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An inventory and condition survey of the Western Australian part of the Nullarbor region

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Front cover: Nullarbor Plain on the Bunda Plateau

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This survey could not have been conducted without the cooperation, advice and assistance of pastoralists throughout the area. Thank you to the pastoralists who took the time to contribute historical details about specific leases. We also thank Jill Campbell for her effort and time in writing the Nullarbor history chapter and for providing historical photographs. The following pastoralists and their managers kindly donated the use of outcamps and shearers quarters for our fieldwork: the Browns at Arubiddy, the Campbells at Kybo, the Days at Gunnadorah, the Forresters at Kananadah, the Hoggs at Kinclaven, the McGraths at Balladonia, Russell Swann at Virginia, Tony Thomas at Balgair and the Woods at Rawlinna. Without this logistical support the project would not have been possible.

This report was edited by PA Waddell and GM Wilson.

Definition

The Nullarbor region, as featured in this report, includes areas covered by the following 1:250 000 map sheets: Balladonia, Culver, Cundeelee, Eucla–Noonaera, Forrest, Loongana, Madura–Burnabbie, Naretha, Seemore and Zanthus.

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An inventory and condition survey of the Western Australian part of the Nullarbor region.

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Contents

Summary

Scope of the survey

1. The area surveyed by field work during 2005, 2006 and 2007 covers about 118 358 km^2 and includes the following 1:250 000 scale map sheets: the entire Culver, Eucla–Noonaera, Forrest, Loongana, Madura–Burnabbie and Naretha sheets, most of the Balladonia, Seemore and Zanthus sheets and a small portion of the Cundeelee sheet.

   The only towns within the survey area are Eucla in the south-east and Rawlinna railway settlement in the central-north. Other areas of habitation aside from pastoral leases include: Forrest airport along the Trans-Australian Railway line and Balladonia, Caiguna, Cocklebiddy, Madura and Mundrabilla roadhouses on the Eyre Highway.

2. Pastoralism is the most extensive land use. Twenty pastoral leases fall wholly within the survey area and collectively occupy about 57 673 km^2 (49 per cent of the area).

   Areas set aside for nature conservation at the time of survey covered approximately 9526 km^2 (8 per cent of the area) consisting of the Eucla National Park, the Great Victoria Desert and the Nuytsland Nature Reserves, as well as some smaller parcels of land.

   An Aboriginal reserve in the north occupies about 149 km^2 (< 0.2 per cent of the area).

   Town commons and various reserves make up less than 0.3 per cent of the survey area.

   There is only one mining enterprise operating where high grade limestone aggregate has been extracted for use in mineral processing in the mining industry. Recent extensive exploration is being undertaken for a variety of minerals including gold and uranium along the western and northern margins of the Eucla Basin. One large gold project has reached mining pre-feasibility stage.

   The remaining 43 per cent of the survey area is composed of large tracts of Unallocated Crown Land which account for about 50 680 km^2.

3. This report provides a regional inventory and descriptive reference of land resources to accompany a land system map. It includes reviews of background information such as land use history, climate, geology and hydrogeology, and declared plants and animals. Detailed accounts are then provided of survey methodology, geomorphology, soils, vegetation, habitat ecology, land systems and resource condition (in terms of pastoral impact). A comprehensive plant species list is supplied as an appendix.

4. Resource condition statements are provided for the whole survey area, for each land system and for the major ecological habitat types. These are derived from visual traverse assessments, which are shown on the accompanying land system map. A total of 6997 traverse points were described and assessed for various biophysical parameters. Within the boundaries of pastoral leases 6276 traverse points were assessed for range condition.

5. This report deals with resource description and assessment, recognising the widespread impact of pastoralism on resources in the process. Based on the findings of this rangeland survey recommendations focusing on pastoral resources and pastoral management of the Nullarbor ecosystems have been included.

Land characteristics

6. The survey area exhibits a characteristically arid or semi-arid climate, with most of the area classified as having hot dry summers with cold winters. Rainfall ranges between about 180 and 270 millimetres a year, with marked differences between coastal and northern inland areas. Most of the annual precipitation comes from localised heavy falls, causing rainfall records to be highly variable. Inland rainfall is distributed more uniformly throughout the year, whilst in the coastal region rainfall occurs predominantly in winter and spring. Maximum summer

temperatures tend to increase further from the coast. Temperatures in summer are high (maxima often exceed 30°C, minima about 15°C), especially in inland areas. Winter temperatures range from about 18 to 20°C maxima to about 5 to 8°C minima.

Based on Normalised Difference Vegetation Index (NDVI) values the seasonal conditions for some of the Western Australian Nullarbor pastoral leases were considered to be in drought from 2002 continuing into the survey period in 2006–2007.

7. The regional geology is characterised by near-horizontal sequences of Cainozoic sediments, predominantly limestones, overlying Cretaceous sedimentary rocks of the Eucla Basin on an irregular basement of Precambrian granite and metamorphic rocks. The survey area may be divided into two distinct geological regions: the Bunda Plateau, dominating the majority of the area; and the coastal Roe and Israelite plains along the south.

   The Bunda Plateau forms a vast and featureless gently undulating plain. At about 250 metres above sea level at the northern perimeter, the plateau slopes gently southwards terminating at southern sea-cliffs and escarpments. There are almost no signs of coordinated surface drainage. Erosion features normally associated with limestone country, such as solution sculptured pits and rock-holes in outcrops, sinkholes, dolines, underground drainage and caves, are scarce in proportion to the total area.

8. Within the survey area 54 land systems have been described and mapped into 15 land types. Thirty-four of the land systems are described for the first time and the other 20 have been described previously in adjacent surveys. With improved aerial photography and the benefit of LANDSAT imagery, the land systems identified in the eastern part of the Western Australian Nullarbor Plain during the 1974 survey have been reassessed and in some cases boundaries have been modified. Four land systems from the 1974 survey were extensively modified resulting in one system renamed and three systems incorporated into others. The land system approach is a classification of land based on predominant biophysical features. At a more detailed level, the component land units of each land system are described by their landform features, soils and vegetation associations.

9. Within the survey area natural characteristics help protect the landscape against inappropriate land use practices. The salient factor most responsible for offering protection to the Nullarbor landscape is the nature of the karst itself, retarded by prolonged dry climatic conditions, the nearly level, areic (self-draining) terrain has not developed the large scale accelerated water-induced erosion features initiated by overgrazing, as seen in other southern rangeland regions. Other protective characteristics include the stony surfaces and cryptogamic soil crusts. On the coastal plains moderately dense vegetation communities comprising species which are largely unaffected by grazing have also contributed to protecting the landscape. The areas in which the landscape is most susceptible to inappropriate land use are the Bunda Plateau escarpment footslopes and the low breakaway scarps of the calcrete plains; various forms of karst depressions (e.g. drainage floors, claypans and dongas); sand dunes along coastal areas; and areas supporting vegetation which is highly preferred by herbivores.

Soils

10. Eighteen soil groups have been identified within the survey area. On the Bunda Plateau soils are dominated by reddish shallow calcareous loams and sands derived from calcareous parent materials. The presence of a stony mantle is a dominant feature. In areas associated with coastal margins soils tended to be deeper, strongly-calcareous and lighter coloured (white – grey – yellow-brown).

11. The most common soil group is calcareous shallow loams occurring on all but coastal and sub-coastal land systems. These soils are divided into three subgroups: sandy loams, loams and clay loams all over calcareous rocks. Red/brown clayey soils occur sporadically throughout the area but rarely dominate. Clayey soils are primarily restricted to clay plains and clay, gilgai and donga depressions. Other soil groups occur infrequently in association with less common geomorphic or geological features. Small areas of saline and gypsiferous soils occur in

lacustrine environs and coastal areas; red sands and red sandy earths are associated with sand banks near Lake Boonderoo; variable stony soils, gritty shallow red sands and bare rock are associated with occasional granite outcrop in the south-west.

Vegetation and habitats

12. In comparison with other biogeographic regions in the State the flora of the Nullarbor area is not particularly diverse with 426 vascular species being recorded during the survey; 383 of these species were native. Eight of the 15 plant species on the Declared Rare and Priority Flora listing for the survey area were collected.

13. Vegetation/soil associations considered at the scale of the land unit have been classified and described as 53 habitat types within 10 habitat type groups. Ecological assessments are made for each habitat type, where habitat types are an ecological classification based on plant community, soil type and landform. Habitat types include woodlands dominated by mallee-form eucalypts, casuarina (*Casuarina pauper*) or myall (*Acacia papyrocarpa*); chenopod-dominated shrublands; bindii-grassland plains; and drainage focus shrublands or groves. The most common genera are *Acacia, Atriplex, Austrodanthonia, Austrostipa, Carrichtera, Chenopodium, Cratystylis, Enchylaena, Enneapogon, Eragrostis, Eremophila, Euphorbia, Eucalyptus, Lycium, Maireana, Myoporum, Olearia, Rhodanthe, Salsola, Sclerolaena, Sida* and *Zygophyllum. Atriplex vesicaria* (bladder saltbush), *Austrostipa scabra* (speargrass) and *Maireana sedifolia* (pearl bluebush) are the most ubiquitous perennials while *Euphorbia drummondii* (balsam), *Salsola tragus* (roly poly) and the introduced *Carrichtera annua* (Ward's weed) are the most widespread annual species.

