

FINAL REPORT

RESTORATION MONITORING PILOT FOR COORONG, LOWER LAKES RESTORATION PROJECT

Ecosystem Function Analysis (EFA) Baseline Monitoring

Department of Environment and Natural Resources (DENR)

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Care Of Our Environment

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Ecosystem Function Analysis (EFA) Baseline Monitoring

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Executive Summary

The Department of Environment and Natural Resources (DENR) Coorong, Lower lakes and Murray Mouth (CLLMM) Program is delivering a five year restoration project in the CLLMM region. As an emergency response to prolonged drought, bioremediation and revegetation activities were initiated in 2009. In July 2011, the project transitioned to building ecological resilience into the natural systems of the Lower Lakes and surrounding lands.

A pilot study (this report) was commissioned to trial components of Ecosystem Function Analysis (EFA) at revegetation and reference sites. The goal of the pilot project is to track trends towards the long term objectives of the restoration program. The monitoring assessed the resilience of the ecosystems surveyed and identified future challenges of the program. To assess restoration activities COOE monitored two specific components at each site:

- **Ecosystem Functional Analysis (EFA)** - to track the ecological and morphological changes at each location in particular to demonstrate that biodiversity and habitat structure are increasing and erosion is decreasing,

- **Physical and chemical stability** - to track the physical and chemical stability of the rehabilitated sites, in particular to demonstrate that no significant acid generation and metal mobilisation in the environment has occurred.

A total of nine sites were surveyed which comprised of seven revegetation and two reference locations around Lakes Alexandrina and Albert. Locations varied in vegetation type, aspect, and slope. At five of the revegetation locations, only one habitat type was identified. At two locations, two habitat types were identified. Three transects were established per habitat type, at each location.

The two reference sites (Bonney Reserve and Mulungushi) were chosen to provide data on both the effectiveness of EFA and to provide target values for the rehabilitated sites. A total of 11 sites/33 transects were assessed. The following summarises the parameters that were assessed at each site and recommends future methods and frequencies:

<u>Photo-point monitoring</u>

At each location a permanent photo-monitoring point was established. This was located to provide a broad overview of the site and will, over time, provide a record of the progress of rehabilitation.

<u>Vegetation monitoring</u>

Vegetation monitoring utilising principles of Ecosystem Function Analysis (EFA) was conducted. A Point-Centered Quarter (PCQ) method was employed to measure key vegetation indicators. Vegetation cover was variable within each site yet all sites were dominated by ground and shrub cover with a large proportion less than 2 m in height. The dominance of ground cover is important for the flow of resources across the ground surface by providing resource mobilisation and transport areas.

The Bonney Reserve reference site recorded the most number of plants per hectare with a median of 11,0942 plants ha^{-1} and also contained a variety of habitat structure from ground cover to mature canopy species.

Landscape organisation and function

Landscape characteristics were determined at each of the transect locations. Along each transect the landscape profile and vegetation patch characteristics were measured. Within each of the landscape characteristics, eleven indicators of soil surface condition were assessed.

The landscape function at the revegetated sites was comparative to the reference sites. However, the sites surveyed were very different in terms of habitat characteristics and as such comparisons between sites will provide erroneous trends. For example, the samphire sites cannot be compared to the reference woodland sites.

We recommended that with on-going monitoring, landscape function be compared within a site rather than between sites or appropriate reference sites are found (potentially on protected areas of Hindmarsh Island).

Habitat complexity

The habitat complexity of a three meter strip, either side of each transect was assessed. This assessment included recording canopy cover, shrub cover, ground vegetation cover, litter and free water availability.

A reference site, Bonney Reserve, recorded the highest score and was the only site to score on each structure index. Most revegetation sites scored very low, due to the lack of structural features.

It is recommended that this method can be assessed on an annual basis to provide a broad overview of the landscape function at each site. Indicators can be adapted for the region and aim of the surveys.

Soil chemistry

Soil was collected from each vegetation transect to establish a chemical baseline. This baseline included soil fertility and metals parameters.

The soils were analysed by ALSE (NATA certified laboratory) for organic matter, electrical conductivity, pH, soil moisture, exchangeable cations (calcium, magnesium, potassium and sodium), minor anions (nitrate, nitrite, reactive phosphorus) and total metals (arsenic, cadmium, chromium, copper, lead, nickel and zinc).

Values obtained for heavy metals were all well below guideline values for soil ecological investigation levels.

The vegetation and soil differences between sites were reflected in the chemical results. In comparison to the woodland and grassy sites, samphire dominated habitats were more saline, had higher organic matter and higher exchangeable cations.

Elevated soil salinity and exchangeable sodium may interfere with plant growth. The results indicated that soils at these sites were strongly sodic However, the results obtained for these samphire sites is a reflection of the depositional landform characteristics at the sites.

Effectiveness of EFA for monitoring restoration activities

One of the desired outcomes of this monitoring trial was to determine the appropriateness of using EFA to assess restoration activities in the CLLMM region. Beyond trialling the method, the objective of this monitoring pilot was to gather baseline data, to track the trends towards the long-term objectives of the restoration program.

The use of EFA has been successful in characterising each site in regards to vegetation structure and landscape function. This report provides the first year's baseline data from which future monitoring can be compared with.

Monitoring of the sites should be undertaken on a yearly basis until the data warrant a longer period of time. Recommendations are provided for reporting on results of future monitoring assessments and also work to maximise rehabilitation at the sites. Regular site visits throughout the year will assist in determine how the site as a whole in functioning.

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1 Introduction

The Department of Environment and Natural Resources (DENR) Coorong, Lower lakes and Murray Mouth (CLLMM) Program is delivering a five year restoration project in the CLLMM region. As an emergency response to prolonged drought, bioremediation and revegetation activities were initiated in 2009. In July 2011, the project transitioned to building ecological resilience into the natural systems of the Lower Lakes and surrounding lands.

To assess the restoration activities in the CLLMM region, a monitoring plan was written up, which recommended the use of EFA to monitor the resilience of the newly established habitat areas.

A pilot study (this report) was commissioned to trial components of Ecosystem Function Analysis (EFA) at revegetation and reference sites. The goal of the pilot project is to track trends towards the long term objectives of the restoration program. The monitoring assessed the resilience of the ecosystems surveyed and identified future challenges of the program.

EFA is a monitoring procedure that uses quickly determined field indicators to assess the functional status of an ecosystem. The conceptual framework is based on the economy of vital resources. It focuses on processes that regulate spatial movement or use of water, topsoil and organic matter in the landscape (Tongway & Hindley 2004).

The EFA field methodology uses simple, visual indicators, which are closely related to a range of physical, chemical and biological processes. These take a few seconds per indicator to assess in the field after training (Tongway & Hindley 2004). The focus of EFA procedures is on landscape processes, not on any specific form of soil, vegetation or biota. Therefore, EFA can be implemented across many landscape types, uses and managements (Tongway & Ludwig 2006).

EFA has been applied and verified across landscapes varying from sandy deserts to tropical rainforest and in different geological settings (Tongway & Hindley 2003).

One of the desired outcomes of this monitoring trial was to determine the appropriateness of using EFA to assess restoration activities in the CLLMM region.

Beyond trialling the method, the objective of this monitoring pilot was to gather baseline data, to track the trends towards the long-term objectives of the restoration program.

Specifically, the following questions have been addressed:

- What are the infiltration, stability and nutrient cycling index scores one year after revegetation site establishment?
- What are the cover and structure levels of the tree, shrub, herb and grass structure layers one year after revegetation site establishment?
- What are the infiltration, stability and nutrient cycling index scores at two reference sites and how do they compare to the relevant revegetation site scores?

2 Methods

The surveys were conducted at nine locations in the CLLMM region, specifically around Lakes Alexandrina and Albert. The components of the monitoring program implemented one year after revegetation site establishment consist of:

- Photo monitoring points for recording change to the landscape and the surrounding natural environment;
- Vegetation transects for measuring the establishment and growth of vegetation; and
- Soil surveys for tracking changes to soil functional status, soil fertility and the build up of selected metals.

2.1 Site characteristics and set-up

Locations chosen for the surveys varied in regards to vegetation type, aspect, geology and soil type. In total eleven sites were chosen to provide a representation of the spatial extent of the revegetation activities as well as representations of the varying habitat types of the region. Detailed descriptions of each site are provided in Appendix A. Surveys were undertaken from the 29th of May to the 2nd of June 2012.

The climate of the region is temperate with an annual median precipitation of 33.6 mm, most of which falls during winter and spring seasons (May-September) (BOM 2012).

Table 1 lists the sites that were chosen for the surveys and the number of habitats identified within each. Two reference locations (Bonney Reserve and Mulungushi) were chosen to provide data on both the effectiveness of EFA and to provide target values for the rehabilitated sites. Bonney Reserve is located next to Camp Coorong and represents a natural landscape for the region. This site has not been cleared. The Mulungushi location on Hindmarsh Island has several sections with different revegetation timelines. The section of site surveyed at Mulungushi was revegetated in 2005 however, some in filling of plants still occurs within this section of the site. Figure 1 identifies where all locations surveyed are within the CLLMM region.

Table 1 Restoration monitoring site list with number of habitats surveyed

Site	Number of Habitat Types
Mundoo	1
Mulungushi (Reference)	1
Finniss	1
Point Sturt (Upper & Lower)	2
Boggy Lake	1
Fiebig Reserve (Upper & Lower)	2
Narrung	1
Camp Coorong	1
Bonney Reserve (Reference)	1

At each site, three 50 m transects were established and marked at each end with an iron picket and yellow cap. A copper tag was also placed on each picket identifying the year, transect number and either the zero or 50 m end. Where possible, the start of the transect was established on the upward slope edge of the local watershed and were spatially distributed to obtain a representation of the heterogeneity of the site. Coordinates for each transect are provided in Appendix B. Detailed maps of the location of each transect and photo-point within each site is illustrated in Appendix C.

A photograph of each transect was taken at the 50 m point to provide an overview of the habitat surveyed and to provide a baseline to detect changes over time (Appendix D).

At Point Sturt and Fiebig Reserve, revegetation occurred within two different vegetation types. These were treated as different sites and surveyed separately.

Point Sturt Upper was located on the high side of the site just below the escarpment and Point Sturt Lower within a samphire dominant zone. Fiebig Reserve Upper was located within a grass/samphire zone and Fiebig Reserve Lower within a samphire/rush zone. In total eleven sites at nine locations (33 transects) were surveyed across the region.

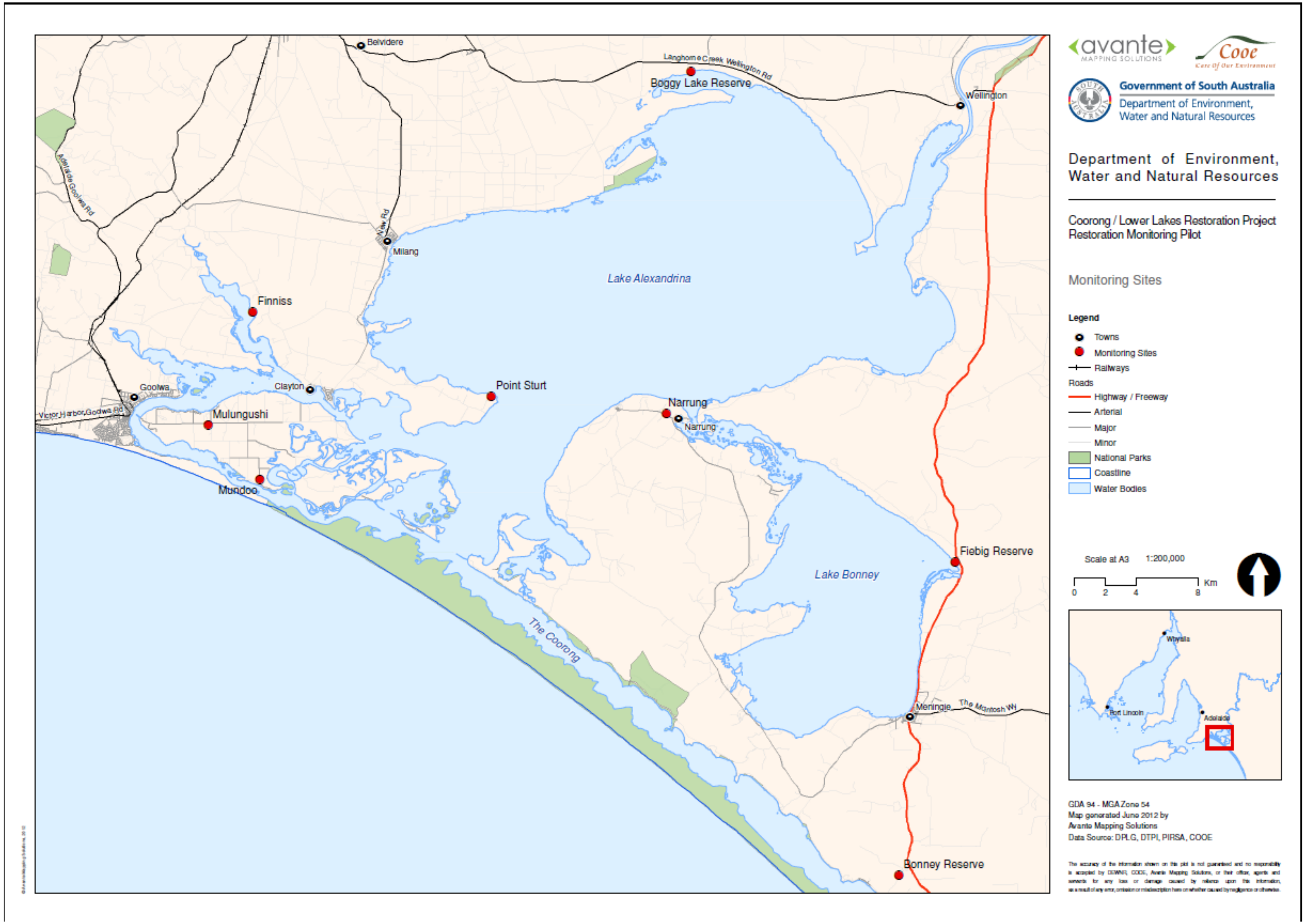


Figure 1 Overview of all locations surveyed in the CLLMM region.

2.2 Landscape photo-monitoring

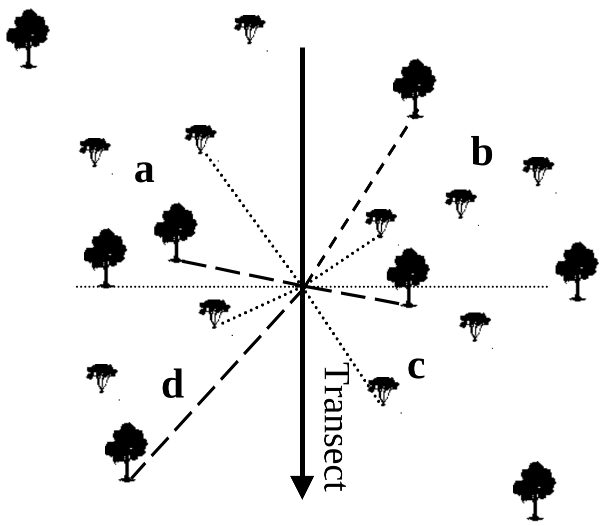
Eleven photo monitoring points were established in order to record large scale landscape changes resulting from the revegetation work. The location of these photo monitoring points were recorded by handheld GPS (Appendix E) and marked with an iron picket and a yellow plastic cap. At two locations, Point Sturt and Narrung, the layout of the site determined that photo-points were established to provide an overview at two aspects. One 0 m picket was established and at two points (45°) from each other a sighter post was located. A copper tag was placed on the 0 m picket identifying it as a photo-monitoring point, the year and 0 m mark. Appendix E identifies the location of the 0 m picket and description of its approximate location at each site.

2.3 Vegetation survey

EFA provides insights into how the landscape is functioning, vegetation establishment and habitat development. In successful rehabilitation, steady improvements are expected in vegetative cover, vegetation development and stability features. EFA data should gradually trend upward and plateau as the ecosystem becomes stable and self-sustaining. Results over time will verify if the ecosystems have achieved these self-sustaining levels and can withstand climatic fluctuations.

A Point-Centered Quarter (PCQ) method was employed to measure key vegetation indicators. Sampling points were established at 5 m intervals. Measurements included plant cover (width and breadth of plant canopy), density (plants per ha) and diversity.

