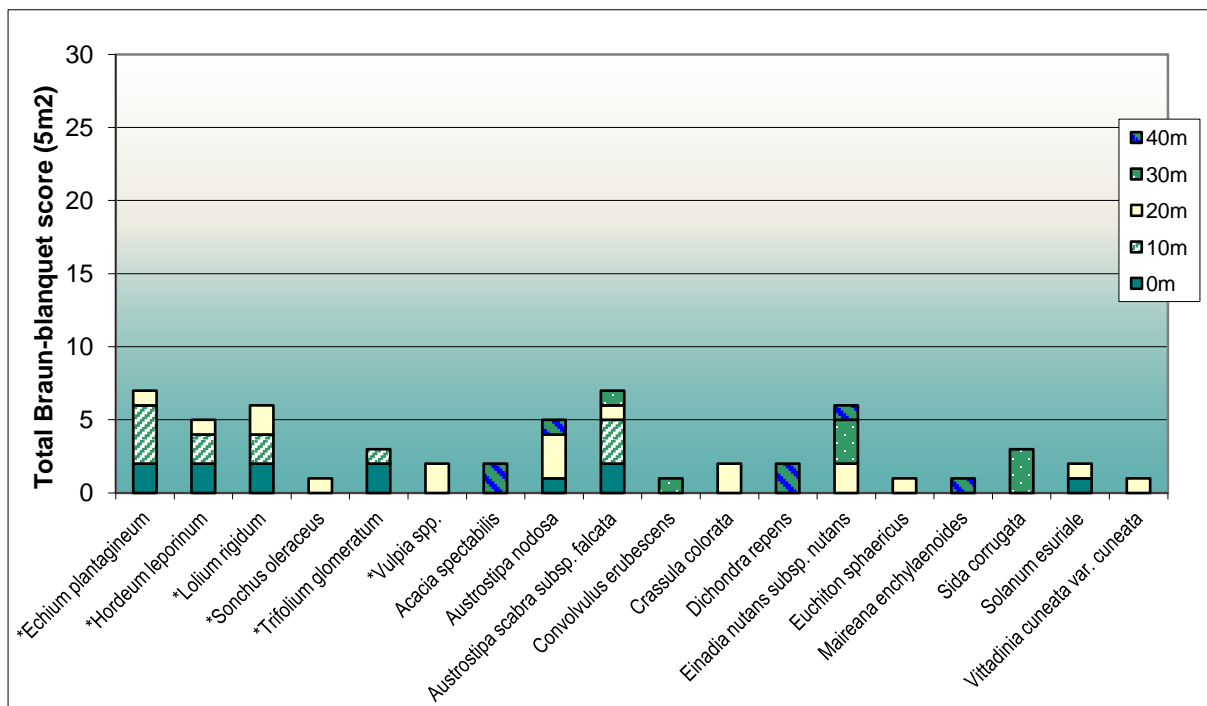


Figure 13-5. Total species recorded across the five, 1m² quadrats using the Braun-blanket scale (max possible score is 30) as a measure of cover abundance.

Table 13-9. List of species and their average cover abundance score across the five, 1m² monitoring quadrats.

Species	0m	10m	20m	30m	40m	Total
* <i>Echium plantagineum</i>	2	4	1			7
* <i>Hordeum leporinum</i>	2	2	1			5
* <i>Lolium rigidum</i>	2	2	2			6
* <i>Sonchus oleraceus</i>			1			1
* <i>Trifolium glomeratum</i>	2	1				3
* <i>Vulpia</i> spp.			2			2
<i>Acacia spectabilis</i>					2	2
<i>Austrostipa nodosa</i>	1		3		1	5
<i>Austrostipa scabra</i> subsp. <i>falcata</i>	2	3	1	1		7
<i>Convolvulus erubescens</i>				1		1
<i>Crassula colorata</i>			2			2
<i>Dichondra repens</i>					2	2
<i>Einadia nutans</i> subsp. <i>nutans</i>			2	3	1	6
<i>Euchiton sphaericus</i>			1			1
<i>Maireana enchylaenoides</i>					1	1
<i>Sida corrugata</i>				3		3
<i>Solanum esuriale</i>	1		1			2
<i>Vittadinia cuneata</i> var. <i>cuneata</i>			1			1
Total cover						57
Sum of cover of native species						33
Percent endemic species cover						57.9

13.8 Floristic diversity

The floristic diversity of the sites was measured using two different methods. One provides an assessment of the average number of species within five, one square metre (m²) sub-quadrats along the vegetation transect, while the other provides the total number of species within the entire 50x20m monitoring plot.

13.8.1 Species diversity per m²

On average the number of native species has increased from 2.8 – 4.0 native species per m² but the number of exotic species has also increased from 1.4 – 2.6 species per m² since 2012 (Table 13-10). The number of native species ranged between one to seven per m², while the number of exotic species ranged between zero and five.

Table 13-10. Species diversity per 1m².

Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	3	1	7	4	5	4	2.2
Exotic	4	4	5	0	0	2.6	2.4
Total	7	5	12	4	5	6.6	3.2

13.8.2 Total species diversity

In 2009, the overall the floristic diversity was moderate with a total of 28 native species recorded in the 50 x 20m monitoring quadrat. In 2013 there were 62 species and this included 46 native species (Figure 13-6, Table 13-11). The sharp increase in the native species diversity curve at 500m² indicates there was a patch of natives and the site was relatively heterogeneous. A list of species recorded within the monitoring site is provided in Appendix 1.

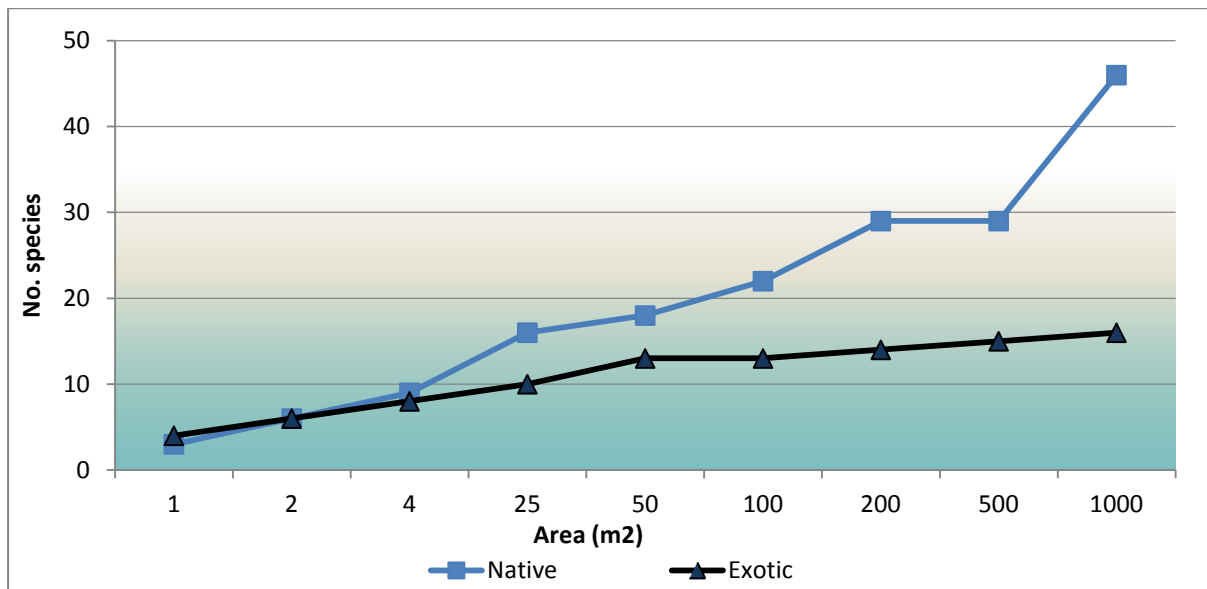


Figure 13-6. Cumulative species in the 50m x 20m (1000m²) monitoring quadrat.

Table 13-11. Cumulative species diversity.

Area (m2)	1	2	4	25	50	100	200	500	1000
Native	3	6	9	16	18	22	29	29	46
Exotic	4	6	8	10	13	13	14	15	16

13.9 Growth forms

Figure 13-7 is a summary of species in each growth form that were recorded in Altona 1999. In 2013 there were 28 herbs including eleven exotics and 15 different grasses including five exotic species. There were six tree, ten shrub and two sub-shrub representatives and these were all native species. There was one reed but no ferns were yet recorded. Compared to the woodland reference there was an appropriate composition of most growth forms, however there was a lack of herb diversity.

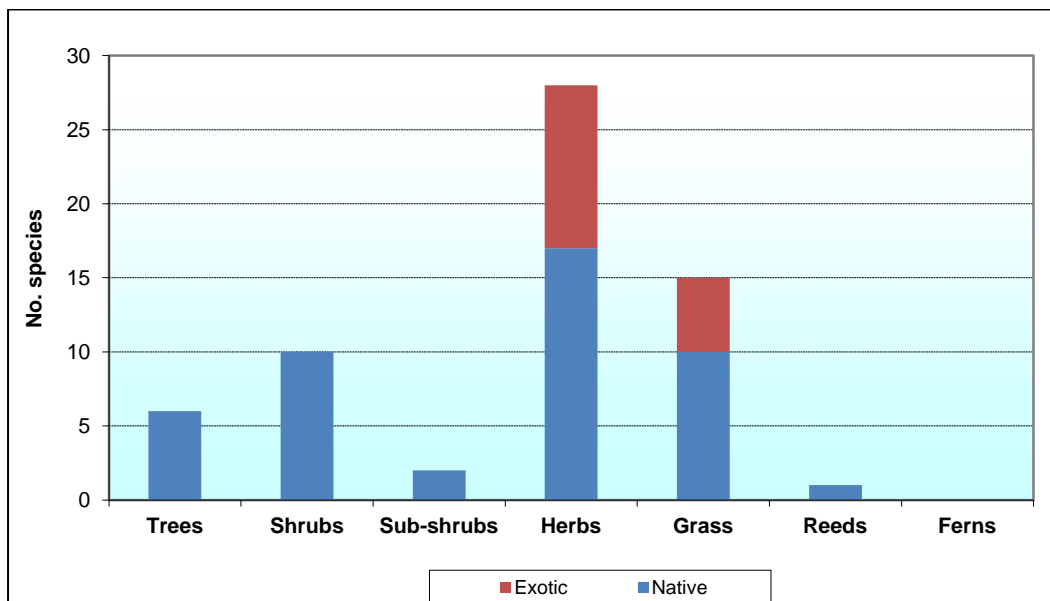


Figure 13-7. Graph illustrating the growth forms of species recorded in the 50m x 20m monitoring quadrat.

13.10 Comparison of rehabilitation data with key performance indicators

Table 13-12 indicates the performance of the rehabilitation monitoring site against the Completion and Desirable Performance Indicators developed for woodland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) for example and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 13-12. Comparison of key performance Indicators recorded in the rehabilitation site Altona 1999 compared to lower and upper limits recorded in the woodland reference sites.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Altona 1999				
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2009	2010	2011	2012	2013
Phase2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	0	5	3	3	3	3	3
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%	62.9	69.0	56.4	68.4	67.3	72.6	67.4
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%	41.1	55.7	41.7	45.2	47.1	50.1	50.4
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%	36.2	53.0	36.6	43.8	44.6	49.7	46.2
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%	100	100	48	73	100	100	85

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Altona 1999				
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising		No.	0	0	0	0	0	0	0
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0	0	0	0	0
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)	6.0	7.1	5.81	5.71	5.82	5.78	5.37
			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)	0.038	0.191	0.088	0.051	0.056	0.046	0.059
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	3.0	4.6	4.5	4.5	3.5	4.4	4.2
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	6.4	17.3	33.5	33.8	28.7	25.1	20.9
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	1.2	1.9	15.6	3.6	4.5	4.1	3.5
			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)	12.0	22.9	8.55	7.65	6.42	7.85	7.53
			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	2.4	0.02	0.44	0.77	0.39	0.8
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees	The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.		species/area	1	6	8	9	7	7	7
				The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		% population	100	100	na	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	53	76	28	51	47	53	62

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Altona 1999				
			Native species richness		The total number of live native plant species provides an indication of the native plant diversity of the site and that it is greater than or comparable to the local remnant vegetation	>No./area	33	53	28	39	40	45	46
			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	13	27	0	12	7	8	16
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees	The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation		No./area	29	110	35	41	115	177	152
	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	4	6	6	6	6	6
			Shrubs	The number of shrub species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	0	3	9	9	9	9	10
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	1	5	3	1	4	5	2
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	33	46	6	23	19	21	28
			Grasses		The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	9	22	4	11	8	11	15
			Reeds		The number of reed, sedge or rush species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	1	0	1	1	1	1
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Ferns		The number of ferns comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	1	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Altona 1999				
Phase 5: Ecosystem & Landuse Development	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	%	47	77	65.8	15.7	59.3	73.5	49.7
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	2	22	0	42.5	0.7	0.5	6.7
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	8	0	2	1.5	0	1
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0	1	1.2	2	2	5.5	3.5
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	3	0	2	1	0	0.5
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	6	11	31.3	24	16.3	8.5	28.5
			Perennial plant cover (< 0.5m)	Percent ground cover provided by live perennial vegetation (< 0.5m in height) is comparable to that of the local remnant vegetation		%	7	25	1.7	11.8	19.2	12	10.1
			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		%	89	95	68.7	76	83.7	91.5	71.5
	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	7	8	2.6	3.8	3.2	2.8	4.0
			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	1	4	0	2.2	1	1.4	2.6
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation		%	63	87	na	52.6	78.6	78.8	57.9

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Altona 1999				
	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	7	89	1	13	33	40	21
			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	2	15	4	8	42	34	23
			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	13	9	3	12	33	25
			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	18	1	3	5	38	43
			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	48	20	14	23	32	40
	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	1	9	8	22	6	8	8
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	6	4	14	12	4	3
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 - 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	9	6	6	6	7	3

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Altona 1999				
			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	17	42	5	7	6	6	6
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	3	3	9	8	9	10	10
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	100	100	na	94	94	94	100
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	6	19	15	17	18	19	17
			Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	18	54	13	13	14	14	15
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees	The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation		% population	83	100	100.0	94.0	94.4	89.5	94.1
			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	7	47	73.3	71.0	50.0	42.1	47.1
			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	44	57	26.7	12.0	38.9	31.6	35.3
			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	0	36	0.0	12.0	5.6	15.8	11.8
			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	17	0.0	6.0	5.6	10.5	5.9

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Altona 1999				
			Mistletoe		The percentage of the tree population which have mistletoe provides an indication of community health and habitat value and that the percentage is comparable to the local remnant vegetation	% population	0	7	0.0	0.0	0	0	0
			Flowers/fruit: Trees	The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation		% population	50	83	60.0	71.0	55.6	63.2	58.8

14 Kundibah 2001 site description

Kundibah 2001 is a small tree planting area located on the Kundibah property to the north of the mining lease and adjacent to Adavale Lane. The site was planted in 2001 and maintains an open woodland structure, scattered shrubs and a mosaic of grassy clearings and bare patches. Vegetation cover was limited beneath the tree canopies but there was generally good leaf litter cover. In 2009, ground cover species were particularly stressed with little active green growth. There has been good establishment and growth with some trees exceeded 6m in height, were mostly healthy and setting seed. Some trees however were showing signs of stress and some insect attack by lerps. Some species (eg. *E. melliodora*) appeared to be stunted. In 2009, Grey Crowned Babblers were observed within the site. In 2011 there was a significant reduction in cover provided by exotic annual ground cover species. In 2012 and 2013 the site continued to be very dry.

14.1 Landscape Function Analysis

14.1.1 Landscape organisation

Kundibah 2001 was originally characterised into shrub and grass patches but due to good growth and development of the site, it was re-characterised this year as a woodland patch, with some small bare interpatch areas (**Error! Reference source not found.**). The woodland patch occupied 94.5% which was a decrease in overall functional patch of 100% recorded last year as a result of the prolonged dry conditions (Table 14-1).

The woodland patches were more functional than the bare interpatches and dominated the overall ecological function within the site. While the stability of the site had slightly declined this year, infiltration and nutrient recycling indices have demonstrated a minor improvement. The resultant LFA indices for stability, infiltration and nutrient recycling were 63.7, 44.4 and 42.1 respectively and these were 0.8, 3.3 and 5.9 LFA units higher than the minimum KPI target and therefore this site met these LFA targets this year.



Figure 14-1. Permanent photo point taken from the top of the LFA transect in 2012 (left) and 2013 (right).

Table 14-1. Summary of landscape organisation and LFA indices from 2009 to 2013.

Kundibah		14/12/2009			23/09/2010			19/10/2011			17/10/2012			15/10/2013		
Number of Patches/10m		1.5			1.5			1.5			1.5			2.0		
Total Patch Area (m2)		162.32			200			200			200			186.18		
Patch Area Index		0.81			1			1			1			0.93		
Landscape Organisation Index		1			1			1			1			0.95		
Average Interpatch Length (m)		NA			NA			NA			NA			0.37		
Range Interpatch length (m)		NA			NA			NA			NA			0.35 to 0.4		
Patch or Interpatch Type		Grass Patch	Shrub Patch		Grass Patch	Shrub Patch		Grass Patch	Shrub Patch		Grass Patch	Shrub Patch		Woodland Patch	Bare interpatch	
Patch or Interpatch Proportion (%)		76	24	100	78	22	100	80	20	100	79	21	100	94.5	5.5	100
Soil Surface Assessment																
Within Individual Zones	Stability	65.5	47.5		73.5	58.8		71.5	60		68	58.8		64.2	55.8	
	Infiltration	42.4	29.9		46.4	37.3		45.3	35.2		36.9	42.2		45.6	23.6	
	Nutrients	39.7	25		44.6	36		46	35.5		39	41.3		43.5	17.8	
		Total			Total			Total			Total			Total		
Individual zones contribution to the whole of Landscape	Stability	49.8	11.4	61.2	57.3	12.9	70.3	57.2	12	69.2	53.7	12.3	66.1	60.6	3.1	63.7
	Infiltration	32.2	7.2	39.4	36.2	8.2	44.4	36.2	7	43.3	29.2	8.9	38	43.1	1.3	44.4
	Nutrients	30.2	6	36.2	34.8	7.9	42.7	36.8	7.1	43.9	30.8	8.7	39.5	41.1	1.0	42.1

14.1.2 Soil Surface Assessment

The scattered perennial grasses provided low to moderate level of protective ground cover and these combined with scattered tree canopies provided variable but often high levels of perennial vegetation cover (Table 14-2). There continued to be high levels of litter cover which were undergoing slight to moderate levels of decomposition which is an indication of good microbial and fungal activity within the site. Cryptogams were frequently encountered in low abundance and occupied bare areas on the soil surface crusts. There was little evidence of erosion within the patch however moderate to high levels of deposition were noted as leaves were often washed into lower lying area and depressions. The soil surface typically remained moderately rough due to the scattered grass tussocks. The clay loam soils were moderately hard and mostly stable, however two samples were slightly unstable when immersed in rain water.

Table 14-2 . Results of the Soils Surface Assessment for the Woodland patches.

Features	Max score	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Rep 6
Soil Cover	5	2	3	2	2	2	3
Per. basal / canopy cover	4	2	2	4	4	2	3
Litter cover, orig & incorp.	10	5ls	5ls	5lm	6lm	5ls	5ls
Cryptogam cover	4	2	2	2	1	2	1
Crust broken-ness	4	4	4	4	4	4	4
Erosion type & severity	4	4	4	4	4	4	3
Deposited materials	4	2	2	1	1	3	3
Soil surface roughness	5	3	3	3	3	3	3
Surface resist. to disturb.	5	3	3	3	3	3	3
Slake test	4	4	3	4	4	4	3
Texture	4	2	2	2	2	2	2

The bare interpatches area had little to no protective or perennial plant cover but there were highly variable levels of litter cover, but most of this was leaf litter which had blown into the area. The soil crusts provided a low soil surface relief and subsequently there were no cryptogams and slight sheet erosion was evident. Despite the limited ability to capture mobilised resources there was some limited deposition within these small areas. The clay loam soils continued were moderately hard to very hard and when immersed in rainwater demonstrated some slumping of the sub-crusts.

Table 14-3. Results of the Soils Surface Assessment for the Bare interpatches.

Features	Max score	Rep1	Rep 2	Rep 3
Soil Cover	5	1	1	1
Per. basal / canopy cover	4	1	1	1
Litter cover, orig & incorp.	10	5tn	2tn	4tn
Cryptogam cover	4	1	1	1
Crust broken-ness	4	4	4	4
Erosion type & severity	4	3	3	3
Deposited materials	4	2	4	3
Soil surface roughness	5	2	2	2
Surface resist. to disturb.	5	3	4	4
Slake test	4	3	3	3
Texture	4	2	2	2

14.2 Soil analyses

The soil pH recorded in Kundibah 2001 has essentially remained unchanged since monitoring in 2009 and this year they fell within acceptable and local pH level and remained slightly acidic (Bruce and Rayment 1982, Table 14-4).

Electrical Conductivity remained similar and within levels typical of the local area. There was a further decline in organic and the site remained deficient in organic matter. Phosphorous and nitrate levels had decreased and while phosphorous levels were within range, nitrate levels were very low this year. The CEC was also within local levels and while the ESP was slightly elevated it remained below the threshold of 5% indicating the soils are non sodic.

Table 14-4. Results of the soil analysis for Kundibah 2001 compared to the upper and lower values for the woodland reference sites and desirable levels from 2009 to 2013.

Nutrient	Units	Kundibah 2001					Lower KPI	Upper KPI	Desirable Level
		2009	2010	2011	2012	2013			
pH (1:5 water)	units	6.23	6.64	6.22	6.22	6.16	5.99	7.10	5.6 – 7.3
Conductivity (1:5 water)	dS/m	0.135	0.048	0.083	0.048	0.042	0.038	0.191	0.150
Organic Matter	%	2.70	2.5	3.1	3.6	2.4	3.0	4.6	>4.5
Phosphorus (Colwell)	mg/kg	33	22	39	29	17	6	17	50
Nitrate	mg/kg	13	1.3	1.4	3.5	1.0	1.2	1.9	13.0
Cation Exchange Capacity	cmol+/Kg	20.6	17.76	14.00	12.55	13.01	12.05	22.87	14.00
Exchangeable Sodium Percentage	%	3.09	2.39	3.09	2.28	3.76	0.29	2.42	<5

14.3 Rill assessment

No rills were observed within the monitoring quadrat in any monitoring year.

14.4 Tree density and health condition

This year there was an addition to the tree population with individuals having an average dbh of 11cm but these ranged between 5 – 20cm, indicating there has been good growth and development (Table 14-5). All individuals were in moderate to healthy condition with ten individuals having reproductive structures such as buds, fruits or flowers and no mistletoe was observed.

The tree population was comprised of two *Acacia* species and eight *Eucalyptus* species and there was one *Casuarina cunninghamiana*. Despite having a natural occurrence in the nearby ridge communities *Eucalyptus viridis* was not considered to be suited to the low lying depressions of this site.

Table 14-5. Summary of tree health and density.

Dominant species	<i>Eucalyptus largiflorens</i> (5), <i>Eucalyptus camaldulensis</i> (4), <i>Eucalyptus populnea</i> (4), <i>Eucalyptus dwyeri</i> (3), <i>Eucalyptus melliodora</i> (3), <i>Eucalyptus microcarpa</i> (3), <i>Eucalyptus albens</i> (2), <i>Eucalyptus viridis</i> (2), <i>Acacia leucoclada</i> (2), <i>Acacia pendula</i> (1), <i>Casuarina cunninghamiana</i> (1)
Average dbh (Cm)	11
Max dbh (cm)	20
Min dbh (cm)	5
Total trees	30
No. with multiple limbs	18
No. Live trees	30
No. Healthy	16
No. Medium Health	14
No. Advanced Dieback	0
No. Dead	0
Mistletoe	0
Flowers / fruit	10

14.5 Shrubs and juvenile trees

This year the shrub population has slightly declined from 66 to 56 as some of the small acacia suckers had died however *A. leucoclada* continued to be the most dominant shrub species and had individuals across all of the range of height classes, with 17 individuals >2.0m in height (Figure 14-2, Table 14-6). The next most common species was *A. hakeoides* which had eight individuals and most of these were greater than 2.0m. There continued to be one small and stunted *Corymbia citriodora* which is considered a non endemic native species.

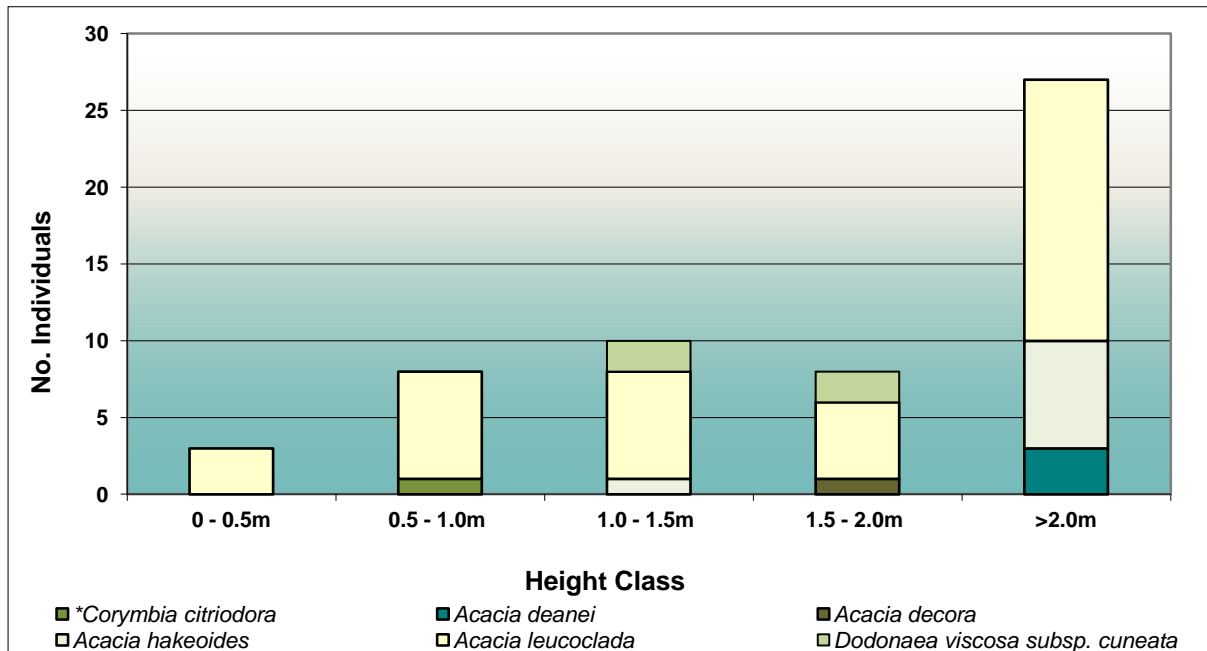


Figure 14-2 Shrubs and juvenile trees occurring within the monitoring site.

Table 14-6. Shrubs and juvenile trees occurring within the monitoring site.

Species	0 - 0.5m	0.5 - 1.0m	1.0 - 1.5m	1.5 - 2.0m	>2.0m	Total	endemic	not endemic
*Corymbia citriodora		1				1		1
Acacia deanei					3	3	3	
Acacia decora				1		1	1	
Acacia hakeoides			1		7	8	8	
Acacia leucoclada	3	7	7	5	17	39	39	
Dodonaea viscosa subsp. cuneata			2	2		4	4	
Total	3	8	10	8	27	56	55	1
% endemic species							98	2

14.6 Structural diversity and habitat complexity

Kundibah consisted of planted rows of trees and shrubs with open areas of sparse grassland in between these rows (Figure 14-3, Figure 14-4). Since 2009 the total average ground cover has continued to increase and the composition fluctuating with changes in the seasonal conditions. This year there was a dramatic reduction in total ground cover which declined from 91.0 – 89.5% as a result of prolonged dry and increased grazing and disturbance by animals. Dead leaf litter continued to provide 70.0% valuable ground cover while 15.5% of cover provided was provided by perennial plants. There was also limited cover provided by cryptogams (Figure 14-4).

Due to the age of the site and row plantings, canopy cover was variable with projected foliage cover greater than 0.5m being recorded in all 2.0m vertical height increments on average indicating good growth and development of the site. Canopy cover greater than 6m continued to be recorded at 10 and 20m along the transect. Average and minimum and maximum values of the structural diversity are recorded in Table 14-7.

2009 Vegetation transect (front)



2009 Vegetation transect (rear)



2010 Vegetation transect (front)



2010 Vegetation transect (rear)



2011 Vegetation transect (front)



2011 Vegetation transect (rear)





Figure 14-3. Permanent photo points taken from the front (left) and rear (right) of the vegetation transect.

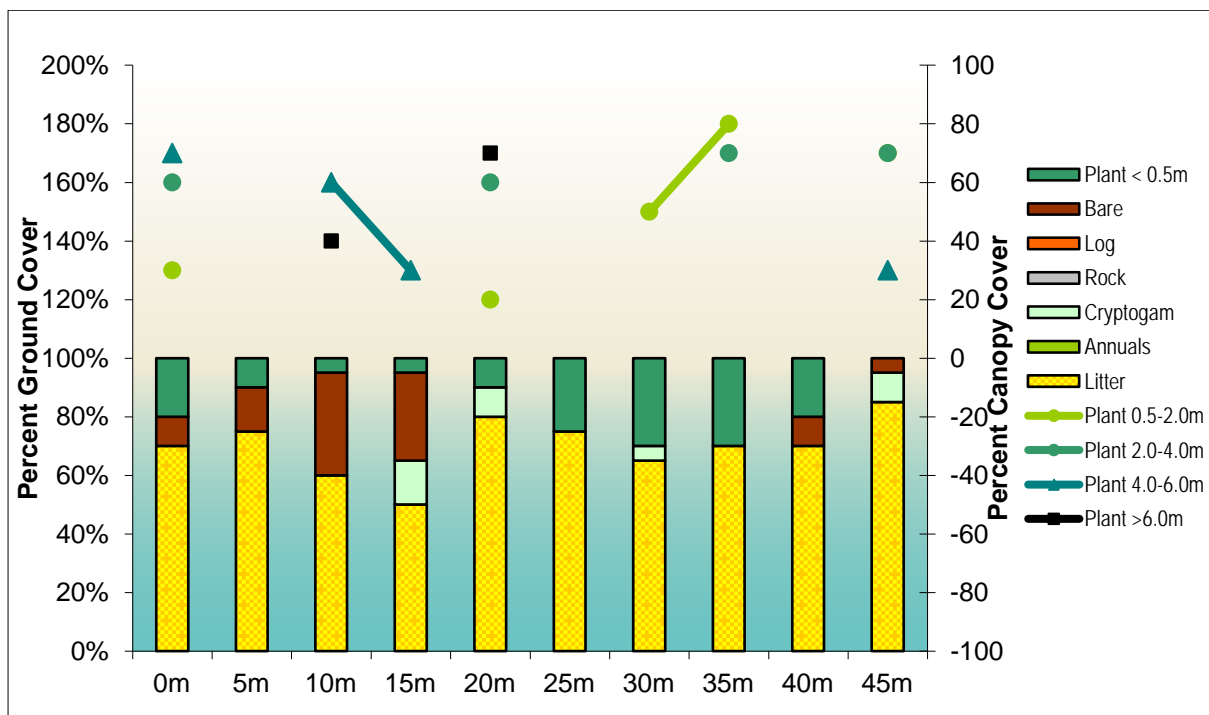


Figure 14-4. Graph illustrating the structural diversity and habitat complexity of the monitoring site.

Table 14-7. Average and minimum and maximum values of the structural diversity of the monitoring site.

Vegetation structure	0m	5m	10m	15m	20m	25m	30m	35m	40m	45m	Average	Min	Max
Litter	70	75	60	50	80	75	65	70	70	85	70	50	85
Annuals	0	0	0	0	0	0	0	0	0	0	0	0	0
Cryptogam	0	0	0	15	10	0	5	0	0	10	4	0	15
Rock	0	0	0	0	0	0	0	0	0	0	0	0	0
Log	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare	10	15	35	30	0	0	0	0	10	5	10.5	0	35
Perennial <0.5m	20	10	5	5	10	25	30	30	20	0	15.5	0	30
Total Ground Cover	90	85	65	70	100	100	100	100	90	95	89.5	65	100
0.5-2.0m	30	0	0	0	20	0	50	80	0	70	25	0	80
2.0-4.0m	60	0	0	0	60	0	0	70	0	70	26	0	70
4.0-6.0m	70	0	60	30	0	0	0	0	0	30	19	0	70
>6.0m	0	0	40	0	70	0	0	0	0	0	11	0	70

14.7 Species cover abundance

This year there were 14 different live plant species including three exotic species recorded along the five 1x1m sub-plots placed at 10m intervals along the vegetation transect. Using the Braun-blauquet scale, the highest possible cover score that can be obtained is 30 and cover abundance is illustrated as a sum of scores (class values) obtained along the five 1m² quadrats.

In previous years the ground covers have changed as a result of the changing seasonal conditions with the exotic annuals *Lolium sp.*, *Trifolium sp.* and *Sonchus oleraceus* being very common and abundant due to the good seasonal conditions. Since then the drier conditions have lead to the dominance of the native perennial grass *Walwhalleya proluta* with *Enteropogon acicularis* and *Chloris truncata* also being relatively common (Figure 14-5, Table 14-8). This year there were also scattered occurrences of some exotic annuals and these were largely persisting in lower lying depressions. The remaining species were recorded on less than two occasions and provided only low cover values. Of the cover scores recorded 72.24% was provided by native species, a reduction from 96.4% recorded last year.

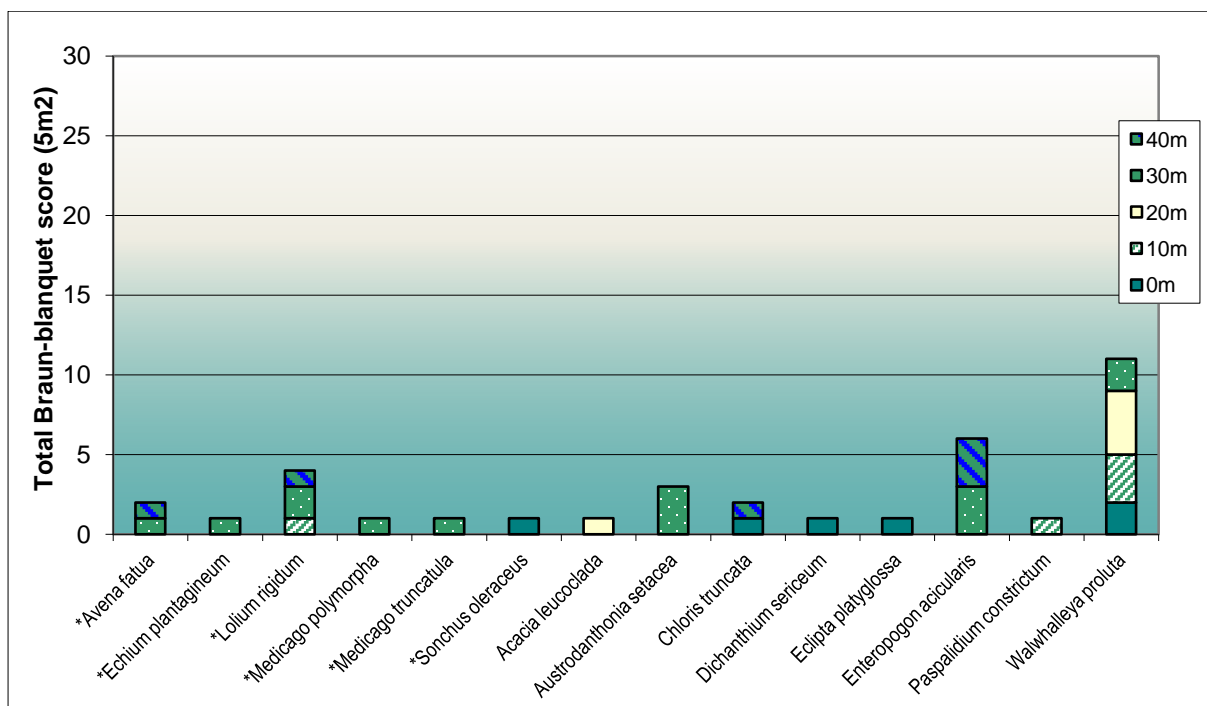


Figure 14-5. Total species recorded across the five, 1m² quadrats using the Braun-blauquet scale (max possible score is 30) as a measure of cover abundance.

Table 14-8. List of species and their average cover abundance score across the five, 1m² monitoring quadrats.

Species	0m	10m	20m	30m	40m	Total
* <i>Avena fatua</i>				1	1	2
* <i>Echium plantagineum</i>				1		1
* <i>Lolium rigidum</i>		1		2	1	4
* <i>Medicago polymorpha</i>				1		1
* <i>Medicago truncatula</i>				1		1
* <i>Sonchus oleraceus</i>	1					1
<i>Acacia leucoclada</i>			1			1
<i>Austrodanthonia setacea</i>				3		3
<i>Chloris truncata</i>	1				1	2
<i>Dichanthium sericeum</i>	1					1
<i>Eclipta platyglossa</i>	1					1
<i>Enteropogon acicularis</i>				3	3	6
<i>Paspalidium constrictum</i>		1				1
<i>Walwhalleya proluta</i>	2	3	4	2		11
Total cover						36
Sum of cover of native species						26
Percent endemic species cover						72.2

14.8 Floristic diversity

The floristic diversity of the sites was measured using two different methods. One provides an assessment of the average number of species within five, one square metre (m²) sub-quadrats along the vegetation transect, while the other provides the total number of species within the entire 50x20m monitoring plot.

14.8.1 Species diversity per m²

This year the average number of native species has further declined from 2.8 – 2.6 native species per m² but there was an increase from 0.2 – 1.8 exotic species per m² (Table 14-9). The number of native species per m² ranged from two to four, while there were 0 - 5 exotic species.

Table 14-9. Species diversity per 1m².

Species /m ²	0m	10m	20m	30m	40m	Avg/m ²	SD
Native	4	2	2	3	2	2.6	0.9
Exotic	1	1	0	5	2	1.8	1.9
Total	5	3	2	8	4	4.4	2.3

14.8.2 Total species diversity

In 2013 there were 56 species and this included 38 native species (Figure 14-6, Table 14-10). A list of species recorded within the monitoring site is provided in Appendix 1.

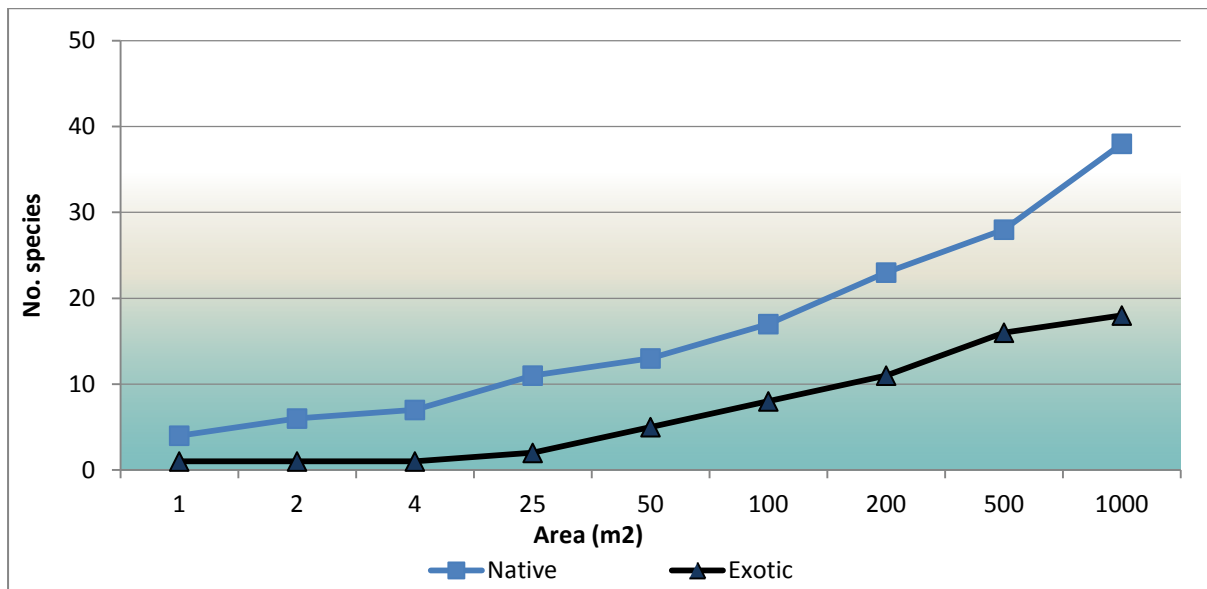


Figure 14-6. Cumulative species in the 50m x 20m (1000m²) monitoring quadrat.

Table 14-10. Cumulative species diversity.

Area (m2)	1	2	4	25	50	100	200	500	1000
Native	4	6	7	11	13	17	23	28	38
Exotic	1	1	1	2	5	8	11	16	18

14.9 Growth forms

Figure 14-7 is a summary of species in each growth form that were recorded in Kundibah 2001. In 2009, trees were the most dominant plant type with nine species, followed by herbs (7), shrubs (5), grasses (5), sub-shrubs (2) and reeds (2). However since then, herbs have been the most common and this year there were 27 herb species including 14 exotic species, followed by ten species of grass of which three were exotic species. There were ten tree species including one non endemic species (a non endemic native), six shrubs and one sub-shrub. There were two reed species but no ferns were yet present. Compared to the woodland reference there was an appropriate composition of most growth forms, however there was a lack of herb diversity.

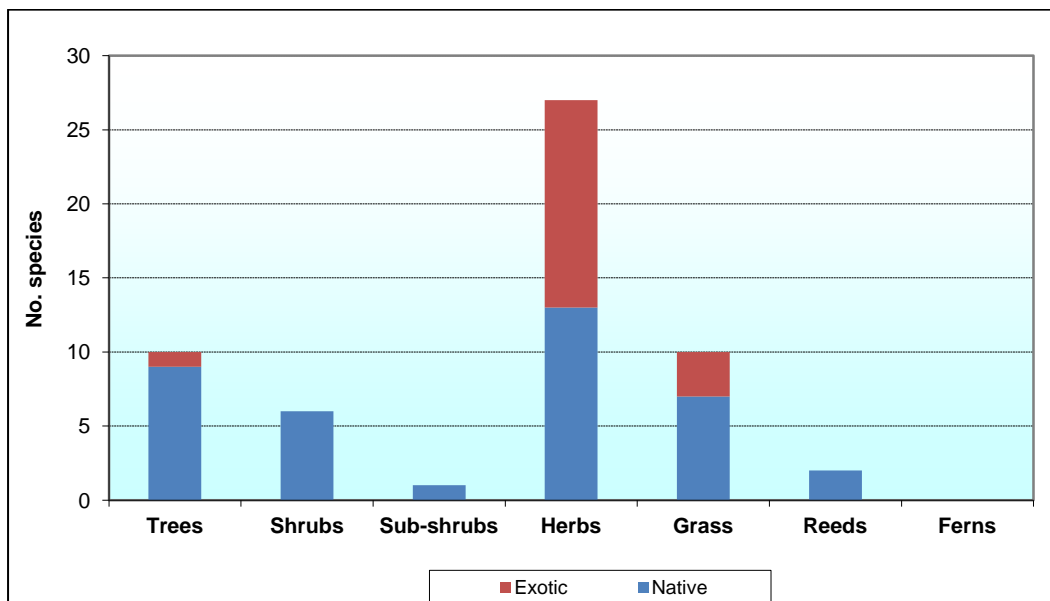


Figure 14-7. Graph illustrating the growth forms of species recorded in the 50m x 20m monitoring quadrat.

14.10 Comparison of rehabilitation data with key performance indicators

Table 14-11 indicates the performance of the rehabilitation monitoring site against the Completion and Desirable Performance Indicators developed for woodland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) for example and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 14-11. Comparison of key performance Indicators recorded in the rehabilitation site Kundibah 2001 compared to lower and upper limits recorded in the woodland reference sites.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Kundibah 2001				
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2009	2010	2011	2012	2013
Phase2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	0	5	0	0	0	0	0
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%	62.9	69.0	61.2	70.3	69.2	66.1	63.7
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%	41.1	55.7	39.4	44.4	43.3	38	44.4
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%	36.2	53.0	36.2	42.7	43.9	39.5	42.1
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%	100	100	100	100	100	100	95

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Kundibah 2001				
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising		No.	0	0	0	0	0	0	0
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0	0	0	0	0
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)	6.0	7.1	6.23	6.64	6.22	6.22	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)	0.038	0.191	0.135	0.048	0.083	0.048	0.042
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	3.0	4.6	2.7	2.5	3.1	3.6	2.4
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	6.4	17.3	32.8	21.6	39.0	29.2	17.0
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	1.2	1.9	13.5	1.3	1.4	3.5	1.0
			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)	12.0	22.9	20.59	17.8	14.00	12.55	13.0
			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	2.4	3.09	2.39	3.09	2.28	3.8
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees	The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.		species/area	1	6	8	8	8	6	6
				The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		% population	100	100	na	97	98	97	98
			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	53	76	30	46	50	45	56

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Kundibah 2001				
			Native species richness		The total number of live native plant species provides an indication of the native plant diversity of the site and that it is greater than or comparable to the local remnant vegetation	>No./area	33	53	30	33	35	35	38
			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	13	27	0	13	15	10	18
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees	The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation		No./area	29	110	38	37	52	66	56
	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	4	9	8	10	11	10
			Shrubs	The number of shrub species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	0	3	5	5	6	6	6
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	1	5	2	2	1	2	1
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	33	46	7	23	21	14	27
			Grasses		The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	9	22	5	7	11	10	10
			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	2	1	1	2	2
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Ferns		The number of ferns comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	1	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Kundibah 2001				
Phase 5: Ecosystem & Landuse Development	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	%	47	77	73	51.3	67	72.5	70
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	< %	2	22	0	22.2	1	0	0
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	8	0	4.5	11	2.5	4
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0	1	0	0	0	0	0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	3	0	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	6	11	17.5	10	1	9	10.5
			Perennial plant cover (< 0.5m)	Percent ground cover provided by live perennial vegetation (< 0.5m in height) is comparable to that of the local remnant vegetation		%	7	25	9.5	12	20	16	15.5
			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		%	89	95	82.5	90	99	91	89.5
	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	7	8	2.4	4.7	4.6	2.8	2.6
			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	1	4	0	3.6	0.6	0.2	1.8
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation		%	63	87	na	49.3	88.9	96.4	72.2

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Kundibah 2001				
	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	7	89	11	3	4	11	3
			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	2	15	5	12	9	9	8
			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	13	4	5	11	13	10
			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	18	3	3	11	9	8
			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	48	15	14	17	24	27
	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	1	9	26	29.5	41	39	25
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	6	2	9	15	26	26
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 - 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	9	0	7	12	13	19
			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	17	42	0	3	5	3	11

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Kundibah 2001				
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	3	3	8	7	10	11	11
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	100	100	na	71	88	93	100
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	6	19	25	25	26	29	30
				Average dbh	Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	18	54	8	9	10	11	11
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees	The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation		% population	83	100	100.0	100.0	100	100	100
			Healthy trees	The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation		% population	7	47	56.0	56.0	46.2	44.8	53
			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	44	57	44.0	44.0	53.8	55.2	46.7
			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	36	0.0	0.0	0	0	0
			Dead Trees		The percentage of the tree population which are dead (stags) and that the percentage is comparable to the local remnant vegetation	% population	0	17	0.0	0.0	0	0	0
			Mistletoe		The percentage of the tree population which have mistletoe provides an indication of community health and habitat value and that the percentage is comparable to the local remnant vegetation	% population	0	7	0.0	0.0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Woodland ecosystem range 2013		Kundibah 2001				
			Flowers/fruit: Trees	The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation		% population	50	83	28.0	36.0	38.5	41.4	33.3

15 TSF1-01 Site Description

This site is located on the north-eastern wall of TSF1. It was a grassy slope with tussocks of native perennial grasses dominated by *Walwhalleya proluta* (Rigid Panic) with scattered *Avena* (Wild Oats) and *Lolium* (Ryegrass). In 2009, grasses and annual species were particularly stressed with little active green growth and the various weed species were dead due to the hot dry seasonal conditions. The upper parts of the slope had less ground cover and more erosion than the lower parts, with some slight sheet erosion occurring between the grass tussocks. In 2010, there was a significant increase in annual plant cover and the perennial grasses were actively growing, with a significant reduction in the amount of bare ground but there was extensive soil erosion from the bare upper slope which contained numerous rills, however the eroded materials were captured within the plant patches down slope. Cryptogams had become extensive and spiders and ants were common. In 2011, there has been a significant increase in perennial plant cover largely due to the native grasses and there were fewer weeds. In 2012 and 2013 the site continued to be very dry.

15.1 Landscape Function Analysis

15.1.1 Landscape organisation

Site TSF1-01 was originally characterised as a pasture patch with small bare areas with the extent of the bare interpatches declining steadily each year and since 2012 no bare areas have been identified (Figure 15-1, Table 15-1). There has been an improvement in infiltration and nutrient recycling capacity between 2009 - 2011 however in 2012 the site was slightly less stable, largely due to the loss of cryptogams and the presence of small patches of crumbly and unstable soil, and an increased in deposited materials after the high rainfall activity over summer.

The prolonged dry has resulted in a further decline in ecological function at this site and this year LFA indices for stability, infiltration and nutrient recycling were 67.0, 39.8 and 40.4 respectively. However compared to the grassland reference sites, infiltration and nutrient recycling indices were 2.5, 10.5 and 12.3 LFA units higher than the minimum target range, therefore fulfilling these LFA KPI targets.



Figure 15-1. Permanent photo point taken from the top of the LFA transect in 2011 (left), 2012 (centre) and 2013 (right).

Table 15-1. Summary of landscape organisation and LFA indices from 2009 to 2013.

TSF1-01		8/12/2009			13/09/2010			18/10/2011			16/10/2012		17/10/2013	
Number of Patches/10m		3.5			2			2.5			0.5		0.5	
Total Patch Area (m2)		97.16			136.77			139.82			200		200.00	
Patch Area Index		0.49			0.68			0.7			1		1.00	
Landscape Organisation Index		0.73			0.88			0.91			1		1.00	
Average Interpatch Length (m)		0.92			0.83			0.43			NA		NA	
Range Interpatch length (m)		0.3 to 2			0.4 to 1.1			0.2 to 1			NA		NA	
Patch or Interpatch Type		Pasture Patch	Bare Interpatch		Pasture Patch	Bare Interpatch		Pasture Patch	Bare Slope		Pasture Patch		Pasture Patch	
Patch or Interpatch Proportion (%)		72.5	27.5	100	87.5	12.5	100	91.4	8.7	100	100	100	100.0	100
Soil Surface Assessment														
Within Individual Zones	Stability	57	52		70	51.7		68	47.5		69.9		67.0	
	Infiltration	41.4	32.7		38.1	28.2		43.1	25.6		43.9		39.8	
	Nutrients	35.1	24.4		37.2	22.5		40	15.4		43.7		40.4	
		Total			Total			Total			Total		Total	
Individual zones contribution to the whole of Landscape	Stability	41.3	14.3	55.6	61.3	6.5	67.7	62.1	4.1	66.2	69.9	69.9	67.0	67.0
	Infiltration	30	9	39	33.3	3.5	36.8	39.3	2.2	41.6	43.9	43.9	39.8	39.8
	Nutrients	25.5	6.7	32.2	32.6	2.8	35.4	36.5	1.3	37.8	43.7	43.7	40.4	40.4

15.1.2 Soil Surface Assessment

The live cover provided by the native perennial grass tussock has declined this year and typically only provided low protection against rain splash as well as low basal cover, with little to no cover provided lower down the slope (Table 15-2). There were slightly higher levels of dead leaf litter which have continued to provide some depth with slight decomposition observed in all samples.

There were fewer cryptogams but these persisted in low abundance on two occasions. Shallow depressions and grass tussocks provided moderately high surface relief and in the majority of the site, there was little erosion or deposition except in the upper part of the transect where slight erosion and deposition continued to be observed. The clay loam soils continued to be hard to very hard and tended to vary in stability from slaking rapidly when immersed in rainwater to heaving only some slumping of the sub-crusts.

Table 15-2 . Results of the Soils Surface Assessment for the Pasture patch.

Features	Max score	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Soil Cover	5	2	3	2	1	1
Per. basal / canopy cover	4	2	3	2	1	1
Litter cover, orig & incorp.	10	6ls	4ls	6ls	6ls	6ls
Cryptogam cover	4	2	1	1	2	1
Crust broken-ness	4	4	4	4	4	4
Erosion type & severity	4	4	3	4	4	4
Deposited materials	4	4	3	4	4	4
Soil surface roughness	5	3	3	3	3	3
Surface resist. to disturb.	5	4	3	3	4	4
Slake test	4	2	3	3	3	3
Texture	4	2	2	2	2	2

15.2 Soil Analyses

The soil pH in TSF1-01 has remained unchanged with the soils being moderately alkaline and similar to the upper KPI target. There has been a relatively large reduction in Electrical Conductivity and this year fell within the local EC levels (Table 15-3). There have been minimal changes in Organic Matter content since 2009 however this year OM levels were within local levels.

Phosphorous and nitrate concentrations have further decreased however they continued to fall within the target KPI or within desirable levels. The Cation Exchange Capacity has declined and this year fell within local target ranges. There was a decline in ESP and the soils remained within local and desirable levels with the soils considered to be non sodic.

Table 15-3. Results of the soil analysis for TSF1-01 compared to the upper and lower values for the grassland reference sites and desirable levels from 2009 to 2013.