Resource condition

Soil erosion

14. The areic drainage system of the Nullarbor region experiences surface water loss via permeation through karst landforms into underground drainage systems. This process has largely protected the Nullarbor surface from the effects of water erosion in overgrazed areas. Wind erosion is the primary mechanism of soil redistribution. Severely degraded and eroded areas are restricted to water point environs. Overgrazing around water points developed on fragile landforms such as karst depressions has resulted in extensive bare piospheres, zones of attenuated impact. The loss of perennial vegetation in conjunction with regular stock movement exacerbates the extent of piosphere degradation. Through deflation such areas are losing their ability to provide suitable conditions for seedling germination and establishment of perennial plants.

15. Land systems most likely to exhibit bared piospheres are those with limestone plains and poorly developed soils. Severely degraded and eroded piospheres areas were identified in 12 of the 54 land systems, representing 5 of the 15 land types. Ten of the land systems with severely degraded and eroded areas occur on the 'deflated limestone plains' land surface type. These included the Arubiddy, Balgair, Bullseye, Gafa, Kinclaven, Kybo, Moonera, Nightshade, Nurina and Shakehole land systems. The two other land systems displaying severely degraded and eroded areas were the Kanandah and Thampanna land systems of the 'limestone plains with deeper soil than found on deflated limestone plains' land type.

Vegetation condition

16. In terms of impact on perennial vegetation by pastoral usage, approximately 66 per cent of traverse records indicated that vegetation was in good or very good condition, 26 per cent indicated fair condition and 8 per cent indicated poor or very poor condition.

    However, with these findings it is important to consider some Nullarbor vegetation communities have undergone ecological changes so dramatic the original perennial species composition has been replaced by an annual component. The elimination of large areas of chenopod shrubland

is likely to be the combined effect of ‘drought’, fire and rabbit impact. Accepting these changes as permanent, some areas now in irreversible transition were assessed on their present form rather than speculating on their former state. This has resulted in some habitat type descriptions describing the present features and composition of an area as the stable state as presently occurs, rather than considering it as a former state in poor condition. This inevitably has resulted in a greater proportion of the survey area considered in better condition than had the poor former state been assessed. Also a large proportion of ratings occurred in areas largely unaffected by grazing or in undeveloped or only very recently developed areas.

17. On the Nullarbor Plain the most palatable feed is often the grasses and herbage that grow between the perennial shrubs. The most frequently observed impact of pastoralism is a reduction in perennial species richness and perennial plant density. Decrease in perennial plant cover and species heterogeneity is a reliable indicator of grazing impact in chenopod shrublands. In dry seasons when grasses and herbage are scarce, the preferred vegetation is often chenopod shrubs, particularly *Atriplex vesicaria,* and browse from *Acacia papyrocarpa, Alectryon oleifolius* (bullock bush), *Cratystylis conocephala* (false bluebush), *Eremophila longifolia* (berrigan) and *Pittosporum angustifolium* (native willow). These perennial shrubs and trees may be killed by overgrazing, leading to a loss of plant cover and increased exposure of soil which increases the susceptibility of areas to wind erosion.

Resource management

18. Within the survey area about 8 per cent of regular traverse assessments showed obvious signs of pastoral overgrazing resulting in a ‘poor’ or ‘very poor’ condition assessment. It is acknowledged that substantial areas have been affected by other disturbances such as rabbits and fires. Severely degraded and eroded areas generally occur near water points. Overlapping grazing radii of closely spaced water points leads to continuous grazing. This results in the deterioration of preferentially grazed habitats such as donga groves, tree-based clumps and drainage focus shrublands. Where grazing radii overlap due to closely spaced water points strategic fencing is needed. New water point installation should consider grazing radii and distance from other water points where radii do not overlap.

19. Most of the Nullarbor Plain is geomorphically and floristically finely patterned. The limited floristic diversity renders the Nullarbor extremely seasonally dependent for pastoral purposes. The irreversible transition of extensive areas of chenopod shrubland and lightly wooded myall chenopod woodland into open bindii grassland has further simplified Nullarbor habitats. The long-term carrying capacity of ecosystems is significantly reduced by degradation of the perennial vegetation communities as systems increasingly lose the ability to support grazing animals during dry periods. Pasture spelling through temporary water point closure and strategic internal paddock fencing would help to preserve karst depression habitats, isolated woodland patches on calcrete rises within the plain and ecologically important grove habitats. The restriction of access to such areas during favourable seasons would assist in preserving important nutritional sources for use during dry seasonal conditions when the more uniform areas of the plain no longer provide a suitable forage reserve. The long-term preservation of core habitats provides a valuable seed source for redispersal after disturbance events.

20. Numerous land systems, habitat types and declared rare or priority flora species are not represented or are poorly represented on lands set aside for nature conservation within the survey area. The WA Government, through its conservation department, is actively purchasing portions of pastoral leases and taking them out of pastoral production as a conservation initiative. As such excisions in the Nullarbor District are small and tend to be associated with protecting caves it is unlikely all threatened species and ecosystems could ever be reserved. Local community participation in addressing these deficiencies is recommended as it is likely to improve the chances of achieving both specific and broad nature conservation goals. Acceptance, encouragement and perhaps compensation and rewarding of local land managers’ participation in activities directly relating to nature conservation are recommended.

21. The contents of this report and its associated maps describe the environment in a spatial context, which is useful for planning future regional conservation strategies or systems of reserves. Furthermore, the maps, land system and habitat type descriptions are useful for planning ecological monitoring on the basis of representativeness or sensitivity to change. The maps and report also provide essential biological information for pastoralists and other stakeholders with interests in accessing rangeland resources, for example, pastoralists preparing property development and management plans.

22. Without undertaking exhaustive monitoring of resources and management it is difficult to evaluate the ecological sustainability of current land management practices. On the basis of visual traverse condition assessments, historical resource use has certainly not always been ecologically sustainable in parts of the landscape which supported vegetation preferred by stock on soils susceptible to wind erosion. In contrast, there were many assessments of ‘good’ condition in a variety of landscapes which have been used for pastoralism for decades. This would indicate that, at this broad level, particularly on resilient land surfaces such as on the stony-surfaced plains, conservative pastoralism can be ecologically sustainable in most land systems.

23. Stocking rates need to be based on strategic and tactical management in response to landscape condition. Permanent monitoring systems provide the systematic means of making informative management decisions. At present resource monitoring is confined largely to measurements of perennial shrub density and size, and soil surface stability (the Western Australian Rangeland Monitoring System—WARMS). Little monitoring of other ecological aspects such as ephemeral plant dynamics, soil fauna and flora, and native macrofauna, occurs over most of the survey area. There is also little or no monitoring of landscape processes at a catchment or sub-catchment scale. Appropriate ecological monitoring systems need to be developed and put in place so that change can be detected through time for the purpose of decision-making and assessing environmental performance outcomes.

Introduction

Rangeland surveys

The findings presented in this report are those of a regional survey of lands in the Western Australian part of the Nullarbor region. The survey was undertaken by a joint team from the Department of Agriculture and Food, Western Australia and Landgate, between 2005 and 2007.

The survey is the thirteenth of its type in a program of rangeland classification, mapping and resource evaluation in the State. Previous surveys in the program have been undertaken in the Gascoyne River catchment (Wilcox & McKinnon 1972), the West Kimberley (Payne et al. 1979), part of the Nullarbor Plain (Mitchell, McCarthy & Hacker 1979), the Carnarvon Basin (Payne, Curry & Spencer 1987), the Ashburton River catchment (Payne, Mitchell & Holman 1988), the Roebourne Plains (Payne & Tille 1992), the Murchison River Catchment (Curry et al. 1994), the north-eastern Goldfields (Pringle, Van Vreeswyk & Gilligan 1994), the Sandstone–Yalgoo–Paynes Find area (Payne et al. 1998), the Pilbara region (Van Vreeswyk et al. 2004), part of the Broome Shire (Cotching 2005) and the lower Murchison River area (Hennig 2009).

The survey area

An area of about 118 358 km^2 was covered in the Nullarbor survey which extends from latitude 30°00'S in the north to 33°00'S in the south, and longitude 123°30'E in the west to 129°00'E in the east (Figure 1). The northern survey limits are defined by pastoral lease boundaries along 30°25'S until 126°00'E where the area extends north to 30°00'S. The southern limits of the survey area extend as far as 33°00'S, though most of the southern limits are bounded by the Southern Ocean. The western limits of the survey area are defined by the westernmost Nullarbor pastoral lease boundaries. The eastern limit of the survey is defined by the Western Australian–South Australian border along longitude 129°00'E (Figure 2).