At each sampling point the sampling area divided into quarters by mentally placing a line perpendicular to the transect line. The width, breadth and species, and distance to the perennial plant nearest to the tape, were measured to obtain the plant cover index value, density and diversity for each quarter Figure 2.



* showing measurements at a single point.

Figure 2 The PCQ method for measuring spatial distribution of vegetation

2.4 Landscape functional characteristics

2.4.1 Landscape organisation

The landscape characteristics, profile and vegetation patch characteristics were determined at or along each transect. The different landscape characteristics along each transect were used to assess the soil surface. Landscape organisation that relate to vegetation cover is defined as the arrangement of zones that reflect run-on and runoff processes.

2.4.2 Soil surface assessments

For each of the landscape characteristics identified, eleven indicators of soil surface condition were visually assessed on three replicate 1 m transects within each patch. The soil surface indicators examine the status of a specific surface process and are assessed as described in Tongway and Hindley (2000).

Three indices reflecting the emergent soil properties of stability, infiltration and nutrient cycling were derived by compiling subsets of these eleven indicators (Table 2). Their values are expressed as a proportion of a total maximum score, converted to a percentage. These indices express the habitat quality and have significance for monitoring in terms of:

1. Stability

    The ability of the soil to withstand erosive forces, and to reform after disturbance;

2. Infiltration

    How the soil partitions rainfall into soil-water (water available for plants to use), and runoff water which is lost from the local system, or may transport material away; and

3. Nutrient cycling

    How efficiently organic matter is cycled back into the soil.

Table 2 The combination of soil condition classes to derive indices of stability, infiltration and nutrient cycling

Indicator	Stability	Infiltration	Nutrient cycling
1. Rainsplash protection	✓		
2. Basal cover of perennial grass		✓	✓
3. Litter cover, origin & degree of decomposition	✓	✓	
4. Biological soil crust cover	✓		✓
5. Physical crust broken-ness	✓		
6. Erosion type & severity	✓		
7. Deposited materials	✓		
8. Surface roughness		✓	✓
9. Surface resistance to disturbance	✓	✓	
10. Slake test	✓	✓	
11. Soil texture		✓	

2.4.3 Habitat complexity

As vegetation develops in size and diversity, environmental niches and habitat structure develop and become more complex for fauna. An increase in habitat size and structure allows for shade, shelter and food resources for fauna.

The habitat complexity index presented in the EFA manual (Tongway & Hindley 2004) is a recently added component of EFA and has not been as rigorously tested as the rest of the methodology. It is assesses on the basis of five features:

1. Canopy cover
2. Shrub cover
3. Ground vegetation cover
4. The amount of litter, fallen logs and rocks; and
5. Free water availability.

A modified version of the method was applied during the surveys. At each transect from the 0 m point an overview of the habitat was assessed for approximately 3 m either side of the transect. A habitat complexity score of between 0-3 were applied for each feature at each transect. This provided a broad overview of the habitat complexity at the site.

2.4.4 Soil chemistry

Soil was collected from the vegetation transects to establish a chemical (soil fertility and metal content) baseline. Thirty-two soil samples were collected at the end (50m) of each transect as this, in most instances, represented the downward end of run-off at each site. After scrapping the surface vegetation and soil, four separate random samples were mixed together from the top 5cm and composited to one sample. Samples were collected and stored in pre-labelled glass jars and store in a cold ice cooler.

The soils were analysed by ALSE (NATA certified laboratory) for organic matter, electrical conductivity, pH, soil moisture, exchangeable cations (calcium, magnesium, potassium and sodium), minor anions (nitrate, nitrite, reactive phosphorus) and total metals (arsenic, cadmium, chromium, copper, lead, nickel and zinc).

Details of the laboratory methods for each analysis is presented in Appendix F.

Using the results of the exchangeable cations the exchangeable sodium percentage (ESP) was calculated to determine soil dispersion properties or the “sodicity” of the soils. The ESP is calculated as follows:

$$\text{ESP} = \text{Exchangeable } \{(\text{Na})/(\text{Ca} + \text{Mg} + \text{K} + \text{Na})\} \times 100$$

The following classifications are used to characterise the ESP percentage: non-sodic <6%; sodic 6 - 0%; moderately sodic 10 - 15%; strongly sodic 15 - 25%; and very strongly sodic >25%.

3 Results and Discussion

3.1 Site characteristics

Sites varied in regards to their vegetation type, slope, soil type and aspect. A detailed assessment of each site is provided in Appendix A.

At four sites, vegetation comprised primarily of saltmarsh species. These included Finniss, Point Sturt Lower, Boggy Lake Reserve, and Fiebig reserve. The sites were situated close to the lakes and were low lying. The soil type at these sites was heavy dark clay. These sites contained few weeds but in some sections, dense kikuyu was observed. On the edges of the samphire zones, shrubby sections were present.

Mundoo and Narrung were low rising sites with fringing samphire zones. Soil type is characterised dark heavy clay within the samphire zones and the grassy zones were sand-loam soils.

The remainder of the sites ranged from dense multi-layered vegetation at the two reference sites and open grass and shrub land at the other sites. The slope at these sites ranged from mildly undulating (e.g. Mulungushi and Camp Coorong) to steep (e.g. Point Sturt Upper and parts of Finniss). The steeper and more undulating sites varied in soil type but generally contained coarser sediment and sand.

Most of the sites have had grazing pressure from stock removed. Occasionally, stock enter Boggy Reserve and may affect revegetated and established plants. Rabbits activity were noted at Boggy reserve, which may be a factor in the revegetation survivorship. Rabbits may be present at other sites but were not observed during the survey.

3.2 Landscape photo-monitoring

A photographic record of each site is provided in Figure 3. Photographs were taken to allow for a broad overview of the areas surveyed at each site.

Mundoo 1	Mundoo 1B
	
Mulungushi 1	**Mulungushi 1B**
	

Figure 3 Photographic record of each site taken from permanent locations. Photograph on the left is taken at the widest zoom and a close-up photograph of the site on the right (B).

Finniss 1	Finniss 1B
	
Point Sturt 1	**Point Sturt 1B**
	
Point Sturt 2	**Point Sturt 2B**
	

Figure 3 Photographic record of each site taken from permanent locations. Photograph on the left is taken at the widest zoom and a close-up photograph of the site on the right (B). **(continued)**

Boggy Lake Reserve 1	Boggy Lake Reserve 1B
	
Fiebig Reserve 1	**Fiebig Reserve 1B**
	
Narrung 1	**Narrung 1B**
	

Figure 3 Photographic record of each site taken from permanent locations. Photograph on the left is taken at the widest zoom and a close-up photograph of the site on the right (B). **(continued)**

Narrung 2	Narrung 2B
	
Camp Coorong 1	**Bonney Reserve 1**
	
Bonney Reserve 1B	
	

Figure 3 Photographic record of each site taken from permanent locations. Photograph on the left is taken at the widest zoom and a close-up photograph of the site on the right (B). **(continued)**

3.3 Vegetation survey

Figure 4 summarises the vegetative cover in square metres per cover per hectare (m^2 ha^{-1}) resolved into 0.5 m height slices for each transect. Vegetation cover was variable within each site yet all sites were dominated by ground and shrub cover with a large proportion less than 2 m in height. The dominance of ground cover is important for the flow of resources across the ground surface by providing areas of resource mobilisation and transport. However, canopy cover is an important component of the habitat providing shelter for fauna as well as protection from erosive forces (wind and rainfall).

Canopy cover was minimal at the sites measured and is mainly a reflection of the site use history. Canopy cover of approximately over 5 m in height was mostly recorded from one transect at the reference site, Mulungushi (Figure 4). Although not recorded from the PCQ measurements canopy cover was dominant around transect 2 at Bonney Reserve. These were not recorded as the nearest plant measured was mostly low shrubs.

Bonney Reserve, a reference site, recorded the most median number of plants per hectare (11,0942 ha^{-1} ±SD 60,640). This site contained a complex habitat structure, from ground cover to mature canopy layers. Bonney Reserve also recorded the highest species diversity of 33 species.

The lowest density of plants was recorded from Point Sturt Upper (658 plants ha^{-1} ±SD 237). Many of the planted species were dead at this section of Point Sturt. Very few mature species were present, numerically demonstrated by the higher distance between plants measured.

Appendix G summarises the data recorded during the PCQ surveys. The lowest species diversity was recorded at Fiebig Reserve Lower and was as a result from the dominance of samphire at this site. The full list of the species identified and their presence within each site is in Appendix H.

Point Sturt Lower and Boggy Lake Reserve were dominated by saltmarsh species. Given that these habitats rarely contain tall plants, it is not expected that the canopy cover measurements will increase over time. Canopy cover will increase on the fringes of these zones where the habitat and soil type is more suitable for trees to establish.

Very few of the surveyed plants appeared grazed. Of all the plants measured only 1.7% were noted as having grazing pressure. Camp Coorong contained the highest number of grazing affected plants with *Allocasuarina verticillata* heavily affected, of which some were infested with mealy bugs. Grazing pressure on *Melaleuca halmaturorum* was noted from Fiebig Reserve Upper and Mundoo. Very few individual plants were noted within Bonney Reserve and this included *Boronia* sp.

Ground cover is important for the functionality of a habitat and flow of resources. It will be important that future monitoring look for trends in vegetation cover including an increase in ground and canopy cover at the sites.

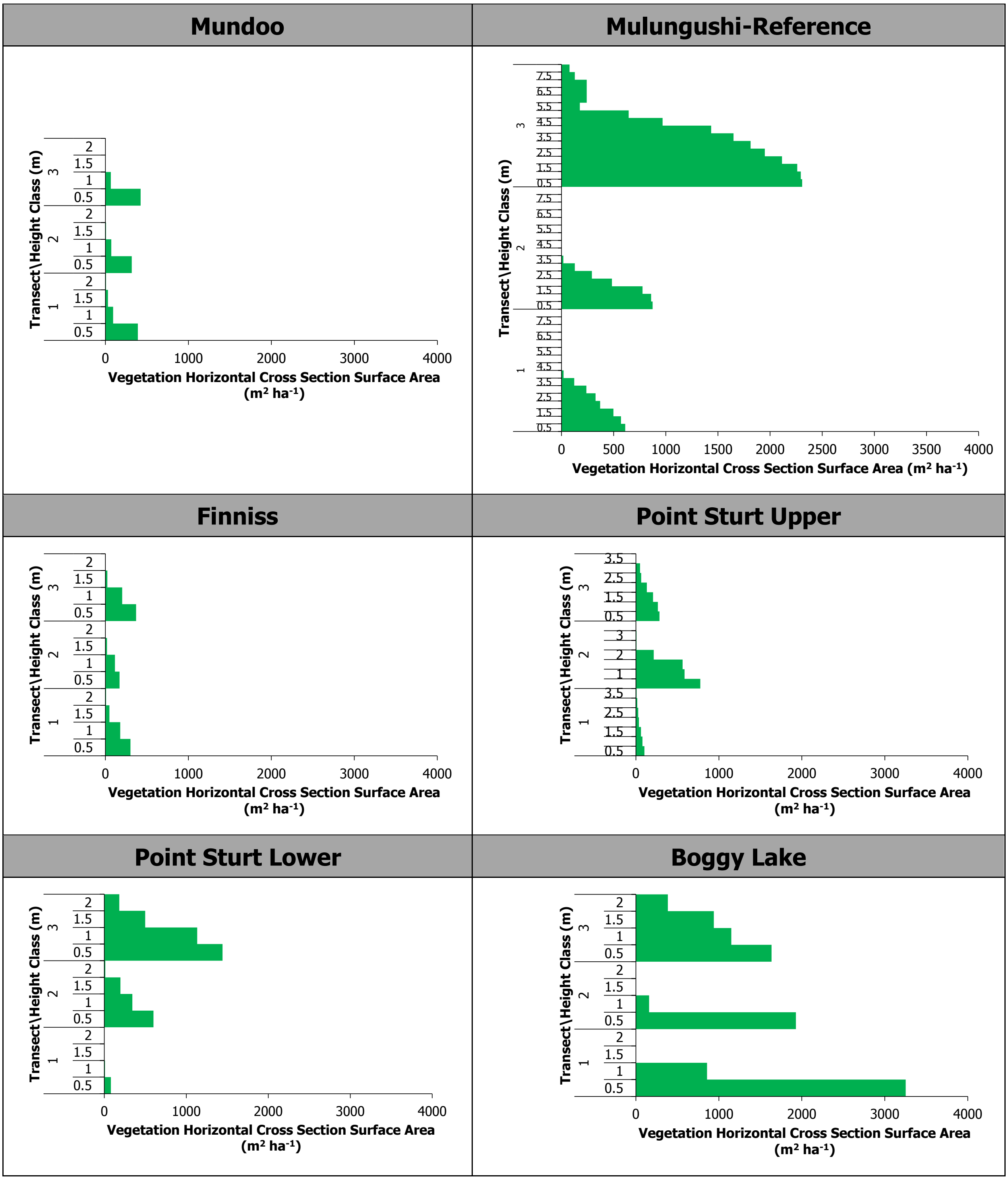


Figure 4 **Vegetation horizontal cross canopy cover and height distribution in 0.5 m classes for each transect at each site**

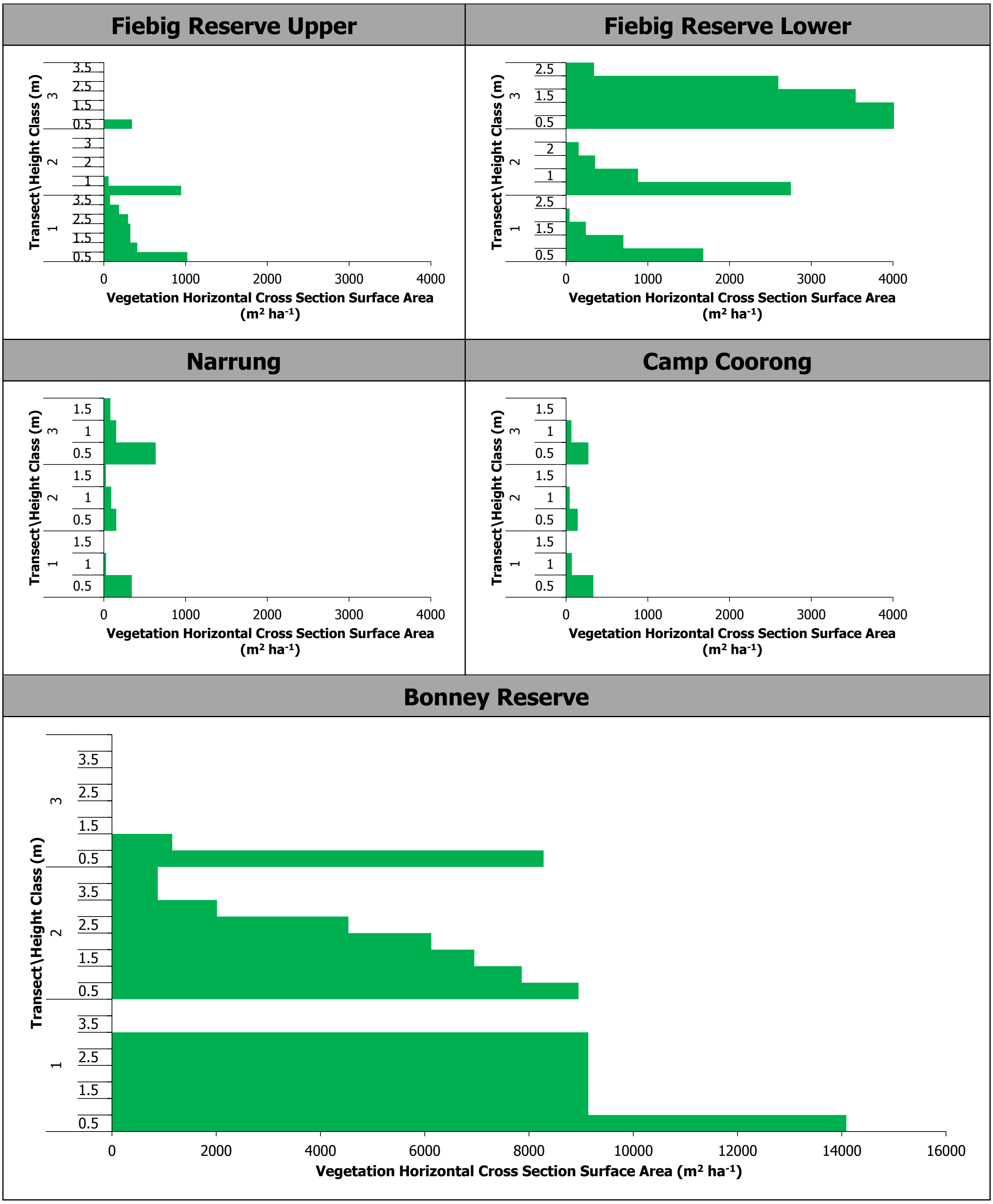


Figure 4 Vegetation horizontal cross canopy cover and height distribution in 0.5 m classes for each transect at each site **(continued)**

3.4 Landscape functional characteristics

3.4.1 Landscape function

Soil surface characteristics involved in the assessment of infiltration index include; perennial grass basal cover and shrub foliage cover, litter cover, soil surface nature, surface resistance to disturbance, slake test, and soil texture.