Nutrient	Units	TSF1-01					Lower KPI	Upper KPI	Desirable Level
		2009	2010	2011	2012	2013			
pH (1:5 water)	units	7.99	7.62	7.93	7.90	7.90	6.73	7.97	5.6 – 7.3
Conductivity (1:5 water)	dS/m	0.182	0.177	0.190	0.223	0.189	0.043	0.198	0.150
Organic Matter	%	1.72	1.2	1.7	1.7	1.9	1.6	4.1	>4.5
Phosphorus (Colwell)	mg/kg	19	18	27	17	11	5	9	50
Nitrate	mg/kg	4.9	0.8	6.0	3.6	2.6	1.2	1.4	13.0
Cation Exchange Capacity	cmol ⁺ /Kg	30.4	36.71	29.57	30.73	27.96	20.41	37.83	14.00
Exchangeable Sodium Percentage	%	4.42	2.75	3.24	4.73	3.59	0.28	4.42	<5

15.3 Rill assessment

A small rill was measured along the vegetation transect in 2009 however due to the increase in ground cover the rill has not been visible or active since 2010.

15.4 Tree density and health condition

No trees (>5cm dbh) were recorded within this site.

15.5 Shrubs and juvenile trees

Two young volunteers of *Maireana brevifolia* were recorded for the first time in 2011 and these have persisted into 2013 (Table 15-4). This year they were 1.0 – 1.5m in height.

Table 15-4. Shrubs and young trees occurring within the monitoring site.

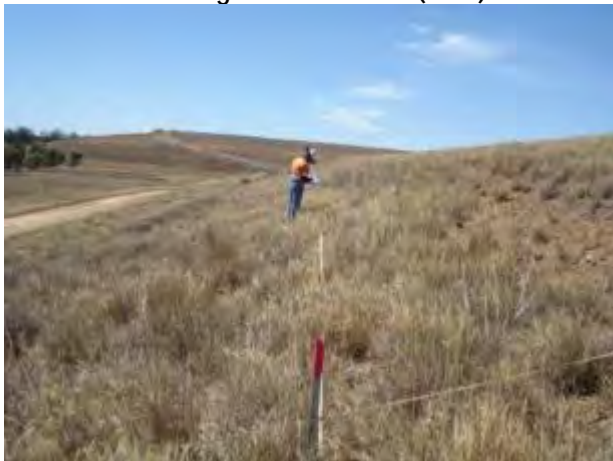
Species	0 - 0.5m	0.5 - 1.0m	1.0 - 1.5m	1.5 - 2.0m	>2.0m	Total	endemic	not endemic
<i>Maireana brevifolia</i>			2			2	2	
Total	0	2	0	0	0	2	2	0
% endemic species							100	0

15.6 Structural diversity and habitat complexity

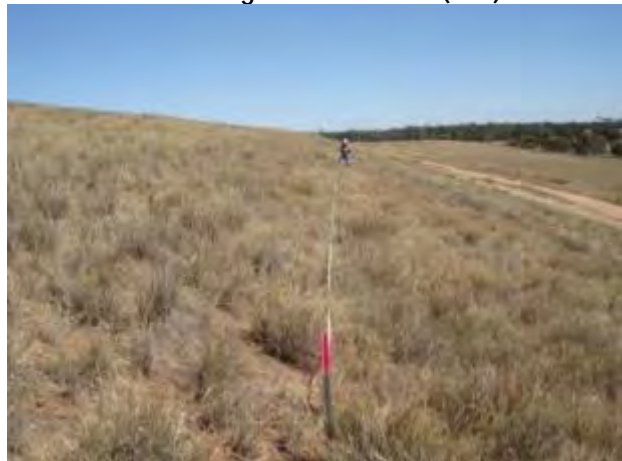
Since 2010 there have been very high levels of total ground cover however the composition has tended to fluctuate with changes in the seasonal conditions. This year there was no change in total ground cover which continued to be 99.5%, however there was an increase in dead leaf litter and annual plants which provided 60.5% and 28.5% cover on average, at the expense of perennial ground covers which now provided only 10.5% cover (Figure 15-2, Figure 15-3).

The taller grasses continued to provide some limited foliage cover greater than 0.5m at 10, 15, 35 and 40m along the transect. Table 15-5 provides the average and minimum and maximum values obtained along the vegetation transect.

2009 Vegetation transect (front)



2009 Vegetation transect (rear)



2010 Vegetation transect (front)



2010 Vegetation transect (rear)



2011 Vegetation transect (front)



2011 Vegetation transect (rear)



2012 Vegetation transect (front)



2012 Vegetation transect (rear)



2013 Vegetation transect (front)



2013 Vegetation transect (rear)



Figure 15-2. Permanent photo points taken from the front (left) and rear (right) of the vegetation transect.

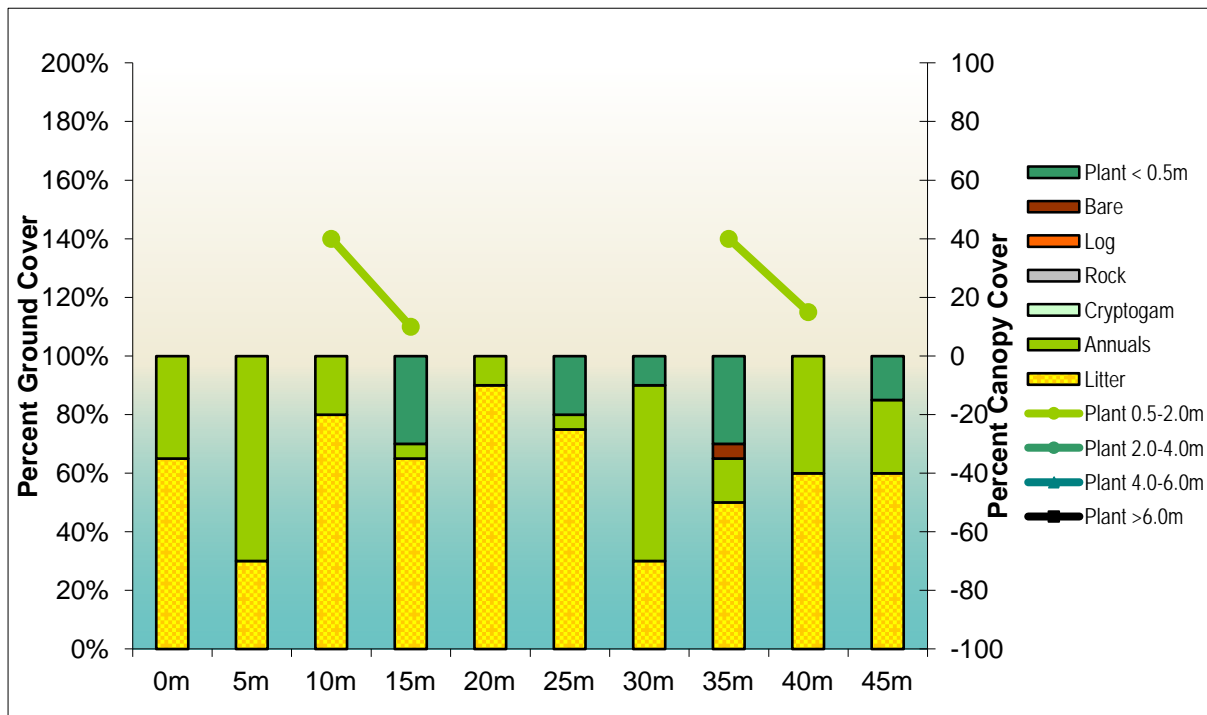


Figure 15-3. Graph illustrating the structural diversity and habitat complexity of the monitoring site.

Table 15-5. Average and minimum and maximum values of the structural diversity of the monitoring site.

Vegetation structure	0m	5m	10m	15m	20m	25m	30m	35m	40m	45m	Average	Min	Max
Litter	65	30	80	65	90	75	30	50	60	60	60.5	30	90
Annuals	35	70	20	5	10	5	60	15	40	25	28.5	5	70
Cryptogam	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0	0	0	0	0	0
Log	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare	0	0	0	0	0	0	0	5	0	0	0.5	0	5
Perennial <0.5m	0	0	0	30	0	20	10	30	0	15	10.5	0	30
Total Ground Cover	100	100	100	100	100	100	100	95	100	100	99.5	95	100
0.5-2.0m	0	0	40	10	0	0	0	40	15	0	10.5	0	40
2.0-4.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0-6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
>6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0

15.7 Species cover abundance

In 2013 there were ten live species recorded along the five 1x1m sub-plots placed at 10m intervals along the vegetation transect but these included six exotic species. Using the Braun-blauquet scale, the highest possible cover score that can be obtained is 30 and cover abundance is illustrated as a sum of scores (class values) obtained along the five 1m² quadrats.

Between 2010 and 2011 there was a significant reduction in cover provided by the exotic annuals *Medicago polymorpha*, *Sonchus oleraceus* and *Avena fatua* which were previously very common and abundant. In 2012 *Walwhalleya proluta* continued to be the most dominant species with *Dichanthium sericeum* and *Vicia villosa* also being relatively common. This year the site was well dominated by *Vicia villosa*, with low covers of *Lactuca saligna* and *Walwhalleya proluta* which were recorded in three replicates (Figure 15-4, Table 15-6). The remaining species were less common and had very low cover values. Of the live plant cover scores recorded 28.3% was provided by native species, a reduction from 67.9% recorded last year.

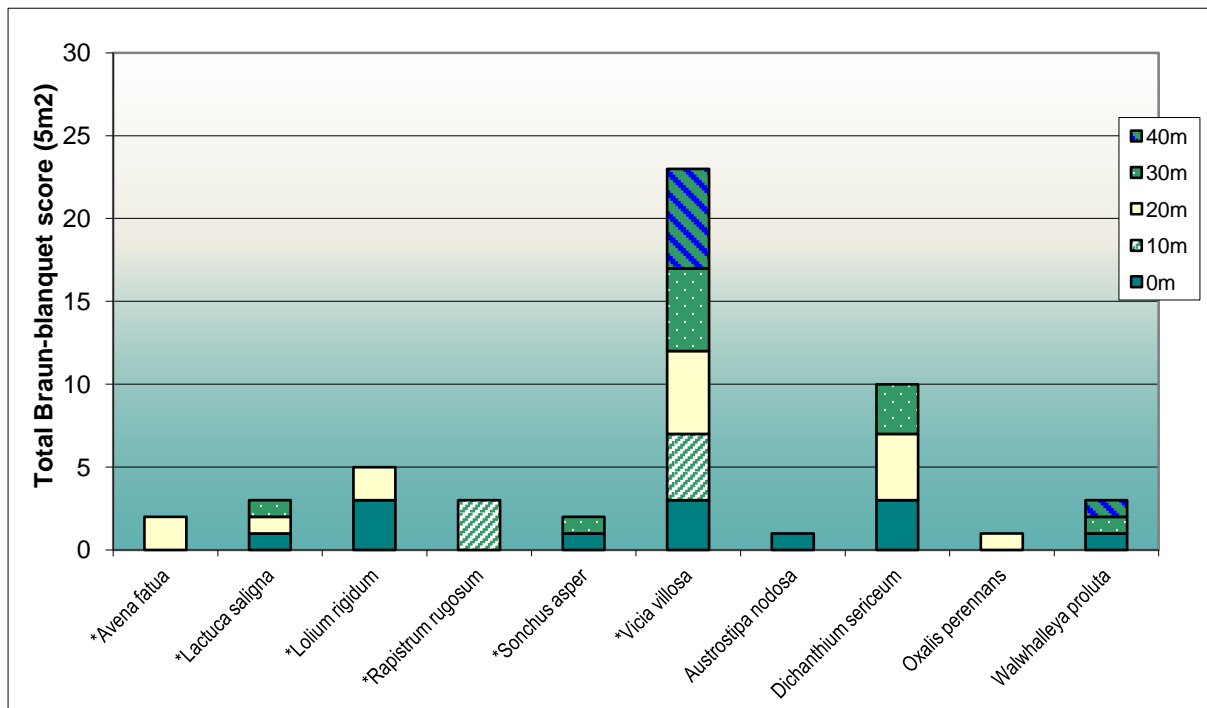


Figure 15-4. Total species recorded across the five, 1m² quadrats using the Braun-blanket scale (max possible score is 30) as a measure of cover abundance.

Table 15-6. List of species and their average cover abundance score across the five, 1m² monitoring quadrats.

Species	0m	10m	20m	30m	40m	Total
*Avena fatua			2			2
*Lactuca saligna	1		1	1		3
*Lolium rigidum	3		2			5
*Rapistrum rugosum		3				3
*Sonchus asper	1			1		2
*Vicia villosa	3	4	5	5	6	23
Austrostipa nodosa	1					1
Dichanthium sericeum	3		4	3		10
Oxalis perennans			1			1
Walwhalleya proluta	1			1	1	3
Total cover						53
Sum of cover of native species						15
Percent endemic species cover						28.3

15.8 Floristic diversity

The floristic diversity of the sites was measured using two different methods. One provides an assessment of the average number of species within five, one square metre (m²) sub-quadrats along the vegetation transect, while the other provides the total number of species within the entire 50x20m monitoring plot.

15.8.1 Species diversity per m²

This year there was a further decrease in the average number of native species per m² and these declined from 2.2 – 1.6 per m². The average number of exotic species however has continued to increase with 1.4 recorded last year and 2.8 species per m² recorded this year (Table 15-7). The

number of native species per m² ranged from 0 - 3, while the number of exotic species ranged from 1 - 4 species per m².

Table 15-7. Species diversity per 1m².

Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	3	0	2	2	1	1.6	1.1
Exotic	4	2	4	3	1	2.8	1.3
Total	7	2	6	5	2	4.4	2.3

15.8.2 Total species diversity

In 2013, there were 24 species including 16 exotic species recorded in the 20x50m monitoring plot (Figure 15-5, Table 15-8). The low flat shape of the species area curve indicates the site was relatively homogenous, with most species being recorded within the first 25m². A list of species recorded within the monitoring site is provided in Appendix 1.

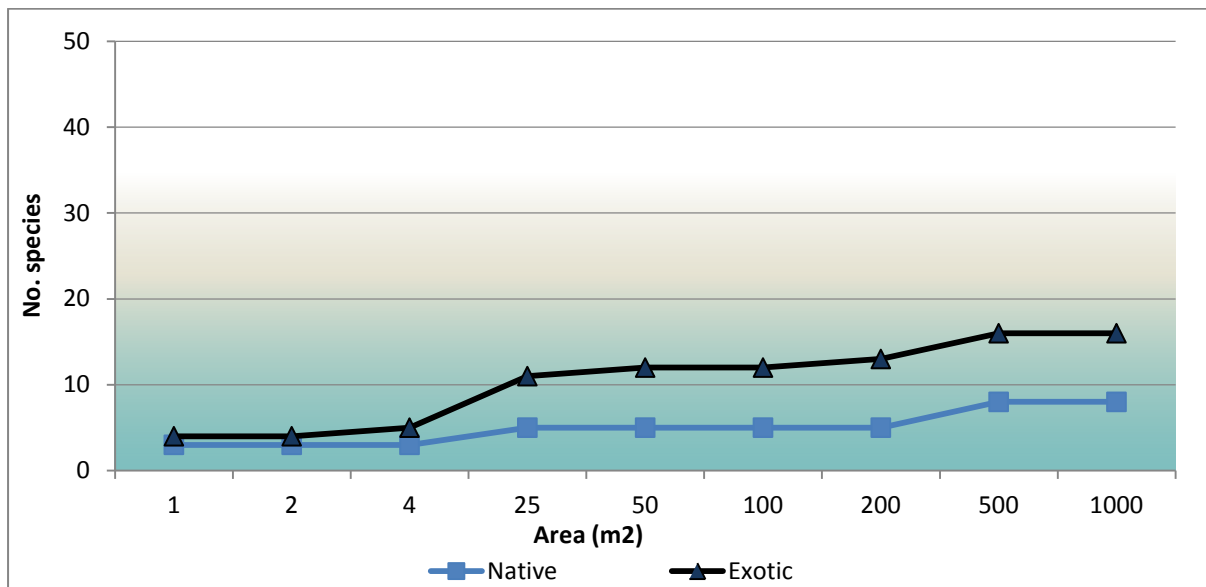


Figure 15-5. Cumulative species in the 50 x 20m (1000m²) monitoring quadrat.

Table 15-8. Cumulative species diversity.

Area (m ²)	1	2	4	25	50	100	200	500	1000
Native	3	3	3	5	5	5	5	8	8
Exotic	4	4	5	11	12	12	13	16	16

15.9 Growth forms

Figure 15-6 is a summary of species in each growth form that were recorded in the site. Herbs continued to be the most dominant growth form with 16 species including 12 exotic species, followed by grasses with seven species including four exotic species. There continued to be one shrub but no sub-shrubs were found this year. There continued to be an absence of trees, reeds or fern representatives. Compared to the grassland reference there was a low diversity of herb and grass species.

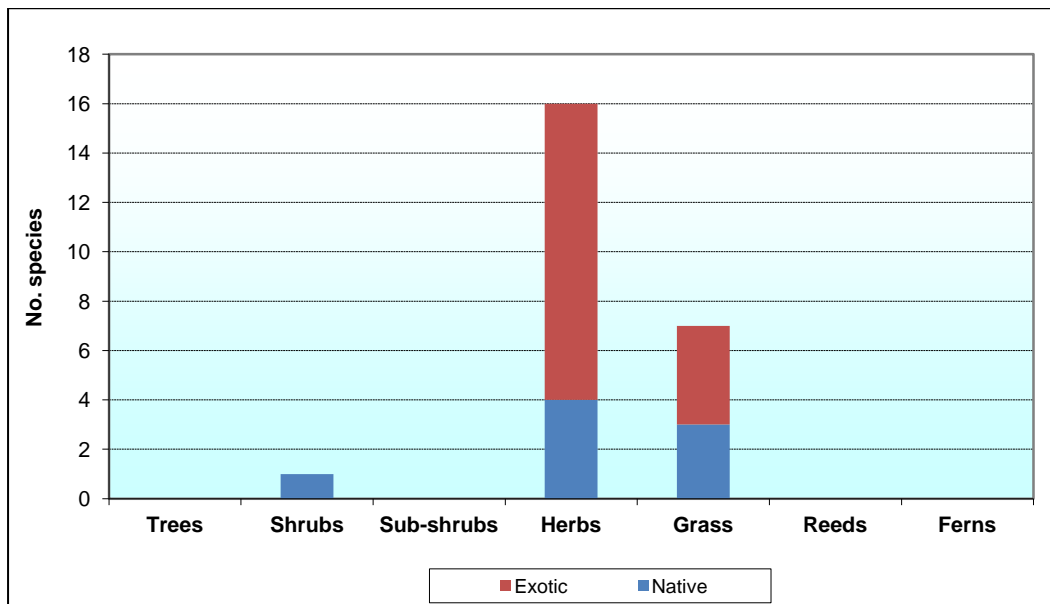


Figure 15-6. Graph illustrating the growth forms of species recorded in the 50m x 20m monitoring quadrat.

15.10 Comparison of rehabilitation data with key performance indicators

Table 15-9 indicates the performance of the rehabilitation monitoring site against the Completion and Desirable Performance Indicators developed for grassland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) for example and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 15-9. Comparison of key performance Indicators recorded in site TSF1-01 compared to lower and upper limits recorded in the grassland reference sites.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-01				
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2009	2010	2011	2012	2013
Phase2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	1	3	14.0	14.0	14.0	14.0	14.0
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%	64.5	73.0	55.6	67.7	66.2	69.9	67.0
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%	29.3	46.3	39.0	36.8	41.6	43.9	39.8
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%	28.1	43.2	32.2	35.4	37.8	43.7	40.4
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%	100	100	73	88	91	100	100

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-01				
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising		No.	0	0	1	0	0	0	0
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0.009	0	0	0	0
Phase 3: Growth medium development	Soil chemical, physical properties and amelioration	Soil properties are suitable for the establishment and maintenance of selected vegetation species	pH	pH is typical of that of the surrounding landscape or falls within desirable ranges provided by the agricultural industry		pH (5.6 - 7.3)	6.73	7.97	7.99	7.62	7.93	7.90	7.90
			EC		Electrical Conductivity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	< dS/m (<0.150)	0.043	0.198	0.182	0.177	0.190	0.223	0.189
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	1.6	4.1	1.7	1.2	1.7	1.7	1.9
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	5.3	8.6	19.0	18.0	26.8	17.4	10.9
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	1.2	1.4	4.9	0.8	6.0	3.6	2.8
			CEC		Cation Exchange Capacity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	Cmol+/kg (>14)	20.4	37.8	30.40	36.71	29.57	30.73	28.0
			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	4.4	4.42	2.75	3.24	4.73	3.6
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees		The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.	species/area	0	0	0	0	1	1	1
					The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation	% population	0	0	na	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	37	52	12	35	32	28	24

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-01				
			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	19	38	11	15	15	14	8
			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	14	20	1	20	17	14	16
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees		The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation	No./area	0	0	0	0	2	2	2
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees		The number of tree species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			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	0	0	1	1	1
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	4	3	2	2	2	0
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	26	34	5	24	20	18	16
			Grasses	The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	11	15	4	9	9	7	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	0	0	0	0	0	0
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			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

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-01				
Phase 5: Ecosystem & Landuse Development	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	%	36	52	62.5	31.5	33.5	52	60.5
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	4	39	0	38.0	1	15.0	28.5
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	17	3	7	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	3	2.5	0	0	0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	3	15	19	1	1	0.5	0.5
			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		%	16	30	12.5	20.0	64.5	32.5	10.5
			Total Ground Cover	Total groundcover is the sum of protective ground cover components (as described above) and that it is comparable to that of the local remnant vegetation		%	86	97	81	99	99	99.5	99.5
	Ground cover diversity	Vegetation contains a diversity of species per square meter comparable to that of the local remnant vegetation	Native understorey abundance		The abundance of native species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has more than or an equal number of native species as the local remnant vegetation	> species/m ²	3	11	1.8	1.6	3.2	2.2	1.6
			Exotic understorey abundance		The abundance of exotic species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has less than or an equal number of exotic species as the local remnant vegetation	< species/m ²	4	7	0	5.4	0.2	1.4	2.8
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation		%	29	77	na	31.6	96.2	67.9	28.3

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-01				
	Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	shrubs and juvenile trees 0 - 0.5m in height		The number of shrubs or juvenile trees < 0.5m in height provides an indication of establishment success and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	2	0	0
			shrubs and juvenile trees 0.5 - 1m in height		The number of shrubs or juvenile trees 0.5-1m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	2	0
			shrubs and juvenile trees 1 - 1.5m in height		The number of shrubs or juvenile trees 1-1.5m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	2
			shrubs and juvenile trees 1.5 - 2m in height		The number of shrubs or juvenile trees 1.5-2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			shrubs and juvenile trees >2m in height		The number of shrubs or juvenile trees > 2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
	Ecosystem structure	The vegetation is developing in structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5 - 2 m	Projected foliage cover provided by perennial plants in the 0.5 - 2m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover	0	5	0	7.3	5.5	2.5	11
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 - 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-01				
			Foliage cover >6m		Projected foliage cover provided by perennial plants > 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	0	0	0	0	0	0	0
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	0	0	na	na	0	0	0
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	0	0	0	0	0	0	0
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees		The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Healthy trees		The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Medium health		The percentage of the tree population which are in a medium health condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Advanced dieback		The percentage of the tree population which are in a state of advanced dieback and that the percentage is comparable to the local remnant vegetation	<% population	0	0	0	0	0	0	0
			Dead Trees		The percentage of the tree population which are dead (stags) and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-01				
			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
			Flowers/fruit: Trees		The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation	% population	0	0	0	0	0	0	0

16 TSF1-02 site description

Site TSF1-02 is located on the north-western wall of TSF 1. It was a grassy slope dominated by annual grasses and medics with few native perennial grasses. *Sonchus oleraceus* was common. There was significant establishment of *Maireana brevifolia* (Yanga Bush) and *Atriplex* species were common. The Yanga Bush was particularly important for the overall function of the site and was important for trapping seeds, soil and litter material. In 2010 however, the Yanga Bush appeared to be very stressed. There was some active erosion in less vegetated areas, but these sediments were trapped within the plant patches. The bare areas had a light cover of annual plants. In 2011 the Yanga Bush has recovered slightly and there has been an increased in litter and perennial plant cover. In 2012 and 2013 the site continued to be very dry.

16.1 Landscape Function Analysis

16.1.1 Landscape organisation

In 2009 the site was characterised as a grass-shrub patch with 6.5% of the transect being bare lower down the slope near a contour drain. In 2010 improved seasonal conditions resulted in a flush of growth especially annual grasses and the loss of the bare patch and there was a significant improvement in the ecological function within the site. Since then there tended to be a decline in shrub cover and this year it was more of a grassy patch, but the site retained and LOI of 100% (Figure 16-1, Table 16-1).

There has been a marginal decline in the ecological function at this site over the last year due to the prolonged dry and this year LFA indices for stability, infiltration and nutrient recycling were 68.5, 40.9 and 39.9 respectively. However compared to the grassland reference sites, infiltration and nutrient recycling indices were 4.0, 11.6 and 11.8 LFA units higher than the minimum target range, therefore it continued to fulfil these LFA KPI targets.



Figure 16-1. Permanent photo point taken from the top of the LFA transect in 2011 (left), 2012 (centre) and 2013 (right).

Table 16-1. Summary of landscape organisation and LFA indices from 2009 to 2013.

TSF1-02		8/12/2009			13/09/2010			18/10/2011			16/10/2012			17/10/2013		
Number of Patches/10m		1			0.5			0.5			0.5			0.5		
Total Patch Area (m ²)		187			200			200			200			200.00		
Patch Area Index		0.94			1			1			1			1.00		
Landscape Organisation Index		0.94			1			1			1			1.00		
Average Interpatch Length (m)		1.3			NA			NA			NA			NA		
Range Interpatch length (m)		1.3 to 1.3			NA			NA			NA			NA		
Patch or Interpatch Type		Grass Patch	Shrub		Grass Patch	Shrub		Grass Patch	Shrub		Grassy Patch	Shrub		Grassy Patch		
Patch or Interpatch Proportion (%)		93.5	6.5	100	100	100		100	100		100	100		100.0	100	
Soil Surface Assessment																
Within Individual Zones	Stability	56	40		68			69			71			68.5		
	Infiltration	36.2	29.1		42.6			41.4			44.8			40.9		
	Nutrients	30.9	18.6		42.3			37.4			40.9			39.9		
		Total			Total			Total			Total			Total		
Individual zones contribution to the whole of Landscape	Stability	52.4	2.6	55	68	68		69	69		71	71		68.5	68.5	
	Infiltration	33.9	1.9	35.8	42.6	42.6		41.4	41.4		44.8	44.8		40.9	40.9	
	Nutrients	28.9	1.2	30.1	42.3	42.3		37.4	37.4		40.9	40.9		39.9	39.9	

16.1.2 Soil Surface Assessment

There has been a rather significant reduction in rain splash protection and perennial plant cover due to the loss of numerous *Maireana brevifolia* (Yanga Bush) and less abundance of native grass cover. There has however continued to be high levels of litter cover which has accumulated to some depth and slight decomposition was observed in all replicates this year (Table 16-2).

Cryptogams were not observed at all probably due to the build up of leaf litter. There was no apparent evidence of active erosion and deposition and the vegetation continued to provide moderate to high soil surface relief. The soils were typically very hard and crusted except lower in transect within the contour drain the soils were loose, crumbly and highly unstable. The soils had generally improved in stability due to the development of the humus layer and in the majority of cases were very stable when immersed in water, except for the less vegetated upper slope which has some slumping of the sub-crusts and within the contour drain which contained highly unstable deposited sediments.

Table 16-2 . Results of the Soils Surface Assessment for the Grassy patch.

Features	Max score	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Soil Cover	5	1	2	4	3	3
Per. basal / canopy cover	4	1	2	3	3	3
Litter cover, orig & incorp.	10	5ls	5ls	5ls	6ls	5ls
Cryptogam cover	4	1	1	1	1	1
Crust broken-ness	4	4	4	4	4	3
Erosion type & severity	4	4	4	4	4	4
Deposited materials	4	4	4	4	4	4
Soil surface roughness	5	3	3	4	3	4
Surface resist. to disturb.	5	4	4	4	4	2
Slake test	4	3	4	4	4	1
Texture	4	2	2	2	1	2

16.2 Soil analyses

The soil pH recorded at TSF1-02 has since declined from being borderline strongly acidic to having soils which were slightly alkaline and while these fell within the local limit they continued to exceed desirable levels. There was an additional increase in Electrical conductivity which continued to exceed the target KPI range and desirable levels with the soils continuing to be slightly saline (Table 16-3). There was negligible change in Organic Matter which remained very low and these soils were deficient in OM and remained below the KPI target.

Both phosphorous and nitrate levels have further decreased and while phosphorous levels were low, nitrate were within the low local nitrate levels this year. The CEC has significantly decreased and this year fell within the local CEC levels. The Exchangeable Sodium Percentage has increased and this year far exceeds the desirable threshold of 5% indicating the soils are sodic.

Table 16-3. Results of the soil analysis for TSF1-02 compared to the upper and lower values for the grassland reference sites and desirable levels from 2009 to 2013.

Nutrient	Units	TSF1-02					Lower KPI	Upper KPI	Desirable Level
		2009	2010	2011	2012	2013			
pH (1:5 water)	units	8.01	8.03	7.89	8.44	7.72	6.73	7.97	5.6 – 7.3
Conductivity (1:5 water)	dS/m	0.212	0.212	0.166	0.241	0.275	0.043	0.198	0.150
Organic Matter	%	1.34	1.4	1.6	1.0	1.1	1.6	4.1	>4.5
Phosphorus (Colwell)	mg/kg	15	14	12	9	6	5	9	50
Nitrate	mg/kg	9.8	1.1	2.3	4.1	1.2	1.2	1.4	13.0
Cation Exchange Capacity	cmol+/Kg	30.0	35.33	26.28	37.25	26.61	20.41	37.83	14.00
Exchangeable Sodium Percentage	%	5.95	4.61	4.79	5.08	8.85	0.28	4.42	<5

16.3 Rill assessment

No rills of concern have been recorded in any monitoring year.

16.4 Tree density and health condition

No trees or shrubs with a dbh >5cm were present in the monitoring plot.

16.5 Shrubs and juvenile trees

TSF1-02 continued to have a significant number of *Maireana brevifolia* (Yanga Bush) establishing throughout the site with the population reaching a peak of 215 individuals in 2011 as a result of a natural recruitment. Since then there has been a declining trend and this year there were 136 individuals as many had died as a result of the prolonged dry conditions and/or had reached the end of their natural life span. While some young individuals continued to be present the majority were more mature and were 0.5 – 1.5m in height, with 1.0m being a typical height at maturity (Figure 16-2, Table 16-4). This native shrub is thought to have established from seed stored in the topsoil.

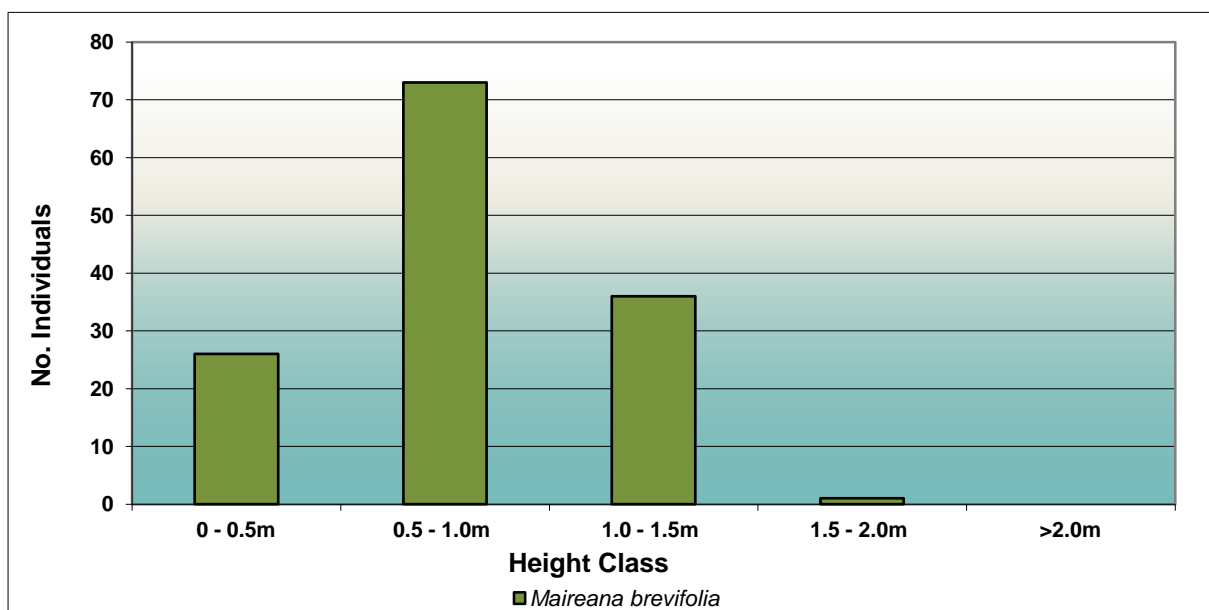


Figure 16-2. Shrubs and young trees occurring within the monitoring site.

Table 16-4. Number of shrubs of each species and their height class.

Species	0 - 0.5m	0.5 - 1.0m	1.0 - 1.5m	1.5 - 2.0m	>2.0m	Total	endemic	not endemic
<i>Maireana brevifolia</i>	26	73	36	1		136	136	
Total	26	73	36	1	0	136	136	0
% endemic species							100	0

16.6 Structural diversity and habitat complexity

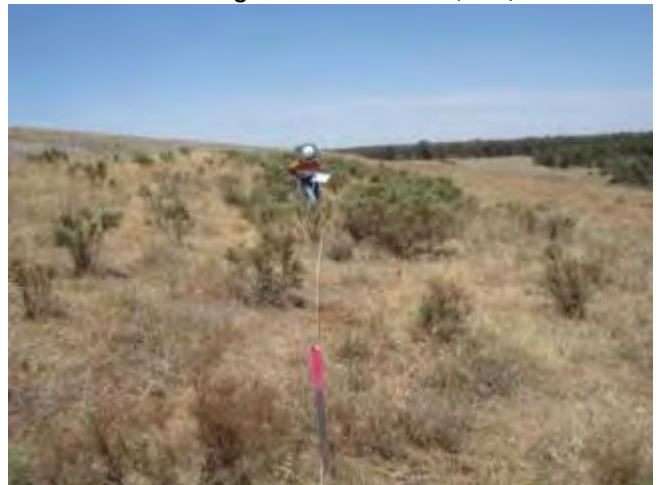
Since 2010 there have been very high levels of total ground maintained within the site however the composition has tended to fluctuate with changes in the seasonal conditions. The prolonged dry conditions has also resulted in a declining trend in total ground cover and while it remains at 96%, there has been a significant transition from having a perennial plant dominated system, to one that has had a significant increase in annual plant cover. This year total ground cover was comprise of 42% dead leaf litter, 27% annual and 27% perennial vegetation cover (Figure 16-3, Figure 16-4).

There continued to be some low (0.5 – 2.0m) projected foliage cover recorded along the vegetation transect due to the scattered chenopod shrubs however the shrubs continued to be stressed resulting in a decline in the density of the low canopy from 7% to 4.5% cover this year, but this ranged between 0 – 20%. Table 16-5 provides the average and minimum and maximum values obtained along the vegetation transect.

2009 Vegetation transect (front)



2009 Vegetation transect (rear)



2010 Vegetation transect (front)



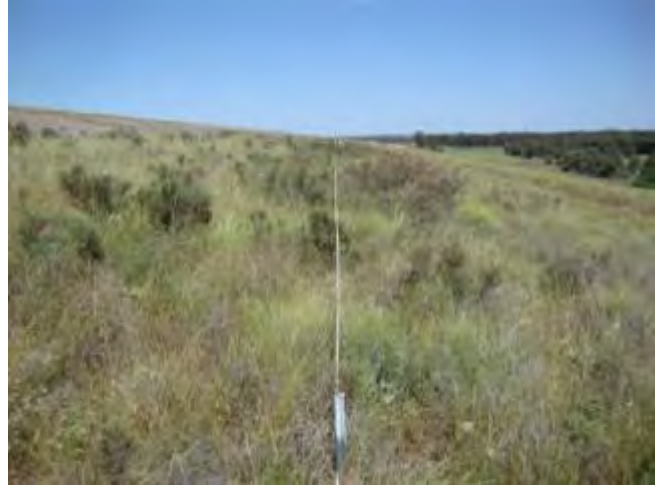
2010 Vegetation transect (rear)



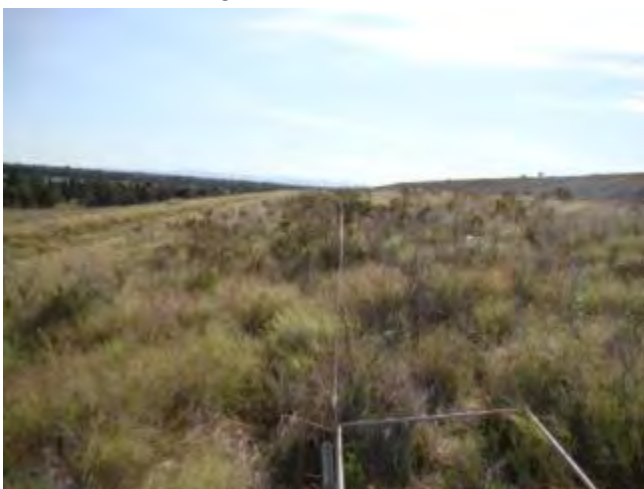
2011 Vegetation transect (front)



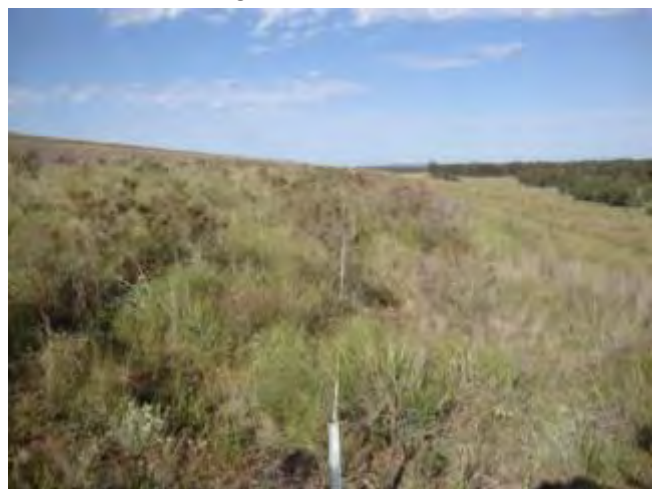
2011 Vegetation transect (rear)



2012 Vegetation transect (front)



2012 Vegetation transect (rear)



2013 Vegetation transect (front)



2013 Vegetation transect (rear)



Figure 16-3. General site photo taken from LFA start point (left) and rear of the vegetation transect (right).

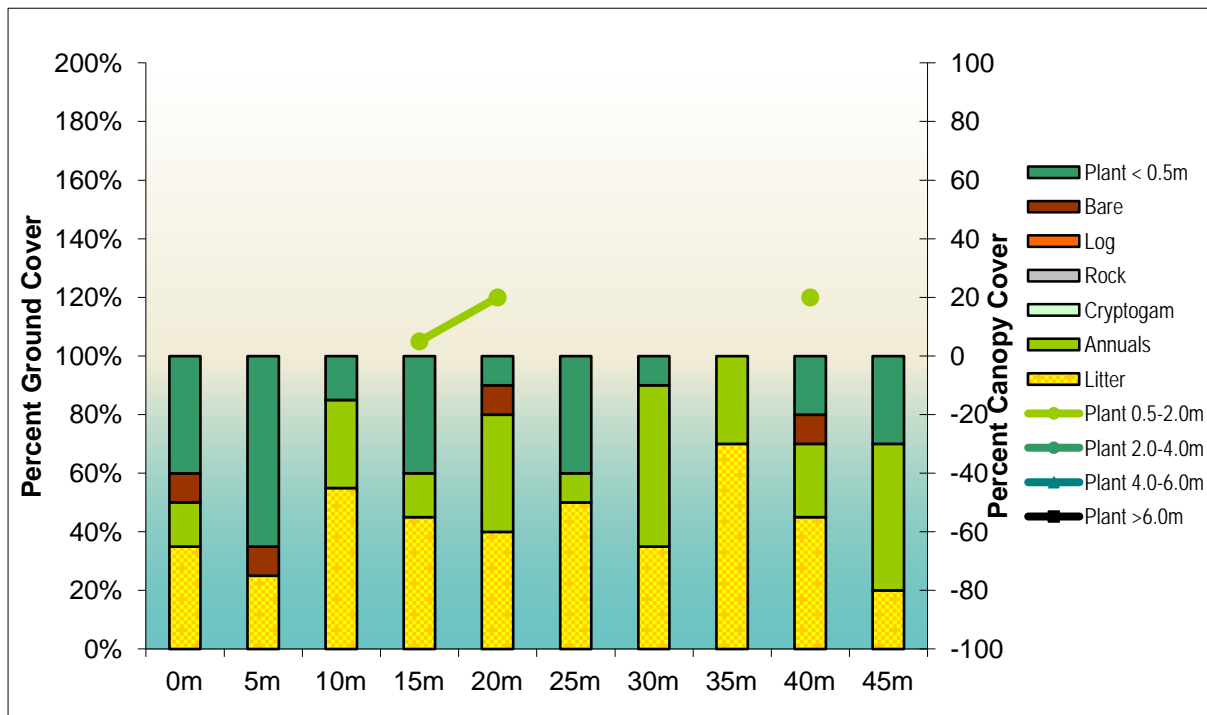


Figure 16-4. Graph illustrating the structural diversity and habitat complexity of the monitoring site.

Table 16-5. Average and minimum and maximum values of the structural diversity of the monitoring site.

Vegetation structure	0m	5m	10m	15m	20m	25m	30m	35m	40m	45m	Average	Min	Max
Litter	35	25	55	45	40	50	35	70	45	20	42	20	70
Annuals	15	0	30	15	40	10	55	30	25	50	27	0	55
Cryptogam	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0	0	0	0	0	0
Log	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare	10	10	0	0	10	0	0	0	10	0	4	0	10
Perennial <0.5m	40	65	15	40	10	40	10	0	20	30	27	0	65
Total Ground Cover	90	90	100	100	90	100	100	100	90	100	96	90	100
0.5-2.0m	0	0	0	5	20	0	0	0	20	0	4.5	0	20
2.0-4.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0-6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
>6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0

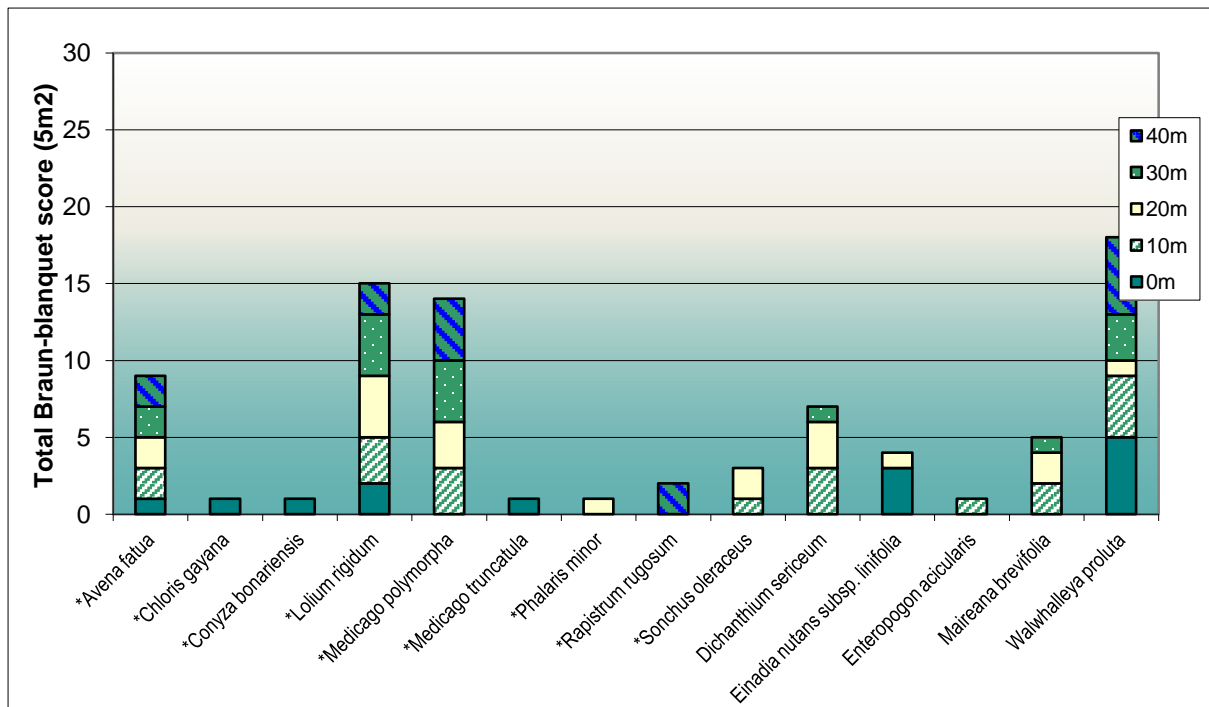
16.7 Species cover abundance

In 2013 there were 14 live species recorded along the five 1m² sub-plots placed at 10m intervals along the vegetation transect but these included nine exotic species. Using the Braun-blauquet scale, the highest possible cover score that can be obtained is 30 and cover abundance is illustrated as a sum of scores (class values) obtained along the five 1m² quadrats.

Last year the exotic annuals *Avena fatua*, *Lolium rigidum* and *Medicago polymorpha* were recorded in numerous sub-plots but they provided much less cover than preceding years and there was a significant increase in cover provided by *Walwhalleya proluta*. This year *Walwhalleya proluta* provided the highest level of cover, however the exotics *Avena fatua*, *Lolium rigidum* and *Medicago polymorpha* collectively dominated the site (Figure 16-5, Table 16-6). *Dichanthium sericeum* and *Maireana brevifolia* were also relatively common but provided comparatively low cover scores. The remaining species were less common or had very low cover values. Of the cover scores recorded 42.3% was provided by native species, a reduction from 57.1% recorded last year.

Table 16-6. List of species and their average cover abundance score across the five, 1m² monitoring quadrats.

Species	0m	10m	20m	30m	40m	Total
* <i>Avena fatua</i>	1	2	2	2	2	9
* <i>Chloris gayana</i>	1					1
* <i>Conyza bonariensis</i>	1					1
* <i>Lolium rigidum</i>	2	3	4	4	2	15
* <i>Medicago polymorpha</i>		3	3	4	4	14
* <i>Medicago truncatula</i>	1					1
* <i>Phalaris minor</i>			1			1
* <i>Rapistrum rugosum</i>					2	2
* <i>Sonchus oleraceus</i>		1	2			3
<i>Dichanthium sericeum</i>		3	3	1		7
<i>Einadia nutans subsp. linifolia</i>	3		1			4
<i>Enteropogon acicularis</i>		1				1
<i>Maireana brevifolia</i>		2	2	1		5
<i>Walwhalleya proluta</i>	5	4	1	3	5	18
Total cover						82
Sum of cover of native species						35
Percent endemic species cover						42.7

Figure 16-5. Total species recorded across the five, 1m² quadrats using the Braun-blanket scale (max possible score is 30) as a measure of cover abundance.

16.8 Floristic diversity

The floristic diversity of the sites was measured using two different methods. One provides an assessment of the average number of species within five, one square metre (m²) sub-quadrats along the vegetation transect, while the other provides the total number of species within the entire 50x20m monitoring plot.

16.8.1 Species diversity per m²

This year there was a further decrease in the average number of native species per m² and these declined from 4.2 – 2.8 per m². The average number of exotic species per m² has also declined from 5.4 species recorded last year to 4.2 species per m² (Table 16-7). The number of native species per m² ranged from 1 - 4, while the number of exotic species ranged from 3 - 5 species per m².

Table 16-7. Species diversity per 1m².

Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	2	4	4	3	1	2.8	1.3
Exotic	5	4	5	3	4	4.2	0.8
Total	7	8	9	6	5	7	1.6

16.8.2 Total species diversity

In 2013 there was a total of 37 species including 17 native species (Figure 16-6, Table 16-8). The low relatively flat shape of the species area curve indicates the site was relatively homogenous. A complete list of species recorded within the monitoring site is provided in Appendix 1.

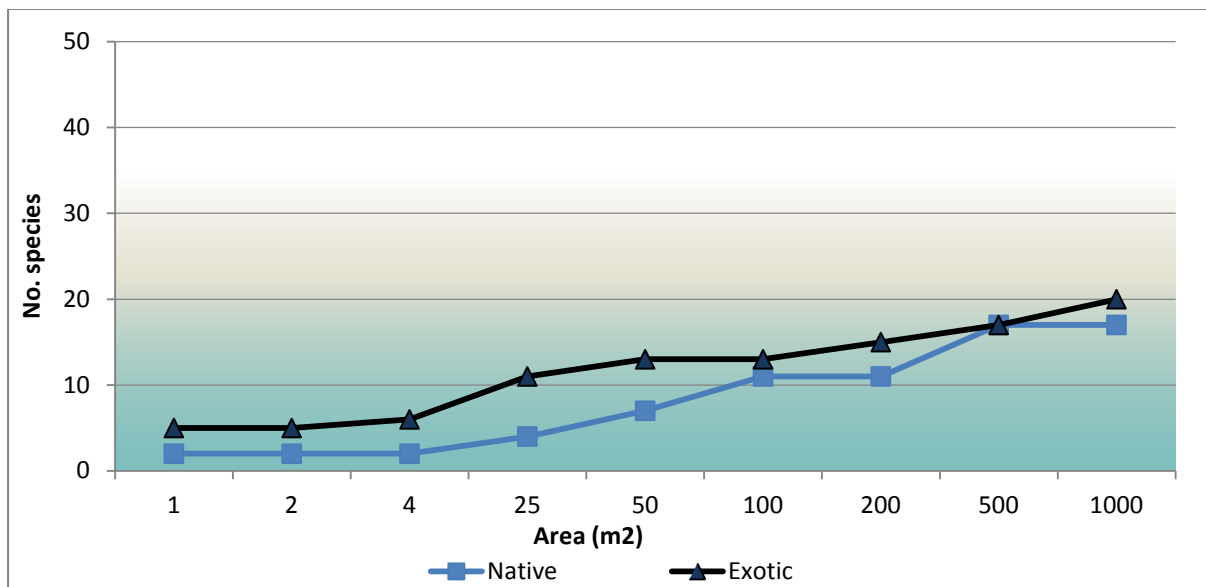


Figure 16-6. Cumulative species in the 50 x 20m (1000m²) monitoring quadrat.

Table 16-8. Cumulative species diversity.

Area (m2)	1	2	4	25	50	100	200	500	1000
Native	2	2	2	4	7	11	11	17	17
Exotic	5	5	6	11	13	13	15	17	20

16.9 Growth forms

Figure 16-7 is a summary of species in each growth form that were recorded in the site. Herbs continued to be the most dominant plant type and there were 24 different species including 15 exotic species followed by ten grasses, half of which were exotic species. There continued to be one shrub and two sub-shrubs. No tree, reed or fern representatives were present. Compared to the grassland reference there was a low diversity of herb and grass species.

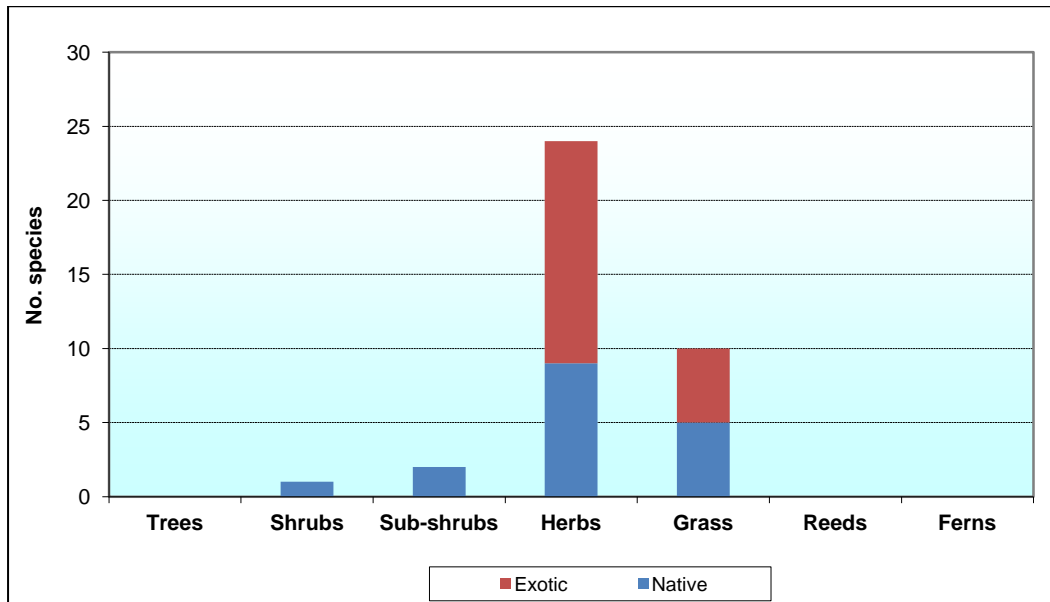


Figure 16-7. Graph illustrating the growth forms of species recorded in the 50m x 20m monitoring quadrat.