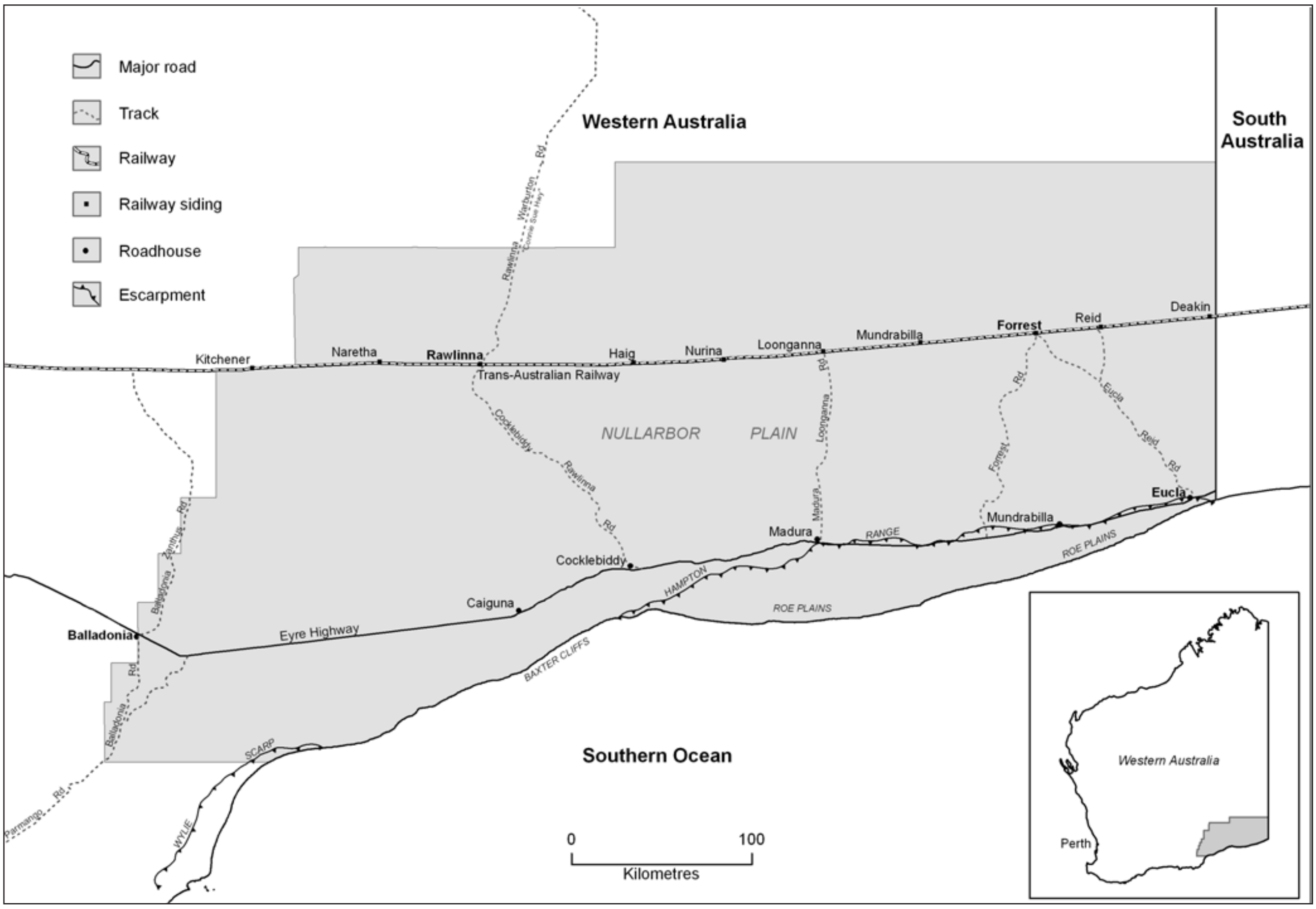

Figure 1 **Location map and major features of the Nullarbor survey area**

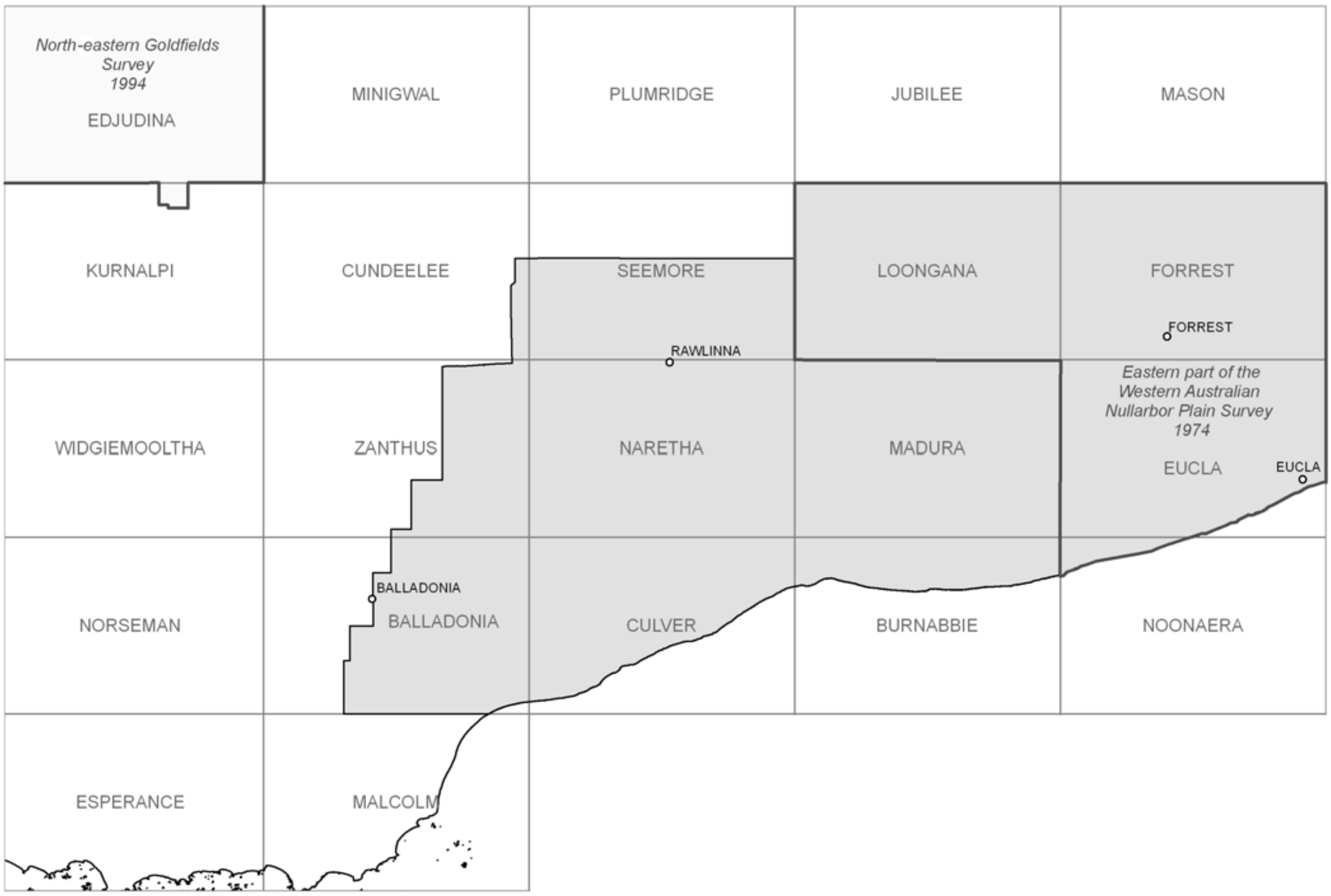

Figure 2 **The 1:250 000 map sheets covering the survey area and showing adjacent survey areas (with field work start dates)**

The survey area includes 20 pastoral leases. The area is serviced by one main road, the Eyre Highway, and by the Trans-Australian Railway. It includes the town of Eucla in the east, while the nearest other town is Norseman to the west. The area also includes the Eucla National Park, the Great Victoria Desert and the Nuytsland Nature Reserves. One Aboriginal reserve is partly included in the north of the survey area. Most of the east of the survey area is composed of large tracts of Unallocated Crown Land (Figure 3).

In 1974 the Pastoral Appraisement Board (now the Pastoral Lands Board) commissioned a joint survey of the Western Australian portion of the Nullarbor region by the Department of Lands and Surveys (now Landgate) and the Department of Agriculture. The initial aim of the 1974 survey was to encompass the entire Western Australian portion of the Nullarbor region; however the survey was reduced to include only the eastern part of the Western Australian Nullarbor region, an area of 47 400 km², within the 1:250 000 map sheets of Eucla, Noonaera, Forrest and Loongana.