The infiltration index indicates how quickly water will permeate into the soil profile, not how much water the soil will store. A sandy soil often has a high infiltration rate, but very low soil moisture storage.

To evaluate soil moisture retention, we require the stability index to describe the soil profile characteristics that relate to water storage capacity, which depends on depth of profile, soil texture of whole profile, and gravel content (Ata Rezaei *et al*. 2006).

The value of stability index is obtained from several observations of the soil surface, but a high stability index does not necessarily always mean that the site has high production potential. If a high stability index value coincides with high nutrient cycling index and landscape organisation index then the high stability index can be associated with extensive vegetation cover, reflecting high soil productivity (Ata Rezaei *et al*. 2006). Although it is a useful index to assess soil stability, it is not simply related to soil productivity and plant production.

Figure 5 summarises each index for each rehabilitated site surveyed and indices are compared with the two reference sites, Mulungushi and Bonney Reserve. The foremost trend to note is that, on the whole, the revegetation sites are already functioning on a similar level to the reference sites. With on-going monitoring the primary concern will be that the landscape function within a site remains at or increases from the baseline values and remain comparable to reference sites. The score for each index at each transect is provided in Appendix I.

The stability index is relatively high across all sites with values ranging between 42.27 % at Mulungushi and 56.44 % at Mundoo. The higher value at a rehabilitated site compared to a reference was from a higher contribution from perennial cover and hence rainsplash protection. Mulungushi contained more loose sandy soils and very low ground cover of perennials. With increasing vegetation, plant litter should also increase therefore influencing the stability index.

The infiltration index was more variable between the sites surveyed. Values ranged between 23.77 % at Boggy Lake and 43.63 % at Mundoo. Again the higher cover of perennial grasses at Mundoo contributed to the higher value. Boggy Lake, a samphire dominated site, had almost no perennial or litter cover. Soil texture, which influences the infiltration index, was at several sites (e.g. Mulungushi, Bonney reserve and Point Sturt Upper) comprised of sandy soil, which was not coherent. Overall, perennial grasses were low in cover at many sites and it can be recommended that revegetation also includes low lying grasses.

The nutrient cycling index is influenced by three indicators: cover of perennial grass, biological crust cover and surface roughness. Values recorded ranged between 16.77 % at Boggy Lake and 29.47 % at Bonney Reserve. The three indicators scored highly at all transects at Bonney reserve. Again due to the dominance of samphire at Boggy Lake and lack of habitat diversity nutrient cycling scored very low.

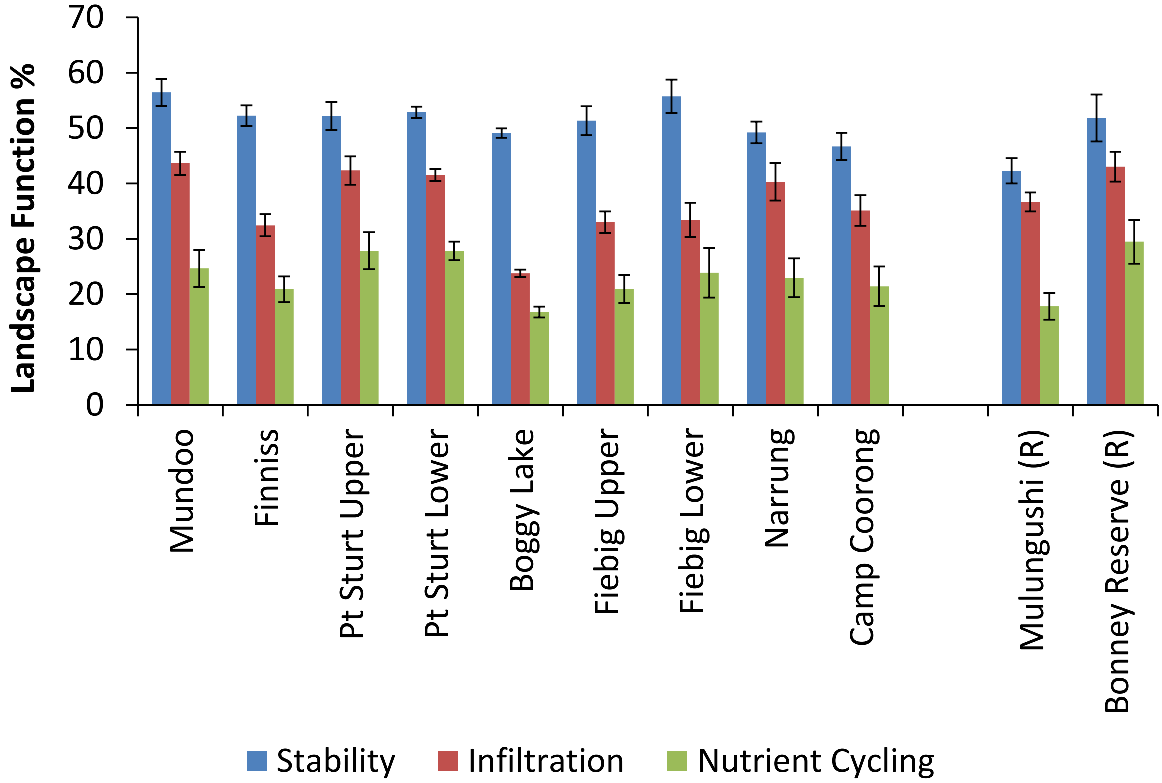


Figure 5 Landscape function of each site based on stability, infiltration and nutrient cycling indices. The two reference sites are represented by (R).

3.4.2 Habitat complexity

Habitat complexity along each transect was measured through visual observation of the overall habitat. Table 3 summarises the mean score for each structure observed and the mean total score for each site. Bonney Reserve recorded the highest score and was the only site to score on each structure index. Most other sites scored very low and contained few structural features.

It rained during the survey week. This influenced soil moisture at many of the sites.

While most indicators are measured during the soil surface assessments, there are often patches of the site that can be missed. Therefore, we assessed the overall habitat complexity of each site and/or transect, to pick up any indicators that were not scored during the soil surface assessments.

As the revegetated plants grow, each habitat complexity score should increase. After further monitoring, it will be possible to alter some of the habitat complexity indicators to be more specific to the region.

Indicators in future surveys can include the following:

- Groundcover--vines, creepers, cryptogams
- Under-storey-grasses, herbs, 0-0.1m
- Mid-storey-small shrubs, 0.5-1.5m
- Upper-storey-tall shrubs, 1.5-3.0m
- Over-storey- >3.0m

- Ants/other fauna (score on species and abundance)
- Scats
- Water availability

Table 3 Summary statistics for habitat complexity scores taken from each transect at each site.

	Mundoo		Mulungushi		Finniss		Point Sturt Upper		Point Sturt Lower	
Structure	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Tree Canopy (%)	0	0	1.67	0.58	0	0	0	0	0	0
Shrub Canopy (%)	0	0	1.33	0.58	1	0	2.33	1.15	0	0
Ground herbage	1	0	0	0	1	0	1	0	1.33	1.15
Logs, rocks, debris etc (%)	0	0	0	0	0	0	1	0	0.33	0.58
Soil Moisture	1	0	1	0	1	0	1	0	2.33	1.15
Mean total (max. 12)	**2**	**0**	**4**	**1**	**3**	**0**	**5.33**	**1.15**	**4**	**1**

	Boggy Lake		Fiebig Reserve Upper		Fiebig Reserve Lower		Narrung		Camp Coorong		Bonney Reserve	
Structure	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Tree Canopy (%)	0	0	0	0	0	0	0	0	0	0	1.33	0.58
Shrub Canopy (%)	0	0	0	0	0	0	1	0	0	0	1.67	0.58
Ground herbage	2	0	2	0	2	0	1	0	0	0	1.67	0.58
Logs, rocks, debris etc (%)	0	0	0	0	0	0	0	0	0	0	1.33	0.58
Soil Moisture	3	0	1	0	1	0	1	0	1	0	1	0
Mean total (max. 12)	**5**	**0**	**3**	**0**	**3**	**0**	**3**	**0**	**1**	**0**	**7**	**0**

3.4.3 Soil chemistry

This section contains some discussion about the results of soil chemical testing. Summary statistics of the results from the soil analyses are in Appendix J.

pH

The pH of soil indicates the strength of acidity or alkalinity in the soil solution that affects plant growth, soil constituents, and soil micro-organisms. Soil is neutral when pH is 7, it is acid when pH is less than 7 and alkaline when it is greater than 7.

Median soil pH across the sites varied from 6.8 to 8.5. Overall soil pH was moderately to strongly alkaline (>7) at most sites except for Finniss and Bonney reserve where pH levels were slightly acidic at just below 7.

Electrical Conductivity

High salt levels can adversely affect plant growth, soil structure, water quality and infrastructure. Soil salinity was variable across all sites and measured between a median of 35 and 5630 µS/cm.

Point Sturt Lower and Boggy Lake were moderately saline and as such dominated by salt tolerant plants, such as samphires. These sites were characterised by heavy loam soils. All other sites were classified as non-saline.

Moisture Content

The amount of water that can be stored in soil and evaporated or used by plants is an important indicator for the production and health of vegetation. Soil moisture is dependent on soil type with coarse, sandy soils holding less water than heavy silty clay soils.

Soil moisture varied widely between the sites sampled with a median between 5 and 32.2 %. Lower soil moisture values were recorded at Camp Coorong, Bonney reserve, and Mulungushi which were sites characterised by sandy soils. Whilst sites with more silt and loam such as Boggy Lake, Point Sturt and Lake Albert recorded higher soil moisture values.

Total Organic Content

Organic matter contributes to soil fertility by increasing available nitrogen and minerals. In addition to providing nutrients and habitat to organisms living in the soil, organic matter also binds soil particles into aggregates and improves the water holding capacity of soil.

The median organic content varied between 0.47 and 8.02 %. Higher organic matter values were recorded for sites with loamy soils (e.g. Bonney reserve, Point Sturt Upper and Fiebig Reserve Lower) whilst sites with sandy soils (e.g. Finniss, Mulungushi and Camp Coorong) recorded lower organic matter (median <2 %).

Total Heavy Metals

Analyses of total metals included arsenic, cadmium, chromium, copper, lead, nickel and zinc.

All soils naturally contain trace levels of metals. The presence of metals in soils is not necessarily indicative of contamination but can be related to the geology of the parent material from which the soil was formed.

Levels recorded from the samples were compared against NEPC guidelines for soil ecological investigation levels (NEPC 1999). All seven metals were well below guideline values at all sites.

Nutrients

Plant nutrients in soil come originally from the parent material from which the soil was formed. Nutrients analysed included nitrite, nitrate and phosphorus. Of all the essential nutrients, nitrogen is required by plants in the largest quantity and is most frequently the limiting factor in plant productivity. After nitrogen, phosphorus is the most important nutrient element for plant growth. Whilst most of the phosphorus in soils is mineralised, reactive Phosphorus, which was tested, is that which is available to plants.

Total oxidised nitrogen (nitrite + nitrate) varied between and within sites. Overall, median values varied between 0.1 and 14.2 mg/kg. Higher values were recorded from damp, loamy soils. Median reactive phosphorus ranged between 0.5 and 40 mg/kg. Lower values were recorded from both reference sites that were dense with native vegetation whilst sites dominated with samphire obtained higher phosphorus levels. Higher levels are due to two reasons – the breakdown of the blue-green algal (cyanobacterial) mat and the fact that it is a depositional environment.

Exchangeable cations

This is a measure of the ability of the soil to hold and exchange nutrients and essential elements with plants, particularly the nutrients calcium, magnesium and potassium. Good fertile soils with high clay content and moderate to high organic matter levels usually have a cation exchange capacity of 10 or higher. The major cations are calcium, magnesium, potassium, sodium. These are held in the soil by organic matter and clay.

All exchangeable cations recorded from Camp Coorong were in low concentrations. At Point Sturt and Fiebig Reserve values exchangeable cation concentrations were high. A high percentage of exchangeable sodium can cause soil structural dysfunction through clay dispersal and very low rates of hydraulic conductivity.

At the Boggy Lake and Point Sturt Lower, soil salinity and exchangeable sodium levels where high enough to interfere with plant growth. This is reflected in the dominance of samphire at both sites.

The exchangeable sodium percentage (ESP) was calculated to determine the sodicity of the soils. A sodic soil, by definition, contains a high level of sodium relative to the other exchangeable cations (i.e. calcium, magnesium and potassium). In sodic soils, much of the chlorine has been washed away which cause clay particles to lose their tendency to stick together when wet. As a result, sodic soils may affect plant growth and such soils tend to develop poor structure and drainage over time.

Soils measured varied from non-sodic (Camp Coorong, Bonney Reserve, Point Sturt Upper, Mulungushi and Narrung) to very strongly sodic (Finniss, Point Sturt Lower and Boggy Lake). Mundoo was classified as sodic, Fiebig Reserve Upper was strongly sodic and Fiebig reserve Lower moderately sodic. The very strongly sodic sites were samphire dominated sites and may be a natural reflection of the nature of the soils in such habitats.

The relationship between electrical conductivity and ESP (EC:ESP) can determine the possible effects of salinity and available sodium on plant growth. A relationship of the EC:ESP ratio was obtained Point Sturt Lower and Boggy Lake indicating both saline and sodic soils. This is a reflection of the natural state of these ecosystems. Plant selection for such sites need to be able to withstand the conditions.

4 Comparison between revegetation and reference sites

Revegetation sites varied from samphire dominated sites to open grassy habitats. Vegetation structure comprised mostly of grasses and low shrubs with minimal to no canopy present. Litter cover was generally very low and cover of perennial grasses was nearly absent at some sites. Soil type at the revegetation sites varied widely depending of the vegetation present. Soils varied from heavy clay soils at the samphire sites to loose sandy soils at sites such as Narrung. Soil salinity, organic matter, and nutrients were higher at some of the revegetation sites. The following provides a direct comparison between the reference sites and adjacent revegetation sites.

<u>Mundoo and Mulungushi</u>

Mundoo was surveyed one year after restoration works whilst Mulungushi represents a revegetated site after five years. The comparison between these two sites indicates what to expect from ongoing monitoring over a four-year period.

Mundoo was primarily an open grassland habitat with a high ground cover of weeds. Litter cover and cover of perennial grasses was low. The surface area of vegetation cover was one of the lowest in comparison to other revegetation sites and clearly lower than that of Mulungushi. However, plants of less than 1 m dominated vegetation cover. As such, habitat complexity was very low. Only ground herbage and soil moisture contributed to habitat complexity scores.

There were clear differences in landscape and habitat function at the reference site, Mulungushi. The area of Mulungushi surveyed represented an open woodland with grasses, shrubs and canopy cover. Litter cover and cover of perennial grasses was much higher in comparison to Mundoo. The surface area of vegetation cover comprised of various canopy heights. The retention of a diversity of canopy heights is an important factor to track over time. Habitat complexity scored well for tree and shrub canopy yet ground herbage was low. Non-natives mostly dominated ground cover.

The landscape function indices were higher at Mundoo compared with Mulungushi. This was primarily a factor of the difference in vegetation and soil types between the sites. Sandier soils were recorded at Mulungushi. As the vegetation matures and hence influences the landscape function indices at Mundoo it may be possible that indices will be comparable with those of Mulungushi. Prior to restoration works, Mulungushi was an open paddock dominated by non-native ground cover, similar to Mundoo. Through ongoing monitoring and comparisons of these sites, it will possible to detect how habitat complexity influences landscape function.

<u>Camp Coorong and Bonney Reserve</u>

Camp Coorong was surveyed one year after restoration works whilst Bonney Reserve represents remnant vegetation for the region. Bonney Reserve provides a long-term target for the restoration program within the region.