16.10 Comparison of rehabilitation data with key performance indicators

Table 16-9 indicates the performance of the rehabilitation monitoring site against the Completion and Desirable Performance Indicators developed for grassland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) for example and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 16-9. Comparison of key performance indicators obtained from site TSF1-02 with the grassland reference sites.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-02				
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2009	2010	2011	2012	2013
Phase2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	1	3	10.0	10.0	10.0	10.0	10.0
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%	64.5	73.0	55.0	68.0	69.0	71.0	68.5
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%	29.3	46.3	35.8	42.6	41.4	44.8	40.9
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%	28.1	43.2	30.1	42.3	37.4	40.9	39.9
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%	100	100	94	100	100	100	100

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-02				
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising		No.	0	0	0	0	0	0	0
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0	0	0	0	0
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)	6.73	7.97	8.01	8.03	7.89	8.44	7.72
			EC		Electrical Conductivity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	< dS/m (<0.150)	0.043	0.198	0.212	0.212	0.166	0.241	0.275
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	1.6	4.1	1.3	1.4	1.6	1.0	1.1
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	5.3	8.6	15.0	14.0	12.3	8.9	5.6
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	1.2	1.4	9.8	1.1	2.3	4.1	1.2
			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)	20.4	37.8	30.00	35.33	26.28	37.25	26.6
			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	4.4	5.95	4.61	4.79	5.08	8.85
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees		The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.	species/area	0	0	1	1	1	1	1
					The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation	% population	0	0	na	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	37	52	18	30	37	36	37

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-02				
			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	19	38	15	16	18	18	17
			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	14	20	3	14	19	18	20
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees		The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation	No./area	0	0	190	190	215	175	136
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees		The number of tree species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Shrubs		The number of shrub species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	1	1	1	1	1
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	4	4	3	4	2	2
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	26	34	8	16	24	25	24
			Grasses	The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	11	15	5	10	8	8	10
			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	0	0	0	0	0	0
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			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

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-02				
Phase 5: Ecosystem & Landuse Development	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	%	36	52	68.5	13.5	44	41.0	42
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	4	39	0	67.5	25.5	10.0	27
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	17	0.0	1.5	0	0	0
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	3	15	22	4.5	1	3.5	4
			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		%	16	30	9.5	13.0	29.5	45.5	27
			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		%	86	97	78	95.5	99	96.5	96
	Ground cover diversity	Vegetation contains a diversity of species per square meter comparable to that of the local remnant vegetation	Native understorey abundance		The abundance of native species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has more than or an equal number of native species as the local remnant vegetation	> species/m ²	3	11	2.0	4.4	5.2	4.2	2.8
			Exotic understorey abundance		The abundance of exotic species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has less than or an equal number of exotic species as the local remnant vegetation	< species/m ²	4	7	0	4	4	5.4	4.2
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation		%	29	77	na	38.8	51.1	57.1	42.7

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-02				
	Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	shrubs and juvenile trees 0 - 0.5m in height		The number of shrubs or juvenile trees < 0.5m in height provides an indication of establishment success and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	66	22	15	16	26
			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	109	128	122	104	73
			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	15	39	78	55	36
			shrubs and juvenile trees 1.5 - 2m in height		The number of shrubs or juvenile trees 1.5-2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	1
			shrubs and juvenile trees >2m in height		The number of shrubs or juvenile trees > 2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
	Ecosystem structure	The vegetation is developing in structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5 - 2 m	Projected foliage cover provided by perennial plants in the 0.5 - 2m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover	0	5	12.5	11.3	8.5	7	4.5
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 -6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-02				
			Foliage cover >6m		Projected foliage cover provided by perennial plants > 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	0	0	0	0	0	0	0
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	0	0	na	na	0	0	0
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	0	0	0	0	0	0	0
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees		The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Healthy trees		The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Medium health		The percentage of the tree population which are in a medium health condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Advanced dieback		The percentage of the tree population which are in a state of advanced dieback and that the percentage is comparable to the local remnant vegetation	<% population	0	0	0	0	0	0	0
			Dead Trees		The percentage of the tree population which are dead (stags) and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF1-02				
			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
			Flowers/fruit: Trees		The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation	% population	0	0	0	0	0	0	0

17 TSF2-01 site description

Rehabilitation monitoring site TSF2-01 is located on the southern wall of TSF 2. It is a grassy slope with scattered tussocks of native perennial grasses (*Walwhalleya proluta*) and in 2009 a heavy cover of *Medicago polymorpha*. There was a small pocket of *Maireana brevifolia* (Yanga Bush) establishing in the table drain, and scattered individuals of *Atriplex* species. In 2009, the grasses and annual plants were particularly stressed with little active green growth or were dead. In 2010, improved seasonal conditions resulted in a flush of annual weed growth. There was evidence of extensive soil erosion from the bare upper slope which contained numerous rills, but the eroded materials were captured within the plant patches down slope. The bare areas had a light cover of annual plants. In 2011, there was a significant increase in perennial plant cover largely due to the native grasses and there were fewer weeds but *Medicago polymorpha* retained its dominance. Some of the older rills on the upper slope were becoming well vegetated and were more stable. In 2012 and 2013 the site continued to be very dry. There were numerous areas where seepage of the tailings materials was being expressed as bare and scalded with white salt crystals and require amelioration.

17.1 Landscape Function Analysis

17.1.1 Landscape organisation

Site TSF2-01 continued to be characterised as a grassy slope with no bare patches and scored a Landscape Organisation Index of 1.0 or 100% (Figure 17-1, Table 17-1). The ecological function of the site improved between 2009 to 2011 due to an increasing cover of cryptogams and significant reductions in erosion and deposition. Since then however there has been a slight reduction in overall function with the resultant LFA indices for stability, infiltration and nutrient recycling of 67.0, 32.8 and 34.2 being recorded this year. There was no net change in the stability index over the past year.

Compared to the grassland reference sites, the sites stability, infiltration and nutrient recycling indices were 2.5, 3.5 and 6.1 LFA units higher than the required minimum target and therefore met these reference targets this year.



Figure 17-1. Permanent photo point taken from the top of the LFA transect in 2011 (left), 2012 (centre) and 2013 (right).

Table 17-1. Summary of landscape organisation and LFA indices from 2009 to 2013.

TSF2-01		8/12/2009		14/09/2010		18/10/2011		16/10/2012		17/10/2013	
Number of Patches/10m		0.5		0.5		0.5		0.5		0.5	
Total Patch Area (m2)		200		200		200		200		200.00	
Patch Area Index		1		1		1		1		1.00	
Landscape Organisation Index		1		1		1		1		1.00	
Average Interpatch Length (m)		NA		NA		NA		NA		NA	
Range Interpatch length (m)		NA		NA		NA		NA		NA	
Patch or Interpatch Type		Grassy Slope		Grassy Slope		Grassy Slope		Grassy Slope		Grassy Slope	
Patch or Interpatch Proportion (%)		100	100	100	100	100	100	100	100	100.0	100
Soil Surface Assessment											
Within Individual Zones	Stability	62		62		70.5		67		67.0	
	Infiltration	35.3		37		38.9		35.4		32.8	
	Nutrients	31.2		33.9		38.4		36.2		34.2	
			Total		Total		Total		Total		Total
Individual zones contribution to the whole of Landscape	Stability	62	62	62	62	70.5	70.5	67	67	67.0	67.0
	Infiltration	35.3	35.3	37	37	38.9	38.9	35.4	35.4	32.8	32.8
	Nutrients	31.2	31.2	33.9	33.9	38.4	38.4	36.2	36.2	34.2	34.2

17.1.2 Soil Surface Assessment

The results of the Soil Surface Assessment (SSA) indicate there continued to be variable levels of rain splash protection provided by some rocks and scattered perennial plants which also typically provided some basal cover however there was a decline in cover provided by the perennial vegetation (Table 17-2). There continued to be high levels of litter cover which was slightly decomposed except in the upper slope where negligible decomposition was apparent

There continued to be an absence of cryptogams despite the crusted soil crusts and this year no active erosion or deposition was evident. The soil surface relief was relatively low in the upper transect, but the increased density of the vegetation lower down the slope provided increased soil surface relief.

The soil types across the site were very patchy and seemed to be dependent on the amount of previous erosion and deposition, with the clay loam soils providing the upper surface layer in most occasions with silty clay lying beneath. In some cases the silty clay had become exposed. This year we observed a lot of silty clay soils and proceeded to reclassify them. These tended to be more stable than the clay loams but these also demonstrated some slumping of the sub-crusts when immersed in water, despite the very hard soil surface.

Table 17-2. Results of the Soils Surface Assessment for the Grassy slope patch.

Features	Max score	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Soil Cover	5	2	3	1	3	3
Per. basal / canopy cover	4	2	3	1	2	3
Litter cover, orig & incorp.	10	5ln	4ln	5ls	5ls	5ls
Cryptogam cover	4	1	1	1	1	1
Crust broken-ness	4	4	4	4	4	4
Erosion type & severity	4	4	4	4	4	4
Deposited materials	4	4	3	3	4	4
Soil surface roughness	5	3	3	2	3	3
Surface resist. to disturb.	5	4	4	4	4	4
Slake test	4	3	3	3	3	3
Texture	4	1	1	1	1	1

17.2 Soil analyses

The pH level recorded at TSF2-01 has dramatically declined from being neutral to moderately acidic last year but this year it has increased to fall within slightly acidic ranges and these remained within the desirable range (Table 17-3). There was also a dramatic increase in Electrical Conductivity last year and when converted to EC_e, a measure of soil salinity (EC (dS/m) x conversion factor 8.6 in clay loam soils) the soils were extremely saline. This year has seen a 50% reduction in EC and while it remained very high it fell within the lesser 'high salinity' classification (Slavich and Petterson 1993). The elevated EC levels are likely to be related to the seepage of the Tailings materials through the TSF walls which are evident as bare scalded white salt patches on the soil surface which were first evident in 2012.

The level of organic matter had increased but remained very low and lower than the reference site values. Phosphorus levels had increased and while they were higher than local levels, remained less than desirable concentrations. Nitrates remained significantly low. The CEC and ESP values have shown a marked decline and are probably associated with the decline in EC, however these continued to far exceed local levels. The extremely high ESP indicates that the soils are highly sodic.

Table 17-3. Results of the soil analysis for TSF2-01 compared to the upper and lower values for the grassland reference sites and desirable levels from 2009 to 2013.

Nutrient	Units	TSF2-01					Lower KPI	Upper KPI	Desirable Level
		2009	2010	2011	2012	2013			
pH (1:5 water)	units	7.35	7.24	7.12	5.96	6.15	6.73	7.97	5.6 – 7.3
Conductivity (1:5 water)	dS/m	0.333	0.388	1.743	2.248	1.022	0.043	0.198	0.150
Organic Matter	%	1.21	0.4	0.8	0.8	1.5	1.6	4.1	>4.5
Phosphorus (Colwell)	mg/kg	16	6	6	5	12	5	9	50
Nitrate	mg/kg	2.5	0.5	1.5	1.4	0.9	1.2	1.4	13.0
Cation Exchange Capacity	cmol+/Kg	24.6	26.32	31.47	34.42	23.93	20.41	37.83	14.00
Exchangeable Sodium Percentage	%	9.90	9.92	21.55	29.18	19.15	0.28	4.42	<5

17.3 Rill Assessment

A rill assessment was undertaken along the 50m vegetation transect. To identify potential rills of concern we have selected the dimensions of 10cm x 30cm (0.03m²) as the minimum value of concern.

While there was a reduction in the number and total cross-sectional area of the rills between 2009 and 2010, there was an increase from four to seven rills recorded in 2012 due to the loss of vegetation as a result of the tailings wall seepage, declining soil characteristics combined with high rainfall activity over the past two summers. Last year, of the seven rills recorded in TSF2-01, two rills exceeding the minimum value of concern. This year there were six rills, but the total cross-sectional area had increased to 0.215m². One rill in particular was recorded at 14.8m along the vegetation transect and with the dimensions of 28 x 50cm, greatly exceeded the minimum value of concern and probably requires amelioration (Figure 17-2).

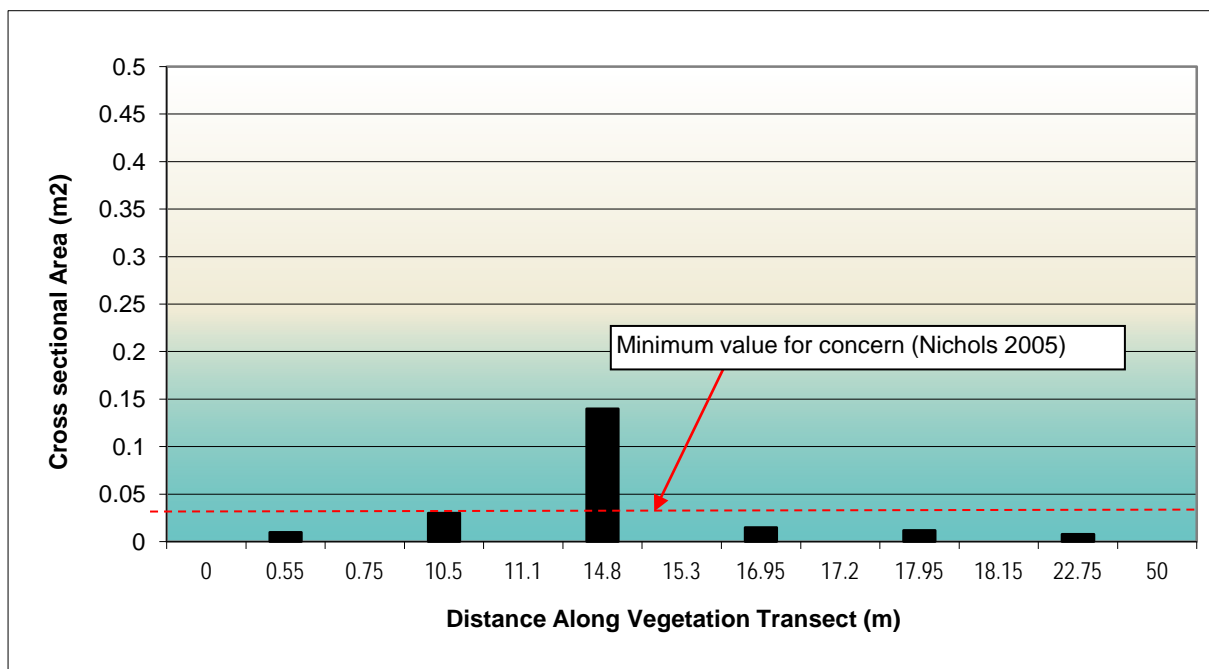


Figure 17-2. Cross-sectional area of the rills recorded along the transect.

17.4 Tree density and health condition

No trees or shrubs with a dbh >5cm were recorded.

17.5 Shrubs and juvenile trees

The number of *Maireana brevifolia* plants recorded in the 50 x 20m plot decreased from five to three in 2012 and all plants remained less than 1.5m in height. This year no changes were recorded (Table 17-4). Several more plants were observed on the contour below the monitoring plot.

Table 17-4. Number of shrubs of each species and their height class.

Species	0 - 0.5m	0.5 - 1.0m	1.0 - 1.5m	1.5 - 2.0m	>2.0m	Total	endemic	not endemic
<i>Maireana brevifolia</i>		2	1			3	3	
Total	0	2	1	0	0	3	3	0
% endemic species							100	0

17.6 Structural diversity and habitat complexity

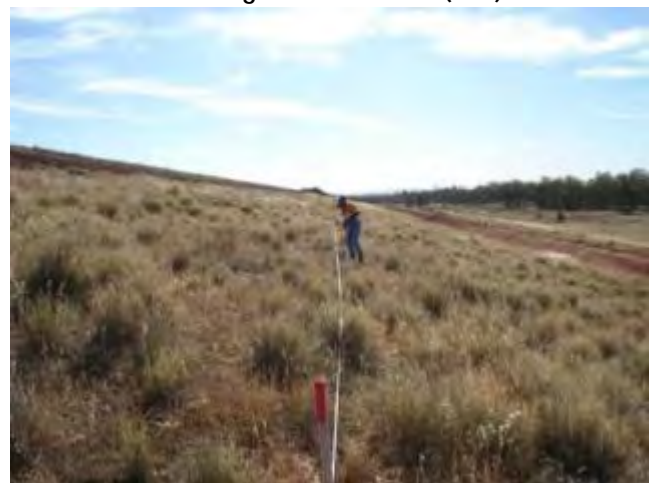
This rehabilitation site continued to be structurally simple and has continued to show some dramatic changes in response to the seasonal conditions and ecological processes occurring within the site (Figure 17-3). While there was a reduction from 90.0 – 72.5% in total ground cover last year which was thought to be largely due to the increasing concentrations of salts which are leaching through the tailings dam walls in conjunction with dry seasonal conditions. This year there have been some improvements in soil chemistry and as a result, there was also an improvement in vegetation cover and this year there was 86.5% total ground cover.

There were slight increases in both annual and perennial vegetation cover which provided 21.0% and 24% of the live plant cover respectively. There was negligible change in dead litter cover which provided 41.5% of the total cover and there continued to be an absence of cryptogams (Figure 17-4). There was no projected foliage cover >0.5m in height. Table 17-5 provides the average and minimum and maximum values obtained along the vegetation transect this year.

2009 Vegetation transect (front)



2009 Vegetation transect (rear)



2010 Vegetation transect (front)



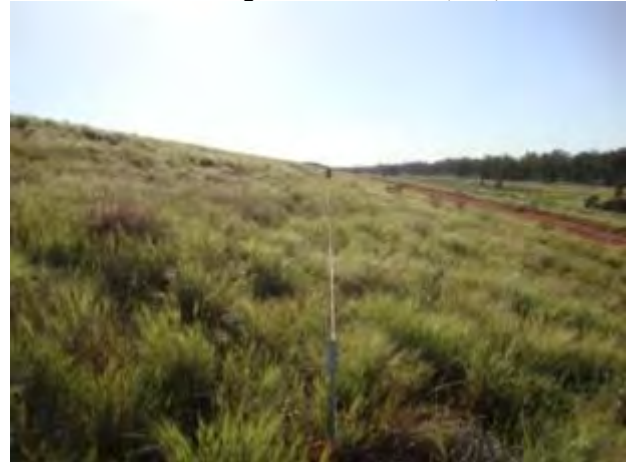
2010 Vegetation transect (rear)



2011 Vegetation transect (front)



2011 Vegetation transect (rear)



2012 Vegetation transect (front)



2012 Vegetation transect (rear)



2013 Vegetation transect (front)



2013 Vegetation transect (rear)

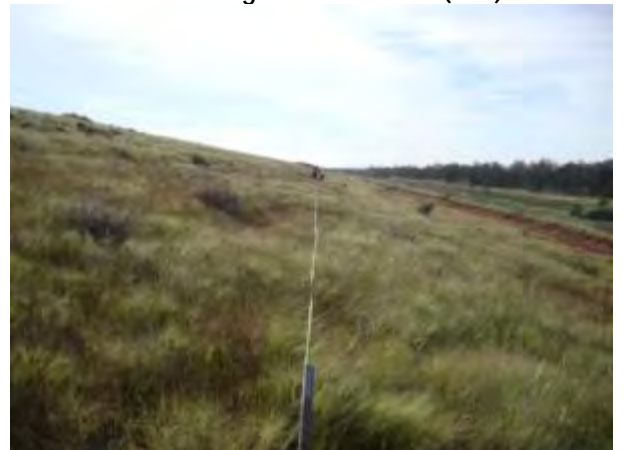


Figure 17-3. Permanent photo points taken from the front (left) and rear (right) of the vegetation transect.

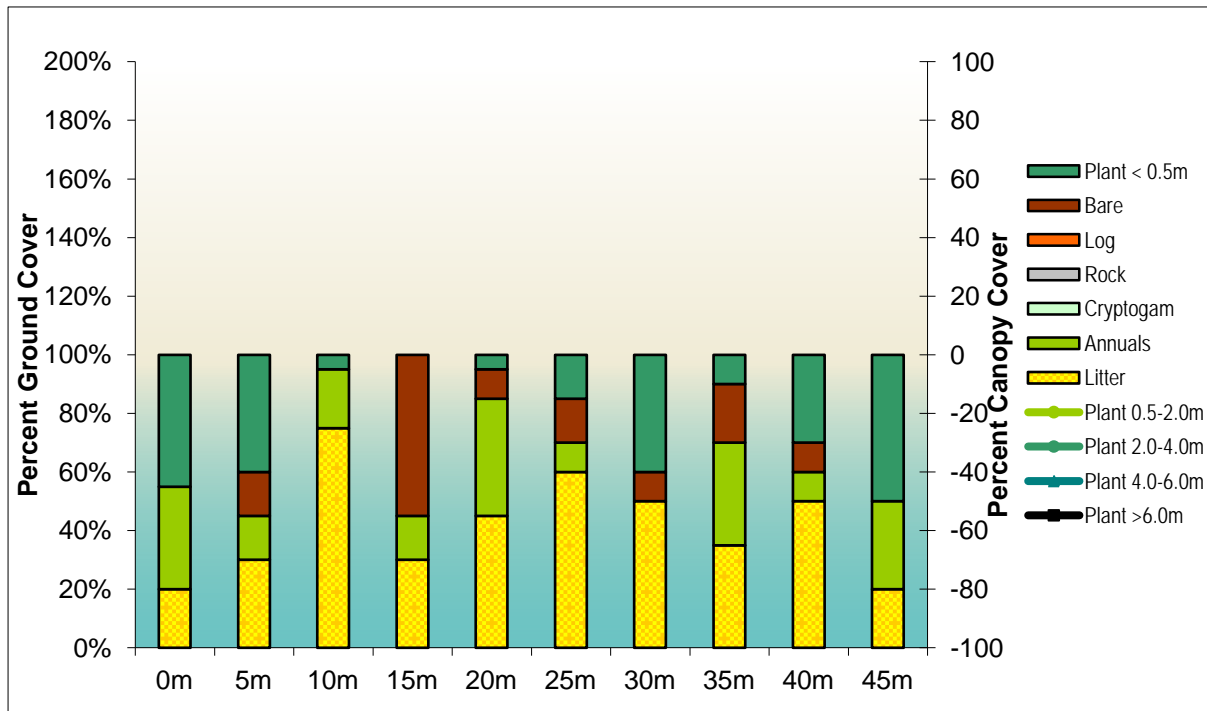


Figure 17-4. Graph illustrating the structural diversity and habitat complexity of the monitoring site.

Table 17-5. Average and minimum and maximum values of the structural diversity of the monitoring site.

Vegetation structure	0m	5m	10m	15m	20m	25m	30m	35m	40m	45m	Average	Min	Max
Litter	20	30	75	30	45	60	50	35	50	20	41.5	20	75
Annuals	35	15	20	15	40	10	0	35	10	30	21	0	40
Cryptogam	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0	0	0	0	0	0
Log	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare	0	15	0	55	10	15	10	20	10	0	13.5	0	55
Perennial <0.5m	45	40	5	0	5	15	40	10	30	50	24	0	50
Total Ground Cover	100	85	100	45	90	85	90	80	90	100	86.5	45	100
0.5-2.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
2.0-4.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0-6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
>6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0

17.7 Species cover abundance

In 2013 there were eight live species recorded along the five 1m² sub-plots placed at 10m intervals along the vegetation transect which included five exotic species (Figure 17-5 and Table 17-6). Using the Braun-blauquet scale, the highest possible cover score that can be obtained is 30 and cover abundance is illustrated as a sum of scores (class values) obtained along the five 1m² quadrats.

In 2010 the site was almost completely dominated the exotic annual *Medicago polymorpha* which nearly reached the maximum abundance with a score of 29 but this has tended to become less prolific with the native perennial grass *Walwhalleya proluta* being most dominant species since that time. The exotic annuals *Lolium rigidum*, *Medicago polymorpha*, *Scorzonera laciniata* and *Sonchus oleraceus* continued to be very common but no live *Avena fatua* was recorded this year. The native species *Chloris truncata* and *Enteropogon acicularis* have also persisted in two - three sub-quadrats. Of the live plant cover scores recorded 40.6% was provided by native species, a reduction from 49.0% recorded last year.

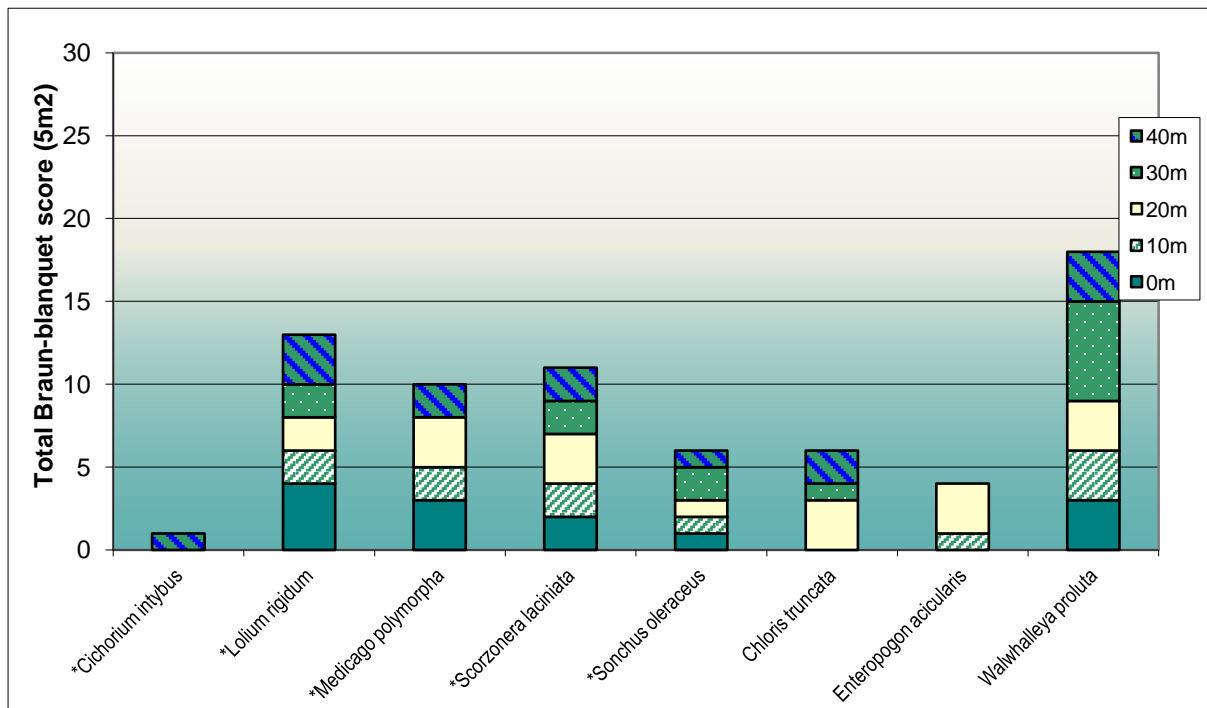


Figure 17-5. Total species recorded across the five, 1m² quadrats using the Braun-blanket scale (max possible score is 30) as a measure of cover abundance.

Table 17-6. List of species and their average cover abundance score across the five, 1m² monitoring quadrats.

Species	0m	10m	20m	30m	40m	Total
*Cichorium intybus					1	1
*Lolium rigidum	4	2	2	2	3	13
*Medicago polymorpha	3	2	3		2	10
*Scorzonera laciniata	2	2	3	2	2	11
*Sonchus oleraceus	1	1	1	2	1	6
Chloris truncata			3	1	2	6
Enteropogon acicularis		1	3			4
Walwhalleya proluta	3	3	3	6	3	18
Total cover						69
Sum of cover of native species						28
Percent endemic species cover						40.6

17.8 Floristic diversity

The floristic diversity of the sites was measured using two different methods. One provides an assessment of the average number of species within five, one square metre (m²) sub-quadrats along the vegetation transect, while the other provides the total number of species within the entire 50x20m monitoring plot.

17.8.1 Species diversity per m²

The average number of native species recorded within the five 1m² sub-plots has slightly increased from 1.8 – 2.0 native species per m² on average over the past year (Table 17-7). The number of exotic species however has also increased from 3.0 – 4.0 species per m². The number of native species per m² ranged from 1 -3, while the number of exotic species ranged from 3 - 5 species per m².

Table 17-7. Species diversity per 1m².

Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	1	2	3	2	2	2	0.7
Exotic	4	4	4	3	5	4	0.7
Total	5	6	7	5	7	6	1.0

17.8.2 Total species diversity

The overall the floristic diversity recorded in the 20x50m monitoring plot has continued to increase and this year there was total of 31 species and this included 15 native species (Figure 17-6, Table 17-8). The low very flat shape of the species area curve indicates the site was relatively homogenous. A list of species recorded within the monitoring site is provided in Appendix 1.

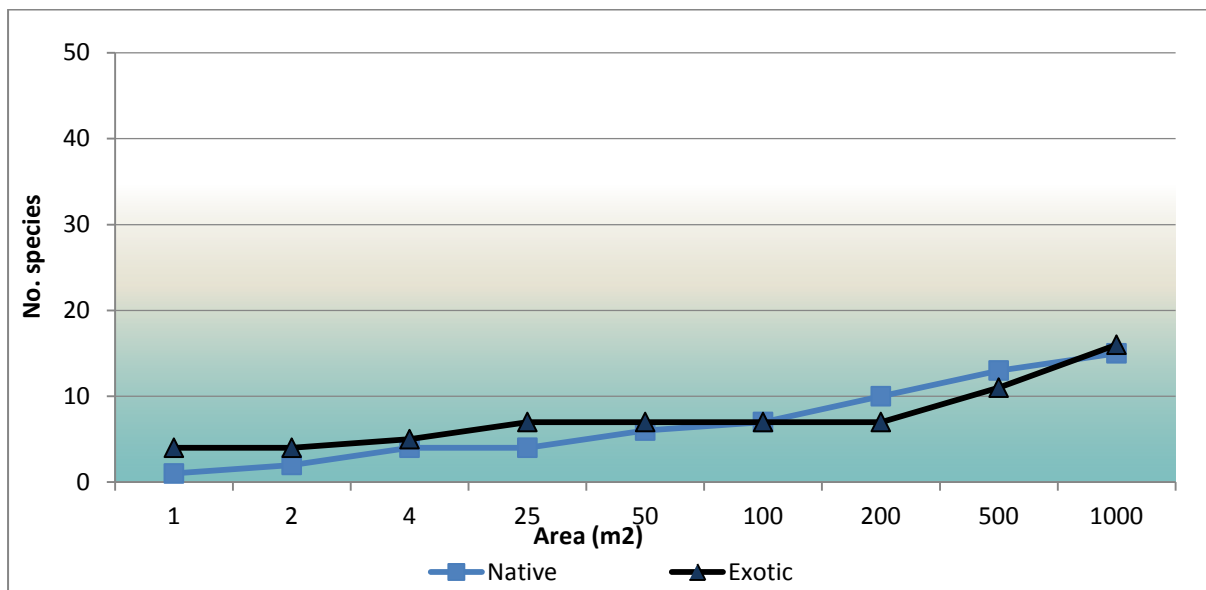
Figure 17-6. Cumulative species in the 50m x 20m (1000m²) monitoring quadrat.

Table 17-8. Cumulative species diversity.

Area (m2)	1	2	4	25	50	100	200	500	1000
Native	1	2	4	4	6	7	10	13	15
Exotic	4	4	5	7	7	7	7	11	16

17.9 Growth forms

Figure 17-7 is a summary of species in each growth form that were recorded in the site. Herbs continued to be the most dominant plant type with 13 different species including ten exotic species. There were 14 species of grasses including six exotic species. There continued to be one shrub and this year three sub-shrubs were recorded. No tree, reed or fern representatives were present. Compared to the grassland reference there was a low diversity of herb and grass species.

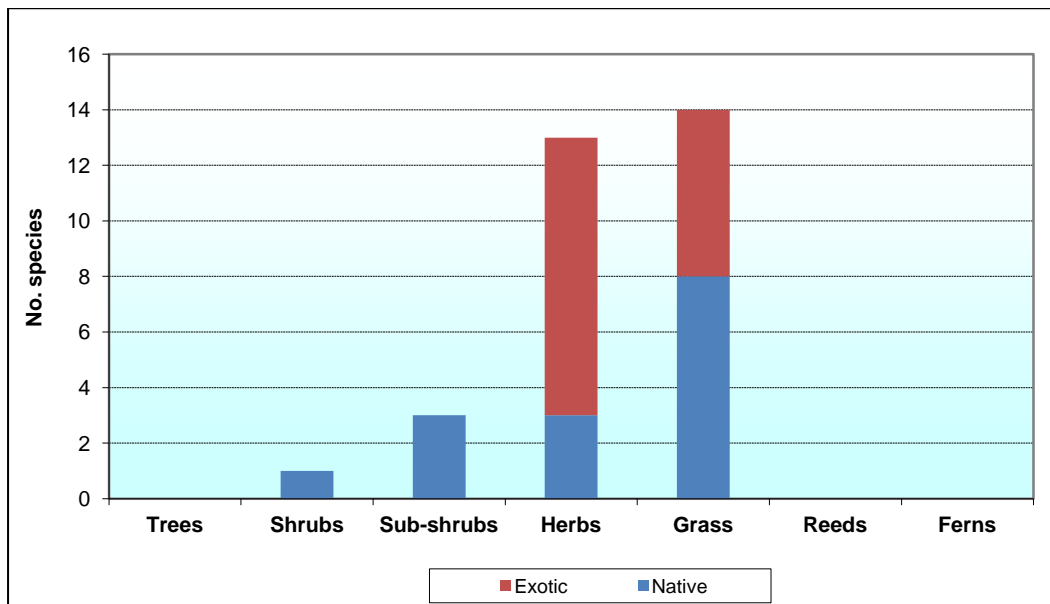


Figure 17-7. Graph illustrating the growth forms of species recorded in the 50m x 20m monitoring quadrat.

17.10 Comparison of rehabilitation data with key performance indicators

Table 17-9 indicates the performance of the rehabilitation monitoring site against the Completion and Desirable Performance Indicators developed for grassland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) for example and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 17-9. Comparison of key performance Indicators recorded in the rehabilitation site TSF2-01 compared to lower and upper limits recorded in the grassland reference sites.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF2-01				
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2009	2010	2011	2012	2013
Phase2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	1	3	11.0	11.0	11.0	11.0	11.0
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%	64.5	73.0	62.0	62.0	70.5	67.0	67.0
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%	29.3	46.3	35.3	37.0	38.9	35.4	32.8
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%	28.1	43.2	31.2	33.9	38.4	36.2	34.2
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%	100	100	100	100	100	100	100

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF2-01				
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising		No.	0	0	3	2	4	7	6
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0.129	0.108	0.115	0.174	0.215
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)	6.73	7.97	7.35	7.24	7.12	5.98	6.15
			EC		Electrical Conductivity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	< dS/m (<0.150)	0.043	0.198	0.333	0.388	1.743	2.248	1.022
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	1.6	4.1	1.2	0.4	0.8	0.8	1.5
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	5.3	8.6	18.4	6.0	5.6	5.3	12.0
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	1.2	1.4	2.5	0.5	1.5	1.4	0.9
			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)	20.4	37.8	24.55	26.20	31.47	34.42	23.9
			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	4.4	9.90	9.92	21.55	29.18	19.15
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees		The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.	species/area	0	0	1	1	1	1	1
					The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation	% population	0	0	na	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	37	52	21	26	26	27	31

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF2-01				
			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	19	38	17	13	11	14	15
			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	14	20	4	10	15	13	16
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees		The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation	No./area	0	0	2	5	5	3	3
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees		The number of tree species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Shrubs		The number of shrub species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	1	1	1	1	1
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	4	2	2	1	2	3
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	26	34	11	9	12	14	13
			Grasses	The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	11	15	7	11	12	10	14
			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	0	0	0	0	0	0
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			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
Phase 5: Ecosystem & Landuse Development	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	%	36	52	65.7	4.5	26.5	42.0	41.5
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	4	39	0.5	85.2	43.0	9.0	21

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF2-01				
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	17	0.0	0	0	0	0
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	3	15	28.5	9	10.0	27.5	13.5
			Perennial plant cover (< 0.5m)	Percent ground cover provided by live perennial vegetation (< 0.5m in height) is comparable to that of the local remnant vegetation		%	16	30	5.3	1.3	20.5	21.5	24
			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		%	86	97	71.5	91	90.0	72.5	86.5
	Ground cover diversity	Vegetation contains a diversity of species per square meter comparable to that of the local remnant vegetation	Native understorey abundance		The abundance of native species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has more than or an equal number of native species as the local remnant vegetation	> species/m ²	3	11	3.4	2.0	1.8	1.8	2.0
			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	4	7	1.0	3.2	2.8	2.6	4
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation		%	29	77	na	30.6	36.7	49.0	40.6
	Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	shrubs and juvenile trees 0 - 0.5m in height		The number of shrubs or juvenile trees < 0.5m in height provides an indication of establishment success and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	2	1	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF2-01				
			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	2	2	3	2	2
			shrubs and juvenile trees 1 - 1.5m in height		The number of shrubs or juvenile trees 1-1.5m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	1	1	1	1
			shrubs and juvenile trees 1.5 - 2m in height		The number of shrubs or juvenile trees 1.5-2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			shrubs and juvenile trees >2m in height		The number of shrubs or juvenile trees > 2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
	Ecosystem structure	The vegetation is developing in structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5 - 2 m	Projected foliage cover provided by perennial plants in the 0.5 - 2m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover	0	5	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	0	0	0
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 - 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
			Foliage cover >6m		Projected foliage cover provided by perennial plants > 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	0	0	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF2-01				
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	0	0	na	na	0	0	0
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	0	0	0	0	0	0	0
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees		The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Healthy trees		The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Medium health		The percentage of the tree population which are in a medium health condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Advanced dieback		The percentage of the tree population which are in a state of advanced dieback and that the percentage is comparable to the local remnant vegetation	<% population	0	0	0	0	0	0	0
			Dead Trees		The percentage of the tree population which are dead (stags) and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			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
			Flowers/fruit: Trees		The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation	% population	0	0	0	0	0	0	0

18 TSF2-02 site description

This grassland rehabilitation site is located on the north-east wall of TSF 2. It is a grassy slope similar to TSF2-01 with scattered tussocks of native perennial grasses (*Walwhalleya proluta*) and a heavy cover of *Medicago polymorpha*. A single *Acacia hakeoides* and *Maireana brevifolia* were noted further along the slope. In 2009, the grasses and annual plants were particularly stressed with little active green growth or were dead. In 2010, there was evidence of extensive soil erosion from the bare upper slope which contained numerous rills, but the eroded materials were captured within the plant patches down slope. The previously bare areas had a light cover of annual plants. In 2011, there was a significant increase in perennial plant cover largely due to the native grasses and there were fewer weeds. In 2012 and 2013 the site continued to be very dry and the top of the slope continues to be bare and eroding.

18.1 Landscape Function Analysis

18.1.1 Landscape organisation

Site TSF2-02 continued to be characterised as a grassy slope with no bare patches and due to the high ground cover scored a Landscape Organisation Index of 100% (Figure 18-1, Table 18-1). The resultant LFA indices for stability, infiltration and nutrient recycling have previously demonstrated an increasing trend and this year this remained true for the stability and nutrient recycling of the site, however infiltration capacity was marginally lower.

The resultant LFA indices for stability, infiltration and nutrient recycling were 76.0, 33.9 and 39.3 respectively. Compared to the grassland reference sites, LFA stability, infiltration and nutrient recycling indices were 11.5, 4.6 and 11.2 LFA units higher than the minimum KPI targets this year.

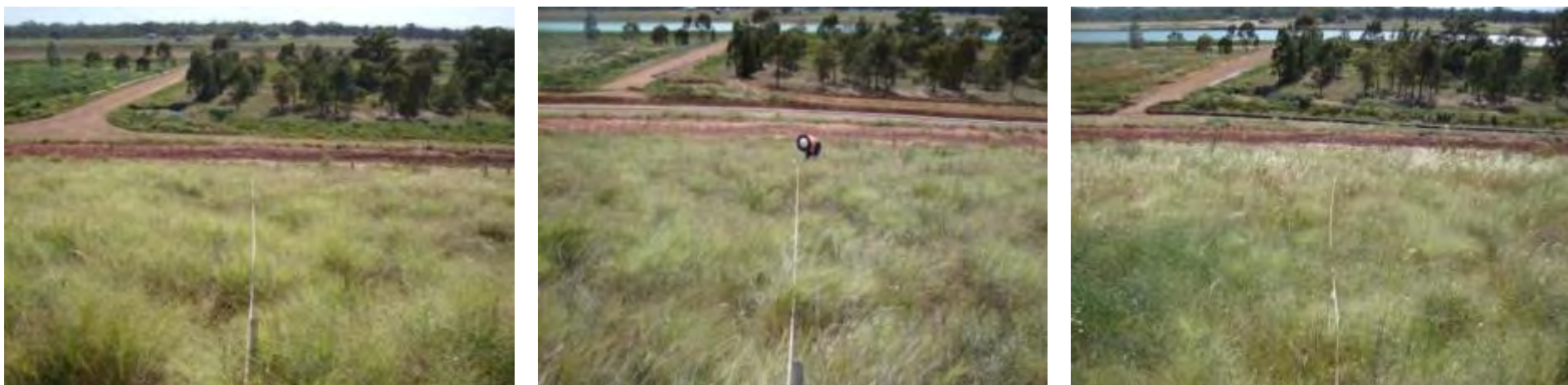


Figure 18-1. Permanent photo point taken from the top of the LFA transect in 2011 (left) , 2012 (centre) and 2013 (right).

Table 18-1. Summary of landscape organisation and LFA indices from 2009 to 2013.

TSF2-02		8/12/2009		13/09/2010		18/10/2011		16/10/2012		17/10/2013	
Number of Patches/10m		0.5		0.5		0.5		0.5		0.5	
Total Patch Area (m2)		200		200		200		200		200.00	
Patch Area Index		1		1		1		1		1.00	
Landscape Organisation Index		1		1		1		1		1.00	
Average Interpatch Length (m)		NA		NA		NA		NA		NA	
Range Interpatch length (m)		NA		NA		NA		NA		NA	
Patch or Interpatch Type		Grassy Slope		Grassy Slope		Grassy Slope		Grassy Slope		Grassy slope	
Patch or Interpatch Proportion (%)		100	100	100	100	100	100	100	100	100.0	100
Soil Surface Assessment											
Within Individual Zones	Stability	55		64.5		70		70		76.0	
	Infiltration	36.2		36		36.5		36.1		33.9	
	Nutrients	28.6		32.6		33.3		34.4		39.3	
			Total		Total		Total		Total		Total
Individual zones contribution to the whole of Landscape	Stability	55	55	64.5	64.5	70	70	70	70	76.0	76.0
	Infiltration	36.2	36.2	36	36	36.5	36.5	36.1	36.1	33.9	33.9
	Nutrients	28.6	28.6	32.6	32.6	33.3	33.3	34.4	34.4	39.3	39.3

18.1.2 Soil Surface Assessment

There continued to be moderate to high levels of protective ground cover which was largely provided by scattered rocks and grass tussocks, with the grasses also providing low to moderate levels of perennial basal cover (Table 18-2). There continued to be high litter cover which had begun to accumulate to some depth, but there was still no evidence of decomposition. Cryptogams were only recorded in low abundance on one occasion last but this year they were in high abundance lower down the transect. There continued to be negligible erosion and deposition across most of the site and the vegetation and rocks provided moderate to high soil surface relief.

The soil types across the site were very patchy and seemed to be dependent on the amount of previous erosion and deposition, with the clay loam soils providing the upper surface layer in most occasions with silty clay lying beneath. In some cases the silty clay had become exposed. This year we observed a lot of silty clay soils. The soils demonstrated some slumping of the sub-crusts when immersed in water, despite the very hard soil surface.

Table 18-2 . Results of the Soils Surface Assessment for the Grassy Slope.

Features	Max score	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Soil Cover	5	4	4	5	4	3
Per. basal / canopy cover	4	2	3	3	3	2
Litter cover, orig & incorp.	10	5ln	4ln	5ln	6ln	5ln
Cryptogam cover	4	1	1	4	4	4
Crust broken-ness	4	4	4	4	4	4
Erosion type & severity	4	4	3	4	4	4
Deposited materials	4	4	4	4	4	4
Soil surface roughness	5	4	4	4	4	4
Surface resist. to disturb.	5	4	4	4	4	4
Slake test	4	3	2	3	3	3
Texture	4	1	1	1	2	2

18.2 Soil analyses

There was little change in soil pH has with the soils categorised as slightly alkaline and these continued to fall within the target range despite being higher than desirable levels (Table 18-3). There was also little change in Electrical Conductivity which continued to fall within the target KPI target and desirable levels. There was a decline in organic matter and it remained slightly lower than the target range. Phosphorus and nitrate levels have slightly declined and while phosphorous levels were typical, nitrate levels were low. The Cation Exchange Capacity has marginally declined and this year fell within local levels. The ESP has slightly increased and remained higher than the desirable level of 5% indicating the soils were sodic.

Table 18-3. Results of the soil analysis for TSF2-02 compared to the upper and lower values for the grassland reference sites and desirable levels from 2009 to 2013.

Nutrient	Units	TSF2-02					Lower KPI	Upper KPI	Desirable Level
		2009	2010	2011	2012	2013			
pH (1:5 water)	units	7.46	7.51	8.02	7.56	7.50	6.73	7.97	5.6 - 7.3
Conductivity (1:5 water)	dS/m	0.208	0.131	0.340	0.142	0.143	0.043	0.198	0.150
Organic Matter	%	0.90	1.3	0.9	1.7	1.3	1.6	4.1	>4.5
Phosphorus (Colwell)	mg/kg	11	14	8	11	5	5	9	50
Nitrate	mg/kg	4.0	1.1	5.6	4.4	1.1	1.2	1.4	13.0
Cation Exchange Capacity	cmol+/Kg	28.4	28.34	29.38	26.18	25.85	20.41	37.83	14.00
Exchangeable Sodium Percentage	%	4.96	4.43	6.86	5.93	6.83	0.28	4.42	<5

18.3 Rill Assessment

No rills of significance were present along the 50m transect.

18.4 Tree density and health condition

No trees with a diameter at breast height (dbh) greater than 5cm were present within the plot.

18.5 Shrubs and juvenile trees

In previous years one small *Maireana brevifolia* was recorded however it was not located this year.

18.6 Structural diversity and habitat complexity

This rehabilitation site continued to be structurally simple and has continued to show some dramatic changes in response to the seasonal conditions and ecological processes occurring within the site (Figure 18-2). Over the last year there has been a slight increase from 92.5 – 99.0 % total ground cover as a result of increased cover of dead leaf litter and annual plants which provided 42% and 27% cover on average. There was however a reduction in perennial plant cover and this year decreased from 36.5% - 30% (Figure 18-3). Some of the scattered grass tussocks provided some vertical height greater than 0.5m almost along the length of the transect. Table 18-4 provides the average and minimum and maximum values obtained along the vegetation transect.

2009 Vegetation transect (front)



2009 Vegetation transect (rear)



2010 Vegetation transect (front)



2010 Vegetation transect (rear)



2011 Vegetation transect (front)



2011 Vegetation transect (rear)



2012 Vegetation transect (front)



2012 Vegetation transect (rear)



2013 Vegetation transect (front)



2013 Vegetation transect (rear)



Figure 18-2. Permanent photo points taken from the front (left) and rear (right) of the vegetation transect.

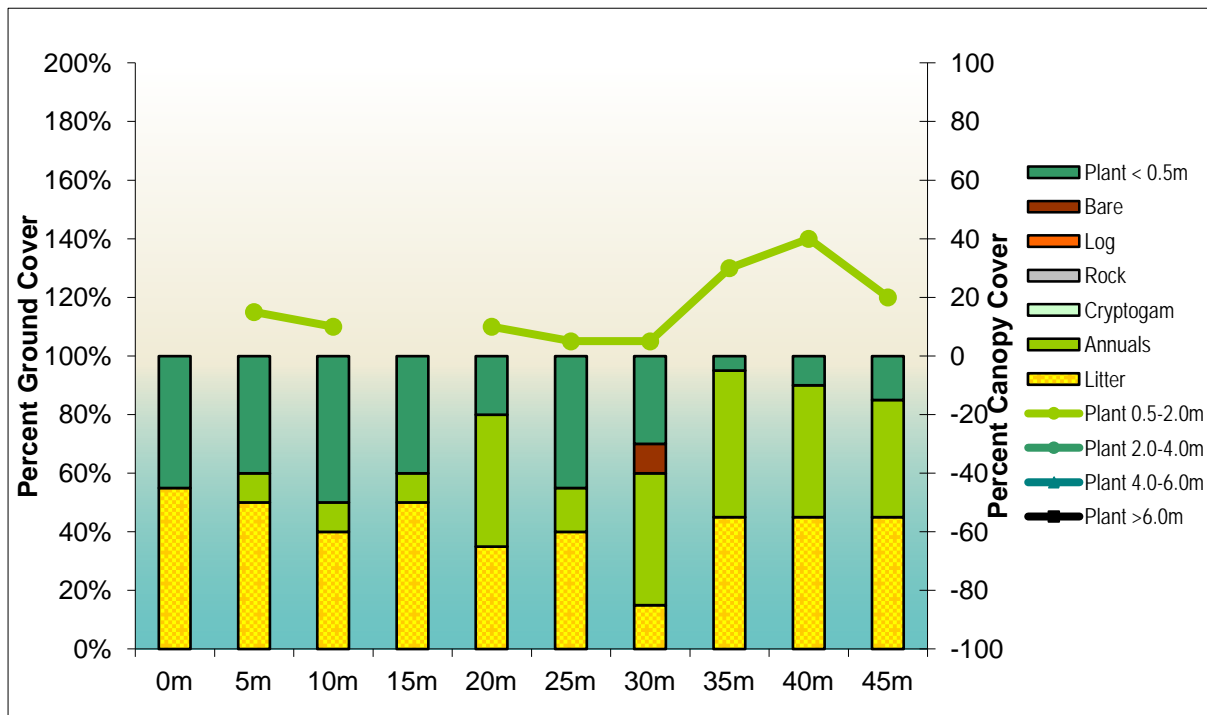


Figure 18-3. Graph illustrating the structural diversity and habitat complexity of the monitoring site.

Table 18-4. Average and minimum and maximum values of the structural diversity of the monitoring site.

Vegetation structure	0m	5m	10m	15m	20m	25m	30m	35m	40m	45m	Average	Min	Max
Litter	55	50	40	50	35	40	15	45	45	45	42	15	55
Annuals	0	10	10	10	45	15	45	50	45	40	27	0	50
Cryptogam	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0	0	0	0	0	0
Log	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare	0	0	0	0	0	0	10	0	0	0	1	0	10
Perennial <0.5m	45	40	50	40	20	45	30	5	10	15	30	5	50
Total Ground Cover	100	100	100	100	100	100	90	100	100	100	99	90	100
0.5-2.0m	0	15	10	0	10	5	5	30	40	20	13.5	0	40
2.0-4.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0-6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
>6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0

18.7 Species cover abundance

In 2013 there were eight live species recorded along the five 1m² sub-plots placed at 10m intervals along the vegetation transect but these included six exotic species. Using the Braun-blauquet scale, the highest possible cover score that can be obtained is 30 and cover abundance is illustrated as a sum of scores (class values) obtained along the five 1m² quadrats.

Since 2010 the exotic annual *Medicago polymorpha* and native perennial grass *Walwhalleya proluta* have dominated the site and this appears to have been the case again this year (Figure 18-4, Table 18-5). The exotic annual *Avena fatua* continued to be very common but provided only low cover scores. The native grasses species *Austrodanthonia setacea* and *Enteropogon acicularis* have also persisted. The remaining species were less common and provided only low cover values. Of the live plant cover scores recorded 36.5% 56.1% was provided by native species, a reduction from 56.1% which was recorded last year.

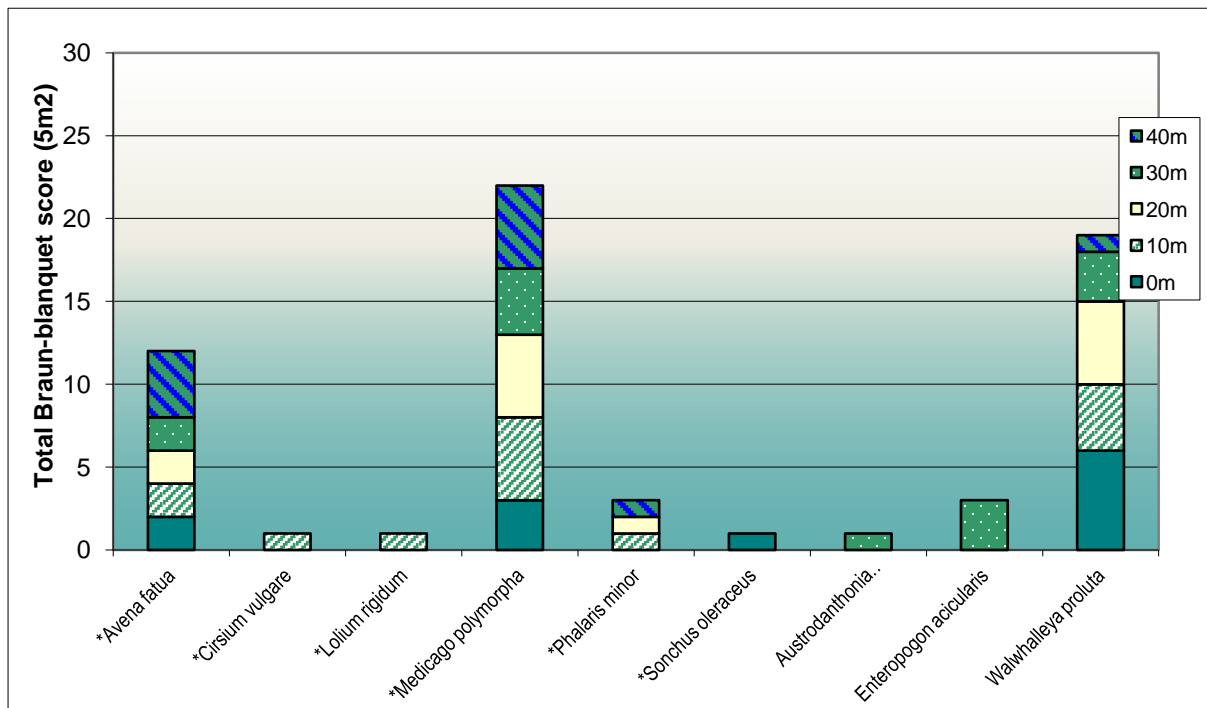


Figure 18-4. Total species recorded across the five, 1m² quadrats using the Braun-blanket scale (max possible score is 30) as a measure of cover abundance.

Table 18-5. List of species and their average cover abundance score across the five, 1m² monitoring quadrats.