Mitchell, McCarthy and Hacker (1979) stated the following reasons for excluding most of the pastorally developed Nullarbor country:

- The inadequacy of the 1961 aerial photography, then the only photo coverage available, meant cross-country navigation was extremely time consuming and inaccurate. The featureless landscape made precise location on the photographs particularly difficult. Compass bearing traverses were hazardous due to the numerous rabbit warrens and the rugged nature of the limestone surface.
- The survey team was rarely confident of its exact position in the recently developed pastoral country when trying to accurately position tracks and infrastructure because of the inadequacy of the aerial photography and the lack of identifiable landmarks.
- Bushfires had changed the vegetation since 1961 and photo patterns did not correspond with ground-truthing.

Information in this report includes the area covered by the 1974 survey of the eastern part

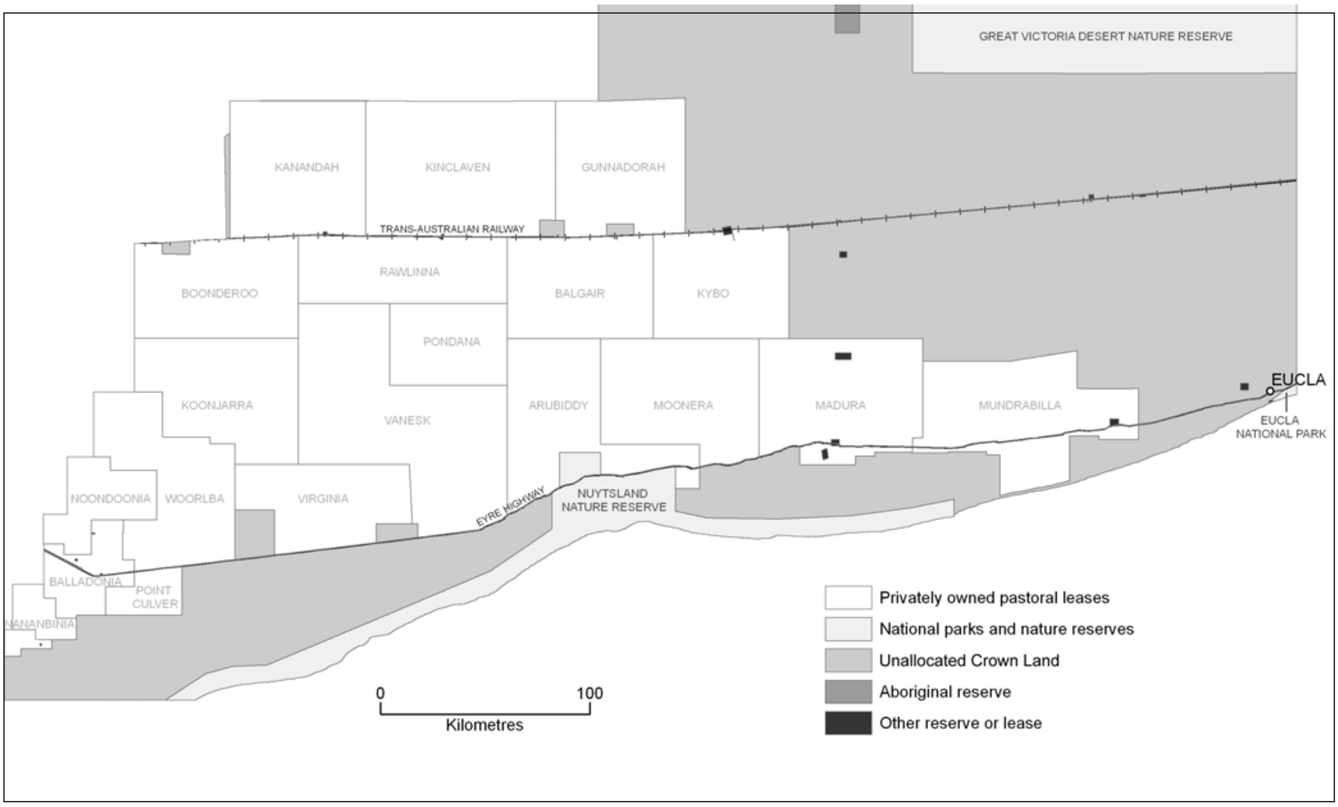

Figure 3 **Land tenure in the survey area**

of the Western Australian Nullarbor Plain (Mitchell, McCarthy & Hacker 1979). With improved aerial photography and the benefit of LANDSAT imagery the land systems from the 1979 survey have been reassessed and in some cases modified, renamed or amalgamated.

Purpose of the survey

The purpose of the survey was to provide a comprehensive description and mapping of the biophysical resources of the region, together with an evaluation of the condition of the soils and vegetation throughout.

The report and accompanying maps are primarily intended as a reference for land managers, land management advisers and land administrators, the people most involved in planning and implementing land management practices. The report and complementary map will also provide researchers and the public with a basic reference on landscape resources of the survey area. The survey inventory also enables the recognition and location of land types, land systems and land units with particular use capabilities, habitat or conservation values for land use planning. Maps at a scale other than that published can be generated as required.

Monitoring of vegetation change is well established in the Western Australian rangelands. This report provides the base description of habitats (ecological site types) necessary for the strategic location of monitoring sites and provides some information for the assessment of resource condition of those habitat types.

Contents of the report

The first section provides a brief overview of particular aspects of the land use and biophysical features of the survey region. In many instances little detailed information has been published and these chapters draw together the disparate information which is available. The land use history, climate, geology, hydrogeology and declared plants and animals chapters serve as an introduction to the later more detailed chapters on soils, vegetation, habitat type ecology and land systems.

No review of the fauna of the Nullarbor region is presented. This was covered as part of the Biological Survey of the Nullarbor Region—South and Western Australia carried out by the Western Australian Department of Conservation and Land Management and South Australian Department of Environment and Planning in 1984 (McKenzie & Robertson 1987).

The second section of the report includes methodology and the findings of the survey. The methodology chapter explains the survey procedure. The geomorphology chapter describes landforms and how they are distributed and formed. It also considers land use impacts on the landforms and landscape processes. Other chapters discuss the soils, vegetation, habitat type ecology and land systems. They provide information on landforms, soil and vegetation at the land unit scale, and used in conjunction with the maps provide a comprehensive inventory of biophysical resources.

The resource condition chapter provides a detailed assessment of the impacts of land use on the vegetation and soil resources. The resource management chapter provides suggestions for the maintenance and improvement of managed Nullarbor habitats.

Station summaries for each of the pastoral leases are presented in the appendices. These were produced using the survey findings and are directed towards the pastoral industry providing general information that will assist in management planning for pastoral leases.

The appendices also comprise lists of plant species and the land system maps. The species lists contain information that is too detailed to include within the main report but provides background information for future research. The 1:500 000 land system maps are a separate attachment.

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Review

Nullarbor land use history (J Campbell[1])

Climate (AK Gardner[2])

Geology (PA Waddell[2])

Hydrogeology (DP Commander[3])

Declared plants and animals (AK Gardner[2])

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Nullarbor land use history

J Campbell

Aboriginal history

Aboriginal populations within the Nullarbor region were considered to be sparse. According to the anthropologist Tindale (1940) who documented tribal boundaries, the Aboriginal tribe called Mirning inhabited the coastal area from Point Culver in Western Australia to the head of the Bight in South Australia. Their neighbours are the Ngadjunmaia west of Point Culver and Naretha towards Esperance in WA, the Murunitja to the north-west, the Ngalea to the north and the Kokata to the north-east in South Australia.

It has been said that the Aborigines feared to enter far into the plains of the Nullarbor as they were afraid of the great serpent that lived there, but they did traverse it particularly in good seasons (Tindale 1940). Life would have revolved around small family groups as the climate and environment would have been too harsh to sustain a larger group, water being the major limiting factor. Rock-holes would have been their main source of water, though the water-holding capacity in Nullarbor rock-holes is generally small and as such would not have been able to support Aboriginal families for long. A rock was commonly used to cover rock-holes to reduce evaporation by sun and wind and also to prevent fouling by animals. It is hard to imagine how the small groups survived, with few trees and very small bushes to protect them from the elements and a scarce food source: kangaroos, emus, lizards, birds and a few berries and grasses. To the south in the timber line, possums were a common food source and there was water from the mallee tree roots.

Early European settlers and explorers' reports on Aborigines in the Nullarbor region were generally that they were sparsely scattered throughout the area. Pastoralist Thomas Muir (1874) of Moopina Station at Eucla, having resided there for two years, recorded in his diary on 21 July 1874, 'I believe I have seen all the natives that belong from Eucla to the Bight, 150 miles, and there are about thirty altogether'. His estimate should probably have been higher but with no census figures available it serves to highlight that the Aboriginal population appears to have been low (Muir 1874). Similarly, John and Alexander Forrest wrote to their parents from Eucla and commented on their low numbers while on their epic trip from Perth to Adelaide. In his diary John Forrest wrote: 'The natives met with appear friendly and harmless; they are entirely destitute of clothing and I think not very numerous' (Jeffery 1979).