Camp Coorong scored very low on habitat complexity with only soil moisture a factor. The tree planting methods employed has heavily modified the landscape. The surface area of vegetation cover was from plants of less than 1 m in height. Much of the sections surveyed showed signs of erosion with minimal litter and perennial cover to protect the soils.

Bonney Reserve contained high-density vegetation and a complex habitat structure. Very few non-native species were observed. Litter cover and cover of perennial grasses scored much higher compared to Camp Coorong. The soil type at Bonney Reserve comprised mostly of sandy soils with low organic matter and low levels of nutrients. The higher score from habitat complexity provides a long-term target for Camp Coorong.

There were clear measured differences between the two reference sites and their adjacent revegetation sites. These differences illustrate that EFA is effective at detecting differences between sites and measuring landscape function and vegetation structure. The complex habitat structure and soil surface qualities were reflected in the results of the reference sites. Similarly, the nature of the ecosystems of the restoration sites was observed through the results. The indices from reference sites provide good long-term targets for restoration activities.

The selection of the reference sites was appropriate to compare with results from Narrung, Camp Coorong, Point Sturt Upper, and sections of Mundoo. The vegetation type, habitat structure and soil type at the reference sites reflected the landscape function targeted for the revegetation sites. For the low-lying samphire dominated sites, appropriate reference sites will reflect the vegetation and habitat structure characterising these sites. At present the reference sites are only appropriate for a selection of the revegetation sites surveyed.

5 Recommendations

The objective of this pilot was to primarily establish a baseline survey of the restoration activities, while determining the functional status of the ecosystem at each location. Whilst comparisons from the data can be made between the sites, habitat resilience will only be determined with on-going monitoring.

Monitoring of the sites should be undertaken on a yearly basis until the data warrant a longer period, to say every 3–5 years. If data are collected regularly, a time series record of ecosystem change or development is provided. By comparing data with reference sites, it is possible to see if the disturbed site is developing adequately.

As already observed from the results, revegetation sites are functioning on a similar level to the reference sites. However, long-term monitoring will have to assess that within each site this landscape function remains at baseline levels or even increases. Appropriate reference sites will need to be chosen for the low-lying samphire sites.

Figure 6 illustrates three potential scenarios from which to assess results obtained from long-term monitoring. When indices are plotted over time, it is possible to analyse the future likelihood of the rehabilitation. Curve A represents an appropriate trajectory shape, implying that the rehabilitation is on-track and no problems have been identified. It is characterised by a steep initial response followed by a steady increase over time. Curve B shows that potential problems have been identified that need further analysis. Curve C shows problems are identified that need urgent attention. All indices at a given site should exceed the critical threshold value if ecosystem rehabilitation is to be judged successful (Tongway and Hindley, 2004). There is no minimum time limit attached to EFA monitoring of rehabilitation. The sigmoidal curve of the results over time is of more significance than the actual individual yearly data.

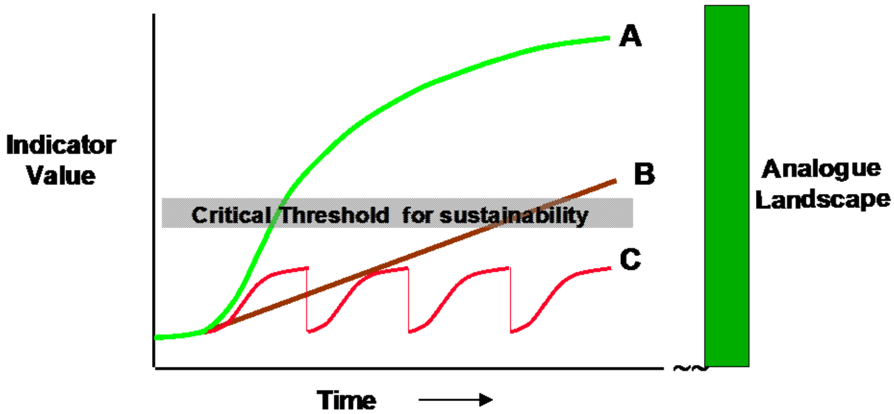
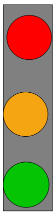


Figure 6 Three contrasting ecosystem rehabilitation trajectories (Tongway & Hindley 2004)

For future reporting, the conceptual application of rehabilitation trajectories can be simplified to Figure 7. With on-going monitoring a trend assessment of rehabilitation can be developed where management actions can be determined through the following system:



There is an urgent problem needing attention.

There is a possible problem. Use a more rigorous method to ascertain its seriousness.

There is no discernible problem with the trend.

Figure 7 Suggested reporting system for rehabilitation trend assessment

Further recommendations for reporting on results of future monitoring assessments include:

- how biological processes are becoming more prominent and ultimately dominant;
- how erosion, sedimentation and litter removal are declining, ultimately to non-discernible levels;
- how soil aggregates no longer slake; and
- how the structure, composition and function of the vegetation is developing.

Further work can be done to maximise rehabilitation and therefore ensuring that basic ecological function is maintained. Management actions could include:

- Retaining woody debris and increasing perennial vegetation cover to retain resources and protect the soil;
- Reducing any remaining grazing pressure from stock to allow native plants to set seed and grow beyond browsing height; and
- Provide any additional protection where successful germination and establishment occurs.

In future, assessments can be done to determine the habitat available for fauna and the status of fauna in the ecosystem. As vegetation becomes larger and more diverse, the site as a whole often develops to be more suitable for fauna (Tongway and Hindley, 2004). This can be done through the habitat complexity method which can be further developed for the region.

There is a potential issue of the scale of the site and location of transects. As the location of the transects are fixed over time, there may be issues over the whole site that are not being captured during the EFA surveys. As such, regular site inspections are recommended. These can incorporate the habitat complexity method on regular intervals to provide an overview of the whole site's function.

The use of LIDAR (Light Detection and Ranging) can be a innovative and useful tool in rehabilitation projects. This method can also overcome the issue of scale by providing a whole site assessment. However, it would not be a replacement for the use of EFA, which provides fine-scale landscape function assessment. LIDAR provides high accuracy maps of the surface of the sites to provide a three-dimensional assessment of erosion. It provides data on basic vegetation height, vegetation strata, biomass and vegetation cover. It is recommended that this can be done every five years, as this will be more efficient at detecting trends.

6 Conclusion

The maintenance of diverse and healthy native vegetation communities requires both active and passive management based on informed decisions relating to habitat quality. Applying EFA techniques to the revegetation sites provides an opportunity to achieve best-practice rehabilitation assessment and monitoring. It is a scientifically valid method of quantifying rehabilitation success. The results presented provide a solid baseline to compare with for future monitoring.

Important information gathered during the surveys includes an overview of the landscape function, vegetation structure and soil health at each site. It is evident that there are distinct differences between the sites mainly due to the natural characteristics present. For example, samphire dominated sites will have distinctive differences in landscape function to woodland or grassy sites. Comparisons between such sites may not be feasible and therefore comparisons can only be made of the ecosystem function within a site over time. It is recommended that more appropriate reference sites be selected for some of the samphire revegetation sites.

The use of EFA at the restoration sites has proved effective at providing a baseline of the current landscape structure and function. For the purposes of measuring restoration activities, EFA has been successful at assessing the vegetation structure and status of the soil surface at each site. With ongoing monitoring EFA will test the changes within a site and assess how indices trend with maturing vegetation. The method will be able to detect over time if the landscape is subject to stress and disturbance. The goal is to follow the trends of the EFA indicators to detect a time when the landscape has become self-sustaining as an ecosystem. The effectiveness of EFA to assess and monitor revegetation activities of the CLLMM region can only be determined with on-going monitoring.

7 References

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Appendices

Appendix A Details of site characteristics at each location

Site No.	1	Date	29/05/12
Site Name	Mundoo	Observers	AC, SS, RW, JB

	Transect 1	Transect 2	Transect 3
Position (GPS) (0m)	0307449/6064504	0307438/6064578	0307495/6064630
Transect Compass Bearing	54°	48°	200°
Position in Landscape	SW corner 50m from gate	NW of entrance gate	Close to samphire zone
Lithology	Fine sediment. Light brown colour	Fine sediment. Light brown colour	Fine sediment. Light brown colour
Soils (Texture/Fraction)	Medium/Sand	Medium/Sand	Medium/Sand
Slope	Flat	Flat	Flat
Aspect	NE	NE	SSW
Vegetation Type	Open grassland	Open grassland	Open grassland
Landuse	Revegetation	Revegetation	Revegetation
State of Soil Surface	Intact/Sandy	Intact/Sandy	Intact/Sandy
Comments			

Appendix A Details of site characteristics at each location **(continued)**

Site No.	2	**Date**	01/06/12
Site Name	Mulungushi	**Observers**	AC, JB

	Transect 1	**Transect 2**	**Transect 3**
Position (GPS) (0m)	0304107/6068021	0304108/6068095	0304125/6068127
Transect Compass Bearing	36°	45°	290°
Position in Landscape	Near stand of Callitris, heading towards main house.	Open scrubland.	Within Allocasuarina patch. Close to main road.
Lithology	Light yellow/brown sand	Light yellow/brown sand	Light yellow/brown sand
Soils (Texture/Fraction)	Light-medium/Sand	Light-medium/Sand	Light-medium/Sand
Slope	Undulating	Undulating	Undulating
Aspect	NNE	NE	NW
Vegetation Type	Open woodland	Open woodland	Open woodland
Landuse	Revegetation (2007)	Revegetation (2007)	Revegetation (2007)
State of Soil Surface	Intact/Sandy	Sandy/some evidence of borrows	Sandy/some evidence of borrows
Comments			

Appendix A Details of site characteristics at each location **(continued)**

Site No.	3	**Date**	29&31/05/12
Site Name	Finniss	**Observers**	AC, RW, JB

	Transect 1	**Transect 2**	**Transect 3**
Position (GPS) (0m)	0307083/6075358	0307037/6075423	0306999/6075462
Transect Compass Bearing	211°	234°	292°
Position in Landscape	Approx. 400m north of picnic area	100m south from the start of the hill	Closer to main house, has steep erosional slope at the start of the transect
Lithology	Fine sediment. Light yellow	Fine sediment. Light colour	Fine sediment. Light-to colour.
Soils (Texture/Fraction)	Medium/sand	Medium/Sand	Medium/Sand
Slope	Flat	Undulating	Steep
Aspect	SSW	SW	WNW
Vegetation Type	Open grassland	Open grassland	Grass/sedges
Landuse	Revegetation	Revegetation	Revegetation
State of Soil Surface	Intact/Sandy	Intact/Sandy	Sandy at the start and ends in damp/muddy soil within reeds.
Comments			

Appendix A Details of site characteristics at each location **(continued)**

Site No.	4	**Date**	31/05/12
Site Name	Point Sturt Upper	**Observers**	AC, JB

	Transect 1	**Transect 2**	**Transect 3**
Position (GPS) (0m)	0322361/6069965	0322412/6069941	0322476/6069861
Transect Compass Bearing	107°	172°	96°
Position in Landscape	Just below escarpment, towards end of site.	Half way across escarpment along site	Closer to strat of site at the end of the scrub section
Lithology	Fine-coarse grained, yellow/grey colour	Fine-coarse grained, yellow/grey colour	Fine-coarse grained, yellow/grey colour
Soils (Texture/Fraction)	Medium/Sand	Medium/Sand	Medium/Sand
Slope	Steep	Steep	Steep
Aspect	East	South	East
Vegetation Type	Grass/shrubs	Grass/shrubs	Grass/shrubs
Landuse	Revegetation	Revegetation	Revegetation
State of Soil Surface	Intact/Sandy	Intact/Sandy	Intact/Sandy
Comments			

Appendix A Details of site characteristics at each location **(continued)**

Site No.	5	**Date**	31/05/12
Site Name	Point Sturt Lower	**Observers**	AC, JB

	Transect 1	**Transect 2**	**Transect 3**
Position (GPS) (0m)	0322404/6069986	0322472/6069926	0322490/6069905
Transect Compass Bearing	119^{o}	140^{o}	103^{o}
Position in Landscape	By corner of fence at western end of site.	Half-way along flat zone	Near swamp at beginning of site.
Lithology	Dark heavy clay	Dark heavy clay	Dark heavy clay
Soils (Texture/Fraction)	Med-heavy/Silt	Med-heavy/Silt	Med-heavy/Silt
Slope	Flat	Flat	Flat
Aspect	East	SE	East
Vegetation Type	Dense grass swards	Grass/Samphire	Grass/samphire
Landuse	Revegetation	Revegetation	Revegetation
State of Soil Surface	Kikuyu dominated/thick	Intact. Damp/muddy	Intact. Damp/muddy
Comments			

Appendix A Details of site characteristics at each location **(continued)**

Site No.	6	**Date**	01/06/12
Site Name	Boggy Lake Reserve	**Observers**	AC, JB

	Transect 1	**Transect 2**	**Transect 3**
Position (GPS) (0m)	0335485/6091185	0335393/6091094	0335528/6091009
Transect Compass Bearing	301°	253°	264°
Position in Landscape	Heads from access track towards depression in middle of site	Closer to lake from transect 1	Within fringing shrub zone close to lake
Lithology	Very dark fine clay	Very dark fine clay	Light brown, fine sediment
Soils (Texture/Fraction)	Med-heavy/Silt	Med-heavy/Silt	Medium/Sand
Slope	Flat	Flat	Flat
Aspect	WNW	East	West
Vegetation Type	Samphire	Samphire	Grass/shrubs
Landuse	Revegetation	Revegetation	Revegetation
State of Soil Surface	Intact. Damp/muddy	Intact. Damp/muddy	Sandy/Intact
Comments			

Appendix A Details of site characteristics at each location **(continued)**

Site No.	7	**Date**	02/06/12
Site Name	Fiebig Reserve Upper	**Observers**	AC, JB

	Transect 1	Transect 2	Transect 3
Position (GPS) (0m)	0352693/6059250	0352665/6059290	0352650/6059326
Transect Compass Bearing	240°	250°	280°
Position in Landscape	Between fence & access track	Between fence & access track	Closer to access gate
Lithology	Fine sediment. Dark colour	Fine sediment. Dark colour	Fine sediment. Dark colour
Soils (Texture/Fraction)	Medium/Silt	Medium/Silt	Medium/Silt
Slope	Flat	Flat	Flat
Aspect	WSW	WSW	West
Vegetation Type	Samphire/grass	Samphire/grass	Samphire/grass
Landuse	Revegetation	Revegetation	Revegetation
State of Soil Surface	Intact. Damp/muddy	Intact. Damp/muddy	Intact. Damp/muddy
Comments	To left of access track as driving in	To left of access track as driving in	To left of access track as driving in

Appendix A Details of site characteristics at each location (continued)

Site No.	8	Date	02/06/12
Site Name	Fiebig Reserve Lower	Observers	AC, JB

	Transect 1	Transect 2	Transect 3
Position (GPS) (0m)	0352496/6059240	0352476/6059270	0352449/6059302
Transect Compass Bearing	48°	68°	67°
Position in Landscape	Towards lake into lignum scrub	Towards lake into lignum scrub	Closer to access gate
Lithology	Dark, fine sediment	Dark, fine sediment	Dark, fine sediment
Soils (Texture/Fraction)	Medium/Silt	Medium/Silt	Medium/Silt
Slope	Flat	Flat	Flat
Aspect	NE	ENE	ENE
Vegetation Type	Samphire/grass-shrubs	Samphire/grass-shrubs	Samphire/grass-shrubs
Landuse	Revegetation	Revegetation	Revegetation
State of Soil Surface	Intact. Damp/muddy	Intact. Damp/muddy	Intact. Damp/muddy
Comments	To right of access track as driving in	To right of access track as driving in	To right of access track as driving in

Appendix A Details of site characteristics at each location **(continued)**

Site No.	9	**Date**	02/06/12
Site Name	Narrung	**Observers**	AC, JB

	Transect 1	**Transect 2**	**Transect 3**
Position (GPS) (0m)	0333839/6068804	0333854/6068770	0333845/6068750
Transect Compass Bearing	11°	93°	114°
Position in Landscape	Parallel to adjoin propoert approx. 30m from fence	Middle of rise, bearing towards old shed by the lake	Closest & paralle to main road, bearing towards pine trees
Lithology	Dark fine sediment at end of transect. Light sandy sediment from the start.	Light yellow/grey, fine sediment	Light yellow/grey, fine sediment
Soils (Texture/Fraction)	Medium/Sand	Medium/Sand	Medium-heavy/Sand-silt
Slope	Undulating	Undulating	Undulating
Aspect	North	East	ESE
Vegetation Type	Open grassland/shrubs	Open grassland/shrubs	Open grassland/shrubs
Landuse	Revegetation	Revegetation	Revegetation
State of Soil Surface	Intact. Sandy-damp	Sandy/Intact	Sandy/Intact
Comments			