Species	0m	10m	20m	30m	40m	Total
*Avena fatua	2	2	2	2	4	12
*Cirsium vulgare		1				1
*Lolium rigidum		1				1
*Medicago polymorpha	3	5	5	4	5	22
*Phalaris minor		1	1		1	3
*Sonchus oleraceus	1					1
Austrodanthonia setacea				1		1
Enteropogon acicularis				3		3
Walwhalleya proluta	6	4	5	3	1	19
Total cover						63
Sum of cover of native species						23
Percent endemic species cover						36.5

18.8 Floristic diversity

The floristic diversity of the sites was measured using two different methods. One provides an assessment of the average number of species within five, one square metre (m²) sub-quadrats along the vegetation transect, while the other provides the total number of species within the entire 50x20m monitoring plot.

18.8.1 Species diversity per m²

The average number of native species recorded in the five 1m² sub-quadrats has been variable over the past three years but has remained very low with only 1.4 native species per m² recorded on average across the site this year. There were slightly more exotic species this year with 3.2 species per m² (Table 18-6). The number of native species per m² ranged from one to three, while the number of exotic species ranged from two to five.

Table 18-6. Species diversity per 1m².

Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	1	1	1	3	1	1.4	0.9
Exotic	3	5	3	2	3	3.2	1.1
Total	4	6	4	5	4	4.6	0.9

18.8.2 Total species diversity

The overall floristic diversity has decreased in 50 x 20m monitoring quadrat, and this year there were 15 native and 17 exotic species. (Figure 18-5, Table 18-7). The low flat shape of the species area curve indicates the site was relatively homogenous. A list of species recorded within the monitoring site is provided in Appendix 1.

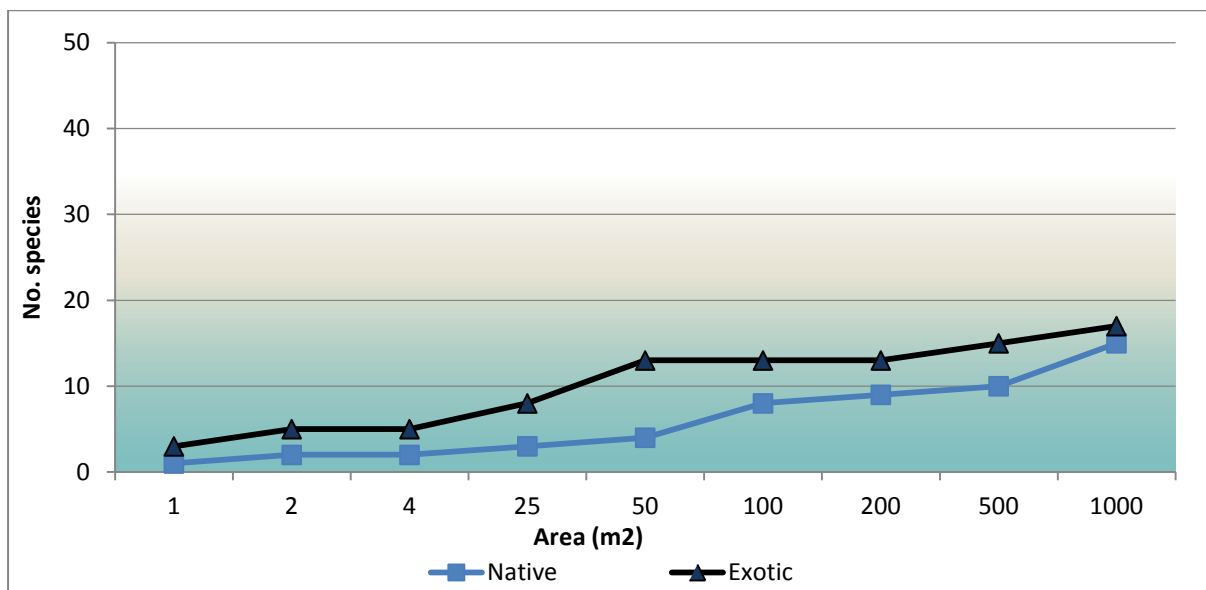
Figure 18-5. Cumulative species in the 50m x 20m (1000m²) monitoring quadrat.

Table 18-7. Cumulative species diversity.

Area (m2)	1	2	4	25	50	100	200	500	1000
Native	1	2	2	3	4	8	9	10	15
Exotic	3	5	5	8	13	13	13	15	17

18.9 Growth forms

Figure 18-6 is a summary of species in each growth form that were recorded in TSF2-02 site. Herbs continued to be the most dominant plant type with 23 different species including 14 exotic species and there were eight grasses. This year there were no shrubs only one sub-shrub was found. There were no tree, reed or fern representatives. Compared to the grassland reference there was a low diversity of herb and grass species this year.

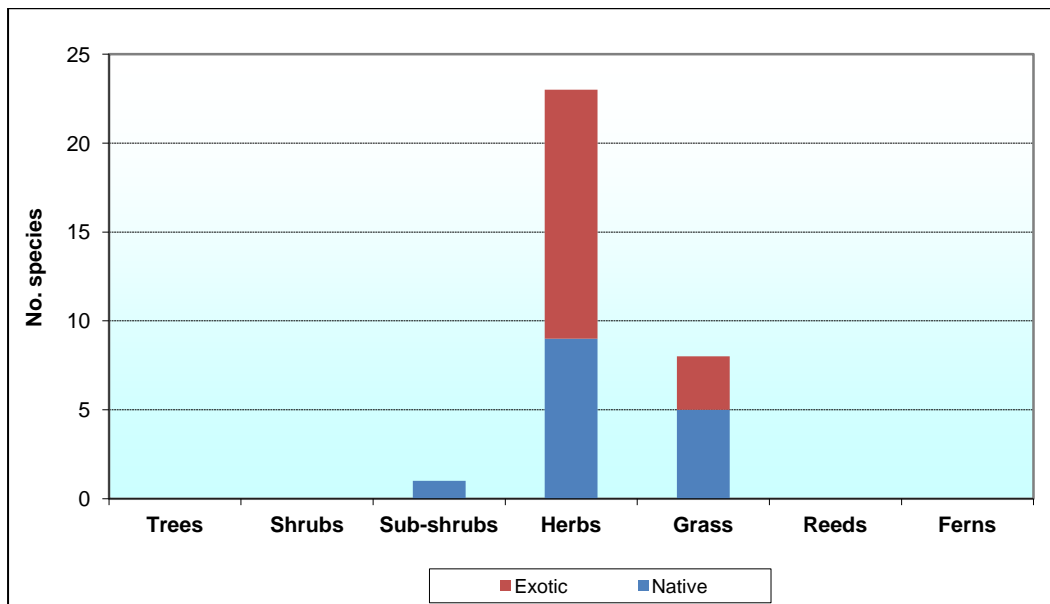


Figure 18-6. Graph illustrating the growth forms of species recorded in the 50m x 20m monitoring quadrat.

18.10 Comparison of rehabilitation data with key performance indicators

Table 18-8 indicates the performance of the rehabilitation monitoring site against the Completion and Desirable Performance Indicators developed for grassland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) for example and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 18-8. Comparison of key performance Indicators recorded in the rehabilitation site TSF2-02 compared to lower and upper limits recorded in the grassland reference sites.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF2-02				
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2009	2010	2011	2012	2013
Phase2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	1	3	13.0	13.0	13.0	13.0	13.0
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%	64.5	73.0	55.0	64.5	70.0	70.0	76.0
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%	29.3	46.3	36.2	36.0	36.5	36.1	33.9
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%	28.1	43.2	28.6	32.6	33.3	34.4	39.3
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%	100	100	100	100	100	100	100

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF2-02				
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising		No.	0	0	0	0	0	0	0
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0	0	0	0	0
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)	6.73	7.97	7.46	7.51	8.02	7.56	7.50
			EC		Electrical Conductivity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	< dS/m (<0.150)	0.043	0.198	0.208	0.131	0.340	0.142	0.143
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	1.6	4.1	0.9	1.3	0.9	1.7	1.3
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	5.3	8.6	10.8	13.8	7.8	11.2	5.0
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	1.2	1.4	4.0	1.1	5.6	4.4	1.1
			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)	20.4	37.8	28.40	28.34	29.38	26.18	25.9
			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	4.4	4.96	4.43	6.86	5.93	6.83
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees		The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.	species/area	0	0	0	0	1	1	0
					The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation	% population	0	0	na	na	100	100	na
			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	37	52	14	19	31	40	32

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF2-02				
			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	19	38	12	8	14	20	15
			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	14	20	2	11	17	20	17
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees		The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation	No./area	0	0	0	0	1	1	0
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees		The number of tree species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			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	0	0	1	1	0
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	4	3	2	2	2	1
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	26	34	7	11	20	26	23
			Grasses	The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	11	15	4	6	8	11	8
			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	0	0	0	0	0	0
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			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
Phase 5: Ecosystem & Landuse Development	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	%	36	52	77	0.5	54	39.5	42
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	4	39	0	99.5	24.0	15.0	27

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF2-02				
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	17	0.0	0	0	1.5	0
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	3	15	23	0	0	7.5	1
			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		%	16	30	0.0	0.0	22.0	36.5	30
			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		%	86	97	77	100	100	92.5	99
	Ground cover diversity	Vegetation contains a diversity of species per square meter comparable to that of the local remnant vegetation	Native understorey abundance		The abundance of native species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has more than or an equal number of native species as the local remnant vegetation	> species/m ²	3	11	1.0	0.6	2.0	2.4	1.4
			Exotic understorey abundance		The abundance of exotic species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has less than or an equal number of exotic species as the local remnant vegetation	< species/m ²	4	7	0	2.4	3.4	2.8	3.2
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation		%	29	77	na	9.8	42.6	56.1	36.5
	Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	shrubs and juvenile trees 0 - 0.5m in height		The number of shrubs or juvenile trees < 0.5m in height provides an indication of establishment success and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	1	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF2-02				
			shrubs and juvenile trees 0.5 - 1m in height		The number of shrubs or juvenile trees 0.5-1m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	1	0
			shrubs and juvenile trees 1 - 1.5m in height		The number of shrubs or juvenile trees 1-1.5m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	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 comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			shrubs and juvenile trees >2m in height		The number of shrubs or juvenile trees > 2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
	Ecosystem structure	The vegetation is developing in structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5 - 2 m	Projected foliage cover provided by perennial plants in the 0.5 - 2m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover	0	5	0	0	6.5	5.5	13.5
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 - 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
			Foliage cover >6m		Projected foliage cover provided by perennial plants > 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	0	0	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		TSF2-02				
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	0	0	na	na	0	0	0
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	0	0	0	0	0	0	0
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees		The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Healthy trees		The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Medium health		The percentage of the tree population which are in a medium health condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Advanced dieback		The percentage of the tree population which are in a state of advanced dieback and that the percentage is comparable to the local remnant vegetation	<% population	0	0	0	0	0	0	0
			Dead Trees		The percentage of the tree population which are dead (stags) and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			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
			Flowers/fruit: Trees		The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation	% population	0	0	0	0	0	0	0

19 E22-01 site description

E22-01 is located on the western batters of the waste emplacement surrounding the E22 open cut and is an open grassy area on the upper slope of the batter. The upper half of the monitoring plot contains less vegetation cover with scattered tussocks of *Walwhalleya proluta* and exotic annuals. The lower part of the slope is more densely vegetated and in 2010 it was dominated by *Vicia*, *Rapistrum rugosum* and various other weeds. Spiny Orb weavers were abundant. Below the site there are some small planted tree lots with little to no ground cover with severe tunnel erosion observed nearby. Some Grey Crowned Babblers were observed in these trees during the monitoring. In 2011, there was a significant increase in perennial plant cover largely due to the native grasses and there were fewer weeds. In 2012 and 2013 the site continued to be very dry.

19.1 Landscape Function Analysis

19.1.1 Landscape organisation

Site E22-01 continued to be characterised as a grassy slope and due to the high levels of ground cover scored a Landscape Organisation Index of 1.0 or 100% (Figure 19-1).

The ecological function at this site has demonstrated an increasing trend since 2009 due to significant increases in perennial plant and litter cover and loss of soil crusts due to the development a humus layer in parts however since 2012 these changes have been much less significant. The prolonged dry has resulted in a lower ecological function across the site. The resultant LFA indices for stability, infiltration and nutrient recycling were 71.8, 47.0 and 47.4 respectively (Table 19-1). Compared to the grassland reference sites, this site were 7.3, 17.7 and 19.3 LFA units higher than the minimum target ranges and therefore continued to meet these completion targets.

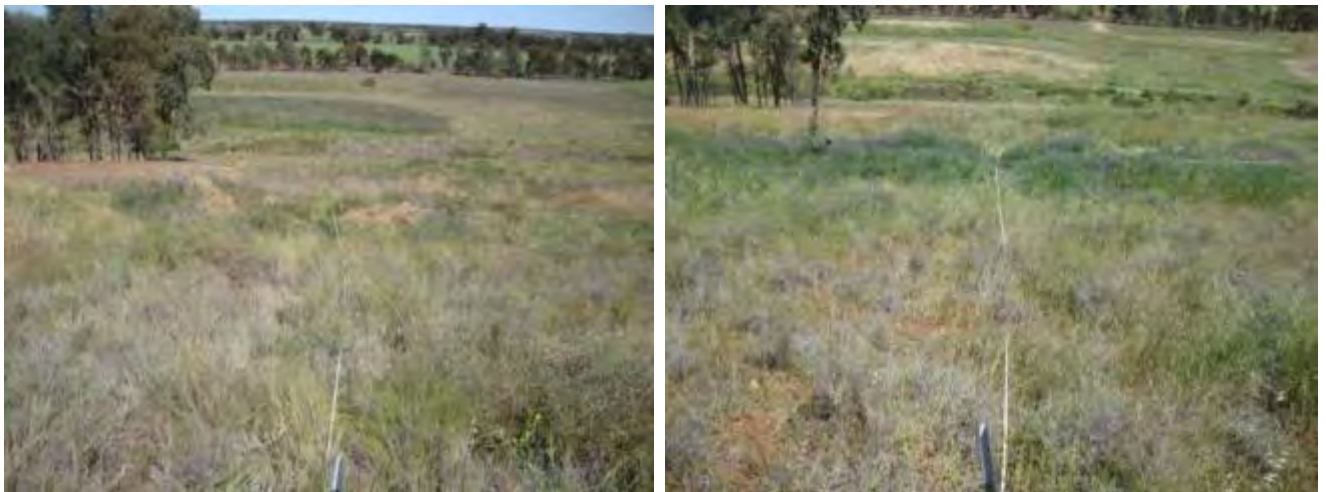


Figure 19-1. Permanent photo point taken from the top of the LFA transect in 2012 (left) and 2013 (right).

Table 19-1. Summary of landscape organisation and LFA indices from 2009 to 2013.

E22-01		9/12/2009		22/09/2010		17/10/2011		15/10/2012		14/10/2013	
Number of Patches/10m		0.5		0.5		0.5		0.5		0.5	
Total Patch Area (m2)		200		200		200		200		200.00	
Patch Area Index		1		1		1		1		1.00	
Landscape Organisation Index		1		1		1		1		1.00	
Average Interpatch Length (m)		NA		NA		NA		NA		NA	
Range Interpatch length (m)		NA		NA		NA		NA		NA	
Patch or Interpatch Type		Grassy Rehab Slope		Grassy Rehab Slope		Grassy Rehab Slope		Grassy Rehab Slope		Grassy Rehab Slope	
Patch or Interpatch Proportion (%)		100	100	100	100	100	100	100	100	100.0	100
Soil Surface Assessment											
Within Individual Zones	Stability	60.5		68.8		75.6		75.5		71.8	
	Infiltration	39.5		43.5		48.2		49.2		47.0	
	Nutrients	33.9		42		48.3		48.8		47.4	
			Total		Total		Total		Total		Total
Individual zones contribution to the whole of Landscape	Stability	60.5	60.5	68.8	68.8	75.6	75.6	75.5	75.5	71.8	71.8
	Infiltration	39.5	39.5	43.5	43.5	48.2	48.2	49.2	49.2	47.0	47.0
	Nutrients	33.9	33.9	42	42	48.3	48.3	48.8	48.8	47.4	47.4

19.1.2 Soil Surface Assessment

There has been a significant increase in perennial plant cover resulting in improved rain splash protection and perennial basal cover since 2009 however over the past year these changes were less evident. There has been a decline in the cover provided by the perennial grasses and weeds and this year there were typically only low levels of protection against rain splash and low basal cover (Table 19-2). Litter cover remained high to very high and had accumulated to some depth and there continued to be slight to moderate levels of decomposition in all replicates indicating active fungal and microbial activity.

Due to the heavy litter layer and development of a humus layer, the soil surface last year had become less crusted in parts along the transect resulting in an absence of cryptogam habitat in two of the five replicates. In the upper slope however, cryptogams were moderately abundant. There continued to be negligible erosion and but there was some areas where slight deposition was evident, with the plants providing moderate to high soil surface relief. The clay loam soils remained moderately hard and were typically very stable.

Table 19-2 . Results of the Soils Surface Assessment for the Grassy Rehab slope patch.

Features	Max score	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Soil Cover	5	3	2	2	2	2
Per. basal / canopy cover	4	3	2	2	2	2
Litter cover, orig & incorp.	10	5ls	6ls	6ls	6lm	6lm
Cryptogam cover	4	3	3	1	0	0
Crust broken-ness	4	4	4	4	0	0
Erosion type & severity	4	4	4	4	4	4
Deposited materials	4	4	3	3	4	4
Soil surface roughness	5	4	3	3	3	3
Surface resist. to disturb.	5	4	3	3	3	3
Slake test	4	3	4	4	4	4
Texture	4	2	2	2	2	2

19.2 Soil analyses

The soil pH recorded in E22-01 remained neutral and continued to fall within local soil pH levels. There was a marginal reduction in Electrical Conductivity and organic matter and both continued to fall within the local target ranges (Table 19-3). Phosphorous and nitrate levels have also declined this year and while phosphorous levels remained higher than the local soil concentrations they remained well within desirable levels, while nitrates were very low. The Cation Exchange Capacity had also decreased and was marginally lower than the target however the low Exchangeable Sodium Percentage continued to indicate that the soils are not sodic.

Table 19-3. Results of the soil analysis for E22-01 compared to the upper and lower values for the grassland reference sites and desirable levels from 2009 to 2013.

Nutrient	Units	E22-01					Lower KPI	Upper KPI	Desirable Level
		2009	2010	2011	2012	2013			
pH (1:5 water)	units	6.96	6.99	7.35	7.14	7.26	6.73	7.97	5.6 - 7.3
Conductivity (1:5 water)	dS/m	0.153	0.117	0.099	0.095	0.088	0.043	0.198	0.150
Organic Matter	%	2.20	3.4	2.6	3.5	2.6	1.6	4.1	>4.5
Phosphorus (Colwell)	mg/kg	15	23	21	25	13	5	9	50
Nitrate	mg/kg	24	2.4	3.4	6.0	0.3	1.2	1.4	13.0
Cation Exchange Capacity	cmol+/Kg	20.7	22.21	19.87	20.57	19.91	20.41	37.83	14.00
Exchangeable Sodium Percentage	%	1.59	1.19	1.66	2.20	2.32	0.28	4.42	<5

19.3 Rill assessment

No rills of concern were evident within the monitoring site E22-01, but parts of the rehabilitation slope contained isolated areas of severe tunnel erosion, particularly near the small patches of planted trees. These erosion areas were probably initiated by kangaroo tracks and/or camps and were presently very active. Amelioration is urgently required.

19.4 Tree density and health condition

No trees with a diameter at breast height (dbh) greater than 5cm have ever been recorded in this monitoring site.

19.5 Shrubs and juvenile trees

As in previous years, one *Acacia decora* and one *Maireana brevifolia* were recorded and these were likely to be volunteer species recruiting from the soil seed bank (Table 19-4).

Table 19-4. Shrubs and young trees occurring within the monitoring site.

Species	0 - 0.5m	0.5 - 1.0m	1.0 - 1.5m	1.5 - 2.0m	>2.0m	Total	endemic	not endemic
<i>Acacia decora</i>				1		1	1	
<i>Maireana brevifolia</i>		1				1	1	
Total	0	1	0	1	0	2	2	0
% endemic species							100	0

19.6 Structural diversity and habitat complexity

This rehabilitation site continued to be structurally simple and has continued to show some dramatic changes in response to the seasonal conditions and ecological processes occurring within the site (Figure 19-2). The site continues to maintain 100.0% total ground cover however there has been an increase in annual plants from 25.0 - 43.5%, resulting in a reduction in dead litter and perennial plant cover which provide a cover of 31% and 25.5% respectively (Figure 19-3). The tall weeds and scattered grass tussocks provided vertical height greater than 0.5m on most occasions along the vegetation transect. Table 19-5 provides the average and minimum and maximum values obtained along the vegetation transect.

2009 Vegetation transect (front)



2009 Vegetation transect (rear)



2010 Vegetation transect (front)



2010 Vegetation transect (rear)



2011 Vegetation transect (front)



2011 Vegetation transect (rear)



2012 Vegetation transect (front)



2012 Vegetation transect (rear)



2013 Vegetation transect (front)



2013 Vegetation transect (rear)



Figure 19-2. Permanent photo points taken from the front (left) and rear (right) of the vegetation transect.

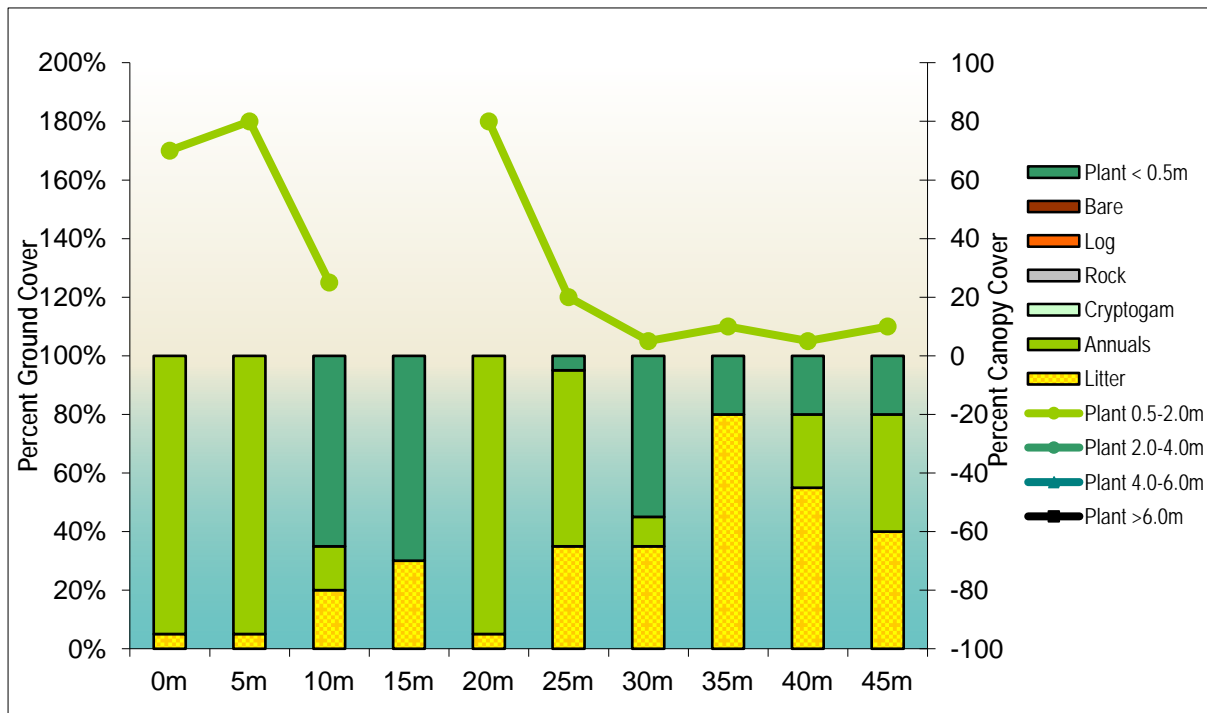


Figure 19-3. Graph illustrating the structural diversity and habitat complexity of the monitoring site.

Table 19-5. Average and minimum and maximum values of the structural diversity of the monitoring site.

Vegetation structure	0m	5m	10m	15m	20m	25m	30m	35m	40m	45m	Average	Min	Max
Litter	5	5	20	30	5	35	35	80	55	40	31	5	80
Annuals	95	95	15	0	95	60	10	0	25	40	43.5	0	95
Cryptogam	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0	0	0	0	0	0
Log	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare	0	0	0	0	0	0	0	0	0	0	0	0	0
Perennial <0.5m	0	0	65	70	0	5	55	20	20	20	25.5	0	70
Total Ground Cover	100	100	100	100	100	100	100	100	100	100	100	100	100
0.5-2.0m	70	80	25	0	80	20	5	10	5	10	30.5	0	80
2.0-4.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0-6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
>6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0

19.7 Species cover abundance

In 2013 there were 11 species recorded in the five 1m² quadrats on the permanent vegetation transect line and all but one species were exotic species. Using the Braun-blauquet scale, the highest possible cover score that can be obtained is 30 and cover abundance is illustrated as a sum of scores (class values) obtained along the five 1m² quadrats.

While *Walwhalleya proluta* was the most abundant and consistent species in 2009, the site had become dominated by the exotic species *Vicia villosa*, *Rapistrum rugosum* and *Echium plantagineum* in 2010 due to improved seasonal conditions. Since 2011, exotic species had become less abundant and the native grass *Walwhalleya proluta* was often co-dominated by *Vicia villosa* and this continued to be the case this year (Figure 19-4, Table 19-6). *Salvia verbenaca* a perennial weed was also common and quite abundant in patches, and this year *Avena fatua*, *Rapistrum rugosum* and *Echium plantagineum* were also relatively common. Most of the remaining species were recorded on only one occasion indicating the site was very patchy and in most cases they provided only low cover values. Of the cover

scores recorded 23.6% was provided by native species and this was reduction from 35.4% recorded last year.

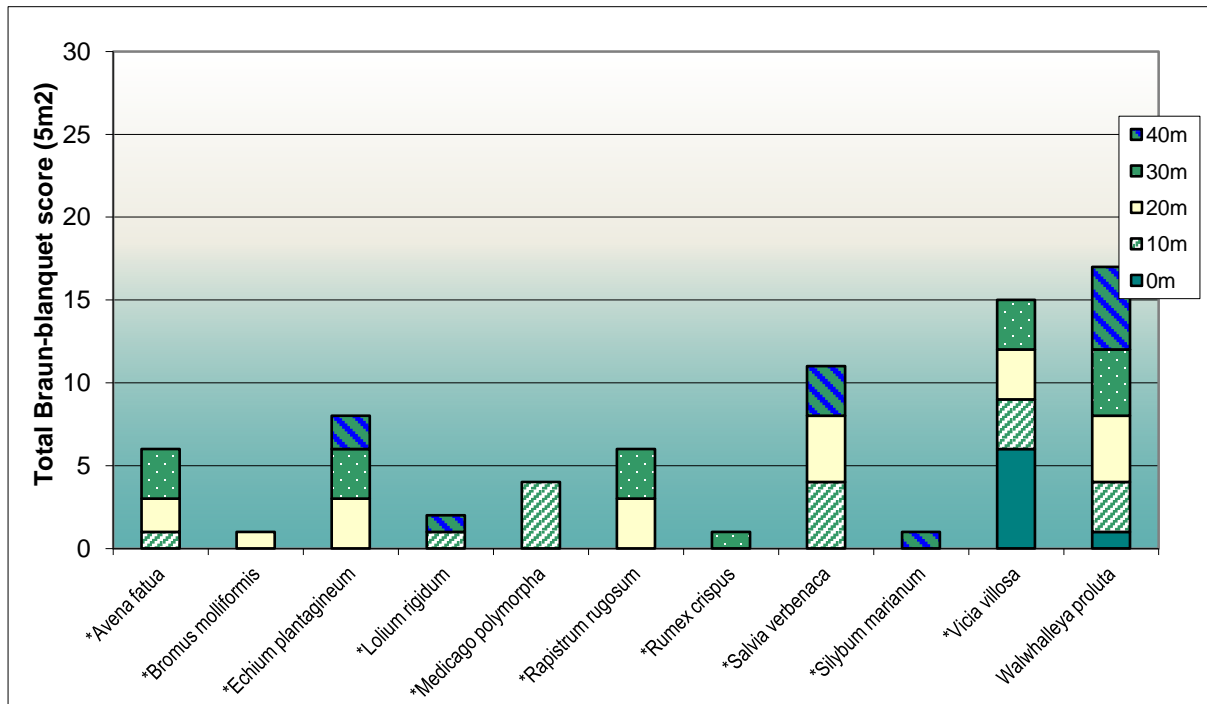


Figure 19-4. Total species recorded across the five, 1m² quadrats using the Braun-blauquet scale (max possible score is 30) as a measure of cover abundance.

Table 19-6. List of species and their average cover abundance score across the five, 1m² monitoring quadrats.

Species	0m	10m	20m	30m	40m	Total
*Avena fatua		1	2	3		6
*Bromus molliformis			1			1
*Echium plantagineum			3	3	2	8
*Lolium rigidum		1			1	2
*Medicago polymorpha		4				4
*Raphistrum rugosum			3	3		6
*Rumex crispus				1		1
*Salvia verbenaca		4	4		3	11
*Silybum marianum					1	1
*Vicia villosa	6	3	3	3		15
Walwhalleya proluta	1	3	4	4	5	17
Total cover						72
Sum of cover of native species						17
Percent endemic species cover						23.6

19.8 Floristic diversity

The floristic diversity of the sites was measured using two different methods. One provides an assessment of the average number of species within five, one square metre (m²) sub-quadrats along the vegetation transect, while the other provides the total number of species within the entire 50x20m monitoring plot.

19.8.1 Species diversity per m²

The average number of native species recorded in the five 1m² sub-quadrats has been very low and variable between years and this year there was a further decrease from 1.4 – 1.0 native species per m² (Table 19-7). The number of exotic species has continued to be higher and the average diversity per m²

has increased this year from 3.0 – 4.2 exotic species per m². There was only one native species which was recorded in all five sub-plots, while the number of exotic species ranged from one to six species per m².

Table 19-7. Species diversity per 1m².

Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	1	1	1	1	1	1	0.0
Exotic	1	5	6	5	4	4.2	1.9
Total	2	6	7	6	5	5.2	1.9

19.8.2 Total species diversity

The total diversity of species remained unchanged however there was a reduction from 16 – 11 native species and an increase from 19 – 24 exotic species (Figure 19-5, Table 19-8). The sharp increases in the species area curve indicate that the site contained some patchiness. A list of species recorded within the monitoring site is provided in Appendix 1.

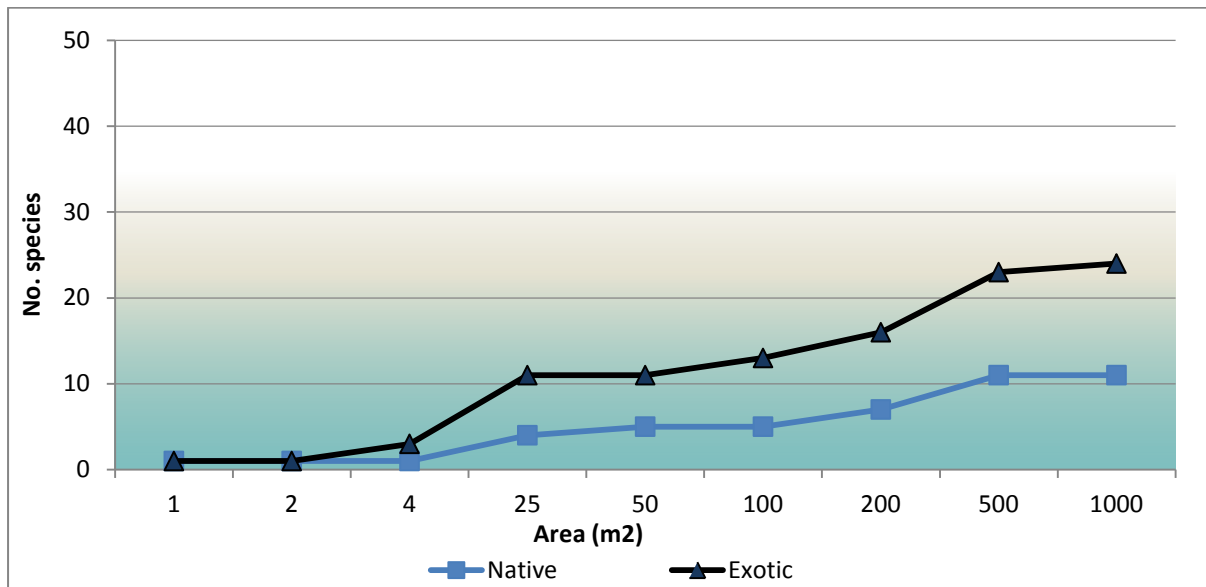


Figure 19-5. Cumulative species in the 50m x20m (1000m²) monitoring quadrat.

Table 19-8. Cumulative species diversity.

Area (m2)	1	2	4	25	50	100	200	500	1000
Native	1	1	1	4	5	5	7	11	11
Exotic	1	1	3	11	11	13	16	23	24

19.9 Growth forms

Figure 19-6 is a summary of species in each growth form that were recorded in this grassland rehabilitation site. Herbs continued to be the dominant growth form with a total of 20 species, including 17 exotic species. There were 12 grasses, including 7 exotic species, two native shrubs and one native sub-shrub. There were no tree, reed or fern representatives present. Compared to the grassland reference there was a low diversity of herb species.

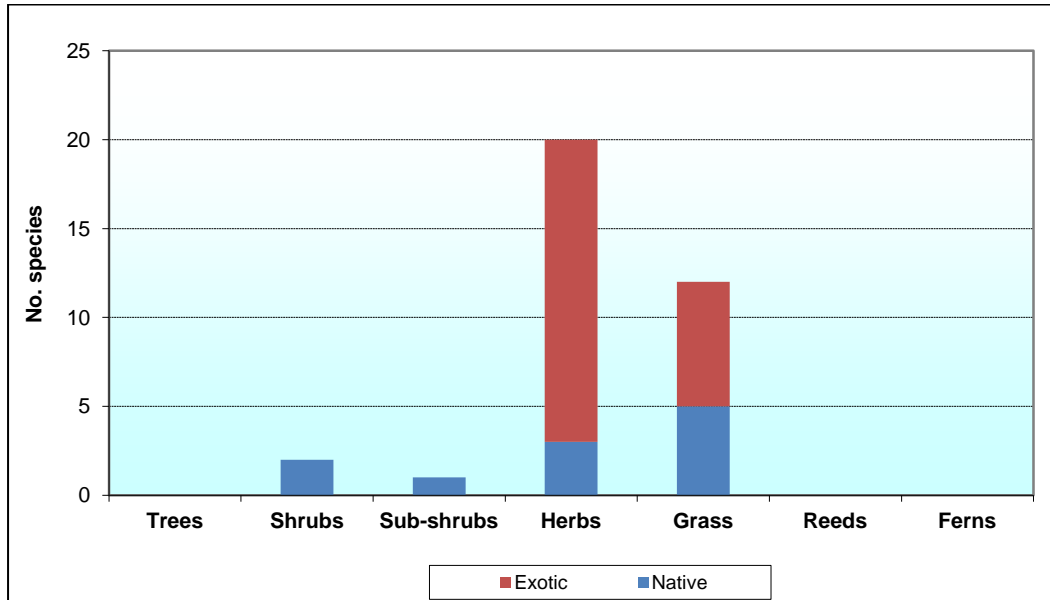


Figure 19-6. Graph illustrating the growth forms of species recorded in the 50m x 20m monitoring quadrat.

19.10 Comparison of rehabilitation data with key performance indicators

Table 19-9 indicates the performance of the rehabilitation monitoring site against the Completion and Desirable Performance Indicators developed for grassland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) for example and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 19-9. Comparison of key performance Indicators recorded in the rehabilitation site E22-01 compared to lower and upper limits recorded in the grassland reference sites.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E22-01				
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2009	2010	2011	2012	2013
Phase2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	1	3	14.0	14.0	14.0	14.0	14.0
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%	64.5	73.0	60.5	68.8	75.6	75.5	71.8
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%	29.3	46.3	39.5	43.5	48.2	49.2	47.0
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%	28.1	43.2	33.9	42.0	48.3	48.8	47.4
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%	100	100	100	100	100	100	100

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E22-01				
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising		No.	0	0	0	0	0	0	0
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0	0	0	0	0
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)	6.73	7.97	6.96	6.99	7.35	7.14	7.26
			EC		Electrical Conductivity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	< dS/m (<0.150)	0.043	0.198	0.153	0.117	0.099	0.095	0.088
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	1.6	4.1	2.2	3.4	2.6	3.5	2.6
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	5.3	8.6	15.4	25.0	20.6	24.8	12.5
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	1.2	1.4	23.8	2.4	3.4	6.0	0.3
			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)	20.4	37.8	20.76	22.21	19.87	20.57	19.94
			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	4.4	1.59	1.19	1.66	2.20	2.3
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees		The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.	species/area	0	0	2	1	1	2	2
					The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation	% population	0	0	na	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	37	52	23	39	38	35	35

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E22-01				
			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	19	38	14	15	16	16	11
			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	14	20	9	24	22	19	24
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees		The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation	No./area	0	0	2	1	1	2	2
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees		The number of tree species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			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	2	1	1	2	2
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	4	1	2	1	1	1
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	26	34	15	28	23	18	20
			Grasses	The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	11	15	5	8	13	14	12
			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	0	0	0	0	0	0
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			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
Phase 5: Ecosystem & Landuse Development	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	%	36	52	91	13.5	31	38.5	31.0
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	4	39	0	74.5	18.0	25.0	43.5

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E22-01				
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	17	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	4	0	0	0	0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	3	15	2.5	1	0	0	0
			Perennial plant cover (< 0.5m)	Percent ground cover provided by live perennial vegetation (< 0.5m in height) is comparable to that of the local remnant vegetation		%	16	30	2.5	11.0	51	36.5	25.5
			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		%	86	97	97.5	99	100	100	100
	Ground cover diversity	Vegetation contains a diversity of species per square meter comparable to that of the local remnant vegetation	Native understorey abundance		The abundance of native species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it has more than or an equal number of native species as the local remnant vegetation	> species/m ²	3	11	2.4	0.8	1.8	1.4	1.0
			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 has less than or an equal number of exotic species as the local remnant vegetation	< species/m ²	4	7	1.4	7.0	3.6	3	4.2
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation		%	29	77	na	11.1	35.6	35.4	23.6
	Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	shrubs and juvenile trees 0 - 0.5m in height		The number of shrubs or juvenile trees < 0.5m in height provides an indication of establishment success and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	1	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E22-01				
			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	1	0	0	1	1
			shrubs and juvenile trees 1 - 1.5m in height		The number of shrubs or juvenile trees 1-1.5m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	1	1	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 comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	1	1
			shrubs and juvenile trees >2m in height		The number of shrubs or juvenile trees > 2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
	Ecosystem structure	The vegetation is developing in structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5 - 2 m	Projected foliage cover provided by perennial plants in the 0.5 - 2m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover	0	5	0	26.5	13	0.5	30.5
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 -6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
			Foliage cover >6m		Projected foliage cover provided by perennial plants > 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	0	0	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E22-01				
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	0	0	na	na	0	0	0
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	0	0	0	0	0	0	0
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees		The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Healthy trees		The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Medium health		The percentage of the tree population which are in a medium health condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Advanced dieback		The percentage of the tree population which are in a state of advanced dieback and that the percentage is comparable to the local remnant vegetation	<% population	0	0	0	0	0	0	0
			Dead Trees		The percentage of the tree population which are dead (stags) and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			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
			Flowers/fruit: Trees		The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation	% population	0	0	0	0	0	0	0

20 E22-02 site description

Site E22-02 is located on the northern batter of the waste rock emplacement that surrounds E22 open cut. It is a rocky north facing slope that appears to have been deep ripped after shaping. There are sparse tussocks of *Walwhalleya proluta* scattered over the site and in 2010 there was a significant increase in ground cover dominated by *Medicago polymorpha*, *Echium plantagineum* and *Rapistrum rugosum*. In 2009 active sheet erosion was observed across the site with one active rill of concern. In 2010 the rills had become vegetated and appeared to have stabilised. In 2011, there has been a significant increase in perennial plant cover largely due to the native grasses and there were fewer weeds but there were still patches of weeds including *Carthamus lanatus* (Saffron thistle). *Vittadinia* (Fuzzweed) was becoming very abundant. There were echidna scratchings at the end of the veg transect. In 2012 and 2013 the site continued to be very dry.

20.1 Landscape Function Analysis

20.1.1 Landscape organisation

In 2009, due to the low occurrence of perennial grasses and sparse litter cover, Site E22-02 was characterised as a rocky slope interpatch with two small grass patches resulting in a very low Landscape Organisation Index (LOI) of 0.04 or 4%. However since 2010, the extent of the patch has continually increase and in 2012 the site was re-characterised as 100% functional patch area, which has been maintained into 2013 (Figure 20-1, Table 20-1).

Despite the maintaining high functional area there has been a reduction in ecological function within the site, largely due to the lower abundance of perennial plant cover. The resultant LFA indices for stability, infiltration and nutrient recycling were 60.5, 39.9 and 35.3 respectively. Compared to the grassland reference sites, infiltration and nutrient recycling indices were 10.6 and 7.2 LFA units higher and continued to fall within the target range but stability was 4.0 LFA units lower.

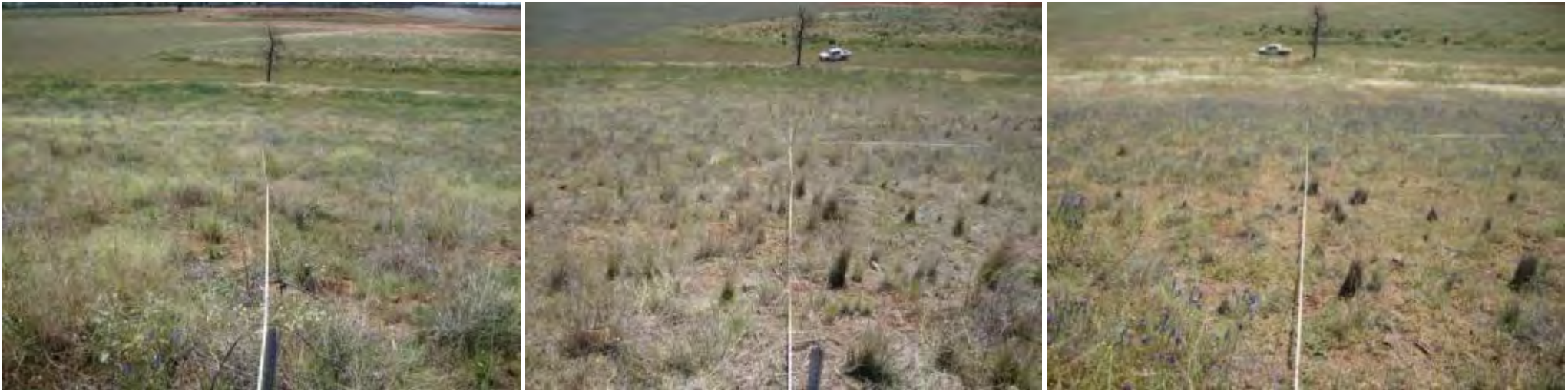


Figure 20-1. Permanent photo point taken from the top of the LFA transect in 2011 (left), 2012 (centre) and 2013 (right).

Table 20-1. Summary of landscape organisation and LFA indices from 2009 to 2013.

E22-02		9/12/2009			22/09/2010			17/10/2011			15/10/2012		14/10/2013	
Number of Patches/10m		1			2.5			1.5			0.5		0.5	
Total Patch Area (m2)		0.57			135.93			183			200		200.00	
Patch Area Index		0			0.68			0.92			1		1.00	
Landscape Organisation Index		0.04			0.85			0.92			1		1.00	
Average Interpatch Length (m)		6.37			0.75			0.85			NA		NA	
Range Interpatch length (m)		4.4	to	9.3	0.4	to	1.1	0.85	to	0.9	NA		NA	
Patch or Interpatch Type		Rocky Slope	Plant Patch		Plant Patch	Rocky Slope		Plant Patch	Rocky Slope Interpatch		Pasture Rehab Slope		Pasture Rehab Slope	
Patch or Interpatch Proportion (%)		95.5	4.5	100	85	15	100	91.5	8.5	100	100	100	100.0	100
Soil Surface Assessment														
Within Individual Zones	Stability	46	47.5		65	54.4		67	50		63		60.5	
	Infiltration	30.5	40.9		39.4	27.7		44.8	31.9		45.4		39.9	
	Nutrients	21.2	29.1		35.8	23.3		41.7	23.8		39.9		35.3	
		Total			Total			Total			Total		Total	
Individual zones contribution to the whole of Landscape	Stability	43.9	2.1	46.1	55.3	8.2	63.4	61.3	4.3	65.6	63	63	60.5	60.5
	Infiltration	29.2	1.8	31	33.5	4.2	37.7	41	2.7	43.7	45.4	45.4	39.9	39.9
	Nutrients	20.2	1.3	21.5	30.4	3.5	33.9	38.1	2	40.2	39.9	39.9	35.3	35.3

20.1.2 Soil Surface Assessment

Scattered rocks and perennial grass tussocks continued to provide low to moderate levels of rain splash protection however this year there was slightly less perennial basal cover (Table 20-2). There was also a reduction in dead leaf litter cover but slight decomposition continued to be observed in all replicates. There was an absence of cryptogams this year but the crumbly soils had typically developed crusts and these provided a more stable and moderately hard soil surface.

There continued to be evidence of slight erosion and deposition in most cases indicating some resources have been mobilised across the site. The loss of some of the perennial grasses has also reduced soil surface relief and in most cases these resources were retained within the patch. There continued to be some variability in the slake test and this year the clay loam soils ranged from being highly unstable to moderately stable where some slumping of the sub crusts occurred when immersed in rainwater.

Table 20-2 . Results of the Soils Surface Assessment for the Pasture Rehab Slope patch.

Features	Max score	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Soil Cover	5	2	3	3	3	3
Per. basal / canopy cover	4	2	2	2	2	2
Litter cover, orig & incorp.	10	5ls	4ls	4ls	5ls	5ls
Cryptogam cover	4	1	1	1	1	1
Crust broken-ness	4	4	4	4	4	4
Erosion type & severity	4	3	3	3	4	3
Deposited materials	4	3	3	3	4	3
Soil surface roughness	5	3	3	2	3	4
Surface resist. to disturb.	5	3	2	3	3	3
Slake test	4	2	3	2	3	3
Texture	4	2	2	2	2	2

20.2 Soil analyses

The soils recorded in E22-02 continued to be moderately alkaline and continued to exceed the target range provided by the reference sites and were higher than the desirable level (Table 20-3). The Electrical Conductivity had marginally declined and continued to fall within local ranges and this year there was a small increase in organic matter content which was similar to local standards. There was no change in phosphorous which was higher than local targets but within acceptable levels but nitrate levels remained very low. There was a minor reduction in Cation Exchange Capacity which fell within targets year. Exchangeable Sodium Percentage continued to meet this KPI target indicating the soils were not sodic.

Table 20-3. Results of the soil analysis for E22-02 compared to the upper and lower values for the grassland reference sites and desirable levels from 2009 to 2013.

Nutrient	Units	E22-02					Lower KPI	Upper KPI	Desirable Level
		2009	2010	2011	2012	2013			
pH (1:5 water)	units	8.08	7.86	8.40	8.42	8.24	6.73	7.97	5.6-7.3
Conductivity (1:5 water)	dS/m	0.156	0.120	0.157	0.120	0.103	0.043	0.198	0.150
Organic Matter	%	1.55	1.6	1.4	1.3	1.6	1.6	4.1	>4.5
Phosphorus (Colwell)	mg/kg	13	17	11	11	11	5	9	50
Nitrate	mg/kg	7.9	0.5	2.8	2.4	0.8	1.2	1.4	13.0
Cation Exchange Capacity	cmol+/Kg	33.0	34.06	34.74	32.34	30.85	20.41	37.83	14.00
Exchangeable Sodium Percentage	%	2.12	1.29	1.13	0.47	0.63	0.28	4.42	<5

20.3 Rill assessment

A rill assessment was undertaken as part of the monitoring program despite most rills being much smaller (< 30cm in width or depth) than warranted to be recorded as prescribed by Nichols 2005. To identify potential rills of concern we have selected the dimensions of 10cm x 30cm (0.03m²) as the minimum value of concern.

In 2009 there were six rills with a total cross-sectional area of 0.171m² and in 2010 only three rills were considered to be active. Since 2011 one rill recorded at 30.3m along the transect has remained active and this year it had the dimensions of 0.25 x 0.45cm or a cross-sectional area of 0.113 m² and therefore continued to exceed the nominated minimum value of concern and may require amelioration (Figure 20-2).

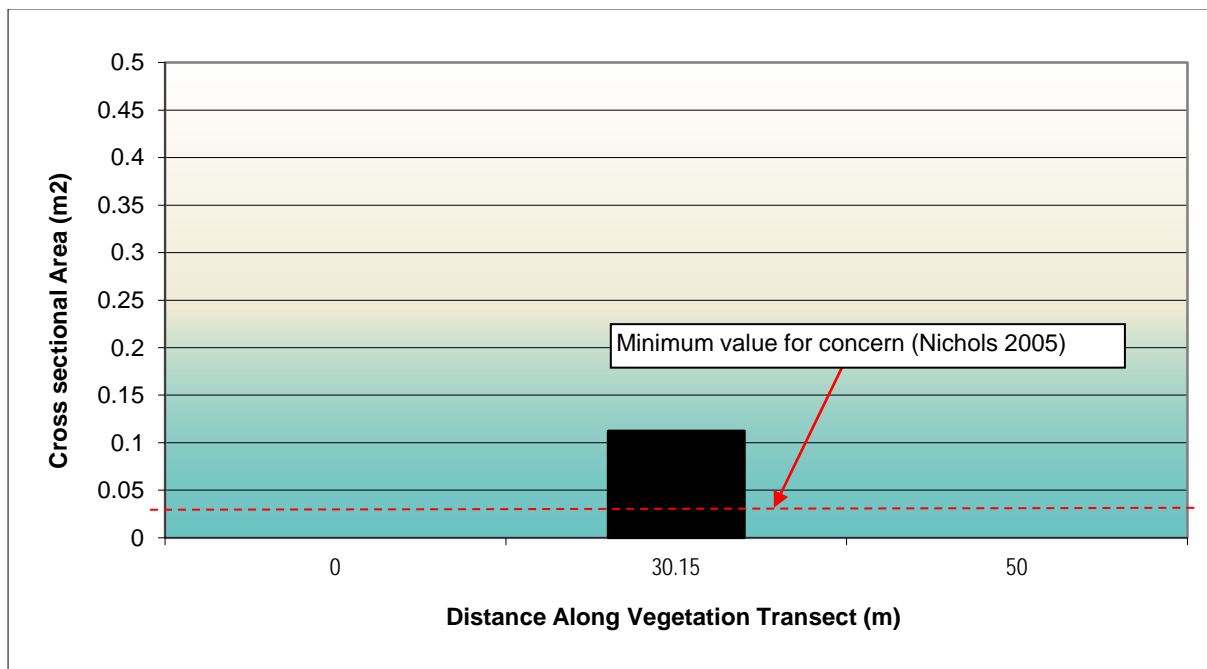


Figure 20-2 Surface area of the rills recorded along the transect.

20.4 Tree density and health condition

No trees with a diameter at breast height (dbh) greater than 5cm were present within the plot.

20.5 Shrubs and juvenile trees

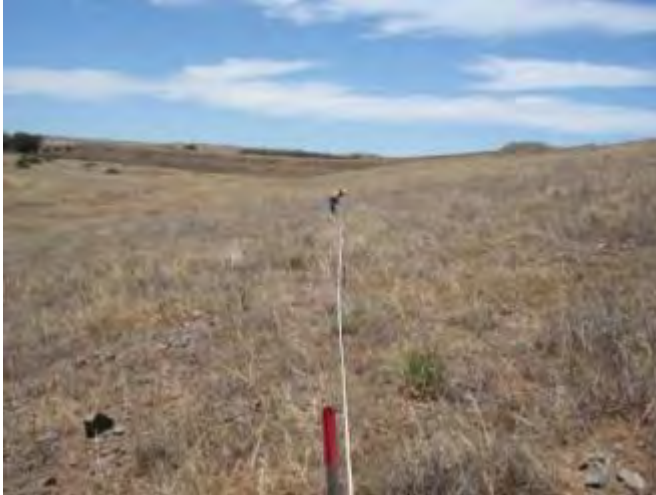
One small volunteer juvenile of *Maireana brevifolia* was recorded in 2012 however it was not relocated in 2013 and assumed to have died.

20.6 Structural diversity and habitat complexity

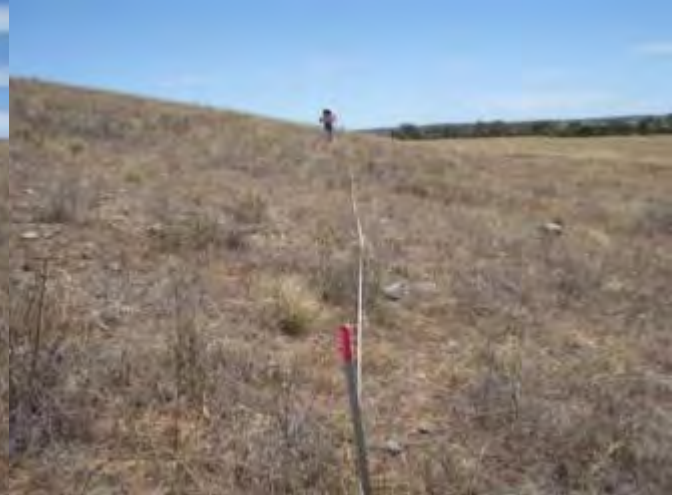
This rehabilitation site also continued to show some dramatic changes in response to the seasonal conditions and ecological processes over the past four years (Figure 20-3). The site continued to be comprised of a combination of dead leaf litter, annual and perennial plants and there has been some limited cryptogam and rock cover (Figure 20-4). There has been a marginal increase in total ground cover this year which provided 96% cover, and this was largely due to an increases in annual plants

which have increased from 17.5 – 31.5% cover, and dead litter which increased from 38.5 – 48.5%. Subsequently there has been a reduction from 26.5 – 11% perennial plants. Rocks continued to be present and provided up to 35% cover on two occasions but no cryptogams cover was recorded this year. A patch of tall grass provided vertical height > 0.5m at 5m along the transect. Table 20-4 provides the average and minimum and maximum values obtained along the vegetation transect.