More than 30 caves on the southern part of the Nullarbor Plain have yielded mammal remains. Bone fragments of one of the largest marsupials known, the Diprotodon, have been found on the western edge of the Nullarbor near Balladonia. Fossil records indicate they were up to 2 m high at the shoulder, 2.5 m in length and weighed up to 1.5 tonnes. It was believed to have looked like an oversized, long legged wombat, its nearest surviving relative (McNamara & Murray 1985).

The effect of increasing aridity, due to climatic changes, on the environment during the Late Pleistocene resulted in extensive changes to the vegetation, placing pressure on many species unable to adapt to the new conditions. During this period Aboriginal people arrived in Australia. Their impact on the environment is likely to have had a profound effect on the vegetation, especially through their use of fire. Such extensive burning practices would have radically altered the vegetation, contributing to the extinction of the large marsupials (McNamara & Murray 1985).

Early coastal exploration

The first recorded sightings of the south coast of Australia were by the Dutch. A Dutch recital states: 'In the year 1627 the south coast of the Great South Land was accidentally discovered by the ship the *Gulden Zeepaart* (Golden Seahorse) for a space of a thousand miles on its outward bound voyage from the Fatherland' (Lewis 1918). The Dutch vessel was under the command of Francois Thijssen and had on board the Honourable Pieter Nuyts after whom the stretch of land bordering the Nullarbor north of the Great Australian Bight was named. Nuyts' Land stretches from King George Sound in Western Australia through to Denial Bay in South Australia.

In the year 1718 Jean Pierre Purry of Neufchatel published a memoir where he entertained founding a colony in the land of Nuyts. The memoir was published in

Amsterdam to prove that Nuyts' Land being in the fifth climate, between 34 and 36 degrees of latitude, ought to be, like all other countries so situated, one of the most habitable, most rich, and most fertile parts of the world' (Lewis 1918). From present day knowledge of the eastern end of Nuyts' Land, it is known to be unsuitable for an agricultural colony. Another reason for a voyage to the Southern Land was to search for certain 'islands of gold', and it is not within the realms of possibility that the idea of hidden gold had been revealed to the Dutch navigators through meetings with Aborigines along the coast (Lewis 1918).

In late 1792 the French navigator Joseph Antoine Raymond Bruni d'Entrecasteaux, in the frigates *La Recherche* and *L'Espérance*, charted the coastline around Esperance and to the south of the Nullarbor. In late 1801 a British expedition under Matthew Flinders surveyed the southern coastline in the 334 tonne sloop-of-war *Investigator* and was near Eucla in January 1802. Matthew Flinders described the area as the 'Great Bight or Gulph of New Holland' later to become the 'Great Australian Bight' (Collins 2008).

Early European exploration

In 1841 Edward John Eyre became the first European to make the epic 1400 kilometre overland journey from east to west. It took him nearly five months, from February to July, to travel from Fowler's Bay in South Australia to Albany in Western Australia. It was an outstanding event of perseverance and endurance as it was made almost entirely on foot. Some two months into the expedition his only European companion, John Baxter, was murdered by two Aborigines who accompanied them on the trip and then deserted the party taking precious food and leaving Eyre and an Aboriginal companion, Wylie, to proceed alone. Desperate attempts to locate water and the lack of adequate food supplies left them weak and near death. In July 1841 they reached Albany.

In 1866 the squatter and surveyor, EA Delisser, seeking grazing land on behalf of the South Australian Government explored between Fowler's Bay and Eucla. Earlier reports of promising land had aroused the interest of pastoralists in the eastern colonies. A Victorian syndicate addressed a petition to the government in Perth on 24 June 1862, requesting pre-emptive grazing rights to the vast area of land between Hopetoun and Eucla. Governor Hampton rejected the request, replying that the unsettled parts of Western Australia were only open to occupation for pastoral purposes defined in the regulations. Delisser took a more favourable view of the pastoral potential of the country than Eyre and PE Warburton, and the Delisser Sandhills a few miles east of Eucla were named after him. It was Delisser who gave the Nullarbor its name; from Latin he derived the name Nullarbor for the treeless limestone plateau north-east of Eucla (Jeffery 1979).

In 1870 the Western Australian Government commissioned an expedition to ascertain the route for an overland telegraph line from Perth to Adelaide. John Forrest led the expedition and was supplied by sea at Esperance, Israelite Bay and Eucla (Forrest 1875). Based on details provided by the expedition, work for the overland telegraph line commenced in 1874 and was completed in 1877.

The northern edge of the Nullarbor Plain was traversed by Ernest Giles' expedition of 1875 that set out from Port Augusta in South Australia. The purpose was to search for potential pastoral country to the west of the Fowler's Bay district. Six days of the expedition involved traversing the northern edge of the Nullarbor Plain proper whilst travelling through the Great Victoria Desert (Giles 1889).

In 1896 the Commissioner for Crown Lands appointed Arthur Mason to lead an expedition to ascertain the extent of the rabbit invasion from South Australia into Western Australia. Rabbits had been introduced into Australia in 1859 and were present in Eucla by 1896 (Mason 1897). During this expedition Mason commented on the rich pastoral potential of the country despite the lack of water.

Pastoralism

Explorers such as Edward John Eyre, John and Alexander Forrest, Major Peter Egerton Warburton, Ernest Giles, Arthur Mason and the many other men who traversed the Nullarbor Plain provided reports on the condition of the country, some proclaiming magnificent grazing land while others condemned it.

Following John Forrest's favourable report for pastoral prospects in the region the whole of the southern section south of the Trans-

Australian Railway line to the Great Australian Bight was taken up, though on paper only. The potential landholders didn't realise water would be the determining factor. Three families did settle their leases in the Eucla area: Kennedy and McGill took up Mundrabilla Station in 1871, while John Muir took up Moopina Station in 1873.

By the early 1870s Moopina Station, 1300 km from Perth and a few kilometres west of the South Australian border, had been taken up by the Muir brothers. John Muir arrived at Port Eucla on the 142 ton brig, *Emily Smith* on 23 February 1872, having on board about 650 sheep, two horses, two sheep dogs, three European men besides himself, an Aboriginal boy named Jacky, plus a year's provisions (Jeffery 1979). The Muirs later requested the Government to build a small jetty to facilitate the loading and unloading of their wool stating 'in shipping wool, the men had to carry it on their shoulders and then were not able to put it on board dry'. Similar conditions faced Kennedy and McGill on Mundrabilla Station, 96 km west of Eucla and 27 km inland from the coast (Fyfe 1983). A Perth newspaper announced early in 1872 the likelihood of new settlement at Eucla 'by our own squatters embarrassed as many are becoming for want of pasturage for their increasing flocks and herds' (Jeffery 1979).

The Muirs claimed in 1883 to cut five to six pounds of greasy fleece, including bellies and locks, from over 4000 sheep. They did not mention the low yield inherent of the sandy country. In 1888 when the average price for their greasy wool was around six to seven pence a pound, a Eucla correspondent wrote to Robert Muir advising that there were kangaroo skins worth nearly fifteen hundred pounds awaiting shipment, representing greater value than the whole of the district's wool clip in the previous season (Fyfe 1983).

During the 1870s and 1880s on the south-western fringes of the Nullarbor area other pastoral stations were becoming established such as Balladonia, Fraser Range and Noondoonia while in the south-east Madura (1876) joined Moopina and Mundrabilla.

The Dimer Family of Nanambinia expanded their enterprise by taking up water leases, resulting in them having stock to the north of their Nanambinia lease at Emu Point, First King and later Seemore Downs. In dry years they

Dimer brothers branding cattle on the Nullarbor Plain, Rawlinna 1939. Photo provided by J Campbell

were known to shepherd their stock ranging as far as Loongana and northwards of the now Trans-Australian Railway.

In the late 1950s and early 1960s the western Nullarbor became the region for the last major pastoral expansion in Australia. Prior to this time the only established pastoral stations were those mentioned above in the country to the south. Seemore Downs Station running cattle around the railway siding of Rawlinna was the only enterprise on the Nullarbor Plain proper. Gunnadorah and Cocklebiddy started in the late 1950s, followed by Rawlinna Proprietors, Kanandah, Moonera and Arubiddy. A few years later Balgair and Kybo were established.

All these northern properties started off running sheep and the country produced some large framed, heavy wool cutting sheep. However, in the late 1960s the crash in the price of wool and low commodity prices led to some properties diversifying into cattle, which once adapted, did extremely well on the vast Nullarbor Plain.

One of the biggest wool clips under single management in Australia came off the Nullarbor from Rawlinna Proprietors. The Nullarbor is prime pastoral and breeding country when seasonal conditions are good. In the past when seasonal conditions have consistently remained above average the combined stations of Rawlinna Proprietors ran over 40 000 to 60 000 sheep and produced 1100 to 1700 bales of wool (Reardon 1996).