Appendix A Details of site characteristics at each location **(continued)**

Site No.	10	**Date**	30/05/12
Site Name	Camp Coorong	**Observers**	AC, RW, JB

	Transect 1	Transect 2	Transect 3
Position (GPS) (0m)	0349100/6038797	0349120/6038855	0349035/6038974
Transect Compass Bearing	340°	115°	354°
Position in Landscape	Top of rise just below dump	Start within middle of site, bearing towards shrub patch.	Close to road on northern side of reserve
Lithology	Fine sediment. Light yellow/grey colour	Fine sediment. Light yellow/grey colour	Fine sediment. Light yellow/grey colour
Soils (Texture/Fraction)	Medium/Sand	Medium/Sand	Medium/Sand
Slope	Undulating	Undulating	Undulating
Aspect	NNW	West	North
Vegetation Type	Open grassland	Open grassland	Open grassland
Landuse	Revegetation	Revegetation	Revegetation
State of Soil Surface	Sandy/Artificial ridges	Sandy/Artificial ridges	Sandy/Artificial ridges
Comments			

Appendix A Details of site characteristics at each location **(continued)**

Site No.	11	**Date**	30/05/12
Site Name	Bonney Reserve	**Observers**	AC, RW, JB

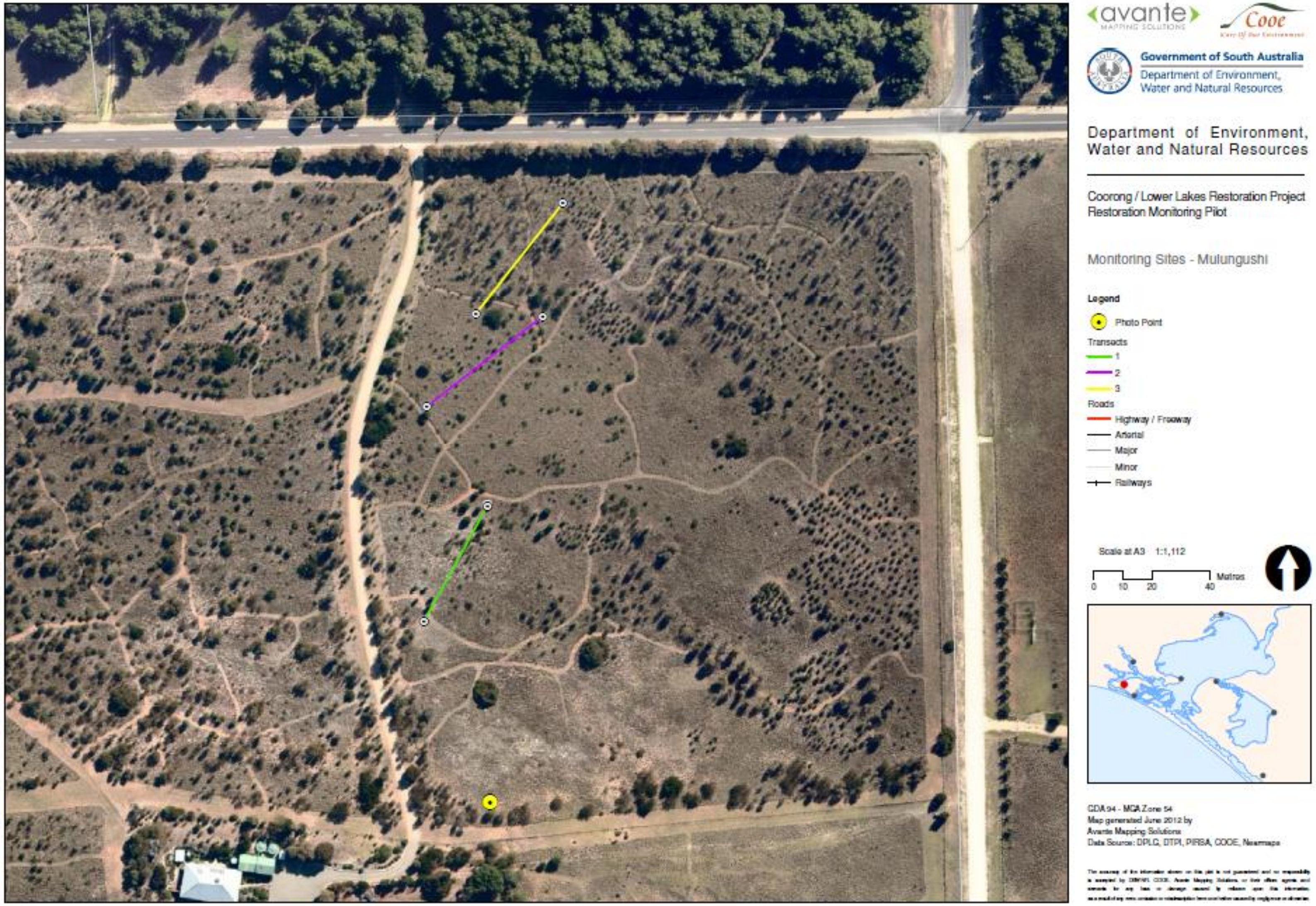
	Transect 1	**Transect 2**	**Transect 3**
Position (GPS) (0m)	0348977/6038545	0348924/6038498	0348816/6038574
Transect Compass Bearing	15°	271°	177°
Position in Landscape	Walk along fence between reserve & Camp Coorong approx. 200m & walk into scrub	Within dense mallee scrub	Within open scrub close to main road
Lithology	Fine sediment. Light yellow/grey colour	Fine sediment with some rock patches	Fine sediment. Light yellow/grey colour
Soils (Texture/Fraction)	Light-medium/Sand	Light-medium/Sand	Light-medium/Sand
Slope	Undulating	Undulating	Undulating
Aspect	NNE	West	South
Vegetation Type	Open woodland	Dense woodland	Open woodland
Landuse	Reserve	Reserve	Reserve
State of Soil Surface	Sandy/Intact	Sandy/rocky. Intact	Sandy/Intact
Comments			

Appendix B GPS coordinates for the start (0 m) and end (50 m) of each transect at all sites (GDA 94)

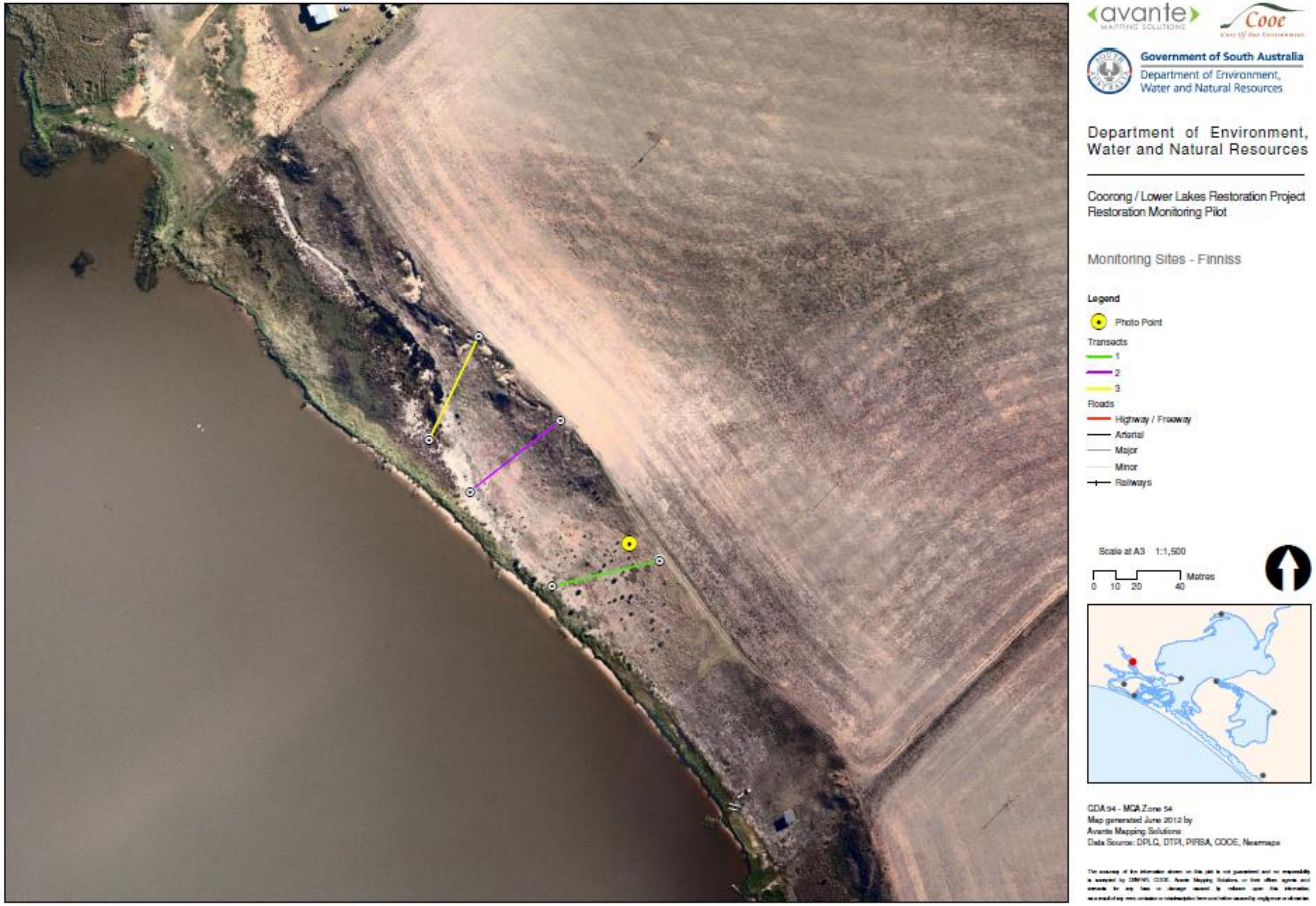
		0 m		50 m	
Site	**Transect**	**Easting**	**Northing**	**Easting**	**Northing**
Mundoo	1	0307449	6064504	0307493	6064535
Mundoo	2	0307438	6064578	0307486	6064596
Mundoo	3	0307495	6064630	0307545	6064651
Mulungushi	1	0304107	6068021	0304129	6068061
Mulungushi	2	0304108	6068095	0304148	6068126
Mulungushi	3	0304125	6068127	0304155	6068165
Finniss	1	0307083	6075358	0307033	6075346
Finniss	2	0307037	6075423	0306995	6075390
Finniss	3	0306999	6075462	0306976	6075414
Point Sturt-Upper	1	0322361	6069965	0322412	6069965
Point Sturt-Upper	2	0322412	6069941	0322459	6069922
Point Sturt-Upper	3	0322476	6069861	0322523	6069845
Point Sturt-Lower	1	0322404	6069986	119^{o}	119^{o}
Point Sturt-Lower	2	0322472	6069926	0322524	6069929
Point Sturt-Lower	3	0322490	6069905	0322547	6069902
Boggy Lake Reserve	1	0335485	6091185	0335530	6091200
Boggy Lake Reserve	2	0335393	6091094	0335442	6091107
Boggy Lake Reserve	3	0335528	6091009	0335477	6091006
Fiebig Reserve-Upper	1	0352693	6059250	0352638	6059239
Fiebig Reserve-Upper	2	0352665	6059290	0352615	6059281
Fiebig Reserve-Upper	3	0352650	6059326	0352586	6059330
Fiebig Reserve-Lower	1	0352496	6059240	0352544	6059259
Fiebig Reserve-Lower	2	0352476	6059270	0352522	6059290
Fiebig Reserve-Lower	3	0352449	6059302	0352494	6059326
Narrung	1	0333839	6068804	0333846	6068852
Narrung	2	0333854	6068770	0333903	6068760
Narrung	3	0333845	6068750	0333889	6068728
Camp Coorong	1	0349100	6038797	0349091	6038859
Camp Coorong	2	0349120	6038855	0349108	6038904
Camp Coorong	3	0349035	6038974	0349014	6039021
Bonney Reserve	1	0348977	6038545	0348986	6038591
Bonney Reserve	2	0348924	6038498	0348877	6038504
Bonney Reserve	3	0348816	6038574	0348826	6038527

Appendix C Transect and photopoint locations within each site

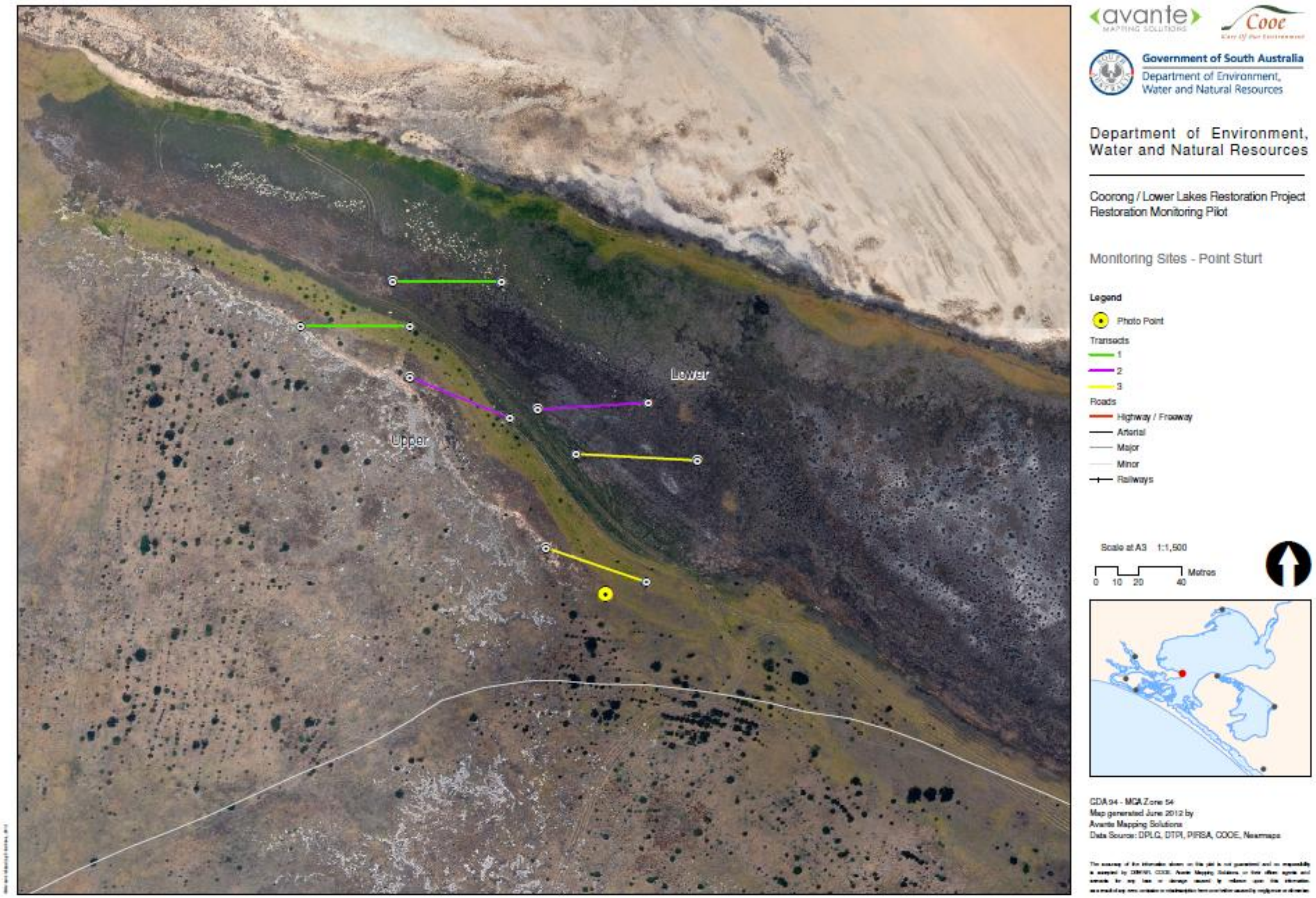
Appendix C Transect and photopoint locations within each site **(continued)**