2009 Vegetation transect (front)



2009 Vegetation transect (rear)



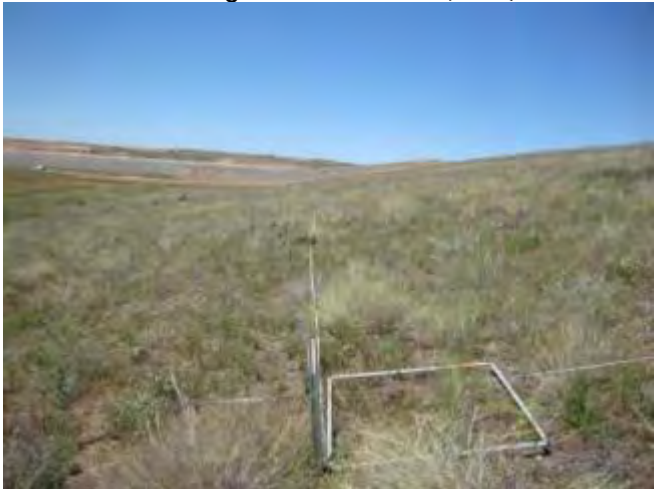
2010 Vegetation transect (front)



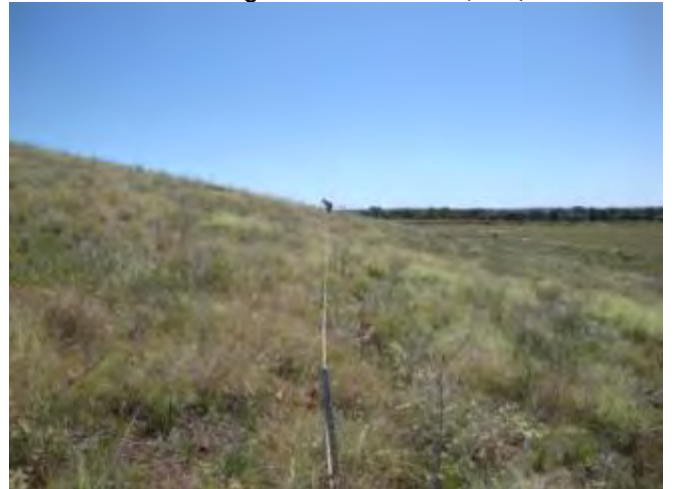
2010 Vegetation transect (rear)



2011 Vegetation transect (front)



2011 Vegetation transect (rear)



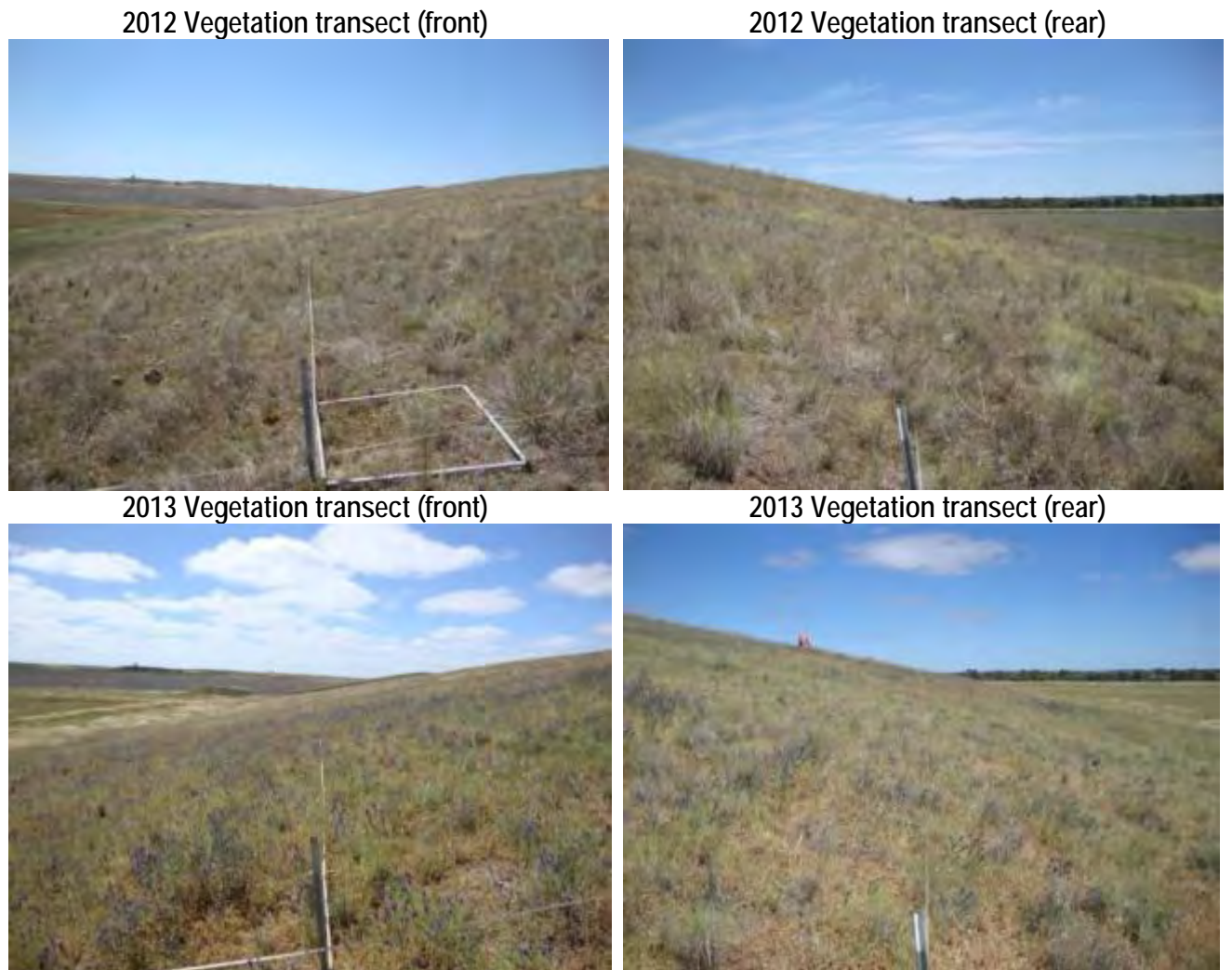


Figure 20-3. Permanent photo points taken from the front (left) and rear (right) of the vegetation transect.

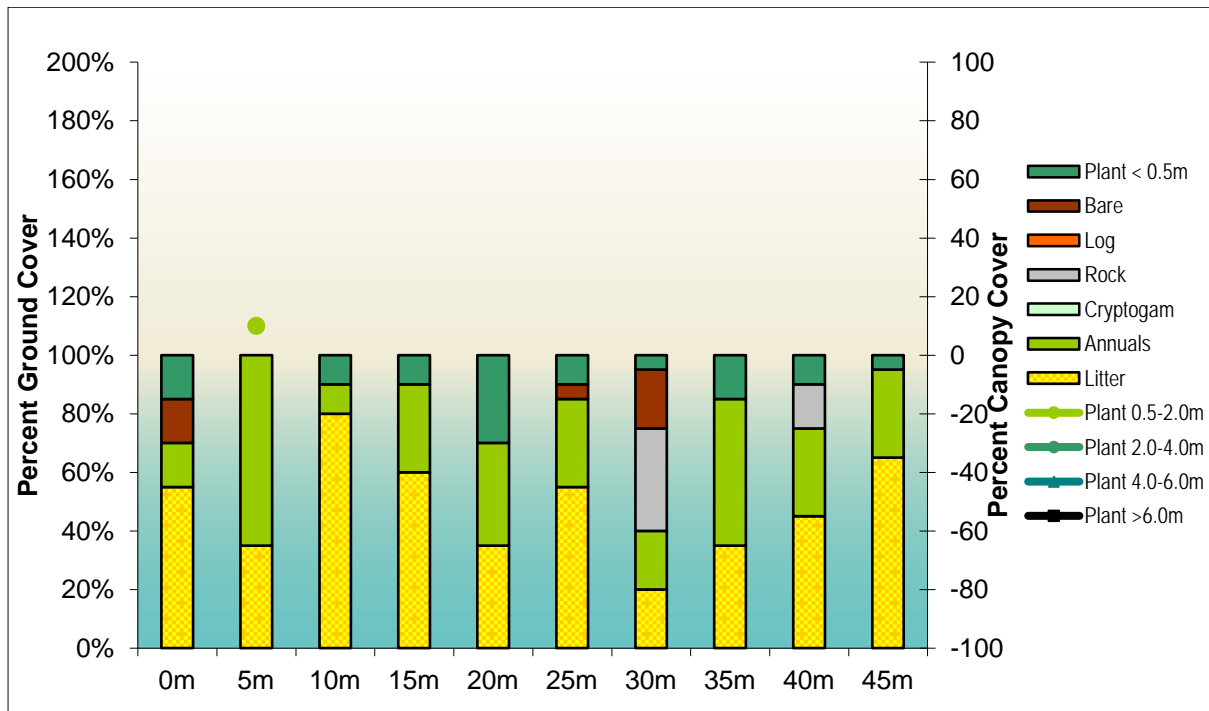


Figure 20-4. Graph illustrating the structural diversity and habitat complexity of the monitoring site.

Table 20-4. Average and minimum and maximum values of the structural diversity of the monitoring site.

Vegetation structure	0m	5m	10m	15m	20m	25m	30m	35m	40m	45m	Average	Min	Max
Litter	55	35	80	60	35	55	20	35	45	65	48.5	20	80
Annuals	15	65	10	30	35	30	20	50	30	30	31.5	10	65
Cryptogam	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	35	0	15	0	5	0	35
Log	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare	15	0	0	0	0	5	20	0	0	0	4	0	20
Perennial <0.5m	15	0	10	10	30	10	5	15	10	5	11	0	30
Total Ground Cover	85	100	100	100	100	95	80	100	100	100	96	80	100
0.5-2.0m	0	10	0	0	0	0	0	0	0	0	1	0	10
2.0-4.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0-6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
>6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0

20.7 Species cover abundance

This year there was 14 species including eight exotic species recorded in the five 1m² quadrats on the permanent vegetation transect line (Figure 20-5, Table 20-5). Using the Braun-blauquet scale, the highest possible cover score that can be obtained is 30 and cover abundance is illustrated as a sum of scores (class values) obtained along the five 1m² quadrats.

While *Atriplex spinibractea*, *Sida trichopoda* and *Lactuca serriola* were the most common species in 2009, *Medicago polymorpha* had almost entirely dominated the site in 2010, with *Echium plantagineum*, *Lolium sp.* and *Rapistrum rugosum* also being common species. Since 2011, *Walwhalleya proluta* and *Medicago polymorpha* have co-dominated the site. This year *Medicago polymorpha* was the most abundant followed by *Walwhalleya proluta*. Other common species included the exotic annual species *Avena fatua*, *Echium plantagineum* as well as *Lolium rigidum* and *Carthamus lanatus*. The native forb *Convolvulus erubescens* was also frequently encountered. The remaining species were generally infrequent or provided only low cover values. Of the cover scores recorded 36.6% was provided by native species, a reduction from 64.2% recorded last year.

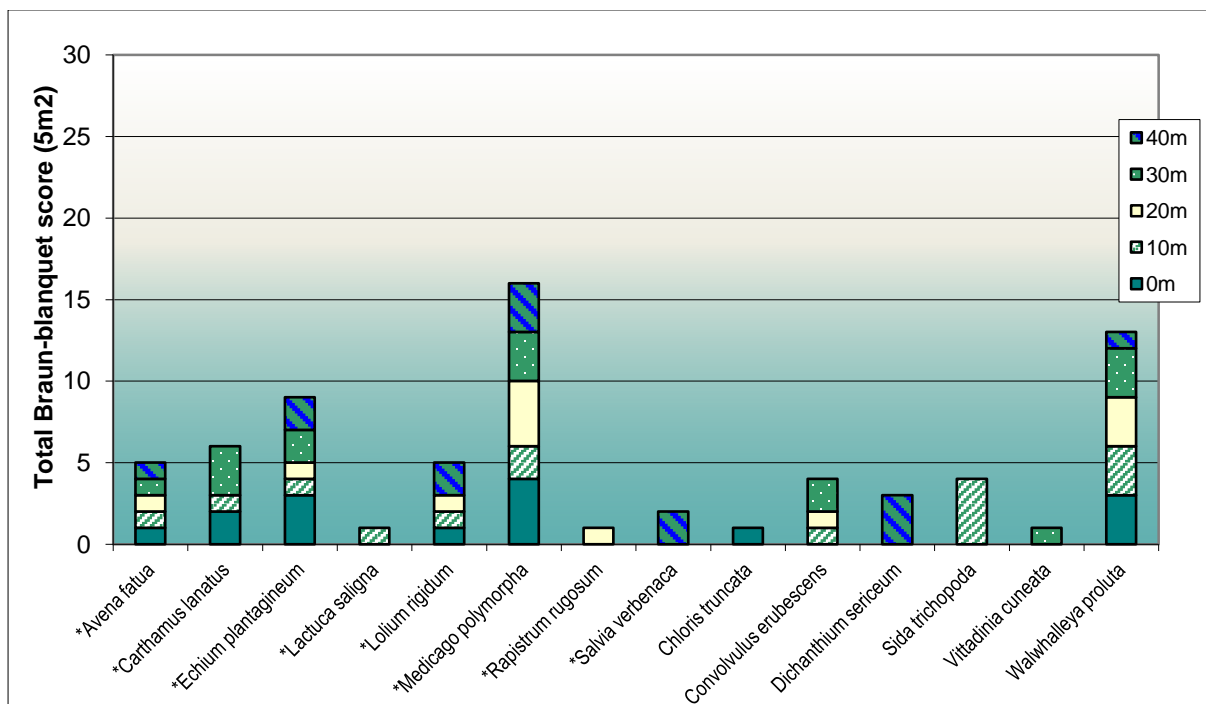


Figure 20-5. Total species recorded across the five, 1m² quadrats using the Braun-blauquet scale (max possible score is 30) as a measure of cover abundance.

Table 20-5. List of species and their average cover abundance score across the five, 1m² monitoring quadrats.

Species	0m	10m	20m	30m	40m	Total
* <i>Avena fatua</i>	1	1	1	1	1	5
* <i>Carthamus lanatus</i>	2	1		3		6
* <i>Echium plantagineum</i>	3	1	1	2	2	9
* <i>Lactuca saligna</i>		1				1
* <i>Lolium rigidum</i>	1	1	1		2	5
* <i>Medicago polymorpha</i>	4	2	4	3	3	16
* <i>Rapistrum rugosum</i>			1			1
* <i>Salvia verbenaca</i>					2	2
<i>Chloris truncata</i>	1					1
<i>Convolvulus erubescens</i>		1	1	2		4
<i>Dichanthium sericeum</i>					3	3
<i>Sida trichopoda</i>		4				4
<i>Vittadinia cuneata</i>				1		1
<i>Walwhalleya proluta</i>	3	3	3	3	1	13
Total cover						71
Sum of cover of native species						26
Percent endemic species cover						36.6

20.8 Floristic diversity

The floristic diversity of the sites was measured using two different methods. One provides an assessment of the average number of species within five, one square metre (m²) sub-quadrats along the vegetation transect, while the other provides the total number of species within the entire 50x20m monitoring plot.

20.8.1 Species diversity per m²

The number of native species recorded in the five 1m² sub-quadrats has decreased from 5.0 – 2.4 species over the past year. The average number of exotic species has however increased from 3.2 – 5.0 exotic species per m² (Table 20-6). The number of native species ranged between two to three species per m², while the number of exotic species ranged between four to six species per m².

Table 20-6. Species diversity per 1m².

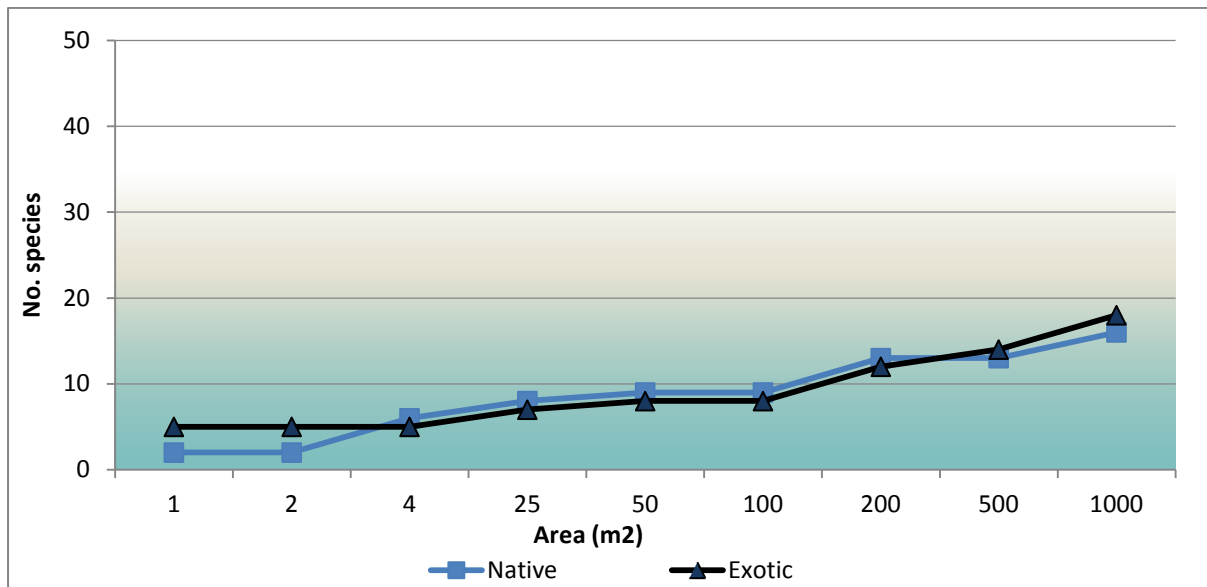
Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	2	3	2	3	2	2.4	0.5
Exotic	5	6	5	4	5	5	0.7
Total	7	9	7	7	7	7.4	0.9

20.8.2 Total species diversity

The overall total diversity recorded in the 20x50m monitoring quadrat has slightly increased from 32 – 34 over the past year. While there continued to be 16 native species, there were now 18 exotic species (Table 20-7, Figure 20-6). The very low and flat species area curve indicates the site was very homogenous. A list of species recorded within the monitoring site is provided in Appendix 1.

Table 20-7. Cumulative species diversity.

Area (m ²)	1	2	4	25	50	100	200	500	1000
Native	2	2	6	8	9	9	13	13	16
Exotic	5	5	5	7	8	8	12	14	18

Figure 20-6. Cumulative species in the 50m x 20m (1000m²) monitoring quadrat.

20.9 Growth forms

Figure 20-7 is a summary of species in each growth form that were recorded in the site. Herbs, continued to be the most dominant plant type with 24 species including 15 exotic species, followed by grasses with nine species including three exotic species and there was one native sub-shrub. No tree, shrub, reed or fern representatives were present this year. Compared to the grassland reference there was a low diversity of herb and grass species.

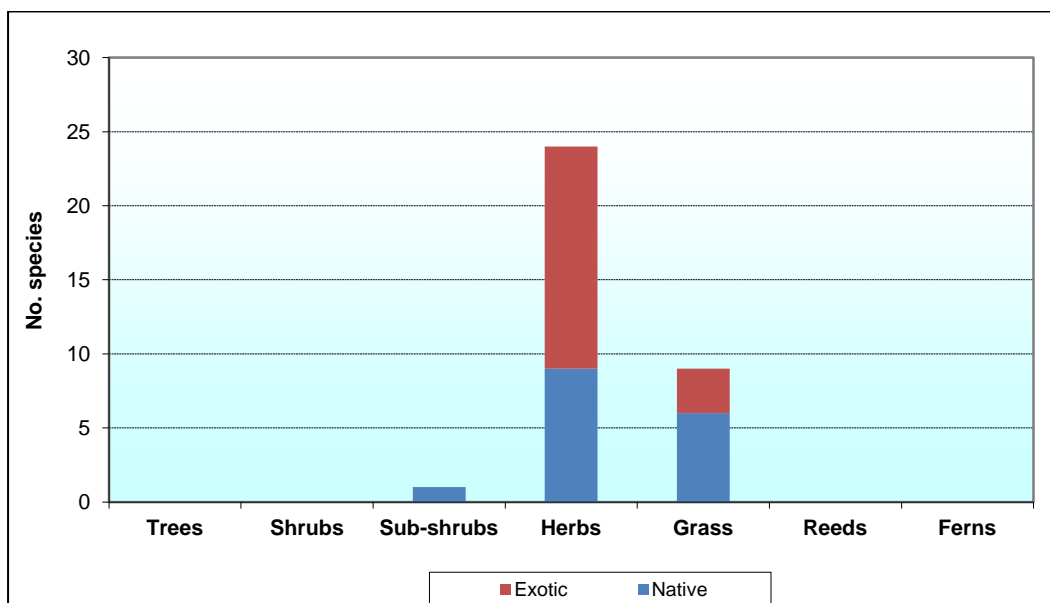


Figure 20-7. Graph illustrating the growth forms of species recorded in the 50m x 20m monitoring quadrat.

20.10 Comparison of rehabilitation data with key performance indicators

Table 20-8 indicates the performance of the rehabilitation monitoring site against the Completion and Desirable Performance Indicators developed for grassland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) for example and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 20-8. Comparison of key performance Indicators recorded in the rehabilitation site E22-02 compared to lower and upper limits recorded in the grassland reference sites.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E22-02				
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2009	2010	2011	2012	2013
Phase2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	1	3	12.0	12.0	12.0	12.0	12.0
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%	64.5	73.0	46.1	63.4	65.6	63.0	60.5
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%	29.3	46.3	31.0	37.7	43.7	45.4	39.9
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%	28.1	43.2	21.5	33.9	40.2	39.9	35.3
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%	100	100	4	85	92	100	100

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E22-02				
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising		No.	0	0	6	3	1	1	1
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0.171	0.135	0.124	0.135	0.113
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)	6.73	7.97	8.08	7.86	8.40	8.42	8.24
			EC		Electrical Conductivity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	< dS/m (<0.150)	0.043	0.198	0.156	0.120	0.157	0.120	0.103
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	1.6	4.1	1.6	1.6	1.4	1.3	1.6
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	5.3	8.6	13.0	17.0	10.6	11.2	11.2
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	1.2	1.4	7.9	0.5	2.8	2.4	0.8
			CEC		Cation Exchange Capacity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	Cmol+/kg (>14)	20.4	37.8	33.01	34.06	34.74	32.34	30.8
			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	4.4	2.12	1.29	1.13	0.47	0.6
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees		The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.	species/area	0	0	0	0	0	1	0
					The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation	% population	0	0	na	na	NA	100	na
			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	37	52	24	29	34	32	34

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E22-02				
			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	19	38	15	14	18	16	16
			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	14	20	9	15	16	16	18
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees		The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	1	0
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees		The number of tree species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			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	0	0	0	1	0
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	4	2	2	1	1	1
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	26	34	17	20	25	23	24
			Grasses	The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	11	15	5	7	8	7	9
			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	0	0	0	0	0	0
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			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
Phase 5: Ecosystem & Landuse Development	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	%	36	52	52	18.0	45	38.5	48.5
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	4	39	0.2	64.3	11	17.5	31.5

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E22-02				
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	17	0.0	0	0	1.5	0
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0	0	5.7	6.7	5.5	6	5
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	3	15	37.8	8.7	10.5	10.0	4
			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		%	16	30	4.3	2.3	28.0	26.5	11.0
			Total Ground Cover	Total groundcover is the sum of protective ground cover components (as described above) and that it is comparable to that of the local remnant vegetation		%	86	97	62.2	91.3	89.5	90.0	96
	Ground cover diversity	Vegetation contains a diversity of species per square meter comparable to that of the local remnant vegetation	Native understorey abundance		The abundance of native species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has more than or an equal number of native species as the local remnant vegetation	> species/m ²	3	11	1.4	1.8	4.0	5	2.4
			Exotic understorey abundance		The abundance of exotic species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has less than or an equal number of exotic species as the local remnant vegetation	< species/m ²	4	7	0.8	5.6	4.8	3.2	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 height) compared to exotic species is comparable to that of the local remnant vegetation		%	29	77	na	16.9	56.6	64.2	36.6
	Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	shrubs and juvenile trees 0 - 0.5m in height		The number of shrubs or juvenile trees < 0.5m in height provides an indication of establishment success and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	1	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E22-02				
			shrubs and juvenile trees 0.5 - 1m in height		The number of shrubs or juvenile trees 0.5-1m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			shrubs and juvenile trees 1 - 1.5m in height		The number of shrubs or juvenile trees 1-1.5m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	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 comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			shrubs and juvenile trees >2m in height		The number of shrubs or juvenile trees > 2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
	Ecosystem structure	The vegetation is developing in structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5 - 2 m	Projected foliage cover provided by perennial plants in the 0.5 - 2m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover	0	5	0	4.8	0	0	1
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 - 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
			Foliage cover >6m		Projected foliage cover provided by perennial plants > 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	0	0	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E22-02				
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	0	0	na	na	0	0	0
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	0	0	0	0	0	0	0
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees		The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Healthy trees		The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Medium health		The percentage of the tree population which are in a medium health condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Advanced dieback		The percentage of the tree population which are in a state of advanced dieback and that the percentage is comparable to the local remnant vegetation	<% population	0	0	0	0	0	0	0
			Dead Trees		The percentage of the tree population which are dead (stags) and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			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
			Flowers/fruit: Trees		The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation	% population	0	0	0	0	0	0	0

21 E26-01 site description

E26-01 is located on the north eastern slope of the waste emplacement surrounding the E26 subsidence zone. This site had generally good ground cover with scattered tussocks of *Walwhalleya proluta* and had a range of exotic annual such as *Avena* and *Lolium*. In 2009, the vegetation was particularly stressed with very little active growth and the floristic diversity was significantly low. In 2010, there was a significant increase in diversity of native and exotic plants and the site was particularly green and stable. In 2011 the site was dominated by a dense sward of *Walwhalleya proluta* with occasional scattered weeds. The site was green and the grasses were actively growing and seeding. In 2012 and 2013 the site was very dry.

21.1 Landscape Function Analysis

21.1.1 Landscape organisation

Site E26-01 continued to be characterised as a grassy slope with no bare patches and continued to score a Landscape Organisation Index of 1.0 or 100% (Figure 21-1, Table 21-1). The onset of dry conditions between 2011 and 2012 had resulted in a decline in active perennial plant cover which subsequently affected the overall ecological function. This year however there has essentially been no further changes recorded in this site indicating this site is particularly resilient and appears to be ecologically very sustainable, despite the adverse conditions. The resultant LFA indices for stability, infiltration and nutrient recycling were 71.0, 46.1 and 41.8 respectively. Compared to the grassland reference sites, stability, infiltration and nutrient recycling indices were 6.5, 16.8 and 13.7 LFA units higher than the minimum KPI targets and therefore continued to satisfy these completion criteria.

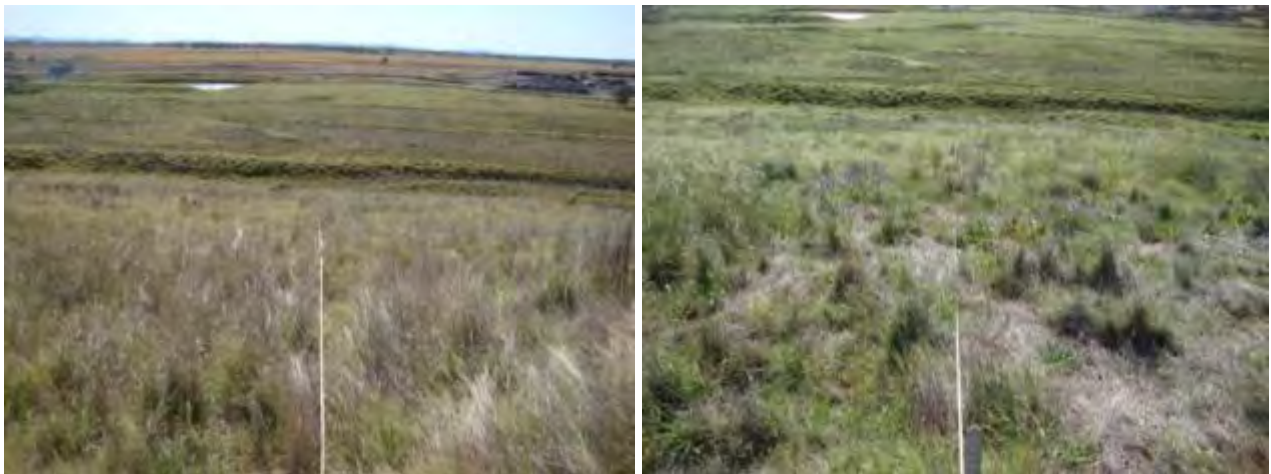


Figure 21-1. Permanent photo point taken from the top of the LFA transect in 2012 (left) and 2013 (right).

Table 21-1. Summary of landscape organisation and LFA indices from 2009 to 2013.

E26-01		9/12/2009		13/09/2010		17/10/2011		15/10/2012		14/10/2013	
Number of Patches/10m		0.5		0.5		0.5		0.5		0.5	
Total Patch Area (m2)		200		200		200		200		20.00	
Patch Area Index		1		1		1		1		0.10	
Landscape Organisation Index		1		1		1		1		1.00	
Average Interpatch Length (m)		NA		NA		NA		NA		NA	
Range Interpatch length (m)		NA		NA		NA		NA		NA	
Patch or Interpatch Type		Grassy Slope		Grassy Slope		Grassy Slope		Grassy Slope		Grassy Slope	
Patch or Interpatch Proportion (%)		100	100	100	100	100	100	100	100	100.0	100
Soil Surface Assessment											
Within Individual Zones	Stability	63		70		74.5		71.5		71.0	
	Infiltration	45.1		46.7		47.5		46.1		46.1	
	Nutrients	39		43		44.6		41.8		41.8	
			Total		Total		Total		Total		Total
Individual zones contribution to the whole of Landscape	Stability	63	63	70	70	74.5	74.5	71.5	71.5	71.0	71.0
	Infiltration	45.1	45.1	46.7	46.7	47.5	47.5	46.1	46.1	46.1	46.1
	Nutrients	39	39	43	43	44.6	44.6	41.8	41.8	41.8	41.8

21.1.2 Soil Surface Assessment

The results of the Soil Surface Assessment (SSA) indicate there has been minor decline in protective plant cover but they continue to provide variable but typically low to moderate levels of protection against rain splash and perennial basal area (Table 21-2). Litter cover continued to be very high and accumulated to some depth along most of the transect and slight decomposition of the dead leaf material was evident in all samples indicating good microbial and fungal activity was occurring within the site. There continued to be an absence of cryptogams probably due to the high ground cover however the soils remained moderately hard and crusted. The relatively dense grass sward continued to provide moderate soil surface relief and this year the extent of erosion and deposition was negligible. The clay loam soils continued to be very stable.

Table 21-2 . Results of the Soils Surface Assessment for the Grassy Slope patch.

Features	Max score	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Soil Cover	5	3	2	3	4	2
Per. basal / canopy cover	4	3	2	3	4	2
Litter cover, orig & incorp.	10	6ls	6ls	5ls	6ls	5ls
Cryptogam cover	4	1	1	1	1	1
Crust broken-ness	4	4	4	4	4	4
Erosion type & severity	4	4	4	4	4	4
Deposited materials	4	4	4	4	4	4
Soil surface roughness	5	3	3	3	4	2
Surface resist. to disturb.	5	3	3	3	3	3
Slake test	4	4	4	4	4	4
Texture	4	2	2	2	2	2

21.2 Soil analyses

The soil pH recorded in E26-01 has slightly increased putting it into the moderately alkaline category, however it continued to fall local pH ranges (Table 21-3). There was little change in Electrical Conductivity and this continued to fall within the target range provided by the reference sites. There was a marginal decline in organic matter levels and while these were low they were typical of the local soils and continued to meet this completion target this year.

Phosphorous and nitrate levels have demonstrated a decline and while phosphorous was higher than local levels it remained with acceptable concentrations and nitrate levels were also typical this year. There was a minor increase in CEC values which were typical of the local area and the ESP values remained low indicating the soils are non sodic.

Table 21-3 . Results of the soil analysis for E26-01 compared to the upper and lower values for the grassland reference sites and desirable levels from 2009 to 2013.

Nutrient	Units	E26-01					Lower KPI	Upper KPI	Desirable Level
		2009	2010	2011	2012	2013			
pH (1:5 water)	units	7.47	7.29	7.48	7.31	7.91	6.73	7.97	5.6 – 7.3
Conductivity (1:5 water)	dS/m	0.123	0.087	0.105	0.084	0.081	0.043	0.198	0.150
Organic Matter	%	2.32	2.8	2.8	3.7	2.4	1.6	4.1	>4.5
Phosphorus (Colwell)	mg/kg	35	47	32	36	19	5	9	50
Nitrate	mg/kg	9.8	1.4	4.8	4.6	1.3	1.2	1.4	13.0
Cation Exchange Capacity	cmol+/Kg	26.5	24.97	23.16	23.37	24.63	20.41	37.83	14.00
Exchangeable Sodium Percentage	%	1.47	0.98	1.96	1.77	1.78	0.28	4.42	<5

21.3 Rill assessment

No rills of concern have been recorded in any monitoring year.

21.4 Tree density and health condition

No trees with a diameter at breast height (dbh) greater than 5cm have been recorded in this monitoring site.

21.5 Shrubs and juvenile trees

There continued to be only one volunteer *Maireana brevifolia* (Yanga Bush) plant recorded in the site and this was 1.0 – 1.5m in height (Table 21-4).

Table 21-4. Shrubs and young trees occurring within the monitoring site.

Species	0 - 0.5m	0.5 - 1.0m	1.0 - 1.5m	1.5 - 2.0m	>2.0m	Total	endemic	not endemic
<i>Maireana brevifolia</i>			1			1	1	
Total	0	0	1	0	0	1	1	0
% endemic species							100	0

21.6 Structural diversity and habitat complexity

This rehabilitation site continued to be structurally simple and has continued to change in response to the seasonal conditions and ecological processes occurring within the site (Figure 21-2). Over the last year the site has maintained high total ground cover levels however this year there has been a significant increase from 2.5 – 29% annual plant cover and a significant reduction on perennial plants which have declined from 54 – 30%. There were negligible changes in dead litter cover which provided the remaining 41% cover (Table 21-5, Figure 21-3). A grass tussock provided low levels of vertical cover greater than 0.5m in height at 0m but typically a short grass cover was maintained. Table 21-5 provides the average and minimum and maximum values obtained along the vegetation transect.

2009 Vegetation transect (front)



2009 Vegetation transect (rear)



2010 Vegetation transect (front)



2010 Vegetation transect (rear)



2011 Vegetation transect (front)



2011 Vegetation transect (rear)



2012 Vegetation transect (front)



2012 Vegetation transect (rear)



2013 Vegetation transect (front)



2013 Vegetation transect (rear)



Figure 21-2. Permanent photo points taken from the front (left) and rear (right) of the vegetation transect.

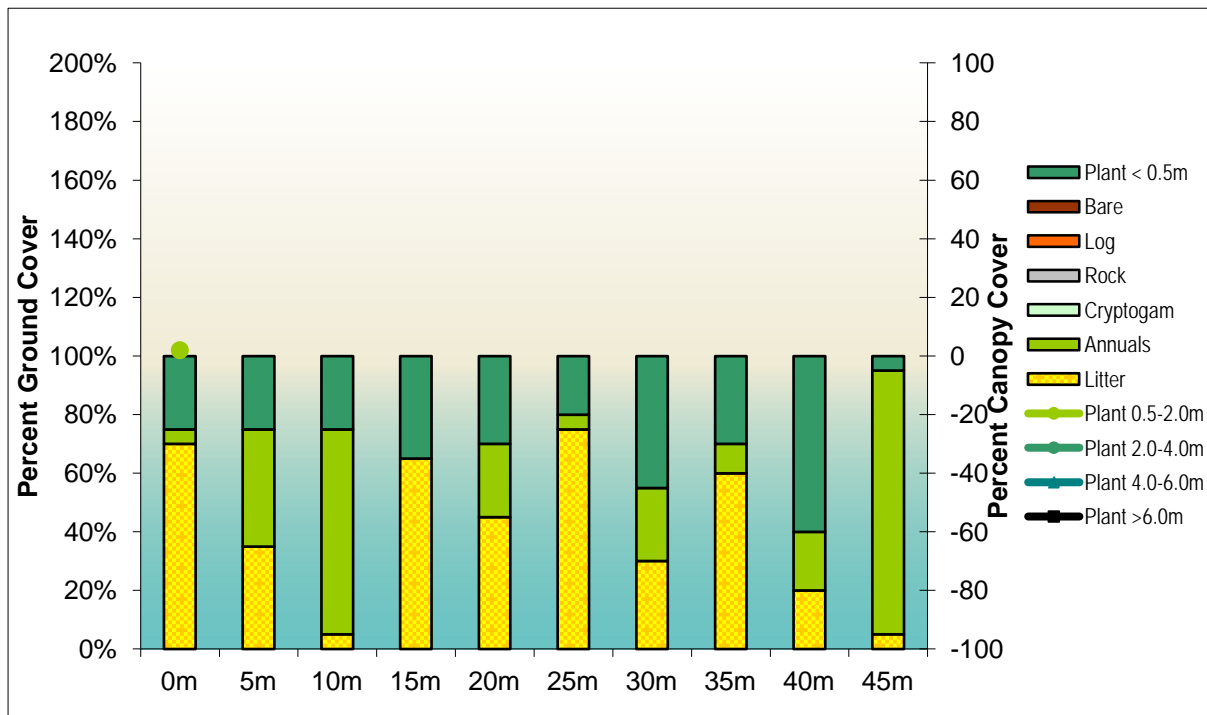


Figure 21-3. Graph illustrating the structural diversity and habitat complexity of the monitoring site.

Table 21-5. Average and minimum and maximum values of the structural diversity of the monitoring site.

Vegetation structure	0m	5m	10m	15m	20m	25m	30m	35m	40m	45m	Average	Min	Max
Litter	70	35	5	65	45	75	30	60	20	5	41	5	75
Annuals	5	40	70	0	25	5	25	10	20	90	29	0	90
Cryptogam	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0	0	0	0	0	0
Log	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare	0	0	0	0	0	0	0	0	0	0	0	0	0
Perennial <0.5m	25	25	25	35	30	20	45	30	60	5	30	5	60
Total Ground Cover	100	100	100	100	100	100	100	100	100	100	100	100	100
0.5-2.0m	2	0	0	0	0	0	0	0	0	0	0.2	0	2
2.0-4.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0-6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
>6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0

21.7 Species cover abundance

There were 15 species recorded in the five 1m² quadrats on the permanent vegetation transect line this year and of these ten were exotic species, eight more than recorded last year. Using the Braun-blauquet scale, the highest possible cover score that can be obtained is 30 and cover abundance is illustrated as a sum of scores (class values) obtained along the five 1m² quadrats.

Since 2009 *Walwhalleya proluta* has provided the most dominant plant cover with the exotics, *Avena fatua*, *Lolium rigidum*, *Bromus diandrus* and *Trifolium repens* also being relatively common or abundant. Since 2011, there has been a marked increase in cover provided by *Walwhalleya proluta* and many of the exotics species being less common with some species not being recorded again. In 2013 *Walwhalleya proluta* continued to dominate the site however the exotic climber *Vicia villosa* was also relatively abundant this year (Figure 21-4, Table 21-6). The remaining species were less frequent and provided low cover scores. Of the cover scores recorded only 52.5% was provided by native species, a reduction from 91.1% recorded last year.

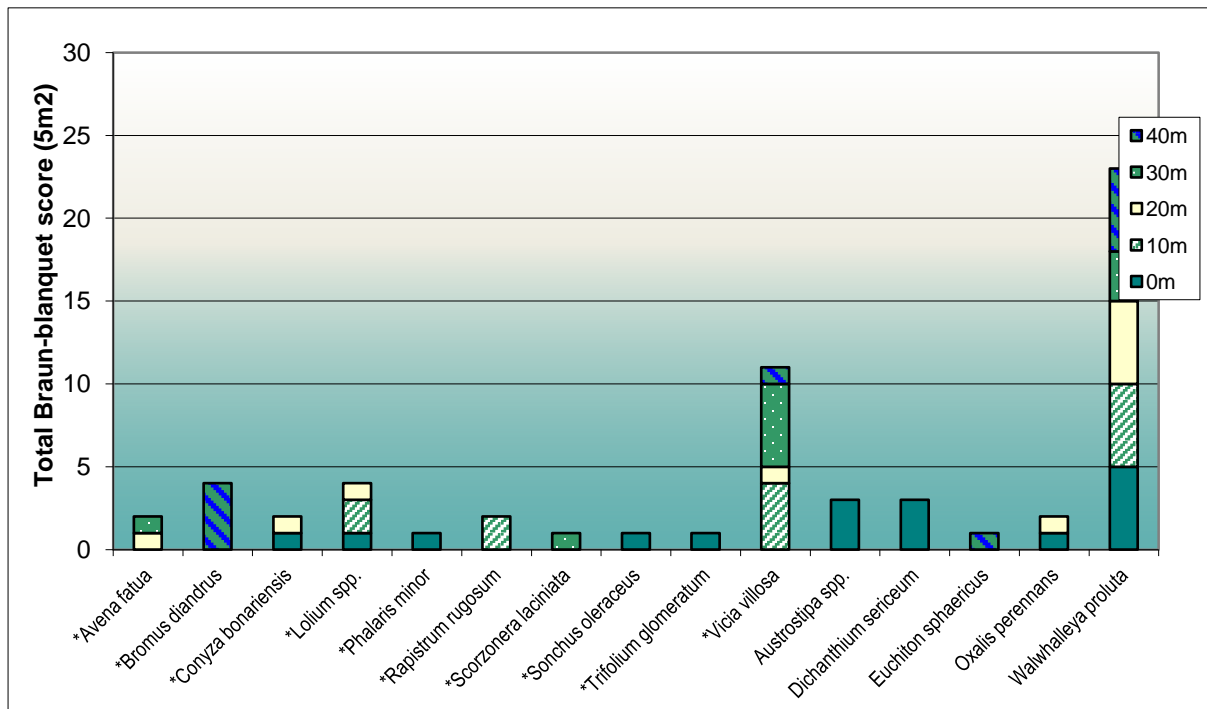


Figure 21-4. Total species recorded across the five, 1m² quadrats using the Braun-blanket scale (max possible score is 30) as a measure of cover abundance.

Table 21-6. List of species and their average cover abundance score across the five, 1m² monitoring quadrats.

Species	0m	10m	20m	30m	40m	Total
*Avena fatua			1	1		2
*Bromus diandrus					4	4
*Conyza bonariensis	1		1			2
*Lolium spp.	1	2	1			4
*Phalaris minor	1					1
*Rapistrum rugosum		2				2
*Scorzonera laciniata				1		1
*Sonchus oleraceus	1					1
*Trifolium glomeratum	1					1
*Vicia villosa		4	1	5	1	11
Austrostipa spp.	3					3
Dichanthium sericeum	3					3
Euphorbia corollata					1	1
Oxalis perennans	1		1			2
Waltheria prolata	5	5	5	3	5	23
Total cover						61
Sum of cover of native species						32
Percent endemic species cover						52.5

21.8 Floristic diversity

The floristic diversity of the sites was measured using two different methods. One provides an assessment of the average number of species within five, one square metre (m²) sub-quadrats along the vegetation transect, while the other provides the total number of species within the entire 50x20m monitoring plot.

21.8.1 Species diversity per m²

This year there has been no change in the average number of native species recorded in the five 1m² sub-quadrats which remained at 2.0 species per m². The average number of exotic species has been more variable and over the past year have increased from 0.4 – 3.4 exotic species per m² (Table 21-7). The number of native species ranged between one and four, while the number of exotic species ranged between two and five species per m².

Table 21-7. Species diversity per 1m².

Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	4	1	2	1	2	2	1.2
Exotic	5	3	4	3	2	3.4	1.1
Total	9	4	6	4	4	5.4	2.2

21.8.2 Total species diversity

There has been an increase from 23 – 36 live plant species recorded in the 50 x 20m monitoring quadrat this year and of these 14 were native species. The sharp increase at 4m² indicates a patch of exotic weeds was encountered but otherwise the site was relatively homogenous (Figure 21-5, Table 21-8). A list of species recorded within the monitoring site is provided in Appendix 1.

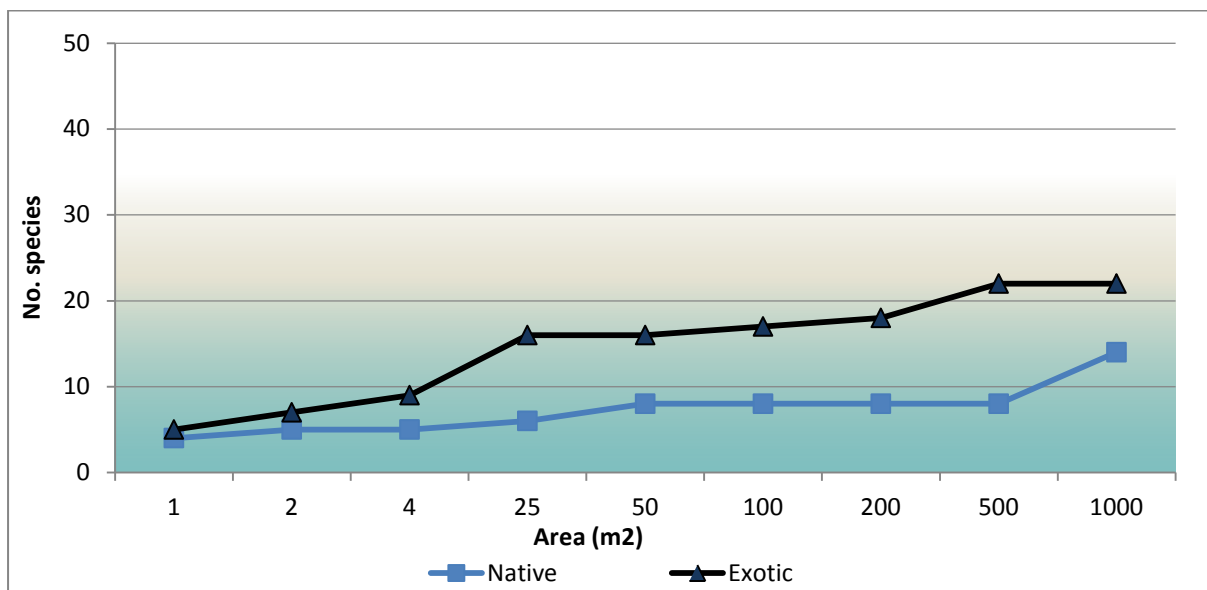


Figure 21-5. Cumulative species in the 50m x 20m (1000m²) monitoring quadrat.

Table 21-8. Cumulative species diversity.

Area (m2)	1	2	4	25	50	100	200	500	1000
Native	4	5	5	6	8	8	8	8	14
Exotic	5	7	9	16	16	17	18	22	22

21.9 Growth forms

Figure 21-6 is a summary of species in each growth form that were recorded in the site. Herbs continued to be the most dominant plant type with 25 species, including 17 exotics species. There were ten species of grass including five exotic species and one native shrub. No tree, sub-shrub, reed or fern representatives were present. Compared to the grassland reference there was a low diversity of herb and grass species.

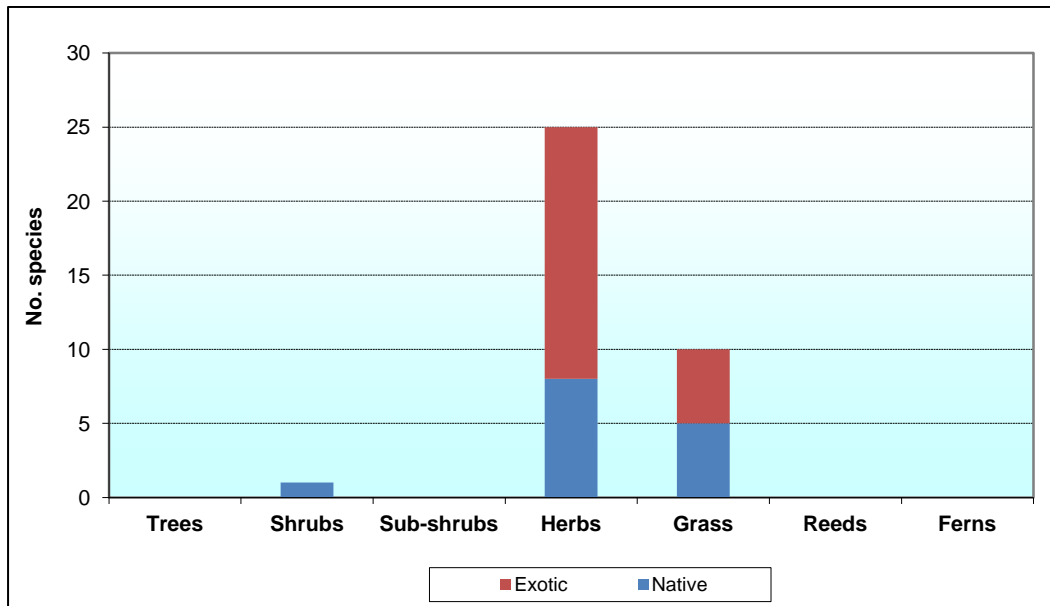


Figure 21-6. Graph illustrating the growth forms of species recorded in the 50m x 20m monitoring quadrat.

21.10 Comparison of rehabilitation data with key performance indicators

Table 21-9 indicates the performance of the rehabilitation monitoring site against the Completion and Desirable Performance Indicators developed for grassland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) for example and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 21-9. Comparison of key performance Indicators recorded in the rehabilitation site E26-01 compared to lower and upper limits recorded in the grassland reference sites.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E26-01				
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2009	2010	2011	2012	2013
Phase2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	1	3	15.0	15.0	15.0	15.0	15.0
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the Sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%	64.5	73.0	63.0	70.0	74.5	71.5	71.0
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%	29.3	46.3	45.1	46.7	47.5	46.1	46.1
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%	28.1	43.2	39.0	43.0	44.6	41.8	41.8
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%	100	100	100	100	100	100	100

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E26-01				
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising		No.	0	0	0	0	0	0	0
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0	0	0	0	0
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)	6.73	7.97	7.47	7.28	7.48	7.31	7.91
			EC		Electrical Conductivity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	< dS/m (<0.150)	0.043	0.198	0.123	0.087	0.105	0.084	0.081
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	1.6	4.1	2.3	2.8	2.8	3.7	2.4
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	5.3	8.6	54.8	17.2	51.5	55.7	18.7
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	1.2	1.4	9.8	1.4	4.8	4.6	1.3
			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)	20.4	37.8	26.54	24.97	23.16	23.37	24.6
			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	4.4	1.47	0.98	1.96	1.77	1.8
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees		The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.	species/area	0	0	1	1	1	1	1
					The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation	% population	0	0	na	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	37	52	5	36	34	23	36

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E26-01				
			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	19	38	5	16	16	12	14
			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	14	20	0	20	18	11	22
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees		The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation	No./area	0	0	1	1	1	1	1
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees		The number of tree species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Shrubs		The number of shrub species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	1	1	1	1	1
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	4	0	1	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	26	34	2	22	23	14	25
			Grasses	The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	11	15	2	12	10	8	10
			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	0	0	0	0	0	0
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			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
Phase 5: Ecosystem & Landuse Development	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	%	36	52	86.5	47	38.5	42.5	41
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	4	39	0	24	4	2.5	29

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E26-01				
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	17	0.0	0	0.5	0	0
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	3	15	0.5	0.5	0.5	1	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		%	16	30	13	28.5	56.5	54	30
			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		%	86	97	99.5	99.5	99.5	99	100
	Ground cover diversity	Vegetation contains a diversity of species per square meter comparable to that of the local remnant vegetation	Native understorey abundance		The abundance of native species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has more than or an equal number of native species as the local remnant vegetation	> species/m ²	3	11	1.2	3.0	2.0	2.0	2.0
			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	4	7	0	3.8	1.8	0.4	3.4
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation		%	29	77	na	46.6	75.5	91.1	52.5
	Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	shrubs and juvenile trees 0 - 0.5m in height		The number of shrubs or juvenile trees < 0.5m in height provides an indication of establishment success and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E26-01				
			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	1	1	0	0	0
			shrubs and juvenile trees 1 - 1.5m in height		The number of shrubs or juvenile trees 1-1.5m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	1	1	1
			shrubs and juvenile trees 1.5 - 2m in height		The number of shrubs or juvenile trees 1.5-2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			shrubs and juvenile trees >2m in height		The number of shrubs or juvenile trees > 2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
	Ecosystem structure	The vegetation is developing in structure and complexity comparable to that of the local remnant vegetation	Foliage cover 0.5 - 2 m	Projected foliage cover provided by perennial plants in the 0.5 - 2m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation		% cover	0	5	0	0	18	0.5	0.2
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 - 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
			Foliage cover >6m		Projected foliage cover provided by perennial plants > 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	0	0	0	0	0	0	0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E26-01				
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	0	0	na	na	0	0	0
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	0	0	0	0	0	0	0
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees		The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Healthy trees		The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Medium health		The percentage of the tree population which are in a medium health condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			Advanced dieback		The percentage of the tree population which are in a state of advanced dieback and that the percentage is comparable to the local remnant vegetation	<% population	0	0	0	0	0	0	0
			Dead Trees		The percentage of the tree population which are dead (stags) and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			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
			Flowers/fruit: Trees		The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation	% population	0	0	0	0	0	0	0

22 E27-01 site description

E27-01 is located on the western side of the E27 open cut waste rock emplacement. The site had generally good ground cover with scattered native perennial grasses and scattered establishment of *Maireana brevifolia* (Yanga Bush), *Senna artemisioides* (Silver Cassia) and *Acacia brachystachya* (Umbrella Mulga). In 2009, there was little green growth with all the annual species being dead. In 2010, there was a significant increase in cover provided a range of annual plants especially *Vicia villosa* and *Medicago polymorpha* which may have compromised the floristic diversity of the site (it was particularly difficult to detect plants beneath the dense cover of *Vicia* and *Medicago*). Well used Kangaroo camps exist under the larger shrubs within the site. In 2011 there was a significant reduction in the abundance of exotic annuals (especially *Vicia* and *Medicago*) and there was an increase in native perennial plant cover. In 2012 and 2013 the site continued to be very dry and Kangaroo camps continue to exist under the larger shrubs within the site.