European development

Work for the overland telegraph line was completed in 1877. At Eucla, halfway along the line, a repeater station was constructed. This locality evolved and in 1885 was proclaimed a townsite. The access track of the telegraph line served as a stock route for the southern

Nullarbor pastoralists. In 1941 the track was upgraded and became the Eyre Highway and was later bituminised.

To gather information for the proposed Trans-Australian Railway John Muir led a survey in 1901 into the Nullarbor Plain, covering 1760 km by camel (Beard 1975). During World War One work on the railway line commenced, then known as the Commonwealth Railway, and was completed in 1917. The railway is famed for its straight section that runs for nearly 500 km without a bend. The railway gave development in the region a huge impetus as direct access to construction material for infrastructure and stock movement became available. Small railway siding settlements also developed along the railway line where water was available. Rawlinna and Forrest are two of the better known sidings. In recent times with the advent of privatisation of the railway these services were lost. Compounding the issue for the northern Nullarbor pastoralists is the lack of an all-weather road. Road transport has become a major problem for those pastoralists once supported by the railway, who relied on meeting export shipping schedules and marketing of their wool via rail.

Besides pastoralism and railway settlements another industry that thrived on the Nullarbor was that of the rabbiters. By the 1940s rabbit numbers were so great there was a substantial commercial trade, with up to 20 000 rabbits a week trapped in the Cocklebiddy area alone (Parsons 1970). The release of the virus myxomatosis in 1954 devastated the industry. Any revival was similarly affected when the rabbit calicivirus was released 1995. Both viruses greatly reduced rabbit numbers across the Nullarbor.

Due to the predominance of limestone the Nullarbor region has not been greatly influenced by mining other than local quarrying for building and road material. Presently there is only one active mining enterprise on the Nullarbor. Near the Rawlinna siding high grade limestone aggregate is extracted. In more recent times there has been extensive exploration for a variety of minerals.

Figure 4 **Present day land tenure in the survey area**

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Pastoral lease history

Arubiddy Station

Peter Brown

Arubiddy Station is a 316 500 hectare property. The homestead is 30 km north of Cocklebiddy on the Eyre Highway and 60 km from the fabulous coast of the Great Australian Bight. The nearest town is Norseman, 470 km west, with most business conducted through Kalgoorlie and Esperance, each almost 700 km away.

The land was first allocated in 1961 and has been in the Brown family since then. Peter and Barbara Brown, with their family, have been living on the station since the early 1970s, running pure Merino sheep and continually developing the property. The station is divided into 43 main paddocks and 17 holding paddocks. There is 1650 km of fencing with the south-west fence being electrified and the northern fence bordering Balgair Station being prepared for electrification.

Subartesian water is found at about 120 to 150 m and ranges from 1200 to 10 000 parts per million total salt content. There are 12 bores and the main homestead bore has a 70 km pipeline running south to water 15 paddocks. The total length of pipelines around the property is 127 km. Most water is extracted using pumps with only one bore now operating with a windmill.

Arubiddy's sheep are originally of Collinsville bloodline and for the last 15 years rams have been sourced from Seven Oaks Stud at Burracoppin. Shearing takes place in March/April and the sheep yield approximately 6 kg per head of 22 micron wool. Depending on the season and stock numbers, 450 to 750 bales of wool are produced annually. Arubiddy's wool has won numerous 'Clip of the Week' awards at the wool sales and prizes at Perth Show. Lambing occurs around June–July with lambs being marked around August. Crutching is done in October. Wool provides the bulk of the station's income along with a number of sheep for live export each year. There are also around 200 head of Murray Grey cross cattle running in the northern paddocks.

Balladonia Station

Susanne McGrath

Stephen Ponton and his brother William arrived in Fremantle as convicts in 1859. After conditional pardons in 1861 the Ponton brothers formed a partnership with John Sharp, who arrived in Fremantle from Scotland in 1859. In 1873 the three travelled overland from Albany with sheep, cattle, horses and wagons and settled on a 500 acre property at Point Malcolm 182 km east of Esperance. Leaving William to care for Point Malcolm, Stephen and John pioneered northward and encountered Balladonia Rock on 8 August 1879 (the Ngadjunmaia Aboriginal people called it Barlajuinya). The Crocker family, descendents of Stephen Ponton, owned Balladonia until 2001 when they sold it to James Ferguson. In 2005 it was purchased by Greg and Cynthia Stoney and family.

The station is 219 km east of Norseman and has an area of 125 000 ha. Balladonia Station is reliant on rain for all of its water needs, the underground water being far too saline, and is equipped with many dams of various sizes. These have been constructed in a variety of ways from hand digging, horse, camel and bullock teams through to the bulldozers of the present day. The rainfall ranges from 75 to 500 mm depending on the season, the average is 200 mm. The main water catchment for the homestead comes off the granite Balladonia rock, from which the station is named.

Balladonia homestead has 17 rooms and was built in two stages, the first in 1881 and the second in 1926. The material used is fossiliferous limestone with an iron roof. This limestone also features in most of the surrounding buildings: a shearing shed and quarters, storage sheds and a disused blacksmith shop. All of the stone was sourced from nearby surrounding ridges. A feature of the station is the 'dry stone' limestone walls which were built by hand in the early days by the Ponton brothers who were stone masons in their native Wiltshire, England.

Stock numbers during the Crocker family's time have varied from 2000 to 8000 sheep and up to 100 breeding Poll Hereford cattle depending on the seasons. The property is presently stocked with a small herd of Droughtmaster cattle with the aim of increasing numbers as sheep based infrastructure is upgraded for cattle.

Gunnadorah Station

Dot Day

Gunnadorah Station is 334 675 ha and is situated 450 km east of Kalgoorlie along the Trans-Australian Railway line.

The Gunnadorah lease was first taken up in 1957 by Colly Day and Dick Nunn. Dick Nunn was bought out in 1985 and Colly Day became the sole owner.

The site for the homestead was chosen because of the close access to the railway line where an existing railway well could be used for water and for freight to come and go. Stock were loaded and unloaded onto the train using the cattle yards at Haig Siding. Today all freight and stock movement is by road.

Gunnadorah today relies on renewable energy to power its homestead with solar and wind systems working alongside each other. There are 23 working bores with most consisting of two holes, one equipped with a windmill and the other a submersible pump to provide water during consecutively windless days. One pump is operated by solar power. There are also 13 dams.

The station carries cattle, primarily Brahman cross and Santa Gertrudis cross.

Brett Day, Colly's eldest son, has been on Gunnadorah for most of his life. He was joined on the station by his wife Dot and together they have raised four children. All the children have done most of their schooling on the station. The two boys are working on the station, allowing them to take time off to also follow their successful bull riding careers.

Kanandah, Boonderoo and Koonjarra leases

Russell Swann, with excerpts from Eric Swann (2008)

The McGregor family was granted three leases, each around 1 million acres in area, on the western edge of the Nullarbor Plain, in the early 1960s. The three leases are: Kanandah, on the northern side of the Trans-Australian Railway line; Boonderoo and Koonjarra, both south of the railway line. Initially the Kanandah leases were owned by Alan and Alistair McGregor, in the early 1970s. A later change in ownership left Alan McGregor the sole owner.

Drilling for water commenced in 1962, working north from Naretha Siding on the Trans-Australian Railway line, and had immediate success with a large proportion of the holes drilled in the first few months finding water. The results provided sufficient encouragement to commence development.

Eric Swann joined the company as the first manager in 1962 after previously managing properties in western Queensland. He set up camp in a tent adjacent to one of the better bores with a pump jack and tank to supply water for water boring contractors. Commencement of what is now Kanandah homestead began in May 1963 on a site 8 miles north of Naretha Siding.

The first building was the workshop and the shed into which the single men moved their camp. The men's quarters soon followed and the Swann family lived in them for a time with Ruth cooking for a large crew while the manager's house, along with the overseers' and mechanics' houses, were under construction.

The success of the early drilling was short-lived. The early successes west of the Naretha fault line were all small supplies, but for three or four holes. Subsequent development of waters was achieved by establishing an extensive system of pipelines sourcing most of the water from the reliable supplies in the south-east sector of the Kanandah lease. In addition, commencing in 1964, large key dams (30 000 yards and greater) were constructed in the north and along the western side of the Kanandah block and pipelines supplied water from these. With over 200 km of pipeline eventually installed, there was much associated development of tanks and pumping systems, including overhead tanks on gravity supply. Initially five major dams with extensive roaded catchment systems were constructed on Kanandah and another three dams in the south. Several more dams were added later.

Despite a lot of drilling in the Boonderoo and Koonjarra blocks no usable water was found, so dams were relied upon for water. Sheep were run on the southern leases in the 1960s and 70s. However with up to a week to drove the sheep either way from the homestead and woolshed, plus the continual presence of wild dogs, sheep management in these leases was more difficult. Having run a herd of cattle as a

smaller and secondary enterprise to sheep since the outset it was decided to expand the cattle enterprise to use the southern two blocks in 1973.