Appendix C Transect and photopoint locations within each site **(continued)**



Appendix C Transect and photopoint locations within each site **(continued)**



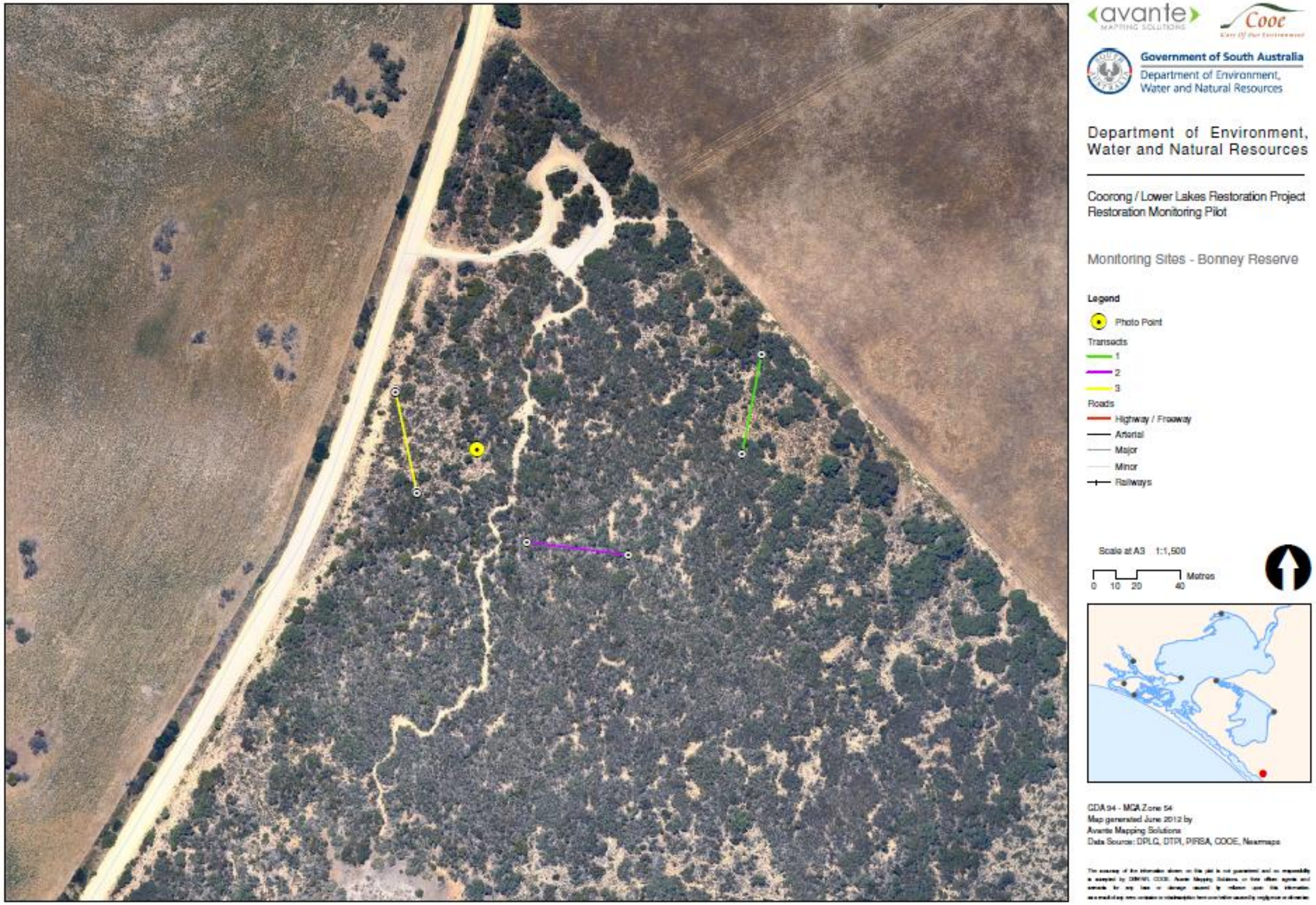
Appendix C Transect and photopoint locations within each site **(continued)**

Appendix C Transect and photopoint locations within each site **(continued)**

Appendix C Transect and photopoint locations within each site **(continued)**

Appendix C Transect and photopoint locations within each site **(continued)**

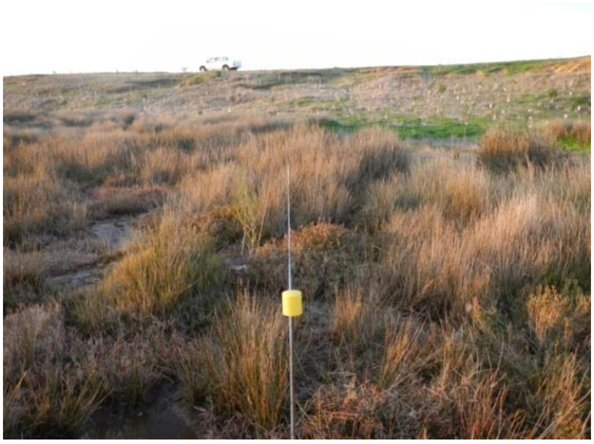
Appendix C Transect and photopoint locations within each site **(continued)**



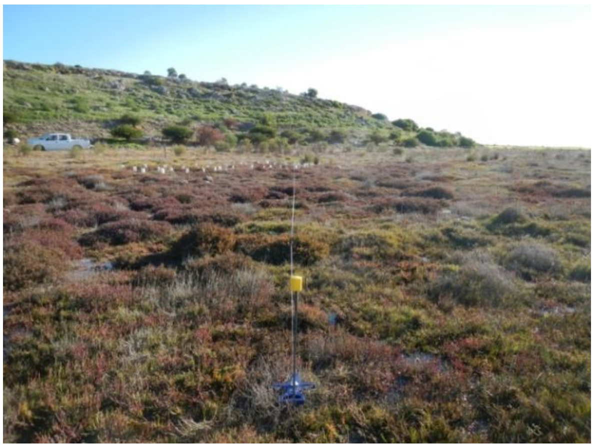
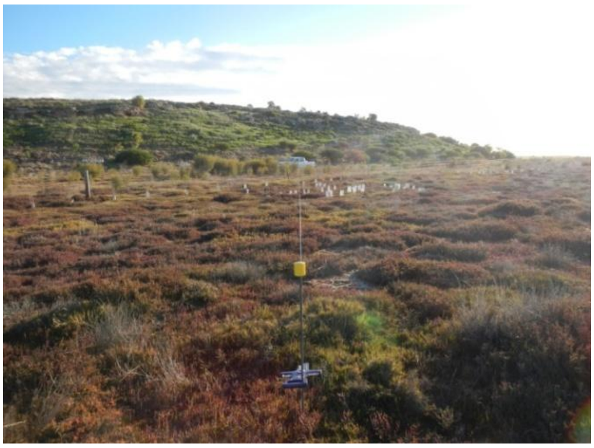
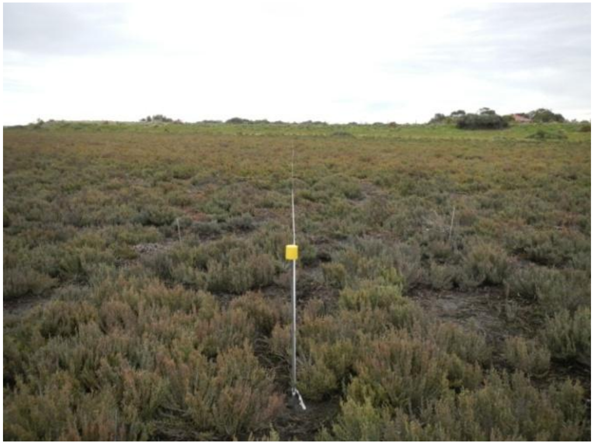
Appendix D Overview of each transect taken from the 50 m point.

Mundoo Transect 1	Mundoo Transect 2
	
Mundoo Transect 3	**Mulungushi Transect 1**
	
Mulungushi Transect 2	**Mulungushi Transect 3**
	

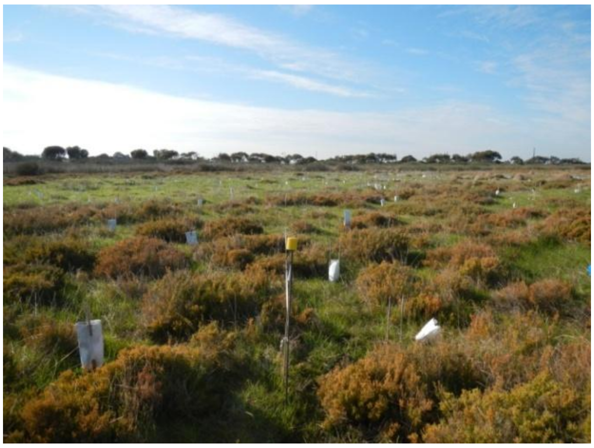
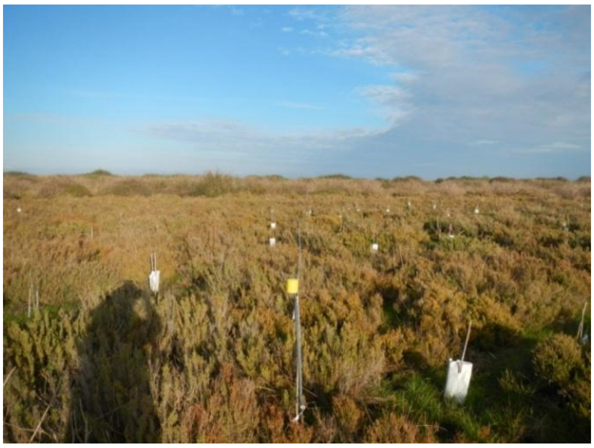
Appendix D Overview of each transect taken from the 50 m point **(continued).**

Finniss Transect 1	**Finniss Transect 2**
	
Point Sturt Upper Transect 1	**Point Sturt Upper Transect 2**
	
Point Sturt Upper Transect 3	**Point Sturt Lower Transect 1**
	

Appendix D Overview of each transect taken from the 50 m point **(continued).**

Point Sturt Lower Transect 2	Point Sturt Lower Transect 3
	
Boggy Lake ReserveTransect 1	**Boggy Lake Reserve Transect 2**
	
Boggy Lake Reserve Transect 3	**Fiebig Reserve Upper Transect 1**
	

Appendix D Overview of each transect taken from the 50 m point **(continued).**

<table>
<tr><th>Fiebig Reserve Upper Transect 2</th><th>Fiebig Reserve Upper Transect 3</th></tr>
<tr><td></td><td></td></tr>
<tr><th>Fiebig Reserve-Lower Transect 1</th><th>Fiebig Reserve-Lower Transect 2</th></tr>
<tr><td></td><td></td></tr>
<tr><th>Fiebig Reserve-Lower Transect 3</th><th>Narrung Transect 1</th></tr>
<tr><td></td><td></td></tr>
</table>

Appendix D Overview of each transect taken from the 50 m point **(continued).**

Narrung Transect 2	Narrung Transect 3
	
Bonney Reserve Transect 1	**Bonney Reserve Transect 2**
	
Bonney Reserve Transect 3	
	

Appendix E Details of the photo-monitoring points at each of the locations surveyed.

Distance of the sighter post from the camera post was 10 m for all points. GPS coordinates were taken at the 0 m mark (GDA 94).

Site	Location	Easting	Northing
Mundoo	Bearing of sighter post from camera post:28^{o} Height of camera post: 830 mm Height of sighter post: 800 mm Comments: SW corner from entrance gate on low rise	0307463	6064513
Mulungushi	Bearing of sighter post from camera post: 27^{o} Height of camera post: 850 mm Height of sighter post: 1000 mm Comments: Top of ridge, close to main house on southern edge of zone. Allocasuarina & Melaleuca in background.	0304130	6067959
Finniss	Bearing of sighter post from camera post: 263^{o} Height of camera post: 800 mm Height of sighter post: 800 mm Comments: Close to picnic area at start of site	0307069	6075366
Point Sturt (2 views)	Bearing of sighter post from camera post: 346^{o} Height of camera post: 980 mm Height of sighter post: 800 mm Comments: Closer to entrance on top of ridge. Overview of escarpment & swamp area. Bearing of sighter post from camera post: 54^{o} Height of camera post: 980 mm Height of sighter post: 830 mm Comments: Closer to entrance on top of ridge. Overview of swamp.	0322504	6069839
Boggy Lake Reserve	Bearing of sighter post from camera post: 37^{o} Height of camera post: 930 mm Height of sighter post: 870 mm Comments: On the rise next to fence of adjoining property. Overlooks samphire area with lake to your right.	0335304	6091027
Fiebig Reserve	Bearing of sighter post from camera post: 90^{o} Height of camera post: 880 mm Height of sighter post: 880 mm Comments: Located on the Upper section, traverses through transect 1	0352647	6059243

Appendix E Details of the photo-monitoring points at each of the locations surveyed **(continued).**

Site	Location	Easting	Northing
Narrung (2 views)	Bearing of sighter post from camera post: 100° Height of camera post: 710 mm Height of sighter post: 810 mm Comments: On top of rise overlooking pintrees & shed adjacent to main road Bearing of sighter post from camera post: 22° Height of camera post: 710 mm Height of sighter post: 810 mm Comments: On top of rise, overlooking across the lake towards the house.	0333841	6068769
Camp Coorong	Bearing of sighter post from camera post: 164° Height of camera post: 1020 mm Height of sighter post: 1040 mm Comments: Just below dump, on main rise of site. Shrub zone in the distance	0349067	6038794
Bonney reserve	Bearing of sighter post from camera post: 277° Height of camera post: n/a (taken at approx.. 140 cm high) Height of sighter post: n/a Comments: No posts were allowed to be staked at this site. Within area of Transect 3.	0348854	6038547

Appendix F Details of methods applied by ALS for each of the components of the soil analyses

Page	: 8 of 9
Work Order	: EM1206328
Client	: COOE (CARE OF OUR ENVIRONMENT)
Project	: DENR EFA 1 Soil Characterisation

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	Method	Matrix	Method Descriptions
pH (1:5)	EA002	SOIL	(APHA 21st ed., 4500H+) pH is determined on soil samples after a 1:5 soil/water leach. This method is compliant with NEPM (1999) Schedule B(3) (Method 103)
Electrical Conductivity (1:5)	EA010	SOIL	(APHA 21st ed., 2510) Conductivity is determined on soil samples using a 1:5 soil/water leach. This method is compliant with NEPM (1999) Schedule B(3) (Method 104)
Moisture Content	EA055-103	SOIL	A gravimetric procedure based on weight loss over a 12 hour drying period at 103-105 degrees C. This method is compliant with NEPM (2010 Draft) Schedule B(3) Section 7.1 and Table 1 (14 day holding time).
Loss on Ignition	EA101	SOIL	In-house, Gravimetric procedure based on weight loss at a nominated temperature.
Total Metals by ICP-AES	EG005T	SOIL	(APHA 21st ed., 3120; USEPA SW 846 - 6010) (ICPAES) Metals are determined following an appropriate acid digestion of the soil. The ICPAES technique ionises samples in a plasma, emitting a characteristic spectrum based on metals present. Intensities at selected wavelengths are compared against those of matrix matched standards. This method is compliant with NEPM (1999) Schedule B(3)
Fluoride - Soluble	EK040S	SOIL	APHA 21st ed., 4500 F--C Soluble Fluoride is determined after a 1:5 soil/water extract using an ion selective electrode.
Nitrite as N - Soluble by Discrete Analyser	EK057G	SOIL	APHA 21st ed., 4500 NO3- B. Nitrite in a water extract is determined by direct colourimetry by Discrete Analyser.
Nitrate as N - Soluble by Discrete Analyser	EK058G	SOIL	APHA 21st ed., 4500 NO3--F. Nitrate in the 1:5 soil:water extract is reduced to nitrite by way of a cadmium reduction column followed by quantification by Discrete Analyser. Nitrite is determined seperately by direct colourimetry and result for Nitrate calculated as the difference between the two results.
Nitrite and Nitrate as N (NOx)- Soluble by Discrete Analyser	EK059G	SOIL	APHA 21st ed., 4500 NO3- F. Combined oxidised Nitrogen (NO2+NO3) in a water extract is determined by Cadmium Reduction, and direct colourimetry by Discrete Analyser.
Reactive Phosphorus as P-Soluble By Discrete Analyser	EK071G	SOIL	APHA 21st ed., 4500 P-F Ammonium molybdate and potassium antimonyl tartrate reacts in acid medium with othophosphate to form a heteropoly acid -phosphomolybdic acid - which is reduced to intensely coloured molybdenum blue by ascorbic acid. Quantification is by Discrete Analyser. This method is compliant with NEPM (1999) Schedule B(3) (Appdx. 2