22.1 Landscape Function Analysis

22.1.1 Landscape organisation

In 2009 and 2010 site E27-01 was characterised as a grassy rehabilitation slope with a small bare area on the contour bank at the lower end of the transect. However since 2011 the site has been characterised as a grassy rehabilitation slope due to the establishment of plants within the contour drain and loss of the bare interpatch area (Figure 22-1). Since then the grassy slope has continued to dominate 100% of the site (Table 22-1) and while it was tending to demonstrate an increasing trend in ecological function, the prolonged dry conditions has resulted in a deterioration in function this year.

The resultant LFA indices for stability, infiltration and nutrient recycling were 69.5, 47.8 and 45.0 respectively. Compared to the minimum LFA targets for stability, infiltration and nutrient recycling indices were 5.0, 18.5 and 16.9 LFA units higher respectively and this year continued to meet all LFA related targets.



Figure 22-1. Permanent photo point taken from the top of the LFA transect in 2011 (left), 2012 (centre) and 2013 (right).

Table 22-1. Summary of landscape organisation and LFA indices from 2009 to 2013.

E27-01		8/12/2009			15/09/2010			17/10/2011		15/10/2012		14/10/2013	
Number of Patches/10m		1			1			0.5		0.5		0.5	
Total Patch Area (m2)		189			195			200		200		200.00	
Patch Area Index		0.93			0.96			1		1		1.00	
Landscape Organisation Index		0.93			0.96			1		1		1.00	
Average Interpatch Length (m)		1.4			0.8			NA		NA		NA	
Range Interpatch length (m)		1.4 to 1.4			0.8 to 0.8			NA		NA		NA	
Patch or Interpatch Type		Grassy Rehab Slope	Contour Drain		Grassy Rehab Slope	Contour drain		Grassy Rehab Slope	Grassy Rehab Slope			Grassy Rehab Slope	
Patch or Interpatch Proportion (%)		93.1	6.9	100	96.1	3.9	100	100	100	100	100	100.0	100
Soil Surface Assessment													
Within Individual Zones	Stability	57.1	47.5		68.1	55		69.6		77.2		69.5	
	Infiltration	46	17.5		48.5	23.3		47.6		52.7		47.8	
	Nutrients	40.9	14		47.8	18.6		46.7		53.4		45.0	
		Total			Total			Total		Total		Total	
Individual zones contribution to the whole of Landscape	Stability	53.1	3.3	56.4	65.4	2.2	67.6	69.6	69.6	77.2	77.2	69.5	69.5
	Infiltration	42.8	1.2	44	46.6	0.9	47.5	47.6	47.6	52.7	52.7	47.8	47.8
	Nutrients	38.1	1	39	45.9	0.7	46.6	46.7	46.7	53.4	53.4	45.0	45.0

22.1.2 Soil Surface Assessment

The results of the Soil Surface Assessment (SSA) indicate there has been minor decline in protective plant cover but they continue to provide low to moderate levels of protection against rain splash and perennial basal area ((Table 22-2)). Litter cover continued to be very high and had accumulated to some depth in patches along most of the transect and slight to moderate decomposition was evident in all samples indicating good microbial and fungal activity was occurring within the site. There was typically an absence of cryptogams probably due to the high ground cover however the soils remained moderately hard and all samples were crusted this year. There continued to be a small population of cryptogams in replicate 3. Fewer grass tussocks also resulted in a lower soil surface relief, however moderate roughness and retention capacity was retained. There was no evidence of erosion and deposition and the clay loam soils continued to be very stable, except on one occasion where some slumping of the sub-crust was observed when immersed in rain water.

Table 22-2 . Results of the Soils Surface Assessment for the Grassy Rehab Slope patch.

Features	Max score	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5
Soil Cover	5	2	2	2	3	2
Per. basal / canopy cover	4	1	2	2	3	2
Litter cover, orig & incorp.	10	6lm	5ls	5ls	6lm	6lm
Cryptogam cover	4	1	1	2	1	1
Crust broken-ness	4	4	4	4	4	4
Erosion type & severity	4	4	4	4	4	4
Deposited materials	4	4	4	4	4	4
Soil surface roughness	5	3	3	3	4	3
Surface resist. to disturb.	5	3	3	3	3	3
Slake test	4	4	3	4	4	4
Texture	4	2	2	2	2	2

22.2 Soil analyses

The soil pH recorded in E27-01 remained bordering on neutral to slightly alkaline but continued to fall within the target range (Table 22-3). There was little change in Electrical Conductivity which remained within the local target range and within desirable levels. There was a slight reduction in organic matter but these remained within local levels. There were reductions in phosphorous and nitrate levels but both continued to either fall within the local ranges or remained within the desirable levels. CEC values have slightly declined but continue to fall within the ranges provided by the reference sites. The low Exchangeable Sodium Percentage indicates the soils continue to be non sodic.

Table 22-3. Results of the soil analysis for E27-01 compared to the upper and lower values for the grassland reference sites and desirable levels from 2009 to 2013.

Nutrient	Units	E27-01					Lower KPI	Upper KPI	Desirable Level
		2009	2010	2011	2012	2013			
pH (1:5 water)	units	7.03	7.06	6.92	7.39	7.34	6.73	7.97	5.6 – 7.3
Conductivity (1:5 water)	dS/m	0.151	0.114	0.116	0.145	0.111	0.043	0.198	0.150
Organic Matter	%	3.31	4.6	3.2	3.3	2.7	1.6	4.1	>4.5
Phosphorus (Colwell)	mg/kg	63	37	35	21	16	5	9	50
Nitrate	mg/kg	16	3.1	7.9	7.6	1.8	1.2	1.4	13.0
Cation Exchange Capacity	cmol+/Kg	29.2	29.02	26.29	26.73	25.29	20.41	37.83	14.00
Exchangeable Sodium Percentage	%	1.77	1.27	1.89	1.29	1.35	0.28	4.42	<5

22.3 Rill assessment

No rills were observed within the monitoring quadrat in any monitoring year.

22.4 Tree density and health condition

In 2012 a single *Acacia brachystachya* was recorded to have a dbh of 6cm thus increasing the tree and mature shrub population to a density of one. In 2013 it had a dbh of 8cm, continued to be healthy and was bearing pods indicating good growth and development.

Table 22-4. Summary of tree health and density.

Dominant species	<i>Acacia brachystachya</i> (1)
Average dbh (Cm)	8
Max dbh (cm)	8
Min dbh (cm)	8
Total trees	1
No. with multiple limbs	1
No. Live trees	1
No. Healthy	0
No. Medium Health	1
No. Advanced Dieback	0
No. Dead	0
Mistletoe	0
Flowers / fruit	1

22.5 Shrubs and juvenile trees

E27-01 continued to have numerous shrubs establishing throughout the site and there was significant recruitment of *Maireana brevifolia* and *Senna artemisioides nothosubsp. artemisioides* and a population which peaked in 2011 with a density of 157 individuals. This year there were 110 individuals as many had died as a result of heavy predation in combination with the prolonged dry conditions. Some however may have been missed in the dense ground covers. While *Senna* was recorded in all height classes, 53% were less than 1.0m tall. The majority of *Maireana brevifolia* were less than 1.0m in height (Figure 22-2, Table 22-5).

Table 22-5. Shrubs and young trees occurring within the monitoring site.

Species	0 - 0.5m	0.5 - 1.0m	1.0 - 1.5m	1.5 - 2.0m	>2.0m	Total	endemic	not endemic
<i>Maireana brevifolia</i>	8	16	6			30	30	
<i>Senna artemisioides subsp. X artemisioides</i>	25	42	10	1	2	80	80	
Total	33	58	16	1	2	110	110	0
% endemic species							100	0

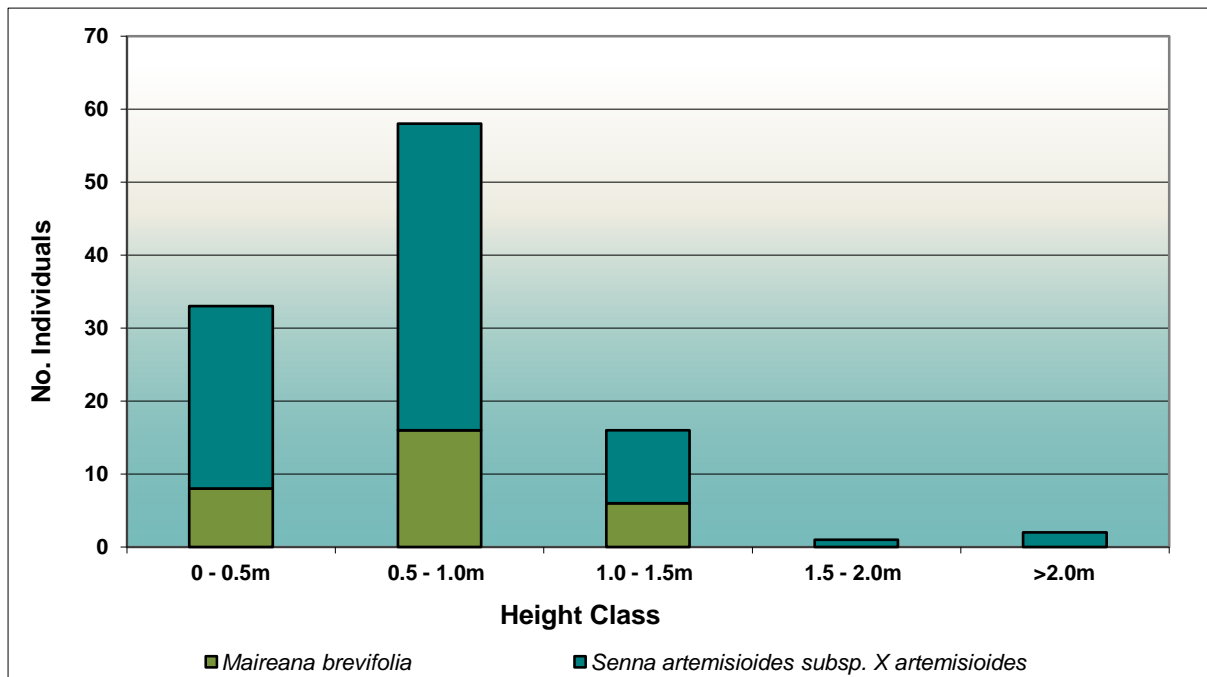


Figure 22-2 Shrubs and juvenile trees occurring within the monitoring site.

22.6 Structural diversity and habitat complexity

This rehabilitation site has continued to change in response to the seasonal conditions and ecological processes occurring within the site (Figure 22-3). The site has maintained relatively good ground cover levels but these have fluctuated as a result of impact by macropods which have numerous tracks and camps in and around the site, especially beneath the larger shrubs leaving large bare areas 25 – 35m along the vegetation transect (Figure 22-4).

Since last year total ground cover levels have marginally improved but this was due to a significant increase in annual plant cover which now dominated 51% of the site. While there little change in dead litter cover which now provided 34% ground cover, however there has been a significant reduction in perennial plants which have declined from 24.5 – 2.0% over the past year (Figure 22-4). Some of the taller grasses provided low levels of vertical cover greater than 0.5m in height early along the transect while an acacia provided some cover at 30m. Table 22-6 provides the average and minimum and maximum values obtained along the vegetation transect.

2009 Vegetation transect (front)



2009 Vegetation transect (rear)



2010 Vegetation transect (front)



2010 Vegetation transect (rear)



2011 Vegetation transect (front)



2011 Vegetation transect (rear)



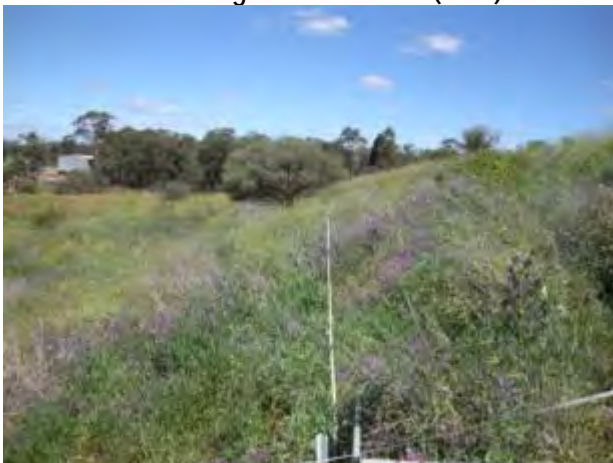
2012 Vegetation transect (front)



2012 Vegetation transect (rear)



2013 Vegetation transect (front)



2013 Vegetation transect (rear)



Figure 22-3. Permanent photo points taken from the front (left) and rear (right) of the vegetation transect.

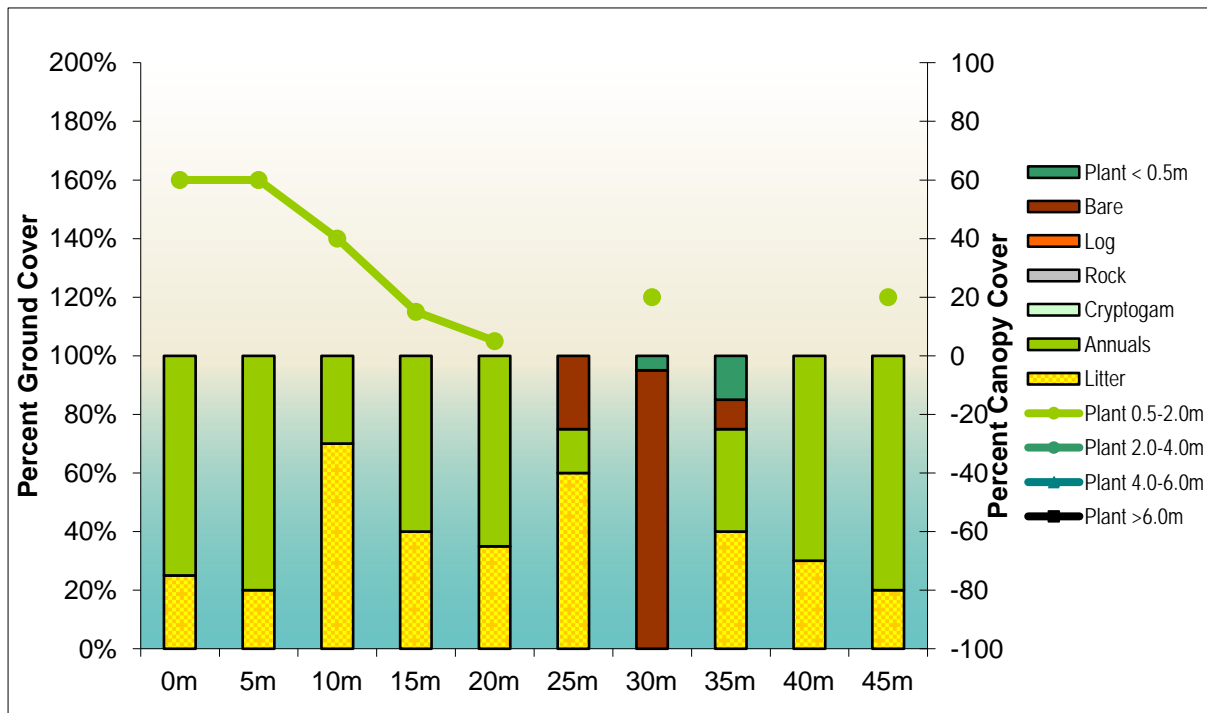


Figure 22-4. Graph illustrating the structural diversity and habitat complexity of the monitoring site.

Table 22-6. Average and minimum and maximum values of the structural diversity of the monitoring site.

Vegetation structure	0m	5m	10m	15m	20m	25m	30m	35m	40m	45m	Average	Min	Max
Litter	25	20	70	40	35	60	0	40	30	20	34	0	70
Annuals	75	80	30	60	65	15	0	35	70	80	51	0	80
Cryptogam	0	0	0	0	0	0	0	0	0	0	0	0	0
Rock	0	0	0	0	0	0	0	0	0	0	0	0	0
Log	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare	0	0	0	0	0	25	95	10	0	0	13	0	95
Perennial <0.5m	0	0	0	0	0	0	5	15	0	0	2	0	15
Total Ground Cover	100	100	100	100	100	75	5	90	100	100	87	5	100
0.5-2.0m	60	60	40	15	5	0	20	0	0	20	22	0	60
2.0-4.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
4.0-6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0
>6.0m	0	0	0	0	0	0	0	0	0	0	0	0	0

22.7 Species cover abundance

There were 12 live species recorded in the five 1m² quadrats on the permanent vegetation transect line over the past year and nine of these were exotic species. Using the Braun-blauquet scale, the highest possible cover score that can be obtained is 30 and cover abundance is illustrated as a sum of scores (class values) obtained along the five 1m² quadrats.

While the site was originally dominated by the native grass *Walwhalleya proluta*, *Vicia villosa* has become increasingly more dominant and last year was co-dominant of the site, with *Chloris gayana* also being relatively abundant. This year *Vicia villosa* was by far the most dominant species, but *Walwhalleya proluta*, *Echium plantagineum* and *Medicago polymorpha* were also relatively common and occurred in at least four of the five sub-plots (Figure 22-5, Table 22-7). The remaining species were recorded less frequently and generally provided limited ground cover. Of the live plant cover scores recorded, 16.7% was provided by native species, a reduction from 28.8% recorded last year.

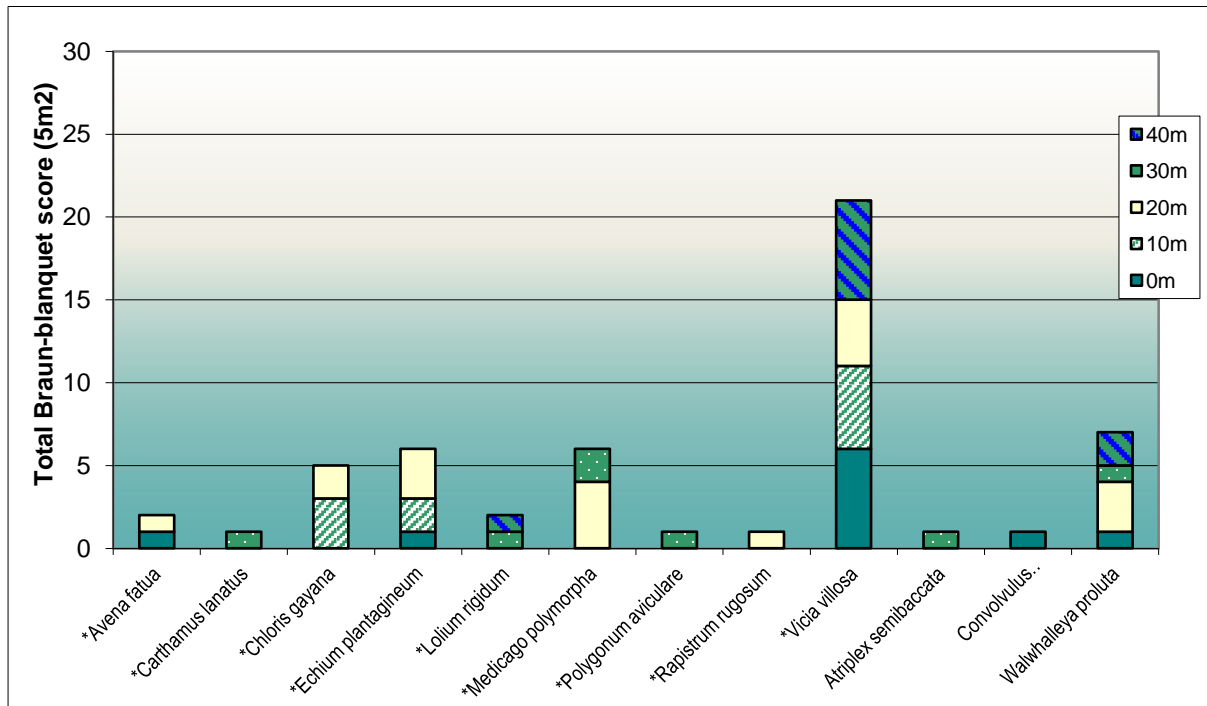


Figure 22-5. Total species recorded across the five, 1m² quadrats using the Braun-blanket scale (max possible score is 30) as a measure of cover abundance.

Table 22-7. List of species and their average cover abundance score across the five, 1m² monitoring quadrats.

Species	0m	10m	20m	30m	40m	Total
*Avena fatua	1		1			2
*Carthamus lanatus				1		1
*Chloris gayana		3	2			5
*Echium plantagineum	1	2	3			6
*Lolium rigidum				1	1	2
*Medicago polymorpha			4	2		6
*Polygonum aviculare				1		1
*Raphistrum rugosum			1			1
*Vicia villosa	6	5	4		6	21
Atriplex semibaccata				1		1
Convolvulus erubescens	1					1
Walwhalleya proluta	1		3	1	2	7
Total cover						54
Sum of cover of native species						9
Percent endemic species cover						16.7

22.8 Floristic diversity

The floristic diversity of the sites was measured using two different methods. One provides an assessment of the average number of species within five, one square metre (m²) sub-quadrats along the vegetation transect, while the other provides the total number of species within the entire 50x20m monitoring plot.

22.8.1 Species diversity per m²

The average number of native species recorded in the five 1m² sub-quadrats has increased from 1.0 – 1.2 species per m² since last year. The average number of exotic species has also increased from 2.4 - 3.6 exotic species per m² (Table 22-8). The number of native species ranged between zero and two species per m², while the number of exotic species ranged between two and six species per m².

Table 22-8. Species diversity per 1m².

Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	2	0	1	2	1	1.2	0.8
Exotic	3	3	6	4	2	3.6	1.5
Total	5	3	7	6	3	4.8	1.8

22.8.2 Total species diversity

There has also been a decline in total species richness, declining from 40 species in 2012 to 38 species recorded in the 50 x 20m monitoring quadrat this year. There were 16 native and 22 exotic species (Figure 22-6, Table 22-9). The small sharp rises along the species area curve indicate the additions of new species and these were largely due to the different habitat provided by the contour bank lower down the slope. A list of species recorded within the monitoring site is provided in Appendix 1.

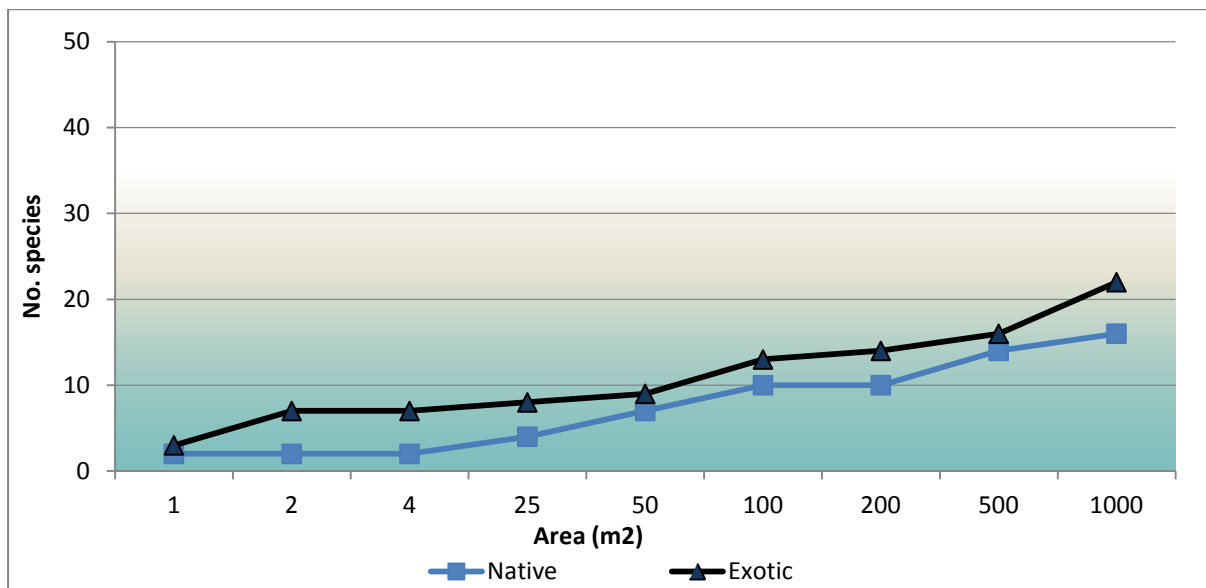
Figure 22-6. Cumulative species in the 50m x 20m (1000m²) monitoring quadrat.

Table 22-9. Cumulative species diversity.

Area (m2)	1	2	4	25	50	100	200	500	1000
Native	2	2	2	4	7	10	10	14	16
Exotic	3	7	7	8	9	13	14	16	22

22.9 Growth forms

Figure 22-7 is a summary of species in each growth form that were recorded in E27-01. Herbs continued to be the most dominant plant type with 22 species including 16 exotic species. There were 12 grasses including six exotics species and there continued to be three native shrubs and one native sub-shrub, one less than last year. There continued to be an absence of tree and fern representatives and this year no reed species were found. Compared to the native grasslands there was a low diversity of herb species.

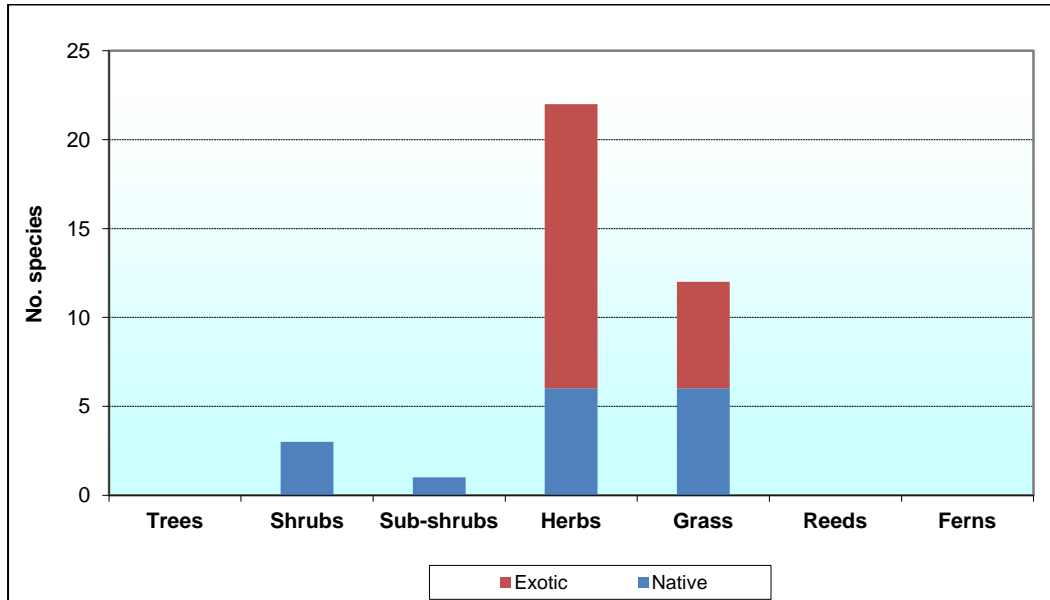


Figure 22-7. Graph illustrating the growth forms of species recorded in the 50m x 20m monitoring quadrat.

22.10 Comparison of rehabilitation data with key performance indicators

Table 22-10 indicates the performance of the rehabilitation monitoring site against the Completion and Desirable Performance Indicators developed for grassland sites during the 2013 monitoring period. The selection of criteria have been presented in order of ecosystem successional processes, beginning with landform establishment and stability (orange) for example and ending with indicators of ecosystem and landuse development (blue). The range values will be amended annually.

Rehabilitation sites meeting or exceeding the range values of their representative community type have identified with a shaded colour box and have therefore been deemed to meet completion criteria targets. In the case of "growth medium development", upper and lower soil property indicators are also based on results obtained from the respective reference sites sampled in 2013. In some cases, the site may not fall within ranges based on these data, but may be within "desirable" levels as prescribed by the agricultural industry. If this scenario occurs, the rehabilitation site has been identified using a striped shaded box to indicate that it falls within "desirable" ranges but does not fall within specified completion criteria targets using the adopted methodology.

Table 22-10. Comparison of key performance Indicators recorded in the rehabilitation site E27-01 compared to lower and upper limits recorded in the grassland reference sites.

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E27-01				
Performance indicators are quantified by the range of values obtained from replicated reference sites							Lower	Upper	2009	2010	2011	2012	2013
Phase2: Landform establishment and stability	Landform slope, gradient	Landform suitable for final landuse and generally compatible with surrounding topography	Slope		Landform is generally compatible within the context of the local topography.	< Degrees (18°)	1	3	15.0	15.0	15.0	15.0	15.0
	Landform function	Landform is functional and performing as it was designed to do	LFA Stability	Based on key physical, biological and chemical characteristics the LFA stability index provides an indication of the sites stability and that it is comparable to or trending towards that of the local remnant vegetation		%	64.5	73.0	56.4	67.6	69.6	77.2	69.5
			LFA Infiltration	Based on key physical, biological and chemical characteristics the LFA infiltration index provides an indication of the sites infiltration capacity and that it is comparable to or trending towards that of the local remnant vegetation		%	29.3	46.3	44.0	47.5	47.6	52.7	47.8
			LFA Nutrient recycling	Based on key physical, biological and chemical characteristics the LFA nutrient recycling index provides an indication of the sites ability to recycle nutrient and that it is comparable to or trending towards that of the local remnant vegetation		%	28.1	43.2	39.0	46.6	46.7	53.4	45.0
			LFA Landscape organisation	The Landscape Organisation Index provides a measure of the ability of the site to retain resources and that it is comparable to that of the local remnant vegetation		%	100	100	93	96	100	100	100

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E27-01				
	Active erosion	Areas of active erosion are limited	No. Rills/Gullies	Provides an assessment of the number of gullies or rills occurring in a 50m transect and that these are limited and stabilising		No.	0	0	0	0	0	0	0
			Cross-sectional area of rills		Provides an assessment of the extent of soil loss due to gully and rill erosion and that it is limited and/or is stabilising	m2	0	0	0	0	0	0	0
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)	6.73	7.97	7.03	7.08	6.92	7.39	7.34
			EC		Electrical Conductivity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	< dS/m (<0.150)	0.043	0.198	0.151	0.114	0.116	0.145	0.111
			Organic Matter	Organic Carbon levels are typical of that of the surrounding landscape, increasing or fall within desirable ranges provided by the agricultural industry		% (>4.5)	1.6	4.1	3.3	4.6	3.2	3.3	2.7
			Phosphorous		Available Phosphorus is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	ppm (50)	5.3	8.6	5.6	5.7	5.6	21.3	15.6
			Nitrate	Nitrate levels are typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry		ppm (>12.5)	1.2	1.4	16.5	3.1	7.9	7.6	1.8
			CEC		Cation Exchange Capacity is typical of that of the surrounding landscape or fall within desirable ranges provided by the agricultural industry	Cmol+/kg (>14)	20.4	37.8	29.18	29.02	26.29	26.73	25.3
			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	4.4	1.77	1.27	1.89	1.29	1.4
Phase 4: Ecosystem & Landuse Establishment	Vegetation diversity	Vegetation contains a diversity of species comparable to that of the local remnant vegetation	Diversity of shrubs and juvenile trees		The diversity of shrubs and juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation.	species/area	0	0	3	3	3	2	2
					The percentage of shrubs and juvenile trees with a stem diameter < 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation	% population	0	0	na	99	99	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	37	52	29	31	48	40	38

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E27-01				
			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	19	38	22	17	21	18	16
			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	14	20	7	14	27	22	22
	Vegetation density	Vegetation contains a density of species comparable to that of the local remnant vegetation	Density of shrubs and juvenile trees		The density of shrubs or juvenile trees with a stem diameter < 5cm is comparable to that of the local remnant vegetation	No./area	0	0	133	97	157	151	110
	Ecosystem composition	The vegetation is comprised by a range of growth forms comparable to that of the local remnant vegetation	Trees		The number of tree species regardless of age comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	0	0
			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	3	3	3	3	3
			Sub-shrubs		The number of sub-shrub species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	4	4	2	2	2	1
			Herbs	The number of herbs or forb species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	26	34	14	15	28	21	22
			Grasses	The number of grass species comprising the vegetation community is comparable to that of the local remnant vegetation		No./area	11	15	7	10	14	13	12
			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	0	1	1	1	1	0
			Vines		The number of vines or climbing species comprising the vegetation community is comparable to that of the local remnant vegetation	No./area	0	0	0	0	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
Phase 5: Ecosystem & Landuse Development	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	%	36	52	54	7.0	29.5	33.5	34.0
			Annual plants		Percent ground cover provided by live annual plants is comparable to that of the local remnant vegetation	<%	4	39	0	73.0	7.5	24.0	51.0

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E27-01				
			Cryptogam cover		Percent ground cover provided by cryptogams (eg mosses, lichens) is comparable to that of the local remnant vegetation	%	0	17	0.5	0	0	0	0
			Rock		Percent ground cover provided by stones or rocks (> 5cm diameter) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0
			Log		Percent ground cover provided by fallen branches and logs (>5cm) is comparable to that of the local remnant vegetation	%	0	0	0	0	0	0	0
			Bare ground		Percentage of bare ground is less than or comparable to that of the local remnant vegetation	< %	3	15	24	18	20.5	18.0	13
			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		%	16	30	21.5	2.0	42.5	24.5	2.0
			Total Ground Cover	Total groundcover is the sum of protective ground cover components (as described above) and that it is comparable to that of the local remnant vegetation		%	86	97	76	82	79.5	82.0	87
	Ground cover diversity	Vegetation contains a diversity of species per square meter comparable to that of the local remnant vegetation	Native understorey abundance		The abundance of native species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has more than or an equal number of native species as the local remnant vegetation	> species/m ²	3	11	1.6	0.4	2.2	1.0	1.2
			Exotic understorey abundance		The abundance of exotic species per square metre averaged across the site provides an indication of the heterogeneity of the site and that it is has less than or an equal number of exotic species as the local remnant vegetation	< species/m ²	4	7	0.6	4	4.8	2.4	3.6
	Native ground cover abundance	Native ground cover abundance is comparable to that of the local remnant vegetation	Percent ground cover provided by native vegetation <0.5m tall	The percent ground cover abundance of native species (<0.5m height) compared to exotic species is comparable to that of the local remnant vegetation		%	29	77	na	7.0	32.8	28.8	16.7
	Ecosystem growth and natural recruitment	The vegetation is maturing and/or natural recruitment is occurring at rates similar to those of the local remnant vegetation	shrubs and juvenile trees 0 - 0.5m in height		The number of shrubs or juvenile trees < 0.5m in height provides an indication of establishment success and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	76	33	62	46	33

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E27-01				
			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	41	53	76	77	58
			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	13	8	15	26	16
			shrubs and juvenile trees 1.5 - 2m in height		The number of shrubs or juvenile trees 1.5-2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	0	0	1	1	1
			shrubs and juvenile trees >2m in height		The number of shrubs or juvenile trees > 2m in height provides an indication of establishment success, growth and/or natural ecosystem recruitment and that it is comparable to that of the local remnant vegetation	No./area	0	0	3	3	3	1	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	5	1	39	6	12	22
			Foliage cover 2 - 4m		Projected foliage cover provided by perennial plants in the 2 - 4m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
			Foliage cover 4 - 6m		Projected foliage cover provided by perennial plants in the 4 - 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
			Foliage cover >6m		Projected foliage cover provided by perennial plants > 6m vertical height stratum indicates the community structure is comparable to that of the local remnant vegetation	% cover	0	0	0	0	0	0	0
	Tree diversity	Vegetation contains a diversity of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree diversity		The diversity of trees or shrubs with a stem diameter > 5cm is comparable to the local remnant vegetation. Species used in rehabilitation will be endemic to the local area	species/area	0	0	0	0	0	1	1

Rehabilitation Phase	Aspect or ecosystem component	Completion criteria	Performance Indicators	Completion Performance Indicators Description	Desirable Performance Indicators Description	Unit of measurement	Grassland ecosystem range 2013		E27-01				
				The percentage of maturing trees and shrubs with a stem diameter > 5cm dbh which are local endemic species and these percentages are comparable to the local remnant vegetation		%	0	0	na	na	0	0	100
	Tree density	Vegetation contains a density of maturing tree and shrubs species comparable to that of the local remnant vegetation	Tree density		The density of shrubs or trees with a stem diameter > 5cm is comparable to that of the local remnant vegetation	No./area	0	0	0	0	0	1	1
			Average dbh		Average tree diameter of the tree population provides a measure of age, (height) and growth rate and that it is trending towards that of the local remnant vegetation.	cm	0	0	0	0	0	6	8
	Ecosystem health	The vegetation is in a condition comparable to that of the local remnant vegetation.	Live trees		The percentage of the tree population which are live individuals and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	100	100
			Healthy trees		The percentage of the tree population which are in healthy condition and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	100	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	0	0	0	0	0	0	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	0	0	0	0	0	0
			Dead Trees		The percentage of the tree population which are dead (stags) and that the percentage is comparable to the local remnant vegetation	% population	0	0	0	0	0	0	0
			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
			Flowers/fruit: Trees		The percentage of the tree population with reproductive structures such as buds, flowers or fruit provides evidence that the ecosystem is maturing, capable of recruitment and can provide habitat resources comparable to that of the local remnant vegetation	% population	0	0	0	0	0	100	100

23 References

- Bruce, R.C. and Rayment, G.E. 1982. *Analytical Methods and Interpretations Used by the Agricultural Chemistry Branch for Soil and Land Use Surveys*, Bulletin No. QB2004, Dept of Primary Industries, Brisbane, Qld.
- Bureau of Meteorology. 2013. *Parkes Airport AWS Monthly Rainfall, 1941-2013*. http://www.bom.gov.au/jsp/ncc/cdio/weatherData/av?p_nccObsCode=139&p_display_type=dataFile&p_startYear=&p_c=-846980701&p_stn_num=065068 Accessed 4th December 2013.
- DnA Environmental. 2010a. *Rehabilitation monitoring methodology and determination of completion criteria for Northparkes Mines*. North Mining Limited.
- DnA Environmental. 2010b. *2009 Rehabilitation Monitoring Report for Northparkes Mines*. North Mining Limited.
- DnA Environmental. 2011. *2010 Rehabilitation Monitoring Report for Northparkes Mines*. North Mining Limited.
- DnA Environmental. 2012. *2011 Rehabilitation Monitoring Report for Northparkes Mines*. North Mining Limited.
- Gibbons (2002). *Methodology for the Grassy Box Woodlands Benchmarking Project in southern NSW Murray-Darling Basin*. CSIRO, Canberra.
- Gibbons, P., Briggs, S.V., Ayers, D.A., Doyle, S., Seddon, J., McElhinny, C., Jones, N. Simes, R. and Doody, J.S. (2008). *Rapidly quantifying reference conditions in modified landscapes*. *Journal of Biological Conservation*.
- Hazelton, P. and Murphy, B. W. 2007. *Interpreting Soil Test Results: What Do All The Numbers Mean?* Victoria, CSIRO Publishing.
- Isbell, R. F. 1996. *The Australian Soil Classification*. CSIRO Publishing, Melbourne.
- Northparkes Mines. 2010. *Management Plan Sitewide Landscape*. Northparkes Mines.
- Nichols, O.G. 2005 *Development of Rehabilitation Completion Criteria for Native Ecosystem Establishment on Coal Mines in the Hunter Valley*. ACARP Project No. C13048 Australian Centre for Minerals Extension and Research PO Box 883, Kenmore QLD 4069.
- NSW I&I: Department of Industry and Investment (2010). *Rehabilitation and Environmental Management Plan (REMP) Guidelines*. Consultation Draft V2.0, June 2010. Minerals and Energy Division, Mineral Resources Branch. Maitland, NSW.
- NSW T&I: Resources and Energy (2012). *ESG3: Mining Operations Plan (MOP) guidelines*. December 2012. NSW Trade and Investment, Regional Infrastructure and Services – Division of Resources and Energy.
- Peverill, K.I., Sparrow, L.A. and Reuter, D.J. 2005. *Soil analysis. An Interpretation Manual*. CSIRO Publishing, Collingwood Victoria.

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

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

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

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

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

Windsor, D. M. 2000a. Native grass survey of North Parkes Mine: Interim Report for North Mining Limited, Parkes. Greening Australia (NSW).

Windsor, D. M. 2000b. Native grass survey of North Parkes Mine: Volume 2 for North Mining Limited, Parkes. Greening Australia (NSW).

Appendix 1. List of flora species recorded in the rehabilitation sites in 2013

Group	Family	exotic	Scientific Name	Common Name	Habit	LFO-01	LFO-02	Beechmoore	Estcourt	Altona	Kundibah	TSF1-01	TSF1-02	TSF2-01	TSF2-02	E22-01	E22-02	E26-01	E27-01
Coniferopsida	Cupressaceae		<i>Callitris glaucophylla</i>	White Cypress Pine	t	1	1	1											
Dicotyledon	Asteraceae	*	<i>Arctotheca calendula</i>	Capeweed	h			1		1									
Dicotyledon	Asteraceae		<i>Brachyscome curvicalpa</i>	Curved-seed Daisy	h			1											
Dicotyledon	Asteraceae		<i>Calotis anthemoides</i>	Cut-leaved Burr-daisy	h			1	1										
Dicotyledon	Asteraceae		<i>Calotis cuneifolia</i>	Purple Burr Daisy	h			1											
Dicotyledon	Asteraceae		<i>Calotis hispidula</i>	Bogan Flea	h						1								
Dicotyledon	Asteraceae	*	<i>Carthamus lanatus</i>	Saffron Thistle	h	1	1		1		1	1	1		1	1	1	1	1
Dicotyledon	Asteraceae	*	<i>Chondrilla juncea</i>	Skeleton Weed	h	1	1										1		
Dicotyledon	Asteraceae	*	<i>Cichorium intybus</i>	Chicory	h									1	1				
Dicotyledon	Asteraceae	*	<i>Cirsium vulgare</i>	Spear Thistle	h	1			1			1		1	1	1		1	
Dicotyledon	Asteraceae	*	<i>Conyza bonariensis</i>	Fleabane	h								1					1	
Dicotyledon	Asteraceae		<i>Eclipta platyglossa</i>	Twin Heads	h						1		1						
Dicotyledon	Asteraceae		<i>Euchiton involucratus</i>	Star Cudweed	h	1	1												
Dicotyledon	Asteraceae		<i>Euchiton sphaericus</i>	Japanese Cudweed	h	1	1			1	1							1	
Dicotyledon	Asteraceae	*	<i>Hypochaeris glabra</i>	Smooth Catsear	h	1													
Dicotyledon	Asteraceae	*	<i>Hypochaeris radicata</i>	Flatweed	h	1	1												
Dicotyledon	Asteraceae	*	<i>Lactuca saligna</i>	Wild Lettuce	h					1		1	1	1	1		1	1	1
Dicotyledon	Asteraceae	*	<i>Lactuca serriola</i>	Prickly Lettuce	h	1	1			1	1	1	1		1			1	1
Dicotyledon	Asteraceae		<i>Leiocarpa panaetioides</i>	Woolly Buttons	h										1		1		
Dicotyledon	Asteraceae		<i>Rhodanthe corymbiflora</i>	Small White Sunray	h		1												
Dicotyledon	Asteraceae	*	<i>Scorzonera laciniata</i>		h							1	1	1	1			1	
Dicotyledon	Asteraceae		<i>Senecio quadridentatus</i>	Cotton Fireweed	h	1													
Dicotyledon	Asteraceae	*	<i>Silybum marianum</i>	Variegated Thistle	h											1		1	
Dicotyledon	Asteraceae	*	<i>Sonchus asper</i>	Prickly Sowthistle	h							1	1					1	
Dicotyledon	Asteraceae	*	<i>Sonchus oleraceus</i>	Milk Thistle	h	1	1			1	1		1	1	1	1	1	1	
Dicotyledon	Asteraceae		<i>Vittadinia cuneata</i>	Fuzzweed	h		1	1			1			1	1	1	1	1	1
Dicotyledon	Asteraceae		<i>Vittadinia cuneata var. cuneata</i>	Fuzzweed	h	1			1	1									
Dicotyledon	Asteraceae		<i>Vittadinia cuneata var. hirsuta</i>	Fuzzweed	h	1													
Dicotyledon	Asteraceae		<i>Vittadinia gracilis</i>	A Fuzzweed	h	1	1			1			1		1		1		1
Dicotyledon	Asteraceae		<i>Vittadinia pterochaeta</i>	Rough Fuzzweed	h	1		1				1	1	1	1		1		1

Group	Family	exotic	Scientific Name	Common Name	Habit	LFO-01	LFO-02	Beechmoore	Estcourt	Altona	Kundibah	TSF1-01	TSF1-02	TSF2-01	TSF2-02	E22-01	E22-02	E26-01	E27-01
Dicotyledon	Asteraceae		<i>Vittadinia sulcata</i>	A Fuzzweed	h					1			1				1	1	
Dicotyledon	Asteraceae		<i>Xerochrysum bracteatum</i>	Golden Everlasting	h	1	1			1									
Dicotyledon	Brassicaceae	*	<i>Brassica juncea</i>	Chinese Mustard	h											1			
Dicotyledon	Brassicaceae	*	<i>Capsella bursa-pastoris</i>	Shepherd's Purse	h	1	1												
Dicotyledon	Brassicaceae	*	<i>Lepidium africanum</i>	Peppergrass	h					1									
Dicotyledon	Brassicaceae	*	<i>Rapistrum rugosum</i>	Turnip Weed	h						1	1	1		1	1	1	1	1
Dicotyledon	Brassicaceae	*	<i>Sisymbrium irio</i>	London Rocket	h	1	1												1
Dicotyledon	Campanulaceae		<i>Wahlenbergia aridicola</i>	A Bluebell	h		1												
Dicotyledon	Campanulaceae		<i>Wahlenbergia gracilentia</i>	Australian Bluebell	h	1		1		1									
Dicotyledon	Campanulaceae		<i>Wahlenbergia gracilis</i>	Sprawling Bluebell	h		1		1										
Dicotyledon	Caryophyllaceae	*	<i>Cerastium glomeratum</i>	Mouse-ear Chickweed	h		1												
Dicotyledon	Caryophyllaceae	*	<i>Petrorhagia nanteuillii</i>	Proliferous Pink	h		1												
Dicotyledon	Caryophyllaceae	*	<i>Polycarpon tetraphyllum</i>	Four-leaved Allseed	h		1												
Dicotyledon	Caryophyllaceae	*	<i>Spergularia rubra</i>	Sandspurry	h			1	1					1					
Dicotyledon	Casuarinaceae		<i>Casuarina cristata</i>	Belah	t				1										
Dicotyledon	Casuarinaceae		<i>Casuarina cunninghamiana</i>	River Sheoak	t			1		1	1								
Dicotyledon	Chenopodiaceae		<i>Atriplex semibaccata</i>	Creeping Saltbush	ss											1	1		1
Dicotyledon	Chenopodiaceae		<i>Atriplex spinibractea</i>	Spiny-fruit Saltbush	ss				1	1			1	1					
Dicotyledon	Chenopodiaceae		<i>Atriplex suberecta</i>	Sprawling saltbush	ss								1	1					
Dicotyledon	Chenopodiaceae		<i>Einadia nutans subsp. linifolia</i>	Climbing Saltbush	h			1	1	1	1		1						1
Dicotyledon	Chenopodiaceae		<i>Einadia nutans subsp. nutans</i>	Climbing Saltbush	h					1	1				1			1	
Dicotyledon	Chenopodiaceae		<i>Enchylaena tomentosa</i>	Ruby Saltbush	ss										1				
Dicotyledon	Chenopodiaceae		<i>Maireana brevifolia</i>	Yanga Bush	s					1		1	1	1		1		1	1
Dicotyledon	Chenopodiaceae		<i>Maireana enchylaenoides</i>	Wingless Fissure Weed	h			1		1									
Dicotyledon	Chenopodiaceae		<i>Maireana microphylla</i>	Eastern Cottonbush	ss			1											
Dicotyledon	Chenopodiaceae		<i>Salsola kali</i>	Buckbush	ss	1	1	1		1				1					
Dicotyledon	Chenopodiaceae		<i>Sclerolaena muricata</i>	Black Roly Poly	ss				1										
Dicotyledon	Convolvulaceae		<i>Convolvulus erubescens</i>	Australian Bindweed	h		1	1	1	1	1	1	1		1		1		1
Dicotyledon	Convolvulaceae		<i>Dichondra repens</i>	Kidney Weed	h	1	1	1	1	1	1							1	
Dicotyledon	Crassulaceae		<i>Crassula colorata</i>	Dense Stonecrop	h	1	1			1									
Dicotyledon	Euphorbiaceae		<i>Chamaesyce drummondii</i>	Caustic Weed	h	1					1		1				1		
Dicotyledon	Fabaceae (Caesalpinoideae)		<i>Senna artemisioides subsp. filifolia</i>	Punty Bush	s			1											

Group	Family	exotic	Scientific Name	Common Name	Habit	LFO-01	LFO-02	Beechmoore	Estcourt	Altona	Kundibah	TSF1-01	TSF1-02	TSF2-01	TSF2-02	E22-01	E22-02	E26-01	E27-01
Dicotyledon	Fabaceae (Caesalpinoideae)		<i>Senna artemisioides</i> subsp. <i>X artemisioides</i>	Silver Cassia	s														1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Medicago minima</i>	Small Woolly Burr Medic	h		1				1					1			1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Medicago polymorpha</i>	Burr Medic	h	1	1				1		1	1	1	1	1	1	1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Medicago sativa</i>	Lucerne	h											1			
Dicotyledon	Fabaceae (Faboideae)	*	<i>Medicago truncatula</i>	Barrel Medic	h	1	1				1	1	1	1			1		1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Melilotus indicus</i>	Hexham Scent	h								1				1		1
Dicotyledon	Fabaceae (Faboideae)		<i>Swainsona</i> spp.?		h											1			
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium angustifolium</i>	Narrow-leaf Clover	h			1				1	1			1	1		1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium arvense</i>	Haresfoot Clover	h		1			1	1								
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium campestre</i>	Hop Clover	h	1	1			1						1			
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium glomeratum</i>	Clustered Clover	h	1	1		1	1	1					1		1	
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium hirtum</i>	Rose Clover	h						1		1	1	1				1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium repens</i>	White Clover	h						1								
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium subterraneum</i>	Subterranean Clover	h				1		1								
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium tomentosum</i>	Woolly Clover	h	1	1			1	1						1		1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Vicia villosa</i>	Vetch	h							1	1		1	1	1	1	1
Dicotyledon	Fabaceae (Mimosoideae)		<i>Acacia brachystachya</i>	Umbrella Mulga	s														1
Dicotyledon	Fabaceae (Mimosoideae)		<i>Acacia dealbata</i>	Silver Wattle	s					1									
Dicotyledon	Fabaceae (Mimosoideae)		<i>Acacia deanei</i>	Green Wattle	s		1	1	1	1	1								
Dicotyledon	Fabaceae (Mimosoideae)		<i>Acacia decora</i>	Western Golden Wattle	s		1			1	1					1			
Dicotyledon	Fabaceae (Mimosoideae)		<i>Acacia hakeoides</i>	Hakea Wattle	s		1	1	1	1	1								
Dicotyledon	Fabaceae (Mimosoideae)		<i>Acacia leucoclada</i>	Northern Silver Wattle	s						1								
Dicotyledon	Fabaceae (Mimosoideae)		<i>Acacia pendula</i>	Myall	s			1		1	1								
Dicotyledon	Fabaceae (Mimosoideae)		<i>Acacia spectabilis</i>	Mudgee Wattle	s					1									
Dicotyledon	Fabaceae (Mimosoideae)		<i>Acacia stenophylla</i>	River Cooba	s			1											