One dramatic event in the history of the Boonderoo lease was the filling of Lake Boonderoo in 1975. Although no rain actually fell on Kanandah, extremely high rainfall influenced by cyclonic activity in the Leonora area resulted in flooding of lakes Raeside and Rebecca with overflow flooding Ponton Creek and floodwater filling Lake Boonderoo. Previously the creek ended as a small, grassed claypan used by the station as a small airstrip, now at the bottom of the lake. After the creek stopped flowing the lake settled to between 50 and 80 km^2. Lake Boonderoo filled again 20 years later in 1995, when heavy rains associated with Cyclone Bobby caused flooding of the salt lakes in the north-eastern goldfields. This again provided valuable stock water until it became too saline as the water level eventually dropped.

It is appropriate to mention the Dimer family who originally pioneered much of the Nullarbor. While not covering much of the land within the Kanandah group of leases, Henry Dimer with his family ran sheep and cattle on what were essentially water leases ranging from Nanambinia Station south of the Eyre Highway up through Rawlinna and at times as far east as Loongana. One Dimer base camp was Emu Point in the south of the Koonjarra block where cattle were watered on small dams, excavated using scoops pulled by camel teams. Another water lease bought by Harry Dimer was Snake Gully in the east of the Kanandah block. This was still in operation by Harry Dimer, some time after Kanandah commenced, with Harry running a herd of Angus–shorthorn mix cattle on Snake Gully bore. Though not big, this bore is still one of the best quality water supplies on the Nullarbor.

Mark Zeuvella, who ran the lime kilns on the transline, purchased some Angus cattle from Harry Dimer and ran them near the kilns on Kanandah. They were later purchased and absorbed into the Kanandah Hereford–shorthorn mix herd. In 1973, 400 cows from Alcoota Station in the Northern Territory were introduced. These cows were mated to Murray Grey and Charolais bulls at Omar in South Australia on their way to Kanandah. With the arrival of these cattle the first Murray Grey bulls were sent to Kanandah from Willalooka Murray Grey Stud in South Australia. Willalooka continued to supply bulls to Kanandah for the next 26 years.

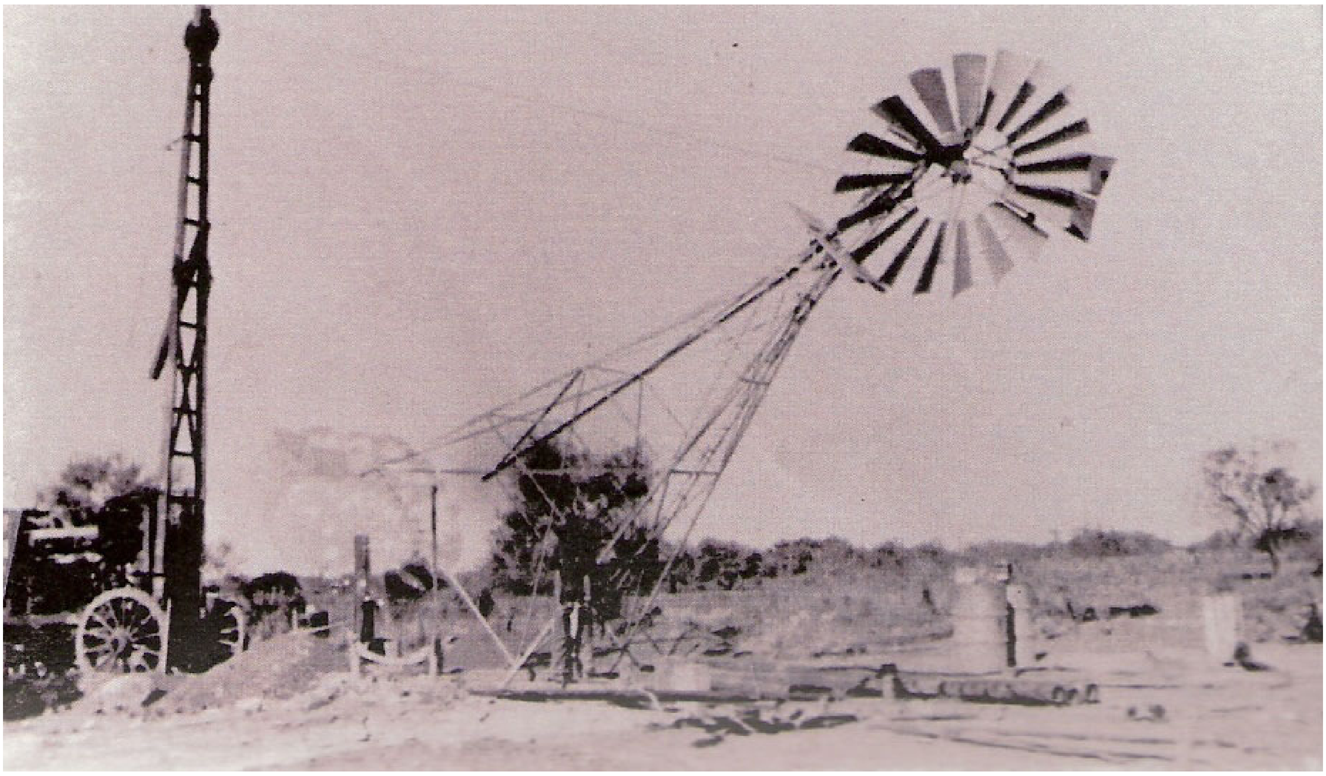
Kanandah suffered from bushfires in the 1960s, again in 1974, 1993, 1995 and 1996.

In the 1970s Eric Swann changed from Collinsville style rams to the bigger, more robust Bungaree style from Anamar in South Australia. These sheep handled the conditions much better and provided stronger wool. When commencing fleece weighing in about 1980 cuts and returns per head had increased significantly. With more robust sheep there was a much better annual turn-off of surplus stock and good shipping-type wethers.

A relatively successful period was experienced through the 1980s and into 1990. In 1991 however there was a drop in sheep and wool values with the huge national wool stockpile. With sheep becoming unsaleable, the stock reduction scheme was introduced and this saw in excess of 7000 sheep being destroyed and buried on the property. After so many years this was a difficult note to finish on with Eric and Ruth Swann retiring for health reasons in 1991. Russell and Judy Swann then took on management of the three leases.

In response to extensive destocking of sheep during 1991 due to drought and the drop in sheep and wool value the decision to expand the cattle enterprise was again entertained. Having bred Murray Greys for the previous 20 years it was obvious that they did not cope as well in drier periods. To increase drought hardiness, Brahman cows were introduced from Thangoo Station near Broome and after calving, mated to Murray Grey bulls from Willalooka. The existing Murray Grey cows on Kanandah were mated to Brahman x Murray Grey bulls also bred on Willalooka. This project was followed over the next two years, by two more consignments of Brahman cows from Flora Valley Station in the Kimberley.

In the early development of Kanandah the three leases were completely enclosed by dingo-proof netting fence. Although in later years being ‘let go’ to a degree in the south, the northern sheep block remained well protected by the dog fence. In 1993 this fence was severely damaged by road construction. The resulting influx of wild dogs made it impractical to continue the economically challenged sheep



Pulling up a windmill with boring plant, Snake Gully 1940. Photo provided by J Campbell

enterprise. In 1993 the decision to focus solely on cattle was made and by 1997 Kanandah was destocked of sheep.

With declining health, Alan McGregor looked towards selling Kanandah and it went to auction in December 1999. It was bought by the Forrester family from Carnarvon who took over in January 2000. Mark and Karen Forrester continued to run a cattle enterprise.

Kinclaven Station (includes Seemore Downs and Premier Downs)

Barbara Hogg

Kinclaven Station covers about 497 600 ha. The station is an amalgamation of various leases. The first pastoral usage of land north of the railway line in the Rawlinna area was by JD Ryan. He leased land 23 km west of Rawlinna, it is believed, to run stock to supply fresh meat to the workers constructing and maintaining the Trans-Australian Railway line during the early 1900s. His lease extended 35 km north of the railway line as well as some land to the south. There was a well and a substantial yard constructed of timber not local to the area. It is understood he also commenced sinking another well 10 km to the north-west but never struck water.

During the late 1920s, the Dimer brothers from Nanambinia expanded their interests into the Rawlinna area. In 1934 the Dimers employed Peter Della, a well sinker, who with an offsider sunk a well using a hammer and tap to a depth of 30 m. The well was equipped with a windmill and tank. A timber cattle yard was constructed and it was soon stocked with cattle. A single-roomed cottage was also constructed.

Over the next five years, the Dimer family took out numerous leases north of the railway line. These ranged from 10 000 to 70 000 ha in a line heading in a north-easterly direction from the railway line following the edge of the timber. The Dimers acquired a No. 2 Southern Brothers boring plant, which was shifted from site to site by a camel team. They drilled for water as they progressed north-east, equipping and stocking up to seven bores as they went.