Preparation Methods	Method	Matrix	Method Descriptions
1:5 solid / water leach for soluble analytes	EN34	SOIL	10 g of soil is mixed with 50 mL of distilled water and tumbled end over end for 1 hour. Water soluble salts are leached from the soil by the continuous suspension. Samples are settled and the water filtered off for analysis.
Hot Block Digest for metals in soils sediments and sludges	EN69	SOIL	USEPA 200.2 Mod. Hot Block Acid Digestion 1.0g of sample is heated with Nitric and Hydrochloric acids, then cooled. Peroxide is added and samples heated and cooled again before being filtered and bulked to volume for analysis. Digest is appropriate for determination of selected metals in sludge, sediments, and soils. This method is compliant with NEPM (1999) Schedule B(3) (Method 202)

Appendix F Details of methods applied by ALS for each of the components of the soil analyses **(continued).**

Page	: 5 of 7
Work Order	: EB1215016
Client	: COOE (CARE OF OUR ENVIRONMENT)
Project	: DENR EFA Soil Characterisation DENR EFA 1

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	*Method*	*Matrix*	*Method Descriptions*
Moisture Content	EA055-103	SOIL	A gravimetric procedure based on weight loss over a 12 hour drying period at 103-105 degrees C. This method is compliant with NEPM (2010 Draft) Schedule B(3) Section 7.1 and Table 1 (14 day holding time).
Exchangeable Cations	ED007	SOIL	Rayment & Higginson (1992) Method 15A1. Cations are exchanged from the sample by contact with Ammonium Chloride. They are then quantitated in the final solution by ICPAES and reported as meq/100g of original soil. This method is compliant with NEPM (1999) Schedule B(3) (Method 301)
Cations - soluble by ICP-AES	ED093S	SOIL	APHA 21st ed., 3120; USEPA SW 846 - 6010 (ICPAES) Water extracts of the soil are analyzed for major cations by ICPAES. The ICPAES technique ionises samples in a plasma, emitting a characteristic spectrum based on metals present. Intensities at selected wavelengths are compared against those of matrix matched standards. This method is compliant with NEPM (1999) Schedule B(3)
Total Organic Carbon	EP003	SOIL	In-house C-IR17. Dried and pulverised sample is reacted with acid to remove inorganic Carbonates, then combusted in a LECO furnace in the presence of strong oxidants / catalysts. The evolved (Organic) Carbon (as CO2) is automaticaly measured by infra-red detector.

Preparation Methods	*Method*	*Matrix*	*Method Descriptions*
Exchangeable Cations Preparation Method	ED007PR	SOIL	Rayment & Higginson (1992) method 15A1. A 1M NH4Cl extraction by end over end tumbling at a ratio of 1:20. There is no pretreatment for soluble salts. Extracts can be run by ICP for cations.
1:5 solid / water leach for soluble analytes	EN34	SOIL	10 g of soil is mixed with 50 mL of distilled water and tumbled end over end for 1 hour. Water soluble salts are leached from the soil by the continuous suspension. Samples are settled and the water filtered off for analysis.

Appendix G Summary of Point Centre Quarter data from each transect at the 11 sites surveyed

Site	Mundoo					Mulungushi-Reference					Finniss				
Transect	1	2	3	Median	SD	1	2	3	Median	SD	1	2	3	Median	SD
Total distance to plants (m)	107.18	113.88	97.34	107.18	8.32	156.51	145.91	115.99	145.91	21.01	133.00	104.52	111.74	111.74	14.81
Mean distance between plants (m)	2.44	2.59	2.21	2.44	0.19	3.56	3.32	2.64	3.32	0.48	3.02	2.38	2.54	2.54	0.34
Number of plants per hectare	1685.30	1492.83	2043.26	1685.30	279.33	790.35	909.36	1439.01	909.36	345.31	1094.47	1772.17	1550.56	1550.56	345.55
				No. of species per site					**No. of species per site**					**No. of species per site**	
No. of species per transect	7	11	6	21		9	8	7	19		8	8	7	13	

Site	Pt Sturt-Upper					Pt Sturt-Lower					Boggy Lake				
Transect	1	2	3	Median	SD	1	2	3	Median	SD	1	2	3	Median	SD
Total distance to plants (m)	260.45	163.24	171.50	171.50	53.90	106.24	63.13	49.11	63.13	29.77	26.94	25.70	53.16	26.94	15.51
Mean distance between plants (m)	5.92	3.71	3.90	3.90	1.22	3.22	1.43	1.12	1.43	1.13	0.61	0.58	1.21	0.61	0.35
Number of plants per hectare	285.40	726.53	658.23	658.23	237.44	964.83	4857.73	8027.23	4857.73	3537.37	26675.35	29311.57	6850.71	26675.35	12277.73
				No. of species per site					**No. of species per site**					**No. of species per site**	
No. of species per transect	13	11	13	20		5	7	5	10		3	2	9	10	

Site	Fiebig Reserve-Upper					Fiebig Reserve-Lower					Narrung				
Transect	1	2	3	Median	SD	1	2	3	Median	SD	1	2	3	Median	SD
Total distance to plants (m)	61.60	49.32	64.01	61.60	7.88	40.60	39.36	41.21	40.60	0.94	96.95	180.34	71.85	96.95	56.79
Mean distance between plants (m)	1.40	1.12	1.49	1.40	0.19	0.92	0.89	0.94	0.92	0.02	2.25	4.10	1.63	2.25	1.28
Number of plants per hectare	5102.04	7959.01	4512.75	5102.04	1843.29	11745.01	12496.70	11399.88	11745.01	560.83	1967.17	595.28	3750.18	1967.17	1581.91
				No. of species per site					**No. of species per site**					**No. of species per site**	
No. of species per transect	9	6	8	14		8	5	3	8		8	9	9	17	

Site	Camp Coorong					Bonney Reserve-Reference				
Transect	1	2	3	Median	SD	1	2	3	Median	SD
Total distance to plants (m)	107.23	153.14	124.46	124.46	23.19	12.02	30.91	13.21	13.21	10.58
Mean distance between plants (m)	2.44	3.48	2.83	2.83	0.53	0.27	0.72	0.30	0.30	0.25
Number of plants per hectare	1683.73	825.52	1249.82	1249.82	429.11	133997.41	19352.58	110942.95	110942.95	60640.67
				No. of species per site					**No. of species per site**	
No. of species per transect	5	7	8	12		18	15	16	32	

Appendix H Presence/absence list of flora species at each transect within each site

Site	Mundoo			Barker Road			Finniss			Point Sturt Upper		
2012 Species/Transect	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Acacia dodonaeifolia		✓			✓							
Acacia ligulata	✓			✓						✓		
Acacia longifolia var. *sophorae*	✓											
Acacia paradoxa	✓			✓						✓	✓	✓
Acacia pycnantha		✓			✓					✓		
Acacia sophorae					✓	✓				✓	✓	
Acacia spinescens												
Acrotriche sp.												
Allocasuarina verticillata	✓	✓		✓		✓		✓	✓	✓	✓	✓
Apium insulare												
Astroloma humifusum												
Atriplex semibacarta							✓		✓			
Atriplex sp.			✓									
Austrodanthonia sp.												
Austrostipa sp.												
Baumea sp.												
Boronia sp.												
Brachyloma ericoides												
Bursaria spinosa		✓			✓	✓		✓	✓			✓
Callistemon rugulosus										✓		
Callitris gracilis		✓		✓								
Carpobrotus sp.												
Chenopod sp. 1												
Chenopod sp. 2												
Chenopod sp. 3												
Clemastis microphylla												
Coronidium scorpioides												
Correa reflexa												
Cyperus gymnocaulos							✓	✓				
Cyprus sp.												
Dianella brevicaulis					✓							

Site	Mundoo			Barker Road			Finniss			Point Sturt Upper		
2012 Species/Transect	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Dianella revoluta											✓	
Dianella sp.												✓
Disphyma crassifolium							✓	✓	✓			
Dodonaea viscosa		✓						✓		✓		✓
Dodonea sp.												
Einadia nutans												
Enchylaena tomentosa			✓							✓	✓	✓
Eucalyptus diversifolia	✓	✓				✓						
Eucalyptus incrassata	✓			✓								
Eucalyptus leucoxylon												
Eucalyptus porosa		✓			✓	✓						
Eucalyptus rugosa												
Felecia odorata										✓	✓	✓
Ficinia nodosa	✓				✓							
Foxtail grass												
Frankenia pauciflora			✓									
Gahnia filum												
Grass sp.												
Hakea mitchellii				✓								
Halosarcia sp.												
Helichrysum sp.												
Hibbertia riparia												
Hibbertia sericea												
Juncus sp.									✓			
Kunzea pomifera												
Lawrencia squamata			✓									
Lepidesperma sp.												
Lepidosperma viscidum							✓					
Lignum sp.												
Lomandra micrantha												
Matt grass												
Melaleuca halmaturorum			✓			✓		✓		✓	✓	✓
Melaleuca lanceolata		✓	✓		✓		✓	✓	✓			
Muehlenbeckia florulenta							✓					

Site	Mundoo			Barker Road			Finniss			Point Sturt Upper		
2012 Species/Transect	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Myoporum insulare		✓					✓	✓			✓	✓
Myoporum sp.		✓										
Nitraria sp.												
Olearia axillaris				✓		✓						
Ozothamnus turbinatus												
Pennisetum alopecuroides												
Pimelea serpyllifolia												
Pittosporum angustifolium											✓	
Pittosporum phylliraeoides												✓
Poa sp. 1										✓	✓	
Poa sp. 2												
Rhagodia candolleana				✓			✓		✓	✓	✓	✓
Samolus repens												
Samphire												
Sedge sp.												
Spear grass										✓		✓
Sueda australis												
Tetragonia implexicoma												✓
Triglochin sp.												
Unknown species												
Unknown species (spiney)												
Xanthorrhoea caespitosa				✓								

Site	Point Sturt Lower			Boggy Lake			Fiebig Reserve Upper			Fiebig Reserve Lower		
2012 Species/Transect	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Acacia dodonaeifolia												
Acacia ligulata												
Acacia longifolia var. *sophorae*												
Acacia paradoxa												
Acacia pycnantha												
Acacia sophorae												
Acacia spinescens												
Acrotriche sp.												
Allocasuarina verticillata		✓										
Apium insulare	✓											
Astroloma humifusum												
Atriplex semibacarta						✓	✓	✓		✓		
Atriplex sp.												
Austrodanthonia sp.							✓	✓				
Austrostipa sp.												
Baumea sp.												
Boronia sp.												
Brachyloma ericoides												
Bursaria spinosa												
Callistemon rugulosus												
Callitris gracilis												
Carpobrotus sp.												
Chenopod sp. 1									✓			
Chenopod sp. 2												
Chenopod sp. 3												
Clemastis microphylla												
Coronidium scorpioides												
Correa reflexa												
Cyperus gymnocaulos						✓						
Cyprus sp.		✓										
Dianella brevicaulis												
Dianella revoluta												

Site	Point Sturt Lower			Boggy Lake			Fiebig Reserve Upper			Fiebig Reserve Lower		
2012 Species/Transect	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Dianella sp.												
Disphyma crassifolium				✓	✓	✓	✓		✓	✓	✓	
Dodonaea viscosa												
Dodonea sp.												
Einadia nutans						✓				✓		✓
Enchylaena tomentosa	✓	✓				✓	✓		✓	✓	✓	
Eucalyptus diversifolia												
Eucalyptus incrassata												
Eucalyptus leucoxylon												
Eucalyptus porosa												
Eucalyptus rugosa										✓		
Felecia odorata												
Ficinia nodosa												
Foxtail grass												
Frankenia pauciflora												
Gahnia filum		✓										
Grass sp.												
Hakea mitchellii												
Halosarcia sp.				✓	✓							
Helichrysum sp.												
Hibbertia riparia												
Hibbertia sericea												
Juncus sp.												
Kunzea pomifera												
Lawrencia squamata												
Lepidesperma sp.												
Lepidosperma viscidum												
Lignum sp.							✓					
Lomandra micrantha												
Matt grass												
Melaleuca halmaturorum	✓	✓	✓					✓				
Melaleuca lanceolata												
Muehlenbeckia florulenta						✓	✓			✓	✓	✓
Myoporum insulare												

Site	Point Sturt Lower			Boggy Lake			Fiebig Reserve Upper			Fiebig Reserve Lower		
2012 Species/Transect	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Myoporum sp.												
Nitraria sp.						✓						
Olearia axillaris												
Ozothamnus turbinatus												
Pennisetum alopecuroides												
Pimelea serpyllifolia												
Pittosporum angustifolium												
Pittosporum phylliraeoides												
Poa sp. 1									✓			
Poa sp. 2							✓	✓				
Rhagodia candolleana												
Samolus repens	✓		✓									
Samphire	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓
Sedge sp.												
Spear grass												
Sueda australis			✓			✓			✓	✓	✓	
Tetragonia implexicoma												
Triglochin sp.		✓	✓									
Unknown species							✓	✓	✓			
Unknown species (spiney)									✓			
Xanthorrhoea caespitosa												

Site	Narrung			Camp Coorong			Bonney Reserve		
2012 Species/Transect	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Acacia dodonaeifolia									
Acacia ligulata									
Acacia longifolia var. *sophorae*									
Acacia paradoxa									
Acacia pycnantha	✓							✓	
Acacia sophorae				✓	✓	✓			
Acacia spinescens								✓	
Acrotriche sp.							✓		
Allocasuarina verticillata				✓	✓	✓			
Apium insulare									
Astroloma humifusum									✓
Atriplex semibacarta	✓	✓	✓						
Atriplex sp.									
Austrodanthonia sp.	✓	✓	✓				✓	✓	✓
Austrostipa sp.							✓		✓
Baumea sp.									✓
Boronia sp.							✓		✓
Brachyloma ericoides									✓
Bursaria spinosa		✓			✓	✓			✓
Callistemon rugulosus									
Callitris gracilis									
Carpobrotus sp.					✓	✓		✓	✓
Chenopod sp. 1	✓		✓						
Chenopod sp. 2	✓								
Chenopod sp. 3		✓	✓						
Clemastis microphylla					✓		✓		
Coronidium scorpioides							✓		
Correa reflexa									✓
Cyperus gymnocaulos		✓							
Cyprus sp.									
Dianella brevicaulis								✓	✓
Dianella revoluta									

Site	Narrung			Camp Coorong			Bonney Reserve		
2012 Species/Transect	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Dianella sp.		✓	✓				✓		
Disphyma crassifolium									
Dodonaea viscosa									
Dodonea sp.						✓			
Einadia nutans			✓						
Enchylaena tomentosa									
Eucalyptus diversifolia				✓		✓	✓	✓	
Eucalyptus incrassata					✓				
Eucalyptus leucoxylon			✓						
Eucalyptus porosa									
Eucalyptus rugosa									
Felecia odorata									
Ficinia nodosa									
Foxtail grass							✓		
Frankenia pauciflora									
Gahnia filum							✓	✓	
Grass sp.		✓							
Hakea mitchellii									
Halosarcia sp.									
Helichrysum sp.							✓		
Hibbertia riparia							✓		✓
Hibbertia sericea								✓	✓
Juncus sp.									
Kunzea pomifera						✓	✓		✓
Lawrencia squamata									
Lepidesperma sp.							✓		
Lepidosperma viscidum								✓	✓
Lignum sp.									
Lomandra micrantha								✓	
Matt grass							✓	✓	✓
Melaleuca halmaturorum	✓				✓				
Melaleuca lanceolata				✓		✓			
Muehlenbeckia florulenta									
Myoporum insulare	✓	✓	✓						

Site	Narrung			Camp Coorong			Bonney Reserve		
2012 Species/Transect	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Myoporum sp.									
Nitraria sp.									
Olearia axillaris		✓		✓				✓	
Ozothamnus turbinatus								✓	
Pennisetum alopecuroides							✓		
Pimelea serpyllifolia							✓	✓	
Pittosporum angustifolium									
Pittosporum phylliraeoides									
Poa sp. 1									
Poa sp. 2									
Rhagodia candolleana							✓	✓	✓
Samolus repens									
Samphire			✓						
Sedge sp.	✓								
Spear grass									
Sueda australis									
Tetragonia implexicoma									
Triglochin sp.									
Unknown species									
Unknown species (spiney)									
Xanthorrhoea caespitosa									

Appendix I Summary of the indices derived from the soil surface assessments for each transect at all sites surveyed.