Group	Family	exotic	Scientific Name	Common Name	Habit	LFO-01	LFO-02	Beechmoore	Estcourt	Altona	Kundibah	TSF1-01	TSF1-02	TSF2-01	TSF2-02	E22-01	E22-02	E26-01	E27-01
Dicotyledon	Fabaceae (Mimosoideae)		<i>Acacia trineura</i>	Three-nerved Wattle	s			1		1									
Dicotyledon	Fumariaceae	*	<i>Fumaria capreolata</i>	White-flowered Fumitory	h													1	
Dicotyledon	Fumariaceae	*	<i>Fumaria densiflora</i>	Dense-flowered Fumitory	h	1													
Dicotyledon	Geraniaceae	*	<i>Erodium cicutarium</i>	Common Crowsfoot	h		1												
Dicotyledon	Geraniaceae		<i>Erodium crinitum</i>	Blue Storksbill	h					1								1	
Dicotyledon	Goodeniaceae		<i>Goodenia fascicularis</i>		h													1	
Dicotyledon	Goodeniaceae		<i>Goodenia pinnatifida</i>	Scrambled Eggs	h			1	1										
Dicotyledon	Lamiaceae	*	<i>Marrubium vulgare</i>	Horehound	h	1	1									1			1
Dicotyledon	Lamiaceae	*	<i>Salvia verbenaca</i>	Wild Sage	h		1					1			1	1	1		
Dicotyledon	Lobeliaceae		<i>Pratia concolor</i>	Poison Pratia	h				1		1								
Dicotyledon	Malvaceae	*	<i>Modiola caroliniana</i>	Red-flowered Mallow	h		1										1		
Dicotyledon	Malvaceae		<i>Sida ammophila</i>		h				1										
Dicotyledon	Malvaceae		<i>Sida corrugata</i>	Corrugated Sida	h				1	1	1				1		1		
Dicotyledon	Malvaceae		<i>Sida cunninghamii</i>	Ridge Sida	h			1											
Dicotyledon	Malvaceae		<i>Sida spp.</i>		h				1										
Dicotyledon	Malvaceae		<i>Sida trichopoda</i>	Hairy Sida	h						1	1	1				1		
Dicotyledon	Myoporaceae		<i>Eremophila debilis</i>	Amulla	ss				1		1								
Dicotyledon	Myrtaceae	*	<i>Corymbia citriodora</i>	Lemon-scented Gum	t						1								
Dicotyledon	Myrtaceae		<i>Eucalyptus albens</i>	White Box	t				1		1								
Dicotyledon	Myrtaceae		<i>Eucalyptus camaldulensis</i>	River Red Gum	t			1		1	1								
Dicotyledon	Myrtaceae		<i>Eucalyptus dwyeri</i>	Dwyer's Red Gum	t					1	1								
Dicotyledon	Myrtaceae		<i>Eucalyptus largiflorens</i>	Black Box	t						1								
Dicotyledon	Myrtaceae		<i>Eucalyptus melliodora</i>	Yellow Box	t			1	1	1	1								
Dicotyledon	Myrtaceae		<i>Eucalyptus microcarpa</i>	Grey Box	t	1	1	1			1								
Dicotyledon	Myrtaceae		<i>Eucalyptus populnea</i>	Bimble Box	t	1	1	1	1		1								
Dicotyledon	Myrtaceae		<i>Eucalyptus viridis</i>	Green Mallee	t				1	1	1								
Dicotyledon	Nyctaginaceae		<i>Boerhavia dominii</i>	Tar Vine	h	1													
Dicotyledon	Onagraceae		<i>Epilobium billardierianum</i>	Willow Herb	h		1												
Dicotyledon	Onagraceae		<i>Epilobium spp.</i>	Willow Herb	h	1													
Dicotyledon	Oxalidaceae		<i>Oxalis perennans</i>	Yellow Wood-sorrel	h		1	1	1	1	1	1		1	1	1		1	1
Dicotyledon	Papaveraceae	*	<i>Papaver hybridum</i>	Rough Poppy	h	1	1												
Dicotyledon	Papaveraceae	*	<i>Papaver somniferum</i>	Opium Poppy	h	1													

Group	Family	exotic	Scientific Name	Common Name	Habit	LFO-01	LFO-02	Beechmoore	Estcourt	Altona	Kundibah	TSF1-01	TSF1-02	TSF2-01	TSF2-02	E22-01	E22-02	E26-01	E27-01
Dicotyledon	Pittosporaceae		<i>Pittosporum angustifolium</i>	Butterbush	s					1									
Dicotyledon	Plantaginaceae	*	<i>Echium plantagineum</i>	Paterson's Curse	h	1	1	1		1	1	1	1	1	1	1	1	1	1
Dicotyledon	Polygonaceae	*	<i>Polygonum aviculare</i>	Wireweed	h												1	1	1
Dicotyledon	Polygonaceae		<i>Rumex brownii</i>	Swamp Dock	h			1	1	1									
Dicotyledon	Polygonaceae	*	<i>Rumex crispus</i>	Curled Dock	h	1	1			1					1	1		1	
Dicotyledon	Polygonaceae		<i>Rumex tenax</i>	Shiny Dock	h										1				
Dicotyledon	Rubiaceae		<i>Asperula conferta</i>	Common Woodruff	h			1					1						
Dicotyledon	Sapindaceae		<i>Dodonaea boroniifolia</i>	Fern-leaf Hopbush	s					1									
Dicotyledon	Sapindaceae		<i>Dodonaea viscosa subsp. cuneata</i>	Wedge-leaf Hopbush	s	1		1	1		1								
Dicotyledon	Scrophulariaceae	*	<i>Verbascum virgatum</i>	Twiggy Mullein	h	1	1												
Dicotyledon	Solanaceae		<i>Solanum esuriale</i>	Quena	h			1		1									
Dicotyledon	Sterculiaceae		<i>Brachychiton populneus</i>	Kurrajong	t			1	1	1									
Dicotyledon	Verbenaceae	*	<i>Verbena officinalis</i>	Common Verbena	h	1													
Monocotyledon	Cyperaceae		<i>Carex inversa</i>	Knob Sedge	r		1	1	1	1	1								
Monocotyledon	Iridaceae	*	<i>Romulea rosea</i>	Onion Grass	h														
Monocotyledon	Juncaceae		<i>Juncus aridicola</i>	Tussock Rush	r		1												
Monocotyledon	Juncaceae		<i>Juncus usitatus</i>		r		1				1								
Monocotyledon	Poaceae		<i>Austrodanthonia bipartita</i>	Wallaby Grass	g			1	1		1								1
Monocotyledon	Poaceae		<i>Austrodanthonia caespitosa</i>	Wallaby Grass	g			1	1	1									
Monocotyledon	Poaceae		<i>Austrodanthonia eriantha</i>	Hill Wallaby Grass	g		1	1		1				1					
Monocotyledon	Poaceae		<i>Austrodanthonia setacea</i>	Small-flowered Wallaby Grass	g			1	1		1		1	1	1	1	1	1	1
Monocotyledon	Poaceae		<i>Austrostipa bigeniculata</i>	Tall Speargrass	g											1			1
Monocotyledon	Poaceae		<i>Austrostipa nodosa</i>	A Speargrass	g			1		1		1							1
Monocotyledon	Poaceae		<i>Austrostipa scabra subsp. falcata</i>	Speargrass	g			1		1									
Monocotyledon	Poaceae		<i>Austrostipa scabra subsp. scabra</i>	Rough Speargrass	g					1				1		1	1		
Monocotyledon	Poaceae		<i>Austrostipa spp.</i>	A Speargrass	g													1	
Monocotyledon	Poaceae	*	<i>Avena fatua</i>	Wild Oats	g	1	1		1	1	1	1	1	1	1	1	1	1	1
Monocotyledon	Poaceae	*	<i>Bromus diandrus</i>	Great Brome	g								1	1		1		1	1
Monocotyledon	Poaceae	*	<i>Bromus molliformis</i>	Soft Brome	g		1		1	1				1		1		1	
Monocotyledon	Poaceae	*	<i>Cenchrus ciliaris</i>	Buffel Grass	g									1		1			
Monocotyledon	Poaceae	*	<i>Chloris gayana</i>	Rhodes Grass	g								1	1		1			1
Monocotyledon	Poaceae		<i>Chloris truncata</i>	Windmill Grass	g					1	1		1	1	1		1		

Group	Family	exotic	Scientific Name	Common Name	Habit	LFO-01	LFO-02	Beechmoore	Estcourt	Altona	Kundibah	TSF1-01	TSF1-02	TSF2-01	TSF2-02	E22-01	E22-02	E26-01	E27-01
Monocotyledon	Poaceae		<i>Dichanthium sericeum</i>	Queensland Bluegrass	g						1	1	1	1	1		1	1	
Monocotyledon	Poaceae		<i>Digitaria spp.</i>		g				1	1									
Monocotyledon	Poaceae		<i>Enteropogon acicularis</i>	Curly Windmill Grass	g			1	1		1		1	1	1	1	1	1	1
Monocotyledon	Poaceae	*	<i>Eragrostis curvula</i>	African Lovegrass	g							1							
Monocotyledon	Poaceae	*	<i>Hordeum leporinum</i>	Barley Grass	g	1	1		1	1						1	1		1
Monocotyledon	Poaceae		<i>Lachnagrostis filiformis</i>	Blown Grass	g					1									
Monocotyledon	Poaceae	*	<i>Lolium rigidum</i>	Wimmera Ryegrass	g	1	1	1	1	1	1	1	1	1	1	1	1		1
Monocotyledon	Poaceae	*	<i>Lolium spp.</i>	A Ryegrass	g													1	
Monocotyledon	Poaceae		<i>Panicum decompositum</i>	Native Millet	g									1					
Monocotyledon	Poaceae		<i>Paspalidium constrictum</i>	Knottybutt Grass	g			1		1	1								
Monocotyledon	Poaceae	*	<i>Phalaris minor</i>	Lesser Canary Grass	g	1					1	1	1		1			1	1
Monocotyledon	Poaceae	*	<i>Rostraria cristata</i>	Annual Cats Tail	g	1	1												
Monocotyledon	Poaceae		<i>Sporobolus caroli</i>	Fairy Grass	g				1										
Monocotyledon	Poaceae	*	<i>Vulpia spp.</i>		g		1			1									
Monocotyledon	Poaceae		<i>Walwhalleya proluta</i>	Rigid Panic	g		1	1	1	1	1	1	1	1	1	1	1	1	1

Appendix 2. List of flora species recorded in the reference sites in 2013

Group	Family	exotic	Scientific Name	Common Name	Habit	RWood01	RWood02	RWood03	RWood04	RGrass01	RGrass02	RGrass03
Coniferopsida	Cupressaceae		<i>Callitris glaucophylla</i>	White Cypress Pine	t	1	1		1			
Dicotyledon	Acanthaceae		<i>Rostellularia adscendens</i> var. <i>Pogonanthera</i>	Pink Tongues	h	1						
Dicotyledon	Amaranthaceae		<i>Ptilotus exaltatus</i>	Lambs Tails	h	1		1		1	1	
Dicotyledon	Amaranthaceae		<i>Ptilotus spathulatus</i>	Pussy Tails	h				1			
Dicotyledon	Apiaceae		<i>Daucus glochidiatus</i>	Australian Carrot	h		1		1	1	1	
Dicotyledon	Asteraceae	*	<i>Arctotheca calendula</i>	Capeweed	h				1	1		
Dicotyledon	Asteraceae		<i>Brachyscome curvicalpa</i>	Curved-seed Daisy	h	1		1				
Dicotyledon	Asteraceae		<i>Calotis anthemoides</i>	Cut-leaved Burr-daisy	h	1	1	1		1		
Dicotyledon	Asteraceae		<i>Calotis cuneifolia</i>	Purple Burr Daisy	h	1	1	1				
Dicotyledon	Asteraceae		<i>Calotis lappulacea</i>	Yellow Burr Daisy	h	1	1	1				
Dicotyledon	Asteraceae	*	<i>Carthamus lanatus</i>	Saffron Thistle	h	1	1		1	1	1	1
Dicotyledon	Asteraceae	*	<i>Centaurea melitensis</i>	Maltese Cockspur	h				1		1	1
Dicotyledon	Asteraceae	*	<i>Centaurea solstitialis</i>	St Barnaby's Thistle	h		1	1				
Dicotyledon	Asteraceae		<i>Chrysocephalum apiculatum</i>	Common Everlasting	h					1		
Dicotyledon	Asteraceae	*	<i>Cirsium vulgare</i>	Spear Thistle	h		1				1	1
Dicotyledon	Asteraceae		<i>Cymbonotus lawsonianus</i>	Bear's Ear	h		1	1				
Dicotyledon	Asteraceae		<i>Euchiton sphaericus</i>	Japanese Cudweed	h			1	1			
Dicotyledon	Asteraceae	*	<i>Gamochaeta americana</i>	Cudweed	h		1					
Dicotyledon	Asteraceae	*	<i>Hedypnois rhagadioloides</i> subsp. <i>cretica</i>	Cretan Weed	h			1	1	1	1	
Dicotyledon	Asteraceae		<i>Hyalosperma semisterile</i>	Orange Sunray	h					1		
Dicotyledon	Asteraceae	*	<i>Hypochaeris glabra</i>	Smooth Catsear	h						1	1
Dicotyledon	Asteraceae	*	<i>Hypochaeris radicata</i>	Flatweed	h						1	
Dicotyledon	Asteraceae	*	<i>Hypochaeris</i> spp.	Flatweed	h			1				
Dicotyledon	Asteraceae	*	<i>Lactuca serriola</i>	Prickly Lettuce	h	1	1	1	1			1
Dicotyledon	Asteraceae		<i>Leiocarpa panaetioides</i>	Woolly Buttons	h			1			1	1
Dicotyledon	Asteraceae		<i>Minuria leptophylla</i>	Minnie Daisy	h	1		1		1		
Dicotyledon	Asteraceae		<i>Rhodanthe corymbiflora</i>	Small White Sunray	h	1						
Dicotyledon	Asteraceae		<i>Rhodanthe pygmaea</i>	Pigmy Sunray	h		1					
Dicotyledon	Asteraceae	*	<i>Sonchus oleraceus</i>	Milk Thistle	h	1	1	1	1	1	1	1
Dicotyledon	Asteraceae		<i>Triptilodiscus pygmaeus</i>	Austral Sunray	h		1		1	1		
Dicotyledon	Asteraceae		<i>Vittadinia cuneata</i>	Fuzzweed	h	1	1	1	1			
Dicotyledon	Asteraceae		<i>Vittadinia cuneata</i> var. <i>hirsuta</i>	Fuzzweed	h				1			
Dicotyledon	Asteraceae		<i>Vittadinia gracilis</i>	A Fuzzweed	h				1			

Group	Family	exotic	Scientific Name	Common Name	Habit	RWood01	RWood02	RWood03	RWood04	RGrass01	RGrass02	RGrass03
Dicotyledon	Asteraceae		<i>Vittadinia muelleri</i>	Fuzzweed	h		1					
Dicotyledon	Asteraceae		<i>Vittadinia pterochaeta</i>	Rough Fuzzweed	h	1						
Dicotyledon	Asteraceae		<i>Vittadinia spp.</i>	Fuzzweed	h					1		
Dicotyledon	Asteraceae		<i>Vittadinia sulcata</i>	A Fuzzweed	h	1						
Dicotyledon	Asteraceae		<i>Vittadinia tenuissima</i>	Western New Holland Daisy	h		1				1	
Dicotyledon	Asteraceae		<i>Xerochrysum bracteatum</i>	Golden Everlasting	h		1		1			1
Dicotyledon	Boraginaceae	*	<i>Buglossoides arvensis</i>	Corn Gromwell	h				1			
Dicotyledon	Brassicaceae	*	<i>Capsella bursa-pastoris</i>	Shepherd's Purse	h				1			
Dicotyledon	Brassicaceae	*	<i>Lepidium africanum</i>	Peppergrass	h	1		1	1			
Dicotyledon	Brassicaceae	*	<i>Rapistrum rugosum</i>	Turnip Weed	h	1						
Dicotyledon	Brassicaceae	*	<i>Sisymbrium irio</i>	London Rocket	h	1	1		1			
Dicotyledon	Campanulaceae		<i>Wahlenbergia gracilentia</i>	Australian Bluebell	h					1	1	
Dicotyledon	Campanulaceae		<i>Wahlenbergia gracilis</i>	Sprawling Bluebell	h					1		
Dicotyledon	Campanulaceae		<i>Wahlenbergia luteola</i>	Australian Bluebell	h		1					
Dicotyledon	Campanulaceae		<i>Wahlenbergia spp.</i>	Bluebell	h			1	1			
Dicotyledon	Campanulaceae		<i>Wahlenbergia stricta</i>	Tall Bluebell	h						1	
Dicotyledon	Caryophyllaceae	*	<i>Petrorhagia nanteuillii</i>	Proliferous Pink	h		1		1		1	
Dicotyledon	Caryophyllaceae	*	<i>Spergularia rubra</i>	Sandspurry	h			1				
Dicotyledon	Casuarinaceae		<i>Allocasuarina luehmannii</i>	Bullock	t	1		1				
Dicotyledon	Chenopodiaceae		<i>Atriplex semibaccata</i>	Creeping Saltbush	ss		1					
Dicotyledon	Chenopodiaceae		<i>Atriplex spinibractea</i>	Spiny-fruit Saltbush	ss	1			1		1	
Dicotyledon	Chenopodiaceae		<i>Chenopodium desertorum</i> subsp. <i>anidiophyllum</i>	Mallee Goosefoot	ss		1	1				
Dicotyledon	Chenopodiaceae		<i>Einadia nutans</i> subsp. <i>linifolia</i>	Climbing Saltbush	h	1		1				
Dicotyledon	Chenopodiaceae		<i>Einadia nutans</i> subsp. <i>nutans</i>	Climbing Saltbush	h		1		1			
Dicotyledon	Chenopodiaceae		<i>Maireana enchylaenoides</i>	Wingless Fissure Weed	h	1	1	1	1		1	1
Dicotyledon	Chenopodiaceae		<i>Maireana excavata</i>	Bottle Bluebush	ss					1		
Dicotyledon	Chenopodiaceae		<i>Maireana microphylla</i>	Eastern Cottonbush	ss	1		1		1	1	
Dicotyledon	Chenopodiaceae		<i>Maireana spp.</i>		ss					1		
Dicotyledon	Chenopodiaceae		<i>Salsola kali</i>	Buckbush	ss	1		1		1		
Dicotyledon	Chenopodiaceae		<i>Sclerolaena diacantha</i>	Grey Copperburr	ss	1		1				
Dicotyledon	Convolvulaceae		<i>Convolvulus erubescens</i>	Australian Bindweed	h	1	1	1	1	1		1
Dicotyledon	Convolvulaceae		<i>Dichondra repens</i>	Kidney Weed	h		1	1	1		1	
Dicotyledon	Crassulaceae		<i>Crassula colorata</i>	Dense Stonecrop	h		1					
Dicotyledon	Euphorbiaceae		<i>Chamaesyce drummondii</i>	Caustic Weed	h					1		1
Dicotyledon	Fabaceae (Caesalpinoideae)		<i>Senna artemisioides</i> subsp. <i>filifolia</i>	Punty Bush	s			1				

Group	Family	exotic	Scientific Name	Common Name	Habit	RWood01	RWood02	RWood03	RWood04	RGrass01	RGrass02	RGrass03
Dicotyledon	Fabaceae (Faboideae)		<i>Glycine clandestina</i>	Climbing Glycine	h	1		1				
Dicotyledon	Fabaceae (Faboideae)		<i>Glycine tabacina</i>	Variable Glycine	h	1	1		1			
Dicotyledon	Fabaceae (Faboideae)	*	<i>Medicago minima</i>	Small Woolly Burr Medic	h	1	1	1	1	1	1	1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Medicago polymorpha</i>	Burr Medic	h		1	1	1	1	1	
Dicotyledon	Fabaceae (Faboideae)	*	<i>Medicago truncatula</i>	Barrel Medic	h						1	
Dicotyledon	Fabaceae (Faboideae)		<i>Swainsona swainsonioides</i>	Downy Darling Pea	h							1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium angustifolium</i>	Narrow-leaf Clover	h		1			1	1	1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium arvense</i>	Haresfoot Clover	h		1		1	1		1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium campestre</i>	Hop Clover	h		1		1		1	1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium glomeratum</i>	Clustered Clover	h	1	1	1	1		1	
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium incarnatum?</i>	Crimson Clover	h						1	
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium scabrum</i>	Rough Clover	h		1					1
Dicotyledon	Fabaceae (Faboideae)	*	<i>Trifolium subterraneum</i>	Subterraneum Clover	h			1	1			
Dicotyledon	Fabaceae (Mimosoideae)		<i>Acacia deanei</i>	Green Wattle	s		1					
Dicotyledon	Fabaceae (Mimosoideae)		<i>Acacia hakeoides</i>	Hakea Wattle	s	1		1				
Dicotyledon	Geraniaceae	*	<i>Erodium cicutarium</i>	Common Crowsfoot	h				1			
Dicotyledon	Geraniaceae		<i>Erodium crinitum</i>	Blue Storksbill	h				1			
Dicotyledon	Geraniaceae		<i>Geranium solanderi</i>	Native Geranium	h							1
Dicotyledon	Goodeniaceae		<i>Goodenia fascicularis</i>		h					1	1	
Dicotyledon	Goodeniaceae		<i>Goodenia pinnatifida</i>	Scrambled Eggs	h	1	1	1		1		
Dicotyledon	Goodeniaceae		<i>Goodenia pusilliflora</i>	Small-flowered Goodenia	h					1		
Dicotyledon	Lamiaceae	*	<i>Marrubium vulgare</i>	Horehound	h	1	1		1			1
Dicotyledon	Lamiaceae	*	<i>Salvia verbenaca</i>	Wild Sage	h	1	1		1	1		1
Dicotyledon	Linaceae		<i>Linum marginale</i>	Native Flax	h					1		
Dicotyledon	Malvaceae		<i>Sida corrugata</i>	Corrugated Sida	h	1	1	1	1	1	1	
Dicotyledon	Malvaceae		<i>Sida fibulifera</i>	Pin Sida	h				1			
Dicotyledon	Malvaceae		<i>Sida platycalyx</i>	Lifesaver Burr	h				1			
Dicotyledon	Malvaceae		<i>Sida spp.</i>		h					1		
Dicotyledon	Malvaceae		<i>Sida trichopoda</i>	Hairy Sida	h						1	
Dicotyledon	Myoporaceae		<i>Eremophila debilis</i>	Amulla	ss	1		1			1	
Dicotyledon	Myrtaceae		<i>Eucalyptus albens</i>	White Box	t		1					
Dicotyledon	Myrtaceae		<i>Eucalyptus melliodora</i>	Yellow Box	t				1			
Dicotyledon	Myrtaceae		<i>Eucalyptus microcarpa</i>	Grey Box	t	1		1				
Dicotyledon	Myrtaceae		<i>Eucalyptus populnea</i>	Bimble Box	t		1		1			
Dicotyledon	Nyctaginaceae		<i>Boerhavia dominii</i>	Tar Vine	h	1			1			

Group	Family	exotic	Scientific Name	Common Name	Habit	RWood01	RWood02	RWood03	RWood04	RGrass01	RGrass02	RGrass03
Dicotyledon	Onagraceae		<i>Epilobium billardierianum</i>	Willow Herb	h					1		
Dicotyledon	Oxalidaceae		<i>Oxalis perennans</i>	Yellow Wood-sorrel	h	1	1	1			1	1
Dicotyledon	Papaveraceae	*	<i>Papaver hybridum</i>	Rough Poppy	h				1			
Dicotyledon	Papaveraceae	*	<i>Papaver somniferum</i>	Opium Poppy	h				1			
Dicotyledon	Plantaginaceae	*	<i>Echium plantagineum</i>	Paterson's Curse	h	1	1		1		1	1
Dicotyledon	Plantaginaceae		<i>Plantago debilis</i>	Plantain	h	1	1	1				
Dicotyledon	Polygonaceae		<i>Rumex brownii</i>	Swamp Dock	h				1			
Dicotyledon	Primulaceae	*	<i>Anagallis arvensis</i>	Scarlet Pimpernel	h					1		
Dicotyledon	Rubiaceae		<i>Asperula conferta</i>	Common Woodruff	h					1	1	1
Dicotyledon	Sapindaceae		<i>Alectryon oleifolius</i>	Rosewood	t	1						
Dicotyledon	Sapindaceae		<i>Dodonaea viscosa subsp. cuneata</i>	Wedge-leaf Hopbush	s	1		1				
Dicotyledon	Schrophulariaceae		<i>Brunoniella australis</i>	Blue Trumpet	h	1		1				
Dicotyledon	Solanaceae		<i>Solanum esuriale</i>	Quena	h		1		1	1	1	1
Dicotyledon	Sterculiaceae		<i>Brachychiton populneus</i>	Kurrajong	t		1					
Monocotyledon	Anthericaceae		<i>Arthropodium minus</i>	Small Vanilla Lily	h		1	1			1	
Monocotyledon	Anthericaceae		<i>Dichopogon spp.</i>	Chocolate Lily	h		1		1			1
Monocotyledon	Asphodelaceae	*	<i>Asphodelus fistulosus</i>	Onion Weed	h							1
Monocotyledon	Asphodelaceae		<i>Bulbine bulbosa</i>	Bulbine Lily	h					1		
Monocotyledon	Asphodelaceae		<i>Bulbine semibarbata</i>	Leek Lily	h			1				
Monocotyledon	Colchicaceae		<i>Wurmbea dioica</i>	Early Nancy	h			1		1		
Monocotyledon	Cyperaceae		<i>Carex inversa</i>	Knob Sedge	r		1					
Monocotyledon	Iridaceae	*	<i>Romulea rosea</i>	Onion Grass	h					1		
Monocotyledon	Lomandraceae		<i>Lomandra glauca</i>	Pale Mat-rush	h		1					
Monocotyledon	Lomandraceae		<i>Lomandra multiflora</i>	Many-flowered Mat-rush	h			1				
Monocotyledon	Lomandraceae		<i>Lomandra spp.</i>		h				1			
Monocotyledon	Phormiaceae		<i>Dianella revoluta</i>	Native Flax Lily	h		1					
Monocotyledon	Poaceae		<i>Aristida behriana</i>	Bunch Wiregrass	g		1		1			
Monocotyledon	Poaceae		<i>Aristida jerichoensis var. jerichoensis</i>	Jericho Wiregrass	g		1				1	
Monocotyledon	Poaceae		<i>Austrodanthonia bipartita</i>	Wallaby Grass	g	1		1		1	1	
Monocotyledon	Poaceae		<i>Austrodanthonia caespitosa</i>	Wallaby Grass	g	1	1	1		1	1	
Monocotyledon	Poaceae		<i>Austrodanthonia eriantha</i>	Hill Wallaby Grass	g		1	1	1		1	1
Monocotyledon	Poaceae		<i>Austrodanthonia setacea</i>	Small-flowered Wallaby Grass	g	1	1				1	1
Monocotyledon	Poaceae		<i>Austrostipa bigeniculata</i>	Tall Speargrass	g		1			1	1	
Monocotyledon	Poaceae		<i>Austrostipa nodosa</i>	A Speargrass	g	1	1	1	1		1	1
Monocotyledon	Poaceae		<i>Austrostipa scabra subsp. falcata</i>	Speargrass	g		1	1	1	1		

Group	Family	exotic	Scientific Name	Common Name	Habit	RWood01	RWood02	RWood03	RWood04	RGrass01	RGrass02	RGrass03
Monocotyledon	Poaceae		<i>Austrostipa scabra subsp. scabra</i>	Rough Speargrass	g	1	1	1	1			
Monocotyledon	Poaceae	*	<i>Avena fatua</i>	Wild Oats	g		1	1			1	1
Monocotyledon	Poaceae		<i>Bothriochloa macra</i>	Red-leg Grass	g		1					1
Monocotyledon	Poaceae	*	<i>Bromus diandrus</i>	Great Brome	g		1					
Monocotyledon	Poaceae	*	<i>Bromus molliformis</i>	Soft Brome	g				1		1	1
Monocotyledon	Poaceae		<i>Chloris truncata</i>	Windmill Grass	g			1		1	1	
Monocotyledon	Poaceae		<i>Dichanthium sericeum</i>	Queensland Bluegrass	g		1			1	1	1
Monocotyledon	Poaceae		<i>Digitaria divaricatissima</i>	Umbrella Grass	g							1
Monocotyledon	Poaceae		<i>Digitaria spp.</i>		g		1			1		
Monocotyledon	Poaceae		<i>Elymus scaber</i>	Common Wheatgrass	g		1	1	1			
Monocotyledon	Poaceae		<i>Enteropogon acicularis</i>	Curly Windmill Grass	g	1	1	1		1	1	1
Monocotyledon	Poaceae		<i>Eulalia aurea</i>	Silky Browntop	g					1		
Monocotyledon	Poaceae	*	<i>Hordeum leporinum</i>	Barley Grass	g	1			1			
Monocotyledon	Poaceae	*	<i>Lamarckia aurea</i>	Golden-Top	g		1					
Monocotyledon	Poaceae	*	<i>Lolium rigidum</i>	Wimmera Ryegrass	g	1	1	1	1	1	1	1
Monocotyledon	Poaceae		<i>Panicum spp.</i>		g		1					
Monocotyledon	Poaceae	*	<i>Parapholis incurva</i>	Curly Rye Grass	g					1		
Monocotyledon	Poaceae		<i>Paspalidium constrictum</i>	Knobbybutt Grass	g	1	1	1				
Monocotyledon	Poaceae		<i>Poa sieberiana</i>	Fine-leaf Tussock	g		1					
Monocotyledon	Poaceae		<i>Sporobolus caroli</i>	Fairy Grass	g			1		1		
Monocotyledon	Poaceae	*	<i>Vulpia spp.</i>		g		1		1	1	1	
Monocotyledon	Poaceae		<i>Walwhalleya proluta</i>	Rigid Panic	g			1		1	1	1
Pteridophyta	Adiantaceae		<i>Cheilanthes sieberi subsp. sieberi</i>	Rock Fern	f		1					

Appendix 3. ROUTINE AGRICULTURAL SOIL ANALYSIS REPORT– Rehabilitation Sites

Soil samples supplied by DnA Environmental on 23rd October, 2013 - Lab Job No. C9596

Site				LF0-01	LF0-02	Estcourt	Beechmore	Altona	Kundibah	TSF1-01	TSF1-02	TSF2-01	TSF2-02	E22-01	E22-02	E26	E27
Method	Nutrient	Units		C9596/1	C9596/2	C9596/7	C9596/12	C9596/13	C9596/14	C9596/3	C9596/4	C9596/5	C9596/6	C9596/8	C9596/9	C9596/10	C9596/11
	Morgan 1	Calcium	C a	617	571	841	815	426	604	1924	1341	959	1185	1282	2492	1720	1491
		Magnesium	M g	115	143	604	396	121	413	717	770	752	735	516	816	610	765
		Potassium	K	252	255	115	155	285	114	111	99	71	99	232	122	152	136
		Phosphorus	P	2.7	1.6	2.3	1.8	2.2	1.6	2.3	1.7	1.9	1.7	2.3	2.4	2.9	3.8
	Bray1	Phosphorus	P	22.6	5.6	2.2	2.8	9.8	4.4	3.4	2.7	3.5	2.3	4.2	4.9	7.6	5.0
	Colwell			53	19	6	10	21	17	11	6	12	5	13	11	19	16
	Bray2			34	9	4	5	16	8	14	6	9	5	9	40	14	11
	KCl	Nitrate Nitrogen	N	1.0	2.4	1.4	1.3	3.5	1.0	2.6	1.2	0.9	1.1	0.3	0.8	1.3	1.8
		Ammonium Nitrogen		11.8	6.0	11.4	7.4	6.9	12.5	13.9	12.4	8.6	9.3	11.7	7.4	8.4	13.3
		Sulfur	S	18.4	9.4	7.0	2.7	12.9	4.9	26.7	78.1	384.9	31.5	6.4	3.6	5.7	6.5
	1:5 Water	pH	units	5.34	5.51	6.51	6.45	5.37	6.16	7.90	7.72	6.15	7.50	7.26	8.24	7.91	7.34
		Conductivity	dS/m	0.063	0.039	0.113	0.057	0.059	0.042	0.189	0.275	1.022	0.143	0.088	0.103	0.081	0.111
	Calculation	Organic Matter	% OM	2.3	1.9	2.6	4.6	4.2	2.4	1.9	1.1	1.5	1.3	2.6	1.6	2.4	2.7
	Ammonium Acetate + Calculations	Calcium	C a	cmol+/Kg	5.29	4.95	8.67	8.15	3.94	5.81	16.16	12.23	8.49	11.79	11.04	18.62	14.50
				kg/ha	2373	2224	3893	3657	1769	2607	7256	5492	3811	5294	4954	8357	6510
				mg/kg	1059	993	1738	1633	790	1164	3239	2452	1701	2364	2211	3731	2906
		Magnesium	M g	cmol+/Kg	1.44	1.79	9.31	5.45	1.43	5.81	9.82	11.16	10.25	11.47	6.73	10.99	8.40
				kg/ha	391	488	2533	1483	389	1581	2672	3039	2789	3122	1832	2993	2287
				mg/kg	175	218	1131	662	174	706	1193	1357	1245	1394	818	1336	1021

Site				LF0-01	LF0-02	Estcourt	Beechmore	Altona	Kundibah	TSF1-01	TSF1-02	TSF2-01	TSF2-02	E22-01	E22-02	E26	E27
		Potassium K	cmol+/Kg	1.53	1.53	0.91	1.12	1.62	0.80	0.95	0.83	0.51	0.80	1.64	1.03	1.27	1.12
			kg/ha	1340	1341	795	985	1423	703	834	730	448	700	1440	899	1110	980
			mg/kg	598	599	355	440	635	314	372	326	200	312	643	401	495	437
		Sodium Na	cmol+/Kg	0.04	0.03	1.86	0.75	0.06	0.49	1.00	2.36	4.58	1.77	0.46	0.19	0.44	0.34
			kg/ha	20	15	957	384	31	252	517	1213	2360	910	238	100	226	176
			mg/kg	9	7	427	171	14	112	231	541	1053	406	106	44	101	79
	KCl	Aluminium Al	cmol+/Kg	0.07	0.05	0.03	0.02	0.09	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
			kg/ha	13	9	5	4	17	4	6	6	7	5	7	4	5	4
			mg/kg	6	4	2	2	8	2	3	2	3	2	3	2	2	2
	Acidity Titration	Hydrogen H ⁺	cmol+/Kg	0.50	0.28	0.00	0.04	0.39	0.08	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
			kg/ha	11	6	0	1	9	2	0	0	2	0	0	0	0	0
			mg/kg	5	3	0	0	4	1	0	0	1	0	0	0	0	0
	Calculation	Effective Cation Exchange Capacity (ECEC)	cmol+/Kg	8.85	8.63	20.77	15.53	7.53	13.01	27.96	26.61	23.93	25.85	19.91	30.85	24.63	25.29
	Base Saturation Calculations	Calcium Ca	%	59.7	57.4	41.8	52.5	52.3	44.6	57.8	46.0	35.5	45.6	55.4	60.3	58.9	52.4
		Magnesium Mg		16.2	20.8	44.8	35.1	19.0	44.6	35.1	41.9	42.8	44.4	33.8	35.6	34.1	41.7
		Potassium K		17.3	17.7	4.4	7.2	21.6	6.2	3.4	3.1	2.1	3.1	8.3	3.3	5.1	4.4
		Sodium - ESP Na		0.4	0.3	8.9	4.8	0.8	3.8	3.6	8.8	19.1	6.8	2.3	0.6	1.8	1.4
		Aluminium Al		0.7	0.5	0.1	0.1	1.1	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
		Hydrogen H ⁺		5.6	3.2	0.0	0.3	5.2	0.6	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
	Calculation	Calcium/ Magnesium Ratio	ratio	3.7	2.8	0.9	1.5	2.8	1.0	1.6	1.1	0.8	1.0	1.6	1.7	1.7	1.3
	DTPA	Zinc Zn	mg/kg	1.3	1.1	0.3	0.9	1.4	0.6	0.4	0.2	0.3	0.3	0.8	0.3	0.6	0.7
		Manganese Mn		93	78	78	75	120	61	16	16	27	18	31	13	12	27

Site				LF0-01	LF0-02	Estcourt	Beechmore	Altona	Kundibah	TSF1-01	TSF1-02	TSF2-01	TSF2-02	E22-01	E22-02	E26	E27
		Iron	Fe	111	80	83	56	205	102	29	27	57	31	21	12	15	27
		Copper	Cu	8.0	10.5	4.2	3.3	15.0	4.0	10.6	3.2	7.1	3.5	14.3	18.1	11.7	49.0
	CaCl ₂	Boron	B	0.86	0.75	1.38	0.89	0.80	0.93	1.43	1.96	1.50	1.61	1.16	1.10	1.17	0.84
		Silicon	Si	80	66	104	92	57	98	47	66	98	86	63	43	64	63
	LECO IR Analyser	Total Carbon	C	1.31	1.09	1.46	2.64	2.39	1.40	1.11	0.64	0.86	0.76	1.46	0.91	1.36	1.53
		Total Nitrogen	N	0.13	0.12	0.14	0.14	0.26	0.11	0.07	0.07	0.12	0.09	0.13	0.05	0.13	0.13
	Calculation	Carbon/ Nitrogen Ratio	ratio	10.4	9.4	10.5	18.3	9.3	12.6	15.2	8.9	7.3	8.9	11.2	18.8	10.6	11.6
		Basic Texture		Clay Loam	Clay Loam	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		Red	Red	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish
	Calculation	Chloride Estimate	equiv. ppm	40	25	72	37	38	27	121	176	654	92	57	66	52	71
	Total Acid Extractable	Calcium	Ca	1,362	1,315	2,029	2,225	1,113	1,317	4,428	2,797	1,983	2,633	2,991	6,252	3,325	3,421
		Magnesium	Mg	2,239	2,068	2,548	1,832	797	1,623	3,845	3,457	2,626	3,228	2,540	6,085	2,576	4,137
		Potassium	K	2,547	2,325	1,473	1,739	2,277	1,352	1,953	1,646	998	1,282	2,277	1,774	1,830	2,157
		Sodium	Na	<50	<50	515	238	<50	148	334	693	1,281	527	160	116	169	150
		Sulfur	S	157	124	140	129	195	116	154	195	580	179	140	345	141	194
	Total Acid Extractable	Phosphorus	P	467	333	140	200	425	202	227	105	150	120	319	423	244	253
	Total Acid Extractable	Zinc	Zn	50	60	18	26	26	17	28	22	17	22	42	44	21	33
		Manganese	Mn	1,445	1,137	951	1,269	1,805	788	794	653	544	541	963	913	511	864
		Iron	Fe	38,457	35,882	16,262	17,215	23,010	13,695	19,461	18,775	22,541	21,436	36,669	25,135	25,732	24,987
		Copper	Cu	82.2	90.6	26.1	28.0	115.5	21.5	158.9	28.3	40.5	32.1	207.8	431.0	92.3	496.2

Site				LF0-01	LF0-02	Estcourt	Beechmore	Altona	Kundibah	TSF1-01	TSF1-02	TSF2-01	TSF2-02	E22-01	E22-02	E26	E27
	Boron	B		<2	<2	2	<2	<2	<2	4	4	3	3	3	4	2	2
	Silicon	Si		817	676	825	579	692	756	603	521	835	513	750	949	582	571
	Aluminium	Al		15,884	15,367	16,157	14,160	10,898	10,768	18,252	18,051	14,785	16,753	18,054	20,017	15,536	19,200
	Total Acid Extractable	Molybdenum	M o	1.0	0.6	0.4	0.4	1.8	0.5	0.9	0.4	0.5	0.4	1.1	0.8	1.0	0.8
		Cobalt	C o	17	16	12	13	15	9	11	10	9	9	16	13	10	14
		Selenium	S e	0.5	0.5	<0.5	<0.5	0.6	<0.5	0.5	<0.5	<0.5	<0.5	0.6	<0.5	0.5	1.1
	Total Acid Extractable	Cadmium	C d	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
		Lead	P b	23	16	11	12	24	12	12	10	10	12	20	17	13	13
		Arsenic	As	8	6	2	3	4	3	3	3	4	3	7	4	4	4
		Chromium	Cr	30	27	21	19	19	18	19	21	20	20	24	17	26	20
		Nickel	Ni	10	10	9	8	7	7	10	9	6	8	11	11	11	10
		Mercury	H g	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
		Silver	A g	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

EAL Soil Testing Notes

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

9. Information relating to testing colour codes is available on Sheet 2 - "*Understanding your soil results*"

Calculations

1. For conductivity 1 dS/m = 1 mS/cm = 1000 µS/cm
2. 1 cmol⁺/Kg = 1 meq/100g; 1 Lb/Acre = 2 ppm (parts per million); kg/ha = 2.24 x ppm; mg/kg = ppm
3. Conversions for 1 cmol⁺/Kg = 230 Kg/Hectare Sodium, 780 Kg/Ha Potassium, 240 Kg/Ha Magnesium, 400 Kg/Ha Calcium
4. Organic Matter = %C x 1.75
5. Chloride Estimate = EC x 640 (most likely over-estimate)
6. ECEC = sum of the exchangeable cations cmol⁺/Kg
7. Base saturation calculations = (cation cmol⁺/Kg) / ECEC x 100
8. Ca/Mg ratio from the exchangeable cmol⁺/Kg results

Understanding your EAL soil results

Soil Acidity - Is the water pH >6.5 or CaCl₂ pH >5.5 – hence no major problem. >7pH indicates alkaline soil. Soil with pH below 4.5 often has high kg/ha exchangeable hydrogen and aluminium (and likely high % exchangeable H and Al).

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

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

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

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

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

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

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

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

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

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

Soil samples supplied by DnA Environmental on 23rd October, 2013 - Lab Job No. C9596

Site				RWood01	RWood02	RWood03	RWood04	RGrass01	RGrass02	RGrass03	Heavy Soil e.g Clay	Medium Soil e.g Clay Loam	Light Soil e.g Loam	Sandy Soil e.g Loamy Sand
Method	Nutrient		Units	C9596/15	C9596/16	C9596/17	C9596/18	C9596/19	C9596/20	C9596/21	Indicative guidelines only- refer Note 6			
	Morgan 1	Calcium	Ca	1508	1183	2118	796	3669	892	7329	1150	750	375	175
		Magnesium	Mg	458	520	682	228	624	584	721	160	105	60	25
		Potassium	K	256	181	134	242	77	77	198	113	75	60	50
		Phosphorus	P	2.9	2.8	2.4	2.0	2.0	1.6	2.7	15	12	10	5.0
	Bray1	Phosphorus	P	6.3	2.9	2.5	3.0	1.8	1.6	1.8	45 ^{note 8}	30 ^{note 8}	24 ^{note 8}	20 ^{note 8}
	Colwell			17	9	6	8	5	9	8	80	50	45	35
	Bray2			11	6	5	9	4	3	6	90 ^{note 8}	60 ^{note 8}	48 ^{note 8}	40 ^{note 8}
	KCl	Nitrate Nitrogen	N	1.7	1.4	1.2	1.9	1.2	1.2	1.4	15	13	10	10
		Ammonium Nitrogen	N	11.7	7.5	7.1	8.1	9.5	11.1	8.7	20	18	15	12
		Sulfur	S	7.1	4.3	8.0	10.1	2.3	3.5	6.4	10.0	8.0	8.0	7.0
	1:5 Water	pH	units	6.89	6.88	7.10	5.99	7.97	6.73	7.57	6.5	6.5	6.3	6.3
		Conductivity	dS/m	0.148	0.053	0.191	0.038	0.167	0.043	0.198	0.200	0.150	0.120	0.100
	Calculation	Organic Matter	% OM	4.6	3.5	3.7	3.0	1.6	2.4	4.1	>5.5	>4.5	>3.5	>2.5
	Ammonium Acetate + Calculations	Calcium	Ca	11.43	11.48	13.73	7.34	19.28	9.45	29.44				
			kg/ha	5131	5153	6165	3294	8653	4242	13215				
			mg/kg	2291	2301	2752	1471	3863	1894	5900	3125	2150	1000	375
		Magnesium	Mg	5.40	6.98	7.65	2.98	6.61	9.40	6.71				
			kg/ha	1469	1899	2081	810	1799	2559	1828				
			mg/kg	656	848	929	362	803	1143	816	290	200	145	75

Site				RWood01	RWood02	RWood03	RWood04	RGrass01	RGrass02	RGrass03	Heavy Soil e.g Clay	Medium Soil e.g Clay Loam	Light Soil e.g Loam	Sandy Soil e.g Loamy Sand	
		Potassium	K	cmol+/Kg	1.65	1.25	0.93	1.56	0.60	0.65	1.56				
				kg/ha	1447	1097	819	1364	528	571	1367				
				mg/kg	646	490	365	609	236	255	610	235	190	150	100
		Sodium	Na	cmol+/Kg	0.35	0.25	0.55	0.04	0.57	0.90	0.11				
				kg/ha	179	129	285	18	292	465	54				
				mg/kg	80	58	127	8	130	207	24	69	60	51	25
	KCl	Aluminium	Al	cmol+/Kg	0.01	0.01	0.01	0.00	0.01	0.01	0.01				
				kg/ha	3	2	1	1	1	1	2				
				mg/kg	1	1	1	0	1	1	1	54	45	41	14
	Acidity Titration	Hydrogen	H ⁺	cmol+/Kg	0.00	0.00	0.00	0.14	0.00	0.00	0.00				
				kg/ha	0	0	0	3	0	0	0				
				mg/kg	0	0	0	1	0	0	0	6	5	5	2
	Calculation	Effective Cation Exchange Capacity (ECEC)		cmol+/Kg	18.84	19.97	22.87	12.05	27.06	20.41	37.83	20	14	7	4
	Base Saturation Calculations	Calcium	Ca	%	60.7	57.5	60.0	60.9	71.2	46.3	77.8	77	76	69	60
		Magnesium	Mg		28.6	34.9	33.4	24.7	24.4	46.1	17.7	12	12	16	20
		Potassium	K		8.8	6.3	4.1	12.9	2.2	3.2	4.1	3	4	5	8
		Sodium - ESP	Na		1.8	1.3	2.4	0.3	2.1	4.4	0.3	2	2	3	3
		Aluminium	Al		0.1	0.0	0.0	0.0	0.0	0.0	0.0	7	7	7	9
		Hydrogen	H ⁺		0.0	0.0	0.0	1.1	0.0	0.0	0.0				
	Calculation	Calcium/ Magnesium Ratio		ratio	2.1	1.6	1.8	2.5	2.9	1.0	4.4	6.4	6.3	4.3	3.0
	DTPA	Zinc	Zn	mg/kg	1.4	0.7	0.5	6.9	0.3	0.3	0.7	6.0	5.0	4.0	3.0
		Manganese	Mn		108	37	46	92	23	44	33	25	22	18	15
		Iron	Fe		40	30	36	61	18	63	23	25	22	18	15

Site				RWood01	RWood02	RWood03	RWood04	RGrass01	RGrass02	RGrass03	Heavy Soil e.g Clay	Medium Soil e.g Clay Loam	Light Soil e.g Loam	Sandy Soil e.g Loamy Sand	
		Copper	Cu		3.5	5.5	3.0	15.8	2.1	3.0	4.0	2.4	2.0	1.6	1.2
	CaCl ₂	Boron	B	mg/kg	1.51	1.32	1.57	1.02	0.65	1.18	0.68	2.0	1.7	1.4	1.0
		Silicon	Si		32	108	34	66	24	81	28	50	45	40	35
	LECO IR Analyser	Total Carbon	C	%	2.63	2.01	2.13	1.72	0.93	1.39	2.36	>3.1	>2.6	>2.0	>1.4
		Total Nitrogen	N	%	0.19	0.14	0.13	0.16	0.16	0.12	0.20	>0.30	>0.25	>0.20	>0.15
	Calculation	Carbon/ Nitrogen Ratio		ratio	13.5	14.2	16.7	10.6	5.9	11.7	11.6	10-12	10-12	10-12	10-12
		Basic Texture			Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	..	..	..	..
		Basic Colour			Brownish	Red	Red	Red	Brownish	Brownish	Red	..	..	..	..
	Calculation	Chloride Estimate	equiv. ppm		95	34	122	24	107	27	127	..	..	..	..
	Total Acid Extractable	Calcium	Ca	mg/kg	3,365	3,267	3,953	2,066	6,196	2,236	13,733	1,000 - 10,000 Ca			
		Magnesium	Mg		1,743	3,216	2,433	2,944	2,958	2,579	3,686	500 - 5,000 Mg			
		Potassium	K		2,161	2,226	1,600	2,603	1,374	1,182	2,464	200 - 2,000 K			
		Sodium	Na		133	130	203	<50	215	273	75	100 - 500 Na			
		Sulfur	S		168	149	167	143	104	133	196	100 - 1,000 S			
	Total Acid Extractable	Phosphorus	P	mg/kg	319	252	191	360	110	135	246	400 - 1,500 P			
	Total Acid Extractable	Zinc	Zn	mg/kg	31	41	23	209	23	18	36	20 - 50 Zn			
		Manganese	Mn		3,206	1,203	694	2,193	848	663	1,110	200 - 2,000 Mn			
		Iron	Fe		19,272	46,449	20,614	42,489	16,171	15,339	35,386	1,000 - 50,000 Fe			
		Copper	Cu		32.8	69.8	29.7	142.3	18.7	20.7	45.8	20 - 50 Cu			
		Boron	B		3	3	3	<2	<2	<2	3	2 - 50 B			
		Silicon	Si		850	548	610	558	594	683	701	1,000 - 3,000 Si			
		Aluminium	Al		13,829	17,763	15,363	18,505	15,698	14,776	19,966	2,000 - 50,000 Al			
Total Acid Extractable	Molybdenum	Mo	mg/kg	0.5	0.4	0.5	1.0	0.2	0.3	0.3	0.5 - 3 Mo				

Site				RWood01	RWood02	RWood03	RWood04	RGrass01	RGrass02	RGrass03	Heavy Soil e.g. Clay	Medium Soil e.g. Clay Loam	Light Soil e.g. Loam	Sandy Soil e.g. Loamy Sand
		Cobalt	Co	14	19	8	17	12	10	22	5 - 50 Co			
		Selenium	Se	0.5	0.5	<0.5	0.6	<0.5	<0.5	0.6	0.1 - 2.0 Se			
	Total Acid Extractable	Cadmium	Cd	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	< 5 Cd			
		Lead	Pb	13	8	13	17	14	11	9	< 75 Pb			
		Arsenic	As	3	4	3	8	3	2	3	< 25 As			
		Chromium	Cr	21	73	21	20	22	20	40	<25 Cr			
		Nickel	Ni	10	20	9	10	12	9	19	<150 Ni			
		Mercury	Hg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	< 3.75 Hg			
		Silver	Ag	<1	<1	<1	<1	<1	<1	<1	.. Ag			

EAL Soil Testing Notes

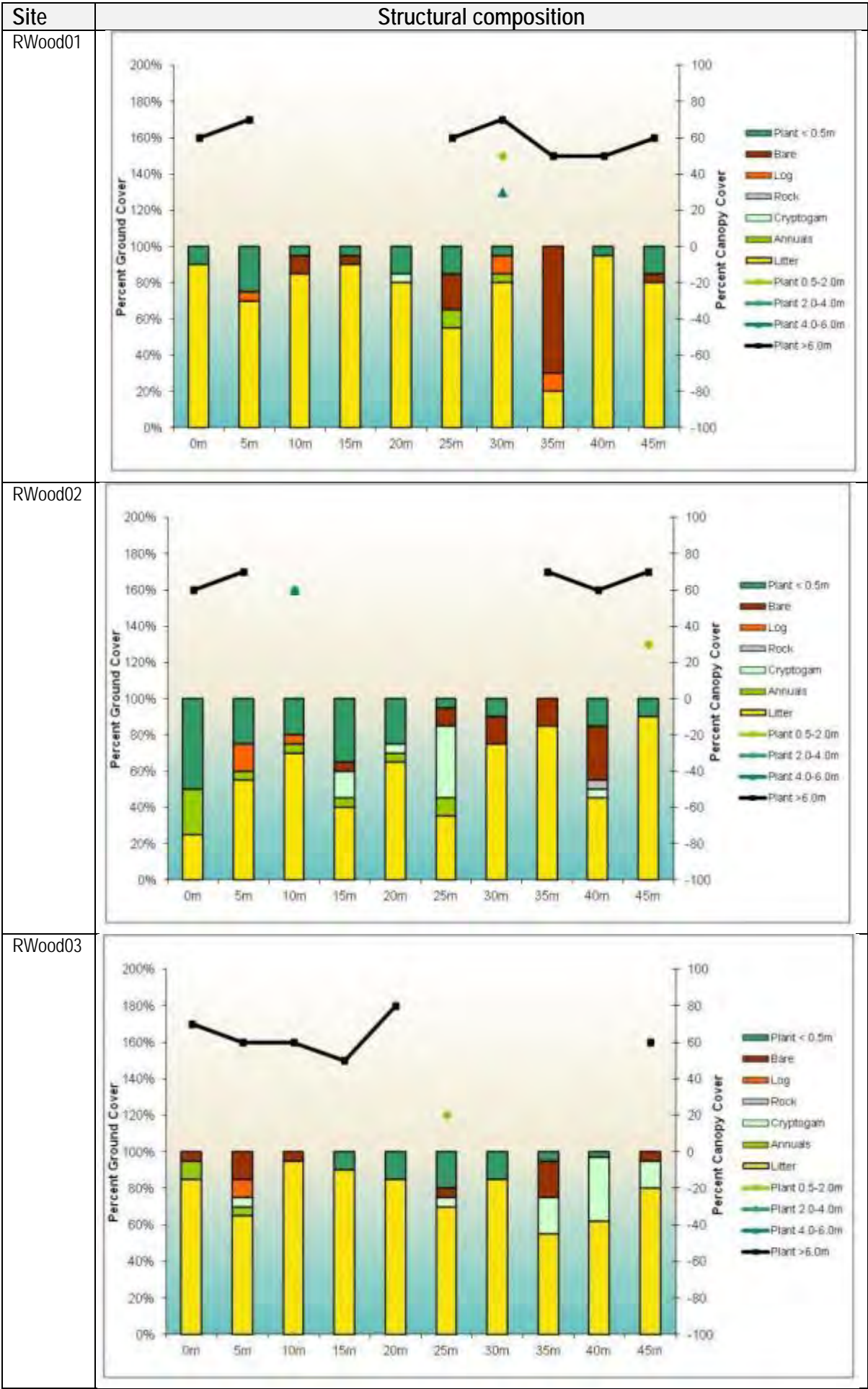
1. All results as dry weight - 40°C oven dried soil crushed to <2mm
2. Methods from Rayment and Lyons, 2011. *Soil Chemical Methods*
3. Soluble Salts included in Exchangeable Cations - NO PRE-WASH
4. 'Morgan 1 Extract' adapted from 'Science in Agriculture', 'Non-Toxic Farming' and Lamonte Soil Handbook.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