In 1936 a homestead was constructed at Seemore Downs. KH Dimer acquired the building from the Eyre repeater station in the south. The building, originally constructed in 1877, was re-erected at its present location at Seemore Downs.

In the early 1960s, the area around Rawlinna was reallocated into larger, more viable leases. KH Dimer continued to run about 600 head of black Angus cattle on three 10 000 ha leases:

Snake Gully—now part of Kanandah Station, Della's Well and an area located on the north side of the Rawlinna township where he lived. MH Kittle from Whyalla in South Australia took up the Seemore Downs and Premier Downs leases which still had some of the improvements remaining from the Dimer brothers' earlier work. He employed contractors and added several internal fences. More bores were drilled and equipped. Stonemasons were employed to construct five tanks at bores around the property and commence construction of a stone homestead and shed at Seemore Downs. An outcamp was also constructed at Endeavour bore. Managers were employed to run the property and its herd of Shorthorn cattle.

Peter Hogg came to the Nullarbor as a boring contractor for BH MacLachlan in 1960. In 1971 the Hogg family was allocated the Kinclaven Pastoral lease, an area of 169 191 ha between Premier Downs and Gunnadorah Station. Peter named the lease after the small Scottish village where he was born. Soon after several bores were equipped, 68 Shorthorn cows and three bulls were purchased.

Development was slow as there were four years of very low rainfall. Capital resources were limited during these years as cattle prices were depressed. By 1978 there were four equipped bores, two holding paddocks, two holding yards, two cattle yards and a homestead and sheds at Kinclaven Bore. There was a total of 700 head of cattle.

At this time the leases of Seemore Downs and Premier Downs became vacant and Peter Hogg proposed an amalgamation to make Kinclaven Station more viable. In 1982 the leases were reallocated to PMM, DJ and NA Hogg. The properties were then run as Kinclaven Pastoral Company.

In 1987 the leases 393/444 and 393/494 known as Della's and Harry's were formally transferred to Kinclaven Pastoral Company. KH Dimer sold the remainder of his herd to AK George, which is still run on Kinclaven under a separate brand.

Kinclaven Station relies on bore water with no permanent surface water. There are 29 bores and five pipelines servicing 34 watering points. The bores range from 30 to 90 m deep. Sixteen windmills, 12 solar-powered mono pumps and two diesel-powered pumps deliver the water to the surface. Supplies range from 60 to 1200 gallons per hour, varying in quality. The entire property is scattered with limestone rock-holes; some hold water for several weeks. Today the herd consists of Santa Gertrudis Shorthorn-cross cattle.

Various mineral leases occur on the property though only one is active, a limestone quarry on lease 393/494. The other leases are exploration only.

Kybo Station

Jill Campbell

In the mid-1960s three blocks of land east of Rawlinna Station were made available. About 32 applicants applied for these blocks which later became known as Balgair, Kybo and Desert Downs.

Graeme and Roderick Campbell were granted the middle 760 000 acre virgin block in 1965 and when choosing a name which was short and concise, they decided on Kybo, an old army abbreviation for 'Keep Your Bowels Open' taken from their father's English army manual.

Kybo Station is situated 505 km east of Kalgoorlie and its northern boundary has approximately a 35 km frontage with the Trans-Australian Railway line. The country is undulating and has a valley system running from north to south through the entire middle section, associated with a geological fault.

Merino sheep were purchased after the first water and paddocks were developed, but foxes killed the lambs and wool prices crashed, so Brahman cattle were introduced in the early 1970s and were crossed over English-bred cows. The purchase of Brahman, Santa Gertrudis and Droughtmaster bulls are rotated over these cows to keep the hybrid vigour in their progeny. About 700 head of cattle free range the eastern side of the unfenced section of Kybo and have four main watering points.

The late 1990s saw Kybo diversify again into fat-tail Damara and Meatmaster sheep mainly bred for the overseas market. The male progeny are sold as entires at about five months when they weigh about 40 kg. They take little maintenance with no mulesing, tailing, crutching or shearing as they lose their fleeces although the first cross is sometimes shorn. The ewes produce twice a year and often have twins. Kybo is stocked with Merino and Damara sheep.

Kybo Station is still only two-thirds developed but has 17 paddocks which are watered from 10 bores and has 11 tanks on pipelines. Water is subartesian and is pumped from about 100 to 150 m by submersible pumps into 5000 to 20 000 gallon tanks and is good stock water.

Today Kybo is managed by Rod and Jill's son Greg and his wife Toni and they have two young sons. Graeme left the station in the 1970s to go into Federal politics. Rod and Jill live on the station for most of the year but often go away doing contract work.

Nanambinia Station

Susanne McGrath

Nanambinia Station was opened in 1902 by Heinrich Diemer (Henry Dimer) who was born 15 February 1861 at Weisloch in Germany and died December 1936. He became a master butcher, a family occupation, before migrating to America. After two years he signed onto the whaling ship, *Platina*, for five years. In 1884 he jumped ship in Albany, Western Australia. Henry headed east to work, during which time he married at Israelite Bay, before taking up Nanambinia. Members of the Dimer family ran the property until 1980 when they sold it to John Peckham. James Ferguson owned the station in 2003 until 2005 when it was bought by Greg and Cynthia Stoney.

The station is 35 km south of the Balladonia Roadhouse on the Eyre Highway and covers 46 300 ha. Nanambinia is reliant on dam water for all station needs as the underground water is too saline. The land was cleared for growing wheat and barley but proved to be only good for two years before becoming unproductive. In 1989 the property had 2500 sheep. Presently station infrastructure is being replaced for the restocking of Droughtmaster cattle.

A three-bedroom homestead is at Nanambinia Rock, the collection area for the house dam. The building is granite and limestone and has a corrugated iron roof. In the absence of human habitation it has been vandalised. The nearby shearing shed, which has succumbed to the ravages of time, was built of similar materials.

A European landmark of significance is a stone camp oven erected by the rock-hole now known as 'Forrest Soak'. Here around 1870 John Forrest led exploration through the area and camped at the rock-hole.

Karl Dimer with the 'Ark' loaded with 26 bales of wool, Nanambinia 1935.

The 'Ark' bogged with a load of wool on route to Point Malcolm 12 miles from Nanambinia 1931.
Photos provided by J Campbell

Noondoonia Station

Susanne McGrath

Noondoonia Station is north-west of Balladonia and was established in 1889 by the sons of John Cook who worked at the Telegraph Station at Israelite Bay. The second son Aleck took a position with the postmaster general at Balladonia, later becoming postmaster. This provided extra money to his brothers to help run Noondoonia. When John Cook died in 1912 his widow moved to the station to become housekeeper for her sons. She died in 1933.

The property was sold to Patrick Prenderville in 1967 and again to John S Crisp in 1978 who kept it until 1999 when James Ferguson became the owner. In 2005 the Stoney family bought the property.

The original area was 56 650 ha. Later the lease was expanded to 126 700 ha. The vegetation and water are similar to Balladonia and Nanambinia. The original buildings are

constructed of rammed earth and stone walls with corrugated iron roofs. Some of these buildings, including the homestead, are still in use. The shearing shed has fallen into disrepair.

Initially, the Cooks ran cattle but later changed to sheep. This stock arrangement remained until the sale in 2005. The plan now is for Droughtmaster cattle.

Madura Station

Hugh MacLachlan

The first recorded lease to include the old Madura Homestead site appears in the name of G Heinzmann, which started on 23 February 1876 for one year. It was not renewed.

This was followed in 1898 by the Ponton brothers and John Sharp. The property was known as Clifton Downs Station.

Since then, the property has had various lessees including Thomas Talbot (circa 1913). He also operated Mundrabilla and Southern Hills Stations in a partnership. Madura was used then for breeding horses and cattle. The number of horses is unknown but cattle numbered 1000. The horses were used to supply the Goldfields for work horses or as remounts for the army.

In the 1950s the property was purchased by George Birmingham, who continued with cattle production. In 1989 the lease was purchased by HG MacLachlan and amalgamated with Moonera Station to form Madura Plains Station. Further fence development has been undertaken to control sheep and a large dingo proof fence has been constructed around three sides of the property to join on the existing similar fence adjoining Moonera Station. The area of Madura Station is approximately 367 000 ha.

Stock numbers in 1969 were 6500 head of sheep and 850 head of cattle. Today the lease runs approximately 22 000 sheep, pressing 500 bales of wool.

Moonera Station

Hugh MacLachlan

Moonera Station is approximately 345 000 ha of grazing country north of the Eyre Highway between Cocklebiddy and Madura.

It runs about 22 000 sheep in a good season. Wool production is 500 bales annually and about 5000 head of sale sheep.

The station was taken up in 1962 by AF Angas from Clare in South Australia. It was quickly developed with a 300 centimetre high netting fence erected on all sides to prevent the ingress of dingoes. In