Site	Transect	Stability	SE	Infiltration	SE	Nutrients	SE
Mundoo	1	54.77	3.50	41.76	3.75	20.85	5.10
Mundoo	2	56.67	2.16	44.79	1.58	24.96	2.15
Mundoo	3	57.87	1.63	44.34	0.96	28.13	2.75
Mulungushi	1	50.21	0.85	36.88	0.86	16.03	1.17
Mulungushi	2	38.43	4.27	33.45	1.59	19.32	2.41
Mulungushi	3	38.17	1.72	39.66	2.67	18.04	3.66
Finniss	1	54.11	1.94	38.49	1.88	21.81	3.09
Finniss	2	52.30	1.56	30.37	1.83	21.86	1.81
Finniss	3	50.32	2.03	28.47	2.24	19.00	2.10
Pt Sturt Upper	1	52.07	0.90	45.64	1.40	26.61	1.48
Pt Sturt Upper	2	56.95	2.20	41.10	1.73	29.14	2.64
Pt Sturt Upper	3	47.57	4.46	40.27	4.53	27.74	5.94
Pt Sturt Lower	1	53.19	1.25	51.64	0.65	34.30	1.39
Pt Sturt Lower	2	55.44	0.61	36.80	1.32	25.39	1.80
Pt Sturt Lower	3	49.99	1.20	36.15	1.34	23.76	1.85
Boggy Lake	1	47.92	1.80	23.91	2.03	16.23	2.96
Boggy Lake	2	43.12	0.00	21.13	0.00	17.05	0.00
Boggy Lake	3	56.27	0.73	26.26	0.00	17.03	0.00
Fiebig Reserve Upper	1	54.69	2.26	32.16	2.64	18.58	2.82
Fiebig Reserve Upper	2	44.06	2.31	29.58	1.28	19.39	1.87
Fiebig Reserve Upper	3	55.26	3.27	37.30	1.89	24.77	2.77
Fiebig Reserve Lower	1	55.11	1.84	29.48	2.21	21.80	3.23
Fiebig Reserve Lower	2	58.33	4.08	31.74	2.96	25.11	4.33
Fiebig Reserve Lower	3	53.70	3.21	39.06	4.05	24.77	5.92
Narrung	1	52.52	0.75	32.04	3.83	19.70	2.21
Narrung	2	48.96	4.77	44.00	5.43	23.80	7.30
Narrung	3	46.16	0.43	44.85	0.97	25.32	1.01
Camp Coorong	1	46.65	1.28	38.59	2.96	20.08	2.09
Camp Coorong	2	42.24	4.77	36.91	3.88	24.86	6.58
Camp Coorong	3	51.24	1.30	29.84	1.44	19.33	2.06
Bonney Reserve	1	55.53	5.05	40.47	2.97	29.80	4.18
Bonney Reserve	2	55.09	3.71	43.86	2.88	32.95	4.18
Bonney Reserve	3	44.85	3.98	44.76	2.25	25.67	3.49

Appendix J Summary statistics from all soil analyses at all sites

Site	Min	Max	Median	SD
pH (pH Unit)				
Mundoo	8	9.5	8.7	0.75
Finniss	6	7.6	6.8	1.13
Camp Coorong	7	8.1	7.6	0.55
Bonney Reserve	6.5	6.9	6.8	0.21
Point Sturt Lower	8.4	9.2	8.5	0.44
Point Sturt Upper	6.2	8.9	8.5	1.46
Barker Road	7.5	7.9	7.8	0.21
Boggy Lake	7.3	8.6	8.2	0.67
Fiebig Reserve Lower	7	8.1	7.3	0.57
Fiebig Reserve Upper	6.5	8.4	8.1	1.02
Narrung	7.4	7.6	7.6	0.12
Conductivity (µS/cm)				
Mundoo	104	1010	319	473.38
Finniss	90	2590	1340	1767.77
Camp Coorong	45	120	70	38.19
Bonney Reserve	44	137	45	53.41
Point Sturt Lower	1670	6660	5290	2578.16
Point Sturt Upper	95	391	309	152.83
Barker Road	34	40	35	3.21
Boggy Lake	4770	9620	5630	2587.86
Fiebig Reserve Lower	110	249	228	74.93
Fiebig Reserve Upper	236	2710	328	1402.56
Narrung	41	85	47	23.86
Moisture Content (%)				
Mundoo	13.3	29.1	18.7	8.03
Finniss	2.9	14.6	8.75	8.27
Camp Coorong	2.8	8.2	5	2.72
Bonney Reserve	12.7	22.3	18.5	4.83
Point Sturt Lower	26.7	45.8	31.2	9.99
Point Sturt Upper	13.3	38.9	31.6	13.19
Barker Road	7.5	10	9.7	1.37
Boggy Lake	25.6	35.8	32.6	5.22
Fiebig Reserve Lower	28.7	32.8	32.2	2.21
Fiebig Reserve Upper	28.6	33.9	29.5	2.84
Narrung	13	29.3	17.1	8.48

Appendix I Summary statistics from all soil analyses at all sites **(continued).**

Site	Min	Max	Median	SD
Total Organic Carbon (%)				
Mundoo	1.49	3.34	1.54	1.05
Finniss	0.26	0.68	0.47	0.30
Camp Coorong	1.08	3.51	1.14	1.39
Bonney Reserve	3.64	5.75	5.13	1.08
Point Sturt Lower	3.39	5.21	4.5	0.92
Point Sturt Upper	4.24	12.4	8.02	4.08
Barker Road	0.95	2.12	1.58	0.59
Boggy Lake	2.25	6.39	5.29	2.14
Fiebig Reserve Lower	6.38	8.03	7.75	0.88
Fiebig Reserve Upper	3.25	9.36	5.16	3.13
Narrung	2.47	4	2.89	0.79
Fluoride (mg/kg)				
Mundoo	1	3	1	1.15
Finniss	1	2	1.5	0.71
Camp Coorong	1	1	1	0.00
Bonney Reserve	1	1	1	0.00
Point Sturt Lower	4	8	4	2.31
Point Sturt Upper	1	5	1	2.31
Barker Road	1	1	1	0.00
Boggy Lake	1	3	2	1.00
Fiebig Reserve Lower	1	1	1	0.00
Fiebig Reserve Upper	1	6	1	2.89
Narrung	1	1	1	0.00

Appendix I Summary statistics from all soil analyses at all sites **(continued).**

Nutrients				
Site	**Min**	**Max**	**Median**	**SD**
Nitrite as N (mg/kg)				
Mundoo	0.7	3.1	1	1.31
Finniss	0.1	0.1	0.1	0.00
Camp Coorong	0.5	1	0.6	0.26
Bonney Reserve	0.2	0.5	0.4	0.15
Point Sturt Lower	0.1	0.2	0.1	0.06
Point Sturt Upper	0.9	2.8	1	1.07
Barker Road	0.4	0.6	0.4	0.12
Boggy Lake	0.1	0.2	0.2	0.06
Fiebig Reserve Lower	0.5	3.8	1.5	1.69
Fiebig Reserve Upper	0.6	1.6	1	0.50
Narrung	0.2	4.2	0.6	2.20
Nitrate as N (mg/kg)				
Mundoo	1.9	13.7	2.2	6.73
Finniss	0.4	2.2	1.3	1.27
Camp Coorong	3.3	4.9	4.4	0.82
Bonney Reserve	0.1	6	1.8	3.04
Point Sturt Lower	0.1	0.1	0.1	0.00
Point Sturt Upper	4.9	14.5	13.2	5.21
Barker Road	1.2	2.8	1.7	0.82
Boggy Lake	0.4	4.3	3.5	2.06
Fiebig Reserve Lower	0.1	0.1	0.1	0.00
Fiebig Reserve Upper	0.1	0.8	0.1	0.40
Narrung	4.1	19	4.3	8.55
Nitrite plus Nitrate as N (NOx) (mg/kg)				
Mundoo	2.6	16.8	3.2	8.03
Finniss	0.4	2.3	1.35	1.34
Camp Coorong	3.8	5.5	5.4	0.95
Bonney Reserve	0.5	6.2	2.2	2.93
Point Sturt Lower	0.1	0.2	0.1	0.06
Point Sturt Upper	5.8	17.3	14.2	5.95
Barker Road	1.6	3.4	2.1	0.93
Boggy Lake	0.6	4.3	3.7	1.99
Fiebig Reserve Lower	0.5	3.8	1.5	1.69
Fiebig Reserve Upper	1	1.6	1.4	0.31
Narrung	4.5	23.2	4.7	10.74

Appendix I Summary statistics from all soil analyses at all sites **(continued).**

Nutrients				
Site	**Min**	**Max**	**Median**	**SD**
Reactive Phosphorus as P (mg/kg)				
Mundoo	3.3	5.6	3.6	1.25
Finniss	0.4	5.6	3	3.68
Camp Coorong	1.2	3.6	2.8	1.22
Bonney Reserve	0.2	1.2	0.6	0.50
Point Sturt Lower	6.4	15.2	9.3	4.48
Point Sturt Upper	10.6	28.3	10.8	10.16
Barker Road	0.4	0.8	0.5	0.21
Boggy Lake	8.2	10.9	10.6	1.48
Fiebig Reserve Lower	12.8	21.9	14.9	4.76
Fiebig Reserve Upper	7	51.9	40	23.26
Narrung	3.7	19.6	5.2	8.78

Total Heavy Metals				
Site	**Min**	**Max**	**Median**	**SD**
Arsenic (mg/kg)				
Mundoo	5	5	5	0.00
Finniss	5	5	5	0.00
Camp Coorong	5	5	5	0.00
Bonney Reserve	5	5	5	0.00
Point Sturt Lower	5	5	5	0.00
Point Sturt Upper	5	9	7	2.00
Barker Road	5	7	5	1.15
Boggy Lake	5	5	5	0.00
Fiebig Reserve Lower	5	5	5	0.00
Fiebig Reserve Upper	5	5	5	0.00
Narrung	5	5	5	0.00
Cadmium (mg/kg)				
Mundoo	1	1	1	0.00
Finniss	1	1	1	0.00
Camp Coorong	1	1	1	0.00
Bonney Reserve	1	1	1	0.00
Point Sturt Lower	1	1	1	0.00
Point Sturt Upper	1	1	1	0.00
Barker Road	1	1	1	0.00
Boggy Lake	1	1	1	0.00
Fiebig Reserve Lower	1	1	1	0.00
Fiebig Reserve Upper	1	1	1	0.00
Narrung	1	1	1	0.00

Appendix I Summary statistics from all soil analyses at all sites **(continued).**

Total Heavy Metals				
Site	**Min**	**Max**	**Median**	**SD**
Chromium (mg/kg)				
Mundoo	6	18	7	6.66
Finniss	2	4	3	1.41
Camp Coorong	2	3	2	0.58
Bonney Reserve	2	3	2	0.58
Point Sturt Lower	14	18	16	2.00
Point Sturt Upper	3	6	5	1.53
Barker Road	5	7	6	1.00
Boggy Lake	20	29	23	4.58
Fiebig Reserve Lower	12	18	13	3.21
Fiebig Reserve Upper	14	21	20	3.79
Narrung	3	33	5	16.77
Copper (mg/kg)				
Mundoo	5	8	5	1.73
Finniss	5	5	5	0.00
Camp Coorong	5	5	5	0.00
Bonney Reserve	5	5	5	0.00
Point Sturt Lower	10	12	12	1.15
Point Sturt Upper	5	7	6	1.00
Barker Road	5	5	5	0.00
Boggy Lake	24	33	25	4.93
Fiebig Reserve Lower	14	19	15	2.65
Fiebig Reserve Upper	15	20	16	2.65
Narrung	5	20	5	8.66
Lead (mg/kg)				
Mundoo	5	7	5	1.15
Finniss	5	8	6.5	2.12
Camp Coorong	5	5	5	0.00
Bonney Reserve	5	5	5	0.00
Point Sturt Lower	12	42	14	16.77
Point Sturt Upper	5	5	5	0.00
Barker Road	5	5	5	0.00
Boggy Lake	15	29	28	7.81
Fiebig Reserve Lower	11	12	12	0.58
Fiebig Reserve Upper	8	14	10	3.06
Narrung	5	12	5	4.04

Appendix I Summary statistics from all soil analyses at all sites **(continued).**

Total Heavy Metals				
Site	**Min**	**Max**	**Median**	**SD**
Nickel (mg/kg)				
Mundoo	2	8	2	3.46
Finniss	2	4	3	1.41
Camp Coorong	2	2	2	0.00
Bonney Reserve	2	2	2	0.00
Point Sturt Lower	9	13	12	2.08
Point Sturt Upper	2	4	3	1.00
Barker Road	2	2	2	0.00
Boggy Lake	16	21	17	2.65
Fiebig Reserve Lower	9	13	9	2.31
Fiebig Reserve Upper	9	15	14	3.21
Narrung	2	23	3	11.85
Zinc (mg/kg)				
Mundoo	6	26	8	11.02
Finniss	5	9	7	2.83
Camp Coorong	5	11	5	3.46
Bonney Reserve	5	5	5	0.00
Point Sturt Lower	20	31	29	5.86
Point Sturt Upper	7	27	22	10.41
Barker Road	5	5	5	0.00
Boggy Lake	64	72	69	4.04
Fiebig Reserve Lower	31	39	35	4.00
Fiebig Reserve Upper	36	54	40	9.45
Narrung	7	38	9	17.35

Appendix I Summary statistics from all soil analyses at all sites **(continued).**

Exchangeable Cations				
Site	**Min**	**Max**	**Median**	**SD**
Exchangeable Calcium (meq/100g)				
Mundoo	26.8	33.2	32.4	3.96
Finniss	4.5	10	7.25	3.89
Camp Coorong	3.8	17.1	4.5	7.48
Bonney Reserve	8.8	13.5	11.7	2.37
Point Sturt Lower	30.6	57.1	44.3	13.25
Point Sturt Upper	13.7	73	41	29.68
Barker Road	4.9	10.7	7.2	2.92
Boggy Lake	32.3	36.8	34.6	2.25
Fiebig Reserve Lower	14.3	15.4	14.7	0.56
Fiebig Reserve Upper	12.5	42.6	20.7	15.56
Narrung	6.8	11.8	8.5	2.54
Exchangeable Magnesium (meq/100g)				
Mundoo	2.3	11.2	3.3	6.29
Finniss	0.4	6.5	3.45	4.31
Camp Coorong	0.8	2	1	0.64
Bonney Reserve	2.4	3.5	2.6	0.59
Point Sturt Lower	17.6	25	19.1	3.91
Point Sturt Upper	3.5	18.8	14.1	7.84
Barker Road	0.9	1.9	1.7	0.53
Boggy Lake	16.6	34.1	25.7	8.75
Fiebig Reserve Lower	13	14.3	13.7	0.65
Fiebig Reserve Upper	15	20	15.6	2.73
Narrung	3.7	17.1	3.7	7.74
Exchangeable Potassium (meq/100g)				
Mundoo	0.4	2.3	0.6	1.20
Finniss	0.1	0.8	0.45	0.49
Camp Coorong	0.2	0.5	0.3	0.15
Bonney Reserve	0.3	0.4	0.3	0.06
Point Sturt Lower	2.8	3.5	2.9	0.38
Point Sturt Upper	0.9	2.6	2.2	0.89
Barker Road	0.3	0.5	0.4	0.10
Boggy Lake	4.9	6.2	5.8	0.67
Fiebig Reserve Lower	2.1	3.3	2.5	0.61
Fiebig Reserve Upper	3	3.8	3.4	0.40
Narrung	1	3.6	1.3	1.42

Appendix I Summary statistics from all soil analyses at all sites **(continued).**

Exchangeable Cations				
Site	**Min**	**Max**	**Median**	**SD**
Exchangeable Sodium (meq/100g)				
Mundoo	0.3	3.6	2.6	2.33
Finniss	0.1	11.8	5.95	8.27
Camp Coorong	0.1	0.3	0.3	0.12
Bonney Reserve	0.2	0.4	0.4	0.12
Point Sturt Lower	15.3	36.9	24.6	10.83
Point Sturt Upper	0.2	3.2	2.2	1.53
Barker Road	0.1	0.4	0.3	0.15
Boggy Lake	43.9	53.8	51.9	5.25
Fiebig Reserve Lower	2.4	8.8	5.2	3.21
Fiebig Reserve Upper	5.3	9	7.7	1.88
Narrung	0.3	4.1	0.4	2.17