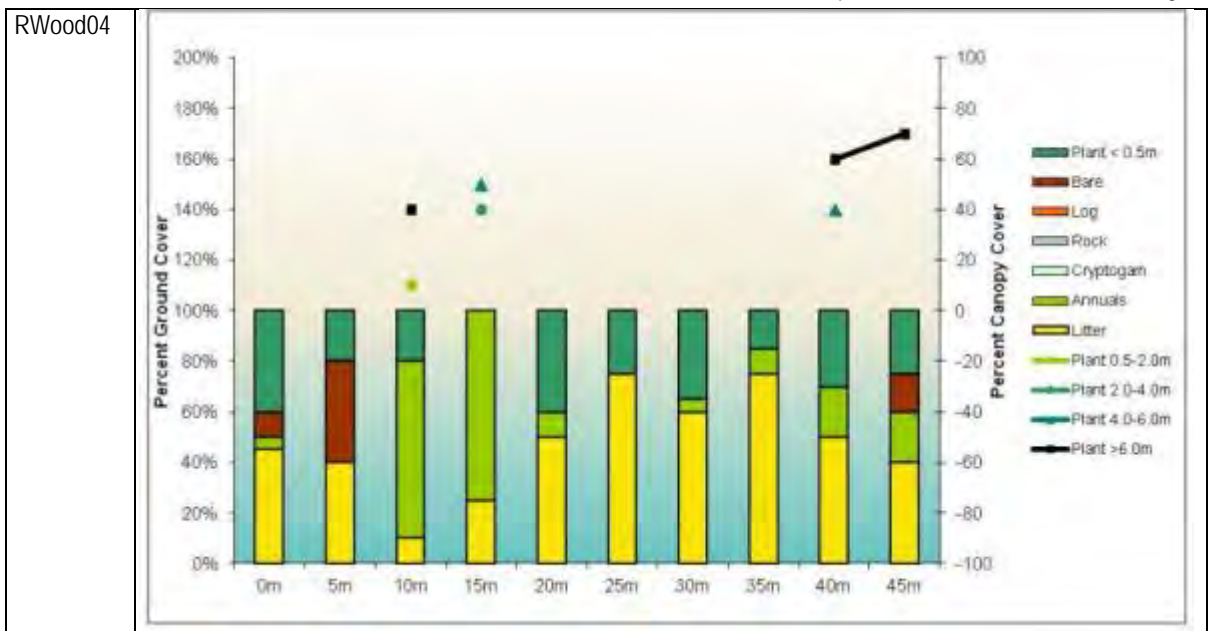
Calculations

1. For conductivity 1 dS/m = 1 mS/cm = 1000 µS/cm
2. 1 cmol⁺/Kg = 1 meq/100g; 1 Lb/Acre = 2 ppm (parts per million); kg/ha = 2.24 x ppm; mg/kg = ppm
3. Conversions for 1 cmol⁺/Kg = 230 Kg/Hectare Sodium, 780 Kg/Ha Potassium, 240 Kg/Ha Magnesium, 400 Kg/Ha Calcium
4. Organic Matter = %C x 1.75
5. Chloride Estimate = EC x 640 (most likely over-estimate)
6. ECEC = sum of the exchangeable cations cmol⁺/Kg
7. Base saturation calculations = (cation cmol⁺/Kg) / ECEC x 100
8. Ca/Mg ratio from the exchangeable cmol⁺/Kg results

Appendix 5. Data obtained from the woodland reference sites in 2013

Site	Vegetation transect (front)	Vegetation transect (rear)
RWood01		
RWood02		
RWood03		
RWood04		



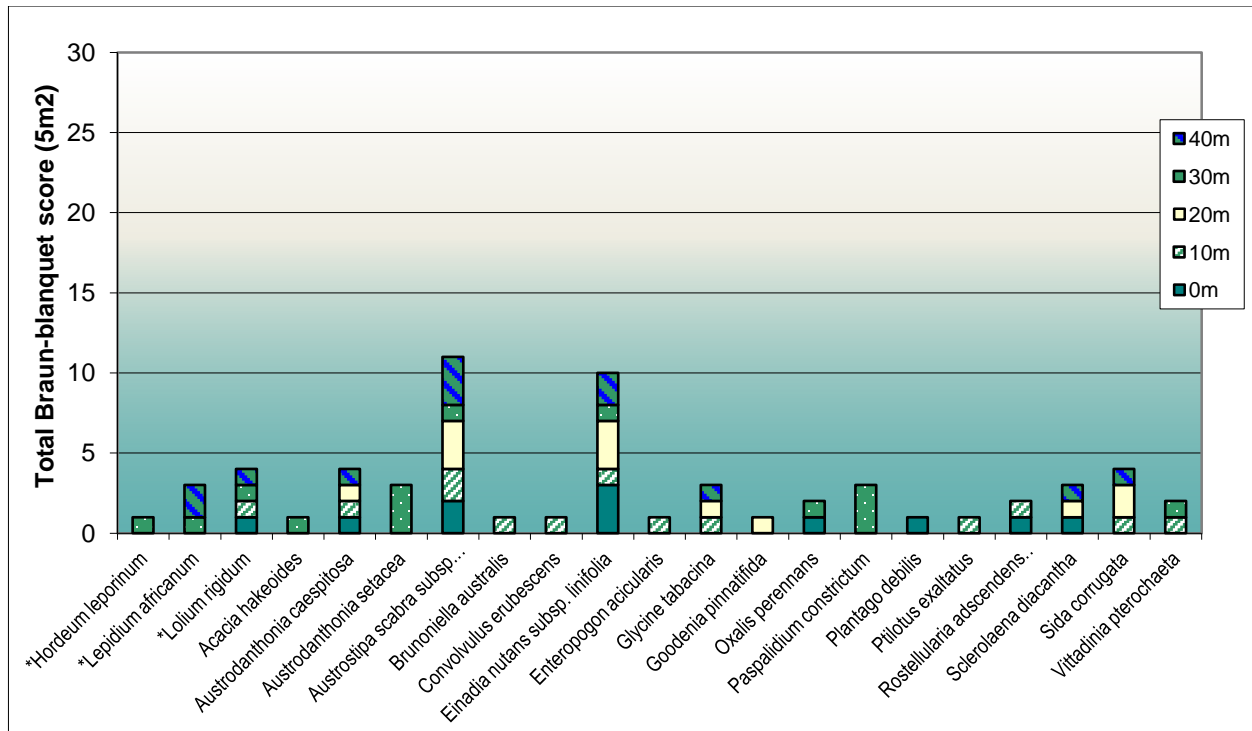


Landscape Function Analysis

Site		RWood01		RWood02		RWood03		RWood04	
Number of Patches/10m		0.5		0.5		0.5		0.5	
Total Patch Area (m2)		200.00		200.00		200.00		200.00	
Patch Area Index		1.00		1.00		1.00		1.00	
Landscape Organisation Index		1.00		1.00		1.00		1.00	
Average Interpatch Length (m)		NA		NA		NA		NA	
Range Interpatch length (m)		NA		NA		NA		NA	
Patch or Interpatch Type		Woodland Patch		Woodland Patch		Woodland Patch		Woodland Patch	
Patch or Interpatch Proportion (%)		100.0	100	100.0	100	100.0	100	100.0	100
Soil Surface Assessment									
Within Individual Zones	Stability	62.9		68.1		69.0		67.5	
	Infiltration	50.3		55.7		42.8		41.1	
	Nutrients	45.8		53.0		42.7		36.2	
			Total		Total		Total		Total
Individual zones contribution to the whole of Landscape	Stability	62.9	62.9	68.1	68.1	69.0	69.0	67.5	67.5
	Infiltration	50.3	50.3	55.7	55.7	42.8	42.8	41.1	41.1
	Nutrients	45.8	45.8	53.0	53.0	42.7	42.7	36.2	36.2

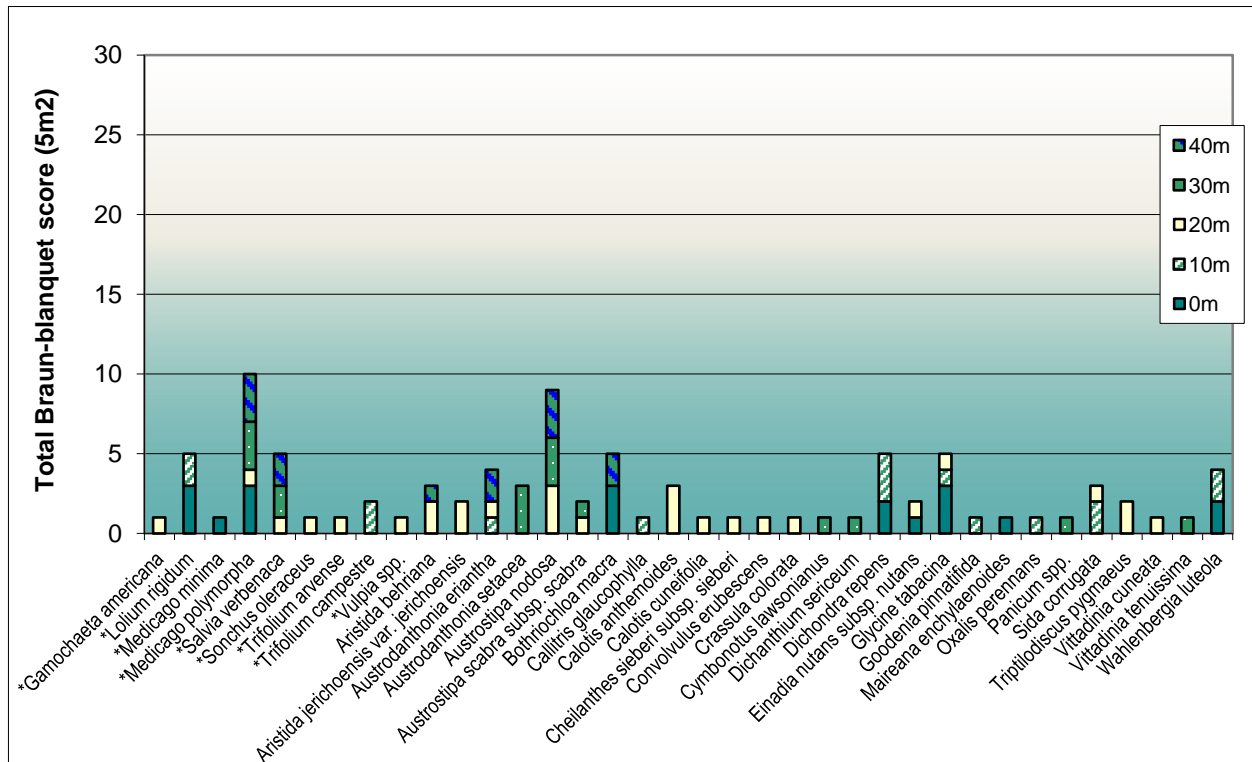
Species cover abundance

RWood01



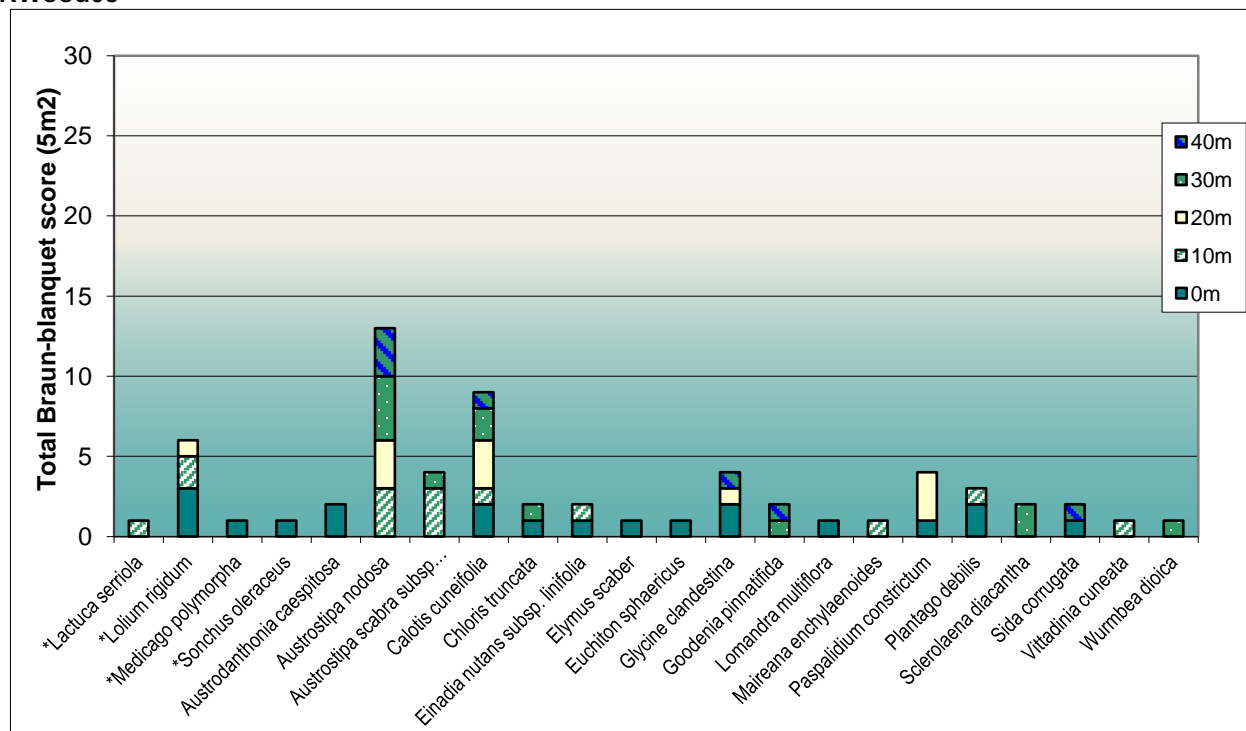
Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	7	11	7	7	6	7.6	1.9
Exotic	1	1	0	3	2	1.4	1.1
Total	8	12	7	10	8	9	2.0

RWood02



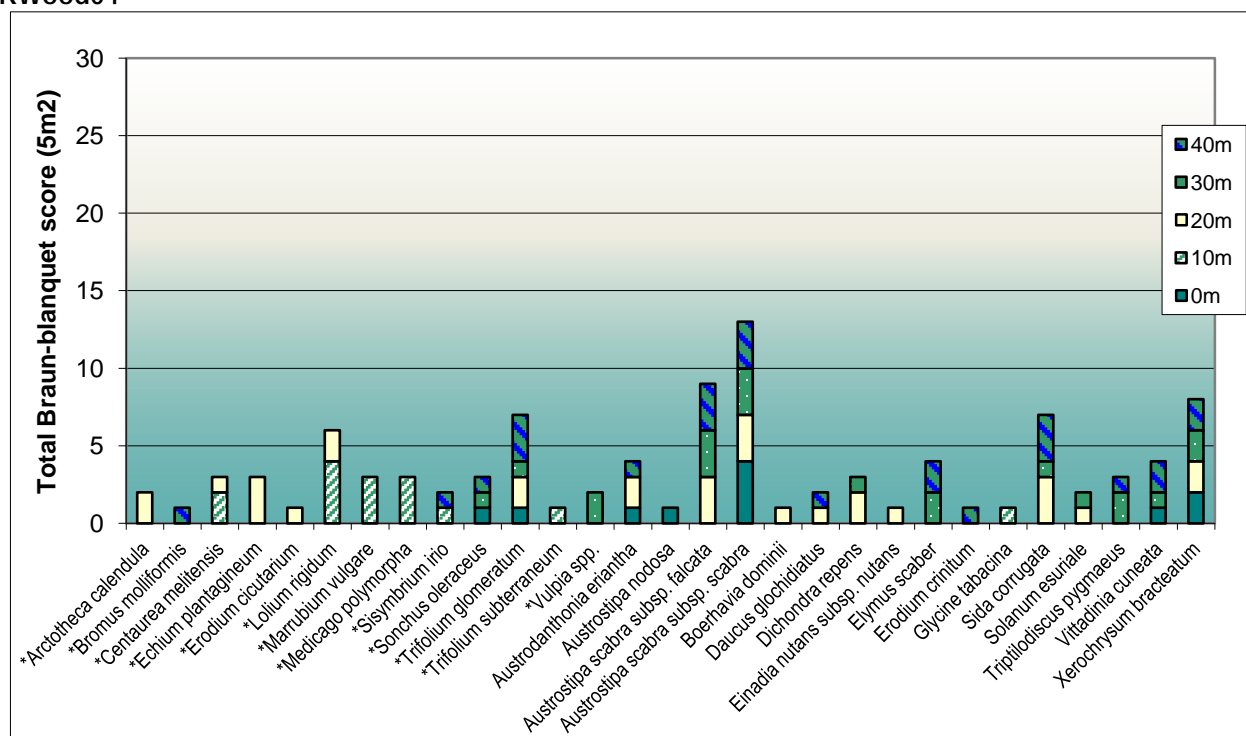
Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	6	8	15	7	4	8	4.2
Exotic	3	2	6	2	2	3	1.7
Total	9	10	21	9	6	11	5.8

RWood03



Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	11	7	4	7	5	6.8	2.7
Exotic	3	1	1	0	0	1	1.2
Total	14	8	5	7	5	7.8	3.7

RWood04

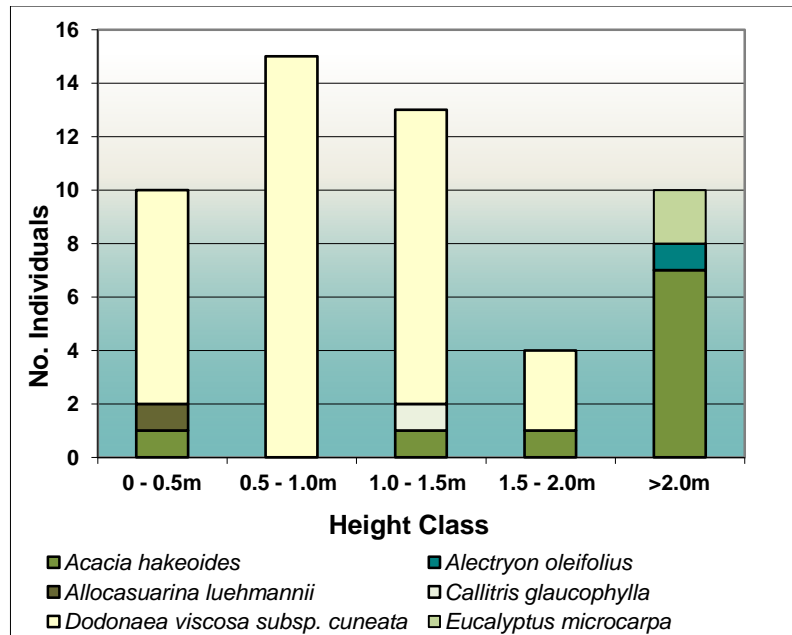


Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	5	1	10	9	10	7	3.9
Exotic	2	6	6	3	4	4.2	1.8
Total	7	7	16	12	14	11.2	4.1

Trees and Shrubs

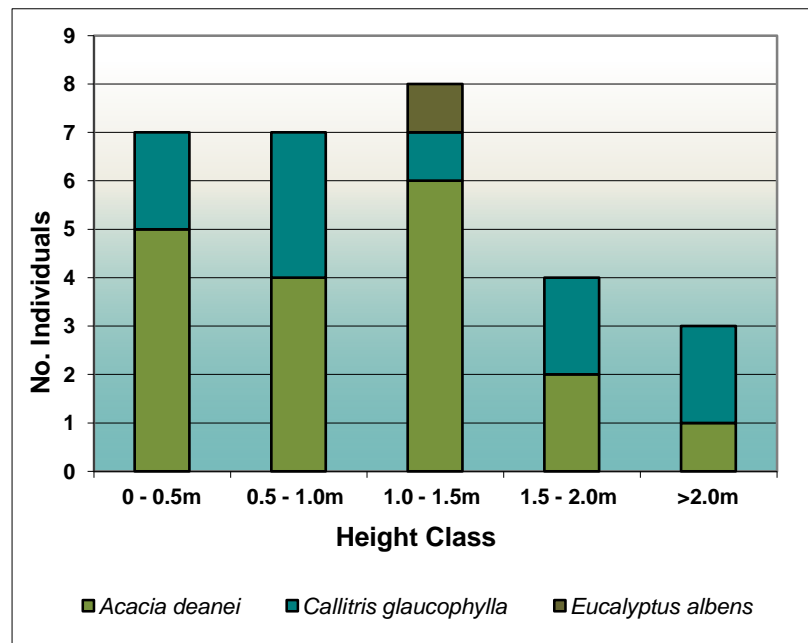
RWood01

Dominant species	<i>Allocasuarina luehmannii</i> (7), <i>Eucalyptus microcarpa</i> (6), <i>Acacia hakeoides</i> (1)
Average dbh (Cm)	36
Max dbh (cm)	76
Min dbh (cm)	12
Total trees	14
No. with multiple limbs	0
No. Live trees	14
No. Healthy	1
No. Medium Health	8
No. Advanced Dieback	5
No. Dead	0
Mistletoe	1
Flowers / fruit	7



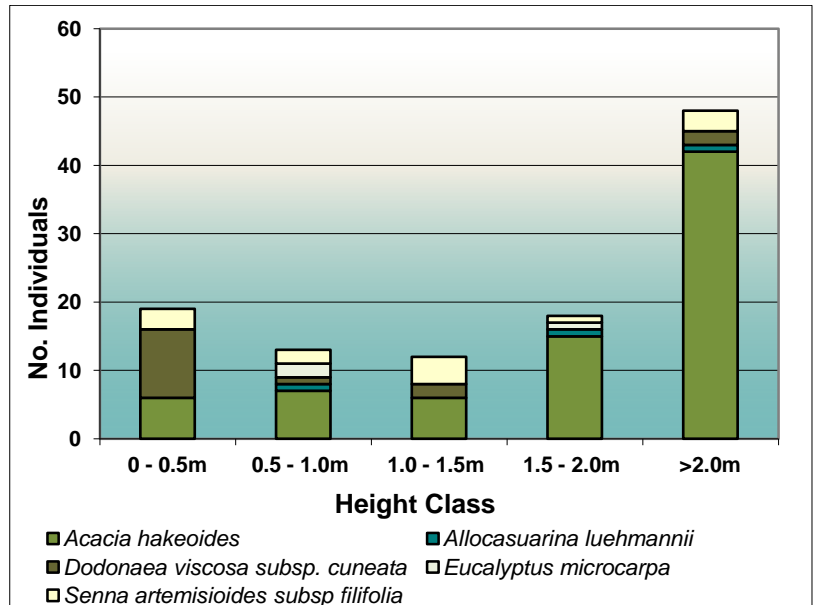
RWood02

Dominant species	<i>Callitris glaucophylla</i> (13), <i>Eucalyptus albens</i> (5), <i>Eucalyptus populnea</i> (1)
Average dbh (Cm)	18
Max dbh (cm)	49
Min dbh (cm)	5
Total trees	19
No. with multiple limbs	1
No. Live trees	19
No. Healthy	9
No. Medium Health	10
No. Advanced Dieback	0
No. Dead	0
Mistletoe	0
Flowers / fruit	10



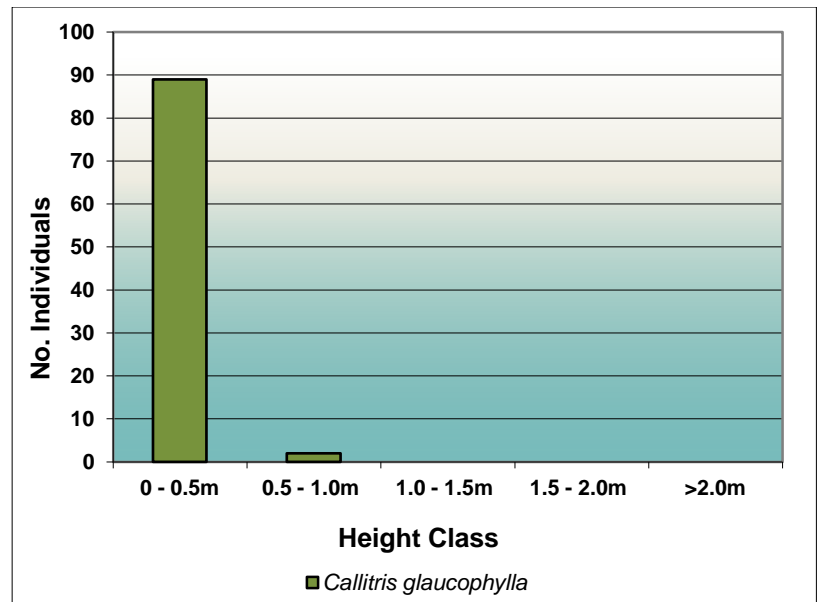
RWood03

Dominant species	<i>Eucalyptus microcarpa</i> (5), <i>Acacia hakeoides</i> (2), <i>Allocasuarina luehmannii</i> (1)
Average dbh (Cm)	35
Max dbh (cm)	66
Min dbh (cm)	5
Total trees	9
No. with multiple limbs	1
No. Live trees	9
No. Healthy	3
No. Medium Health	4
No. Advanced Dieback	2
No. Dead	0
Mistletoe	0
Flowers / fruit	5

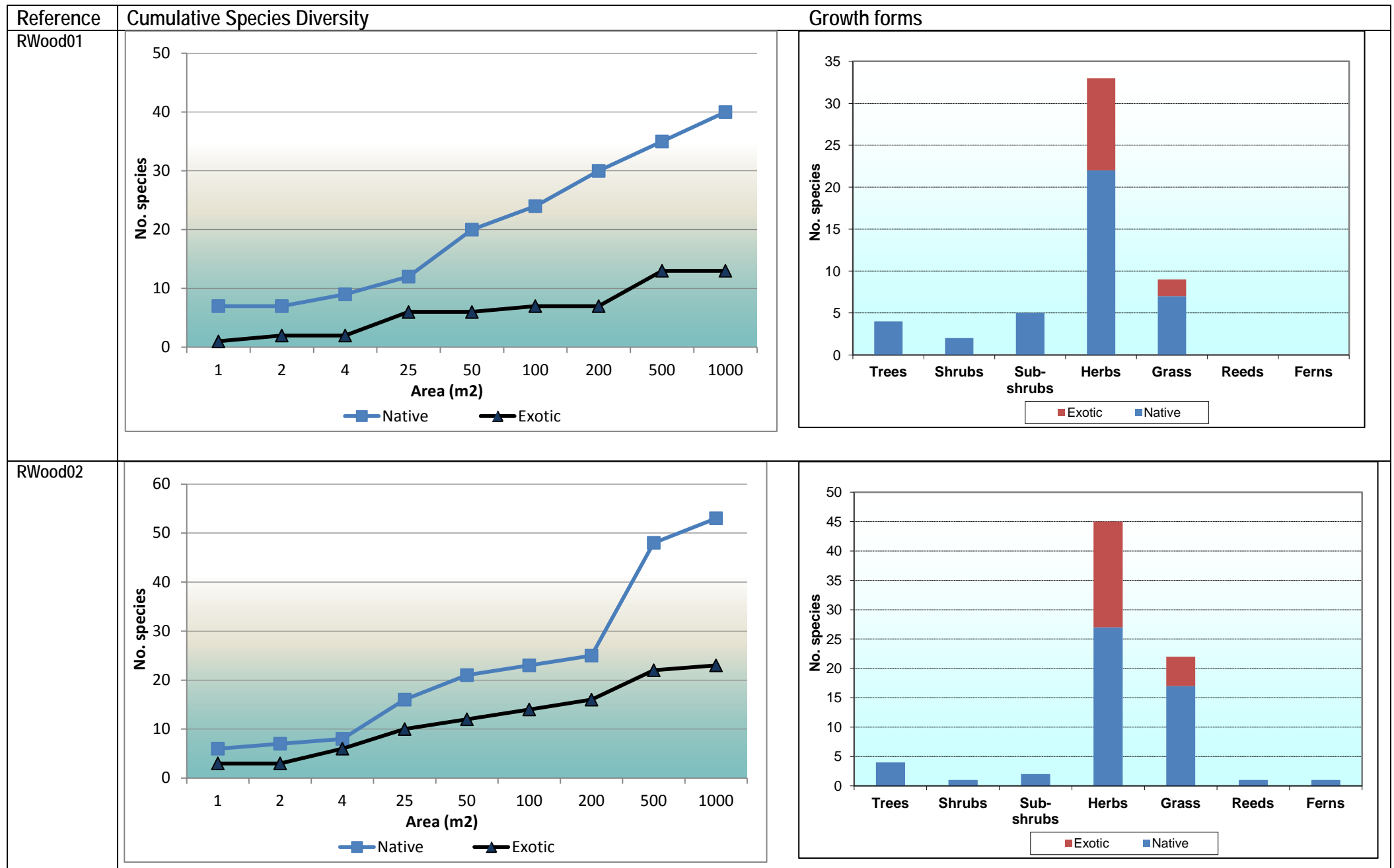


RWood04

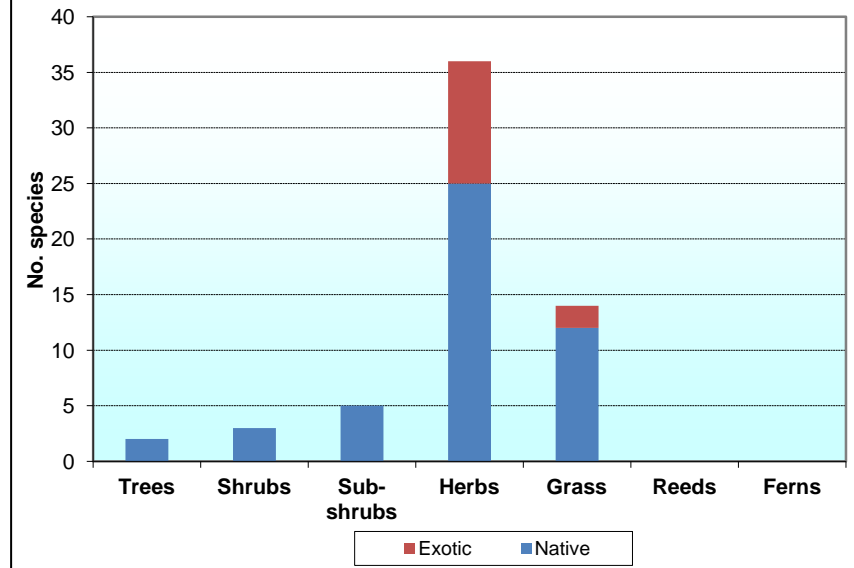
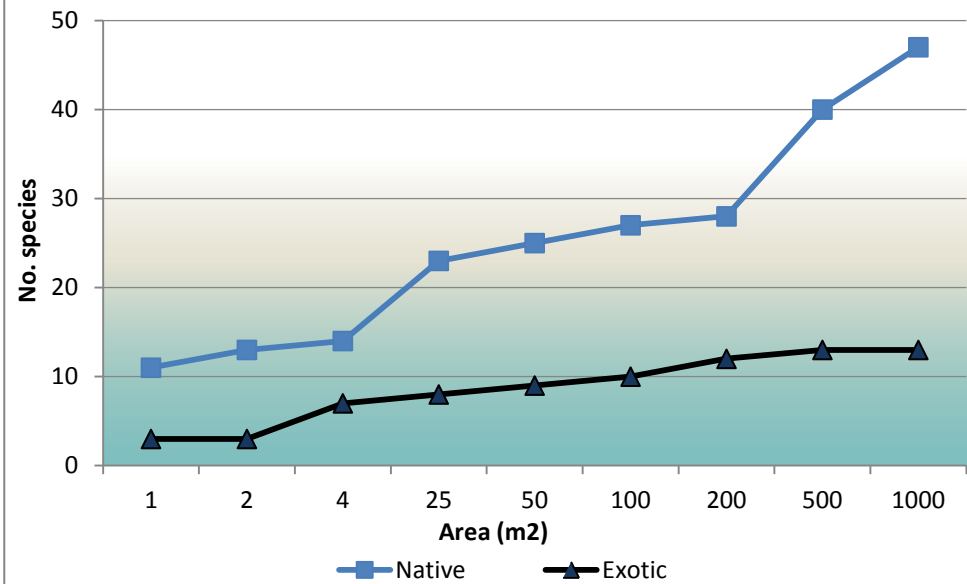
Dominant species	<i>Callitris glaucophylla</i> (2), <i>Eucalyptus populnea</i> (2), <i>Eucalyptus melliodora</i> (1)
Average dbh (Cm)	54
Max dbh (cm)	82
Min dbh (cm)	35
Total trees	6
No. with multiple limbs	0
No. Live trees	5
No. Healthy	2
No. Medium Health	3
No. Advanced Dieback	0
No. Dead	1
Mistletoe	0
Flowers / fruit	5



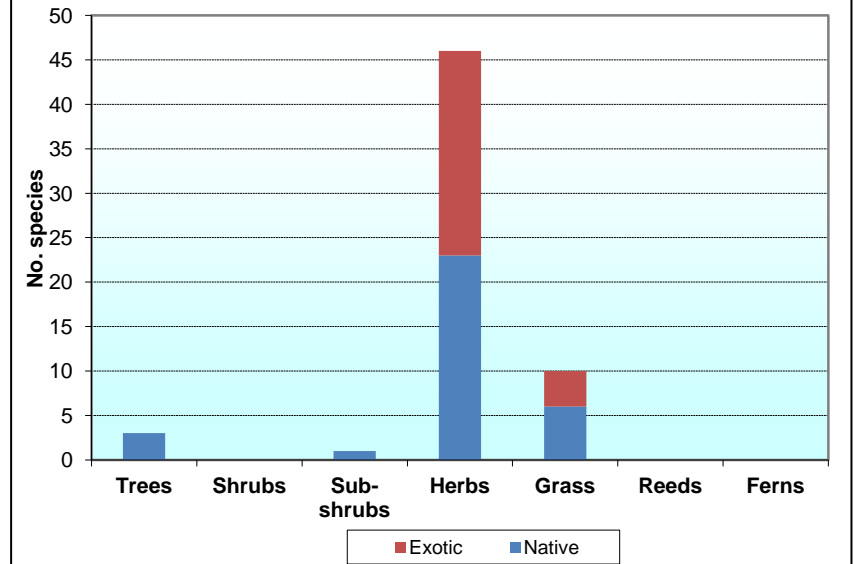
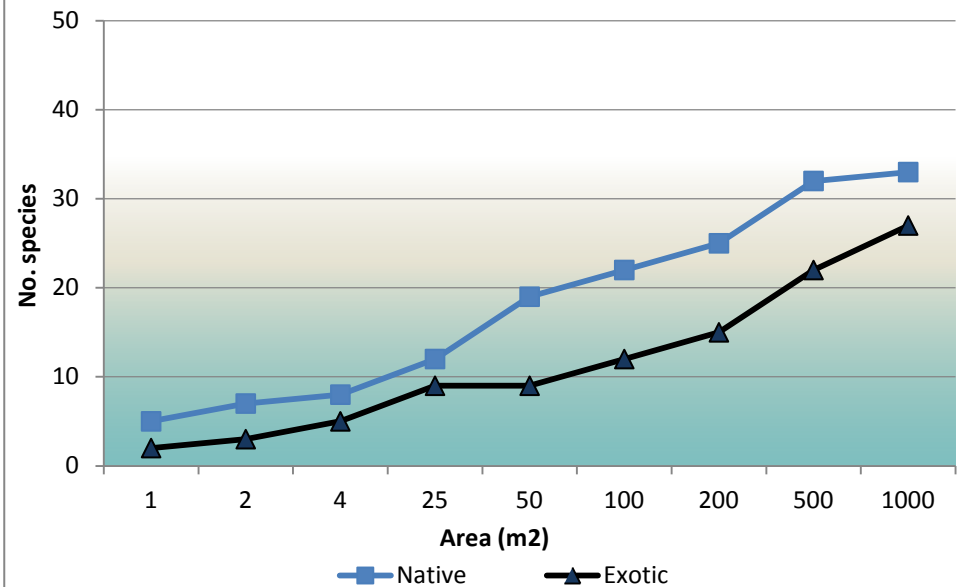
Species diversity and community composition




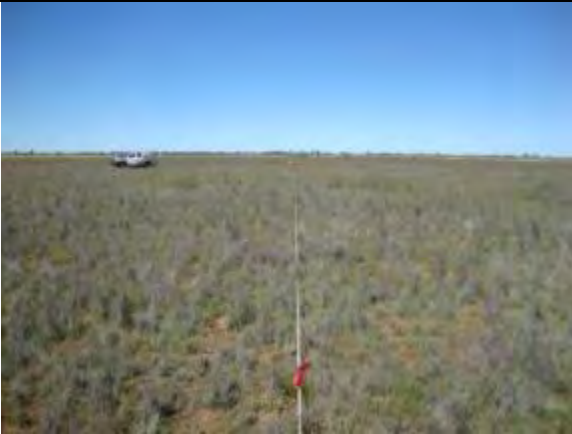
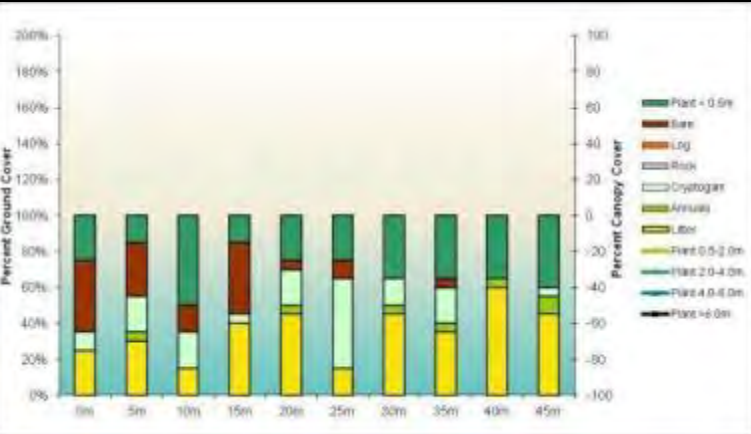


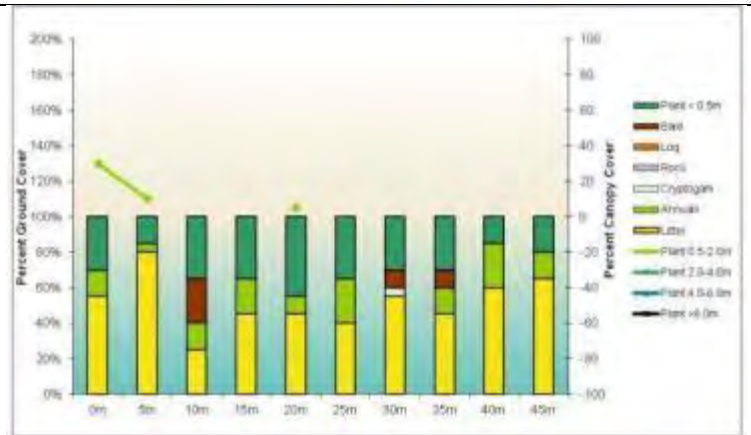


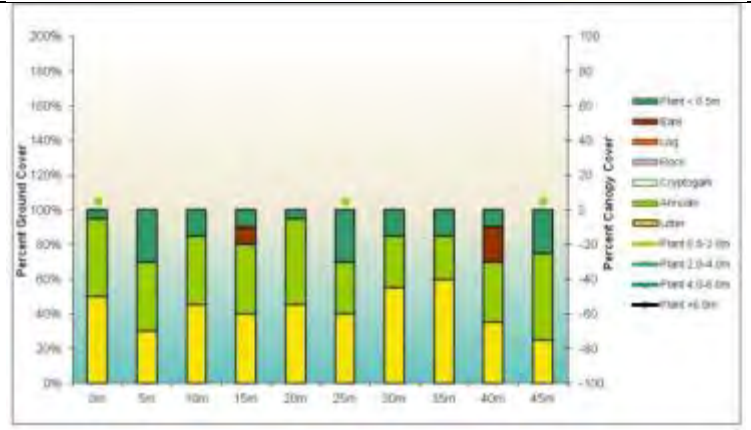
RWood03



RWood04



Appendix 6. Data obtained from the grassland reference sites in 2013

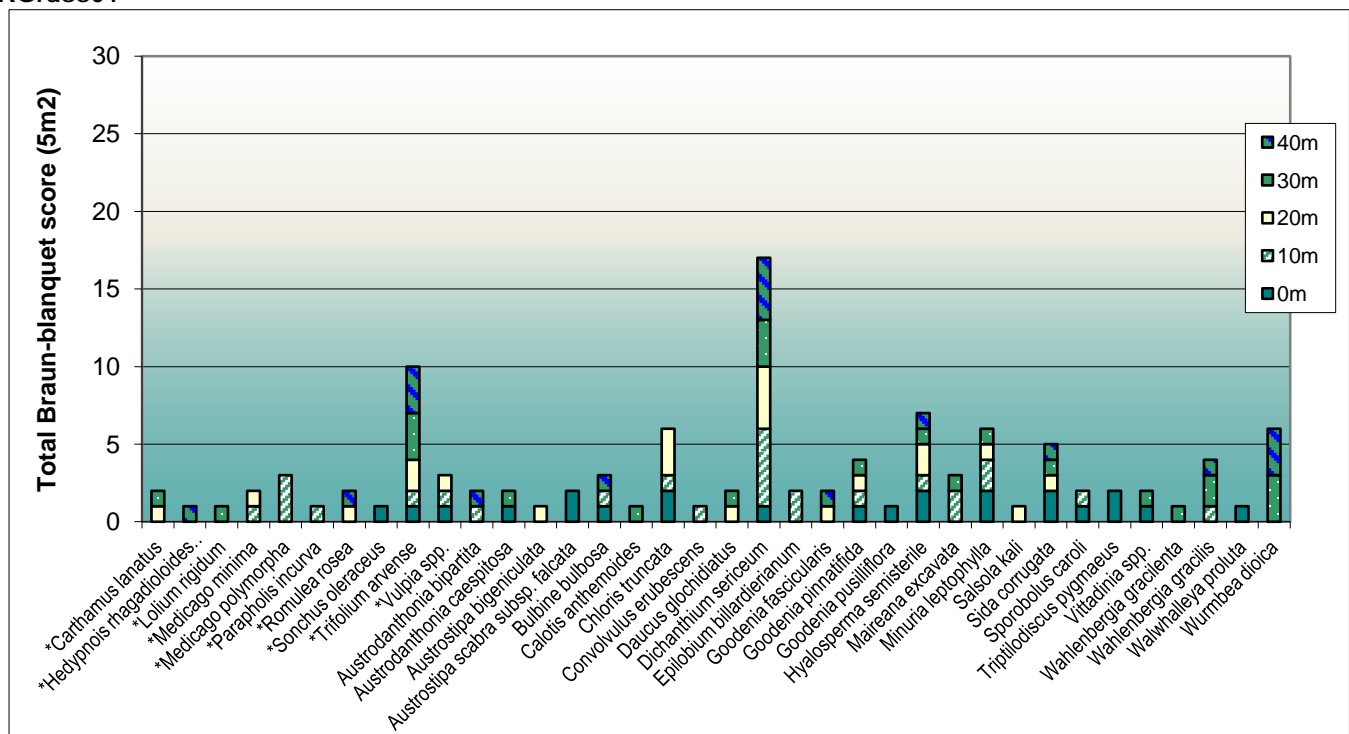
Site	Vegetation transect (front)	Vegetation transect (rear)	Structural composition
RGrass01			
RGrass02			
RGrass03			

Landscape Function Analysis

Site		RGrass01		RGrass02		RGrass03	
Number of Patches/10m		0.5		0.5		0.5	
Total Patch Area (m2)		200.00		200.00		200.00	
Patch Area Index		1.00		1.00		1.00	
Landscape Organisation Index		1.00		1.00		1.00	
Average Interpatch Length (m)		NA		NA		NA	
Range Interpatch length (m)		NA		NA		NA	
Patch or Interpatch Type		Grassland Patch		Grassland Patch		Grassland Patch	
Patch or Interpatch Proportion (%)		100.0	100	100.0	100	100.0	100
Soil Surface Assessment							
Within Individual Zones	Stability	64.5		73.0		70.5	
	Infiltration	29.3		39.6		46.3	
	Nutrients	28.1		41.3		43.2	
			Total		Total		Total
Individual zones contribution to the whole of Landscape	Stability	64.5	64.5	73.0	73.0	70.5	70.5
	Infiltration	29.3	29.3	39.6	39.6	46.3	46.3
	Nutrients	28.1	28.1	41.3	41.3	43.2	43.2

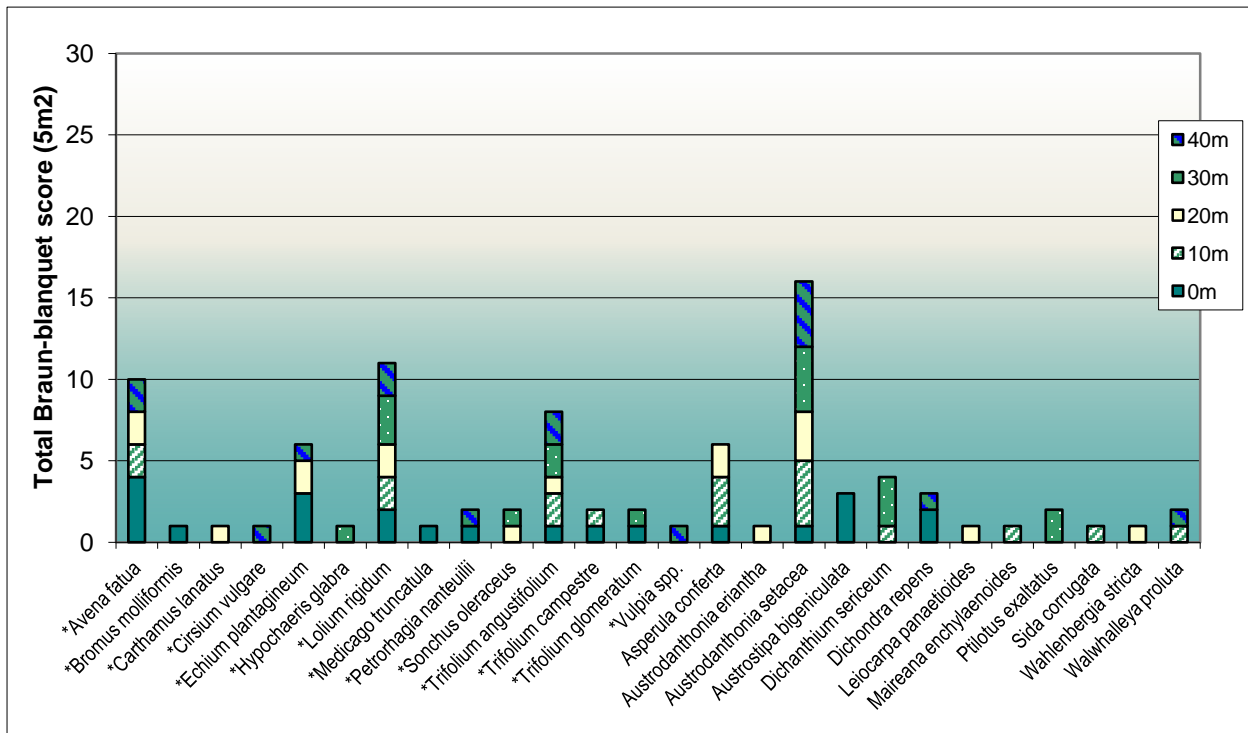
Species cover abundance

RGrass01



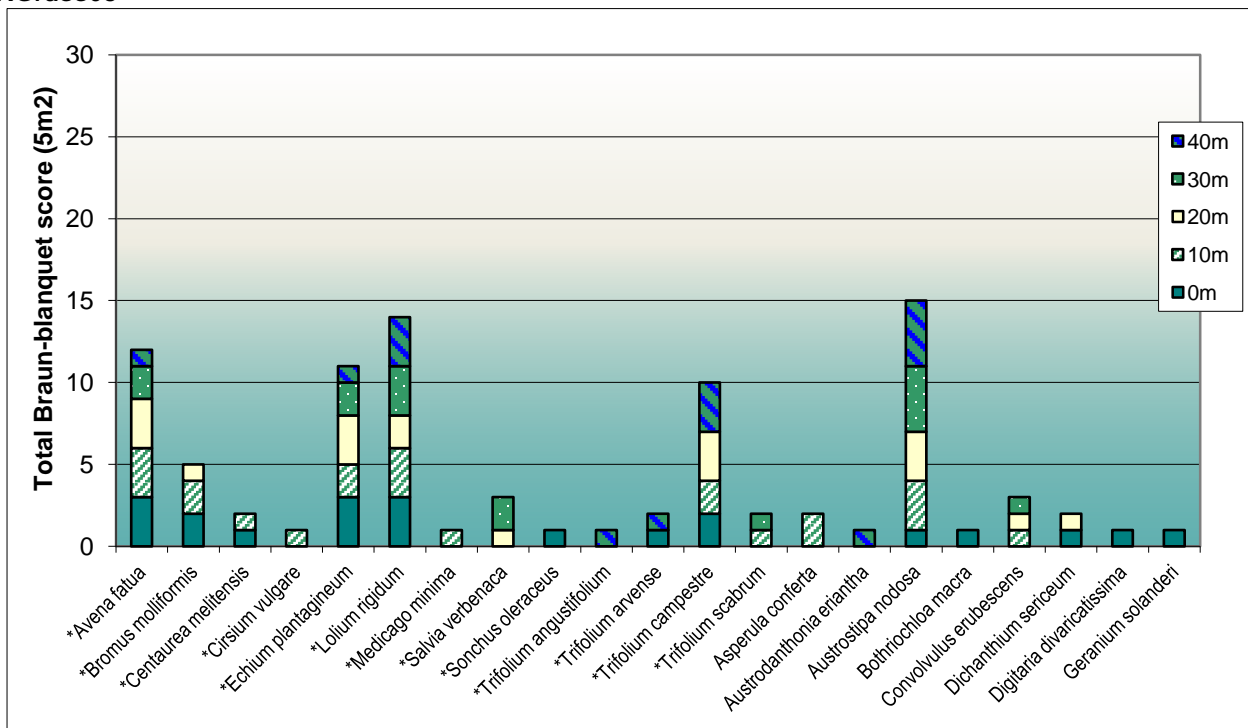
Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	14	12	10	13	8	11.4	2.4
Exotic	3	5	5	3	3	3.8	1.1
Total	17	17	15	16	11	15.2	2.5

RGrass02



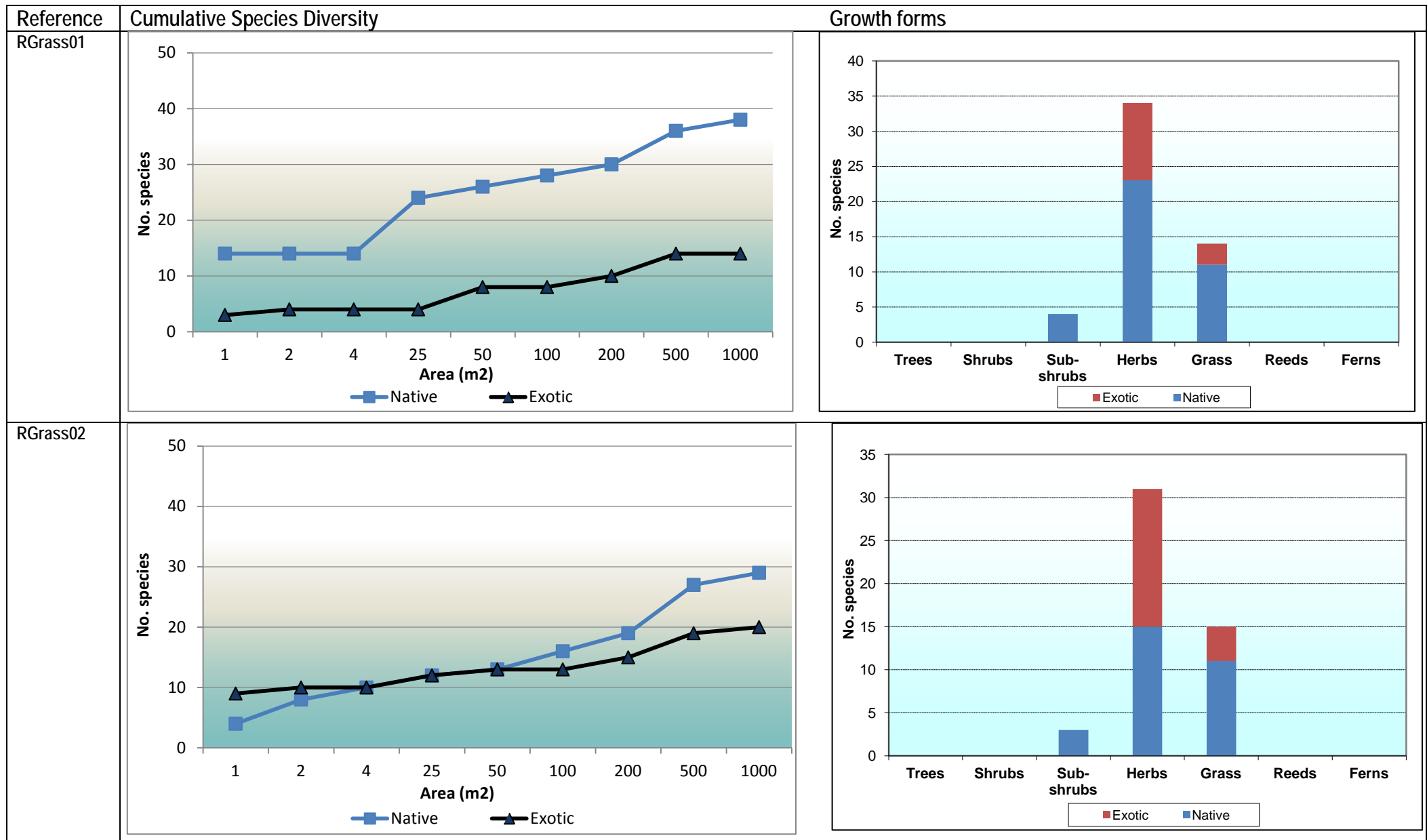
Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	4	6	5	3	3	4.2	1.3
Exotic	9	4	6	5	7	6.2	1.9
Total	13	10	11	8	10	10.4	1.8

RGrass03



Species /m2	0m	10m	20m	30m	40m	Avg/m2	SD
Native	5	3	3	2	2	3	1.2
Exotic	8	9	6	5	6	6.8	1.6
Total	13	12	9	7	8	9.8	2.6

Species diversity and community composition



RGrass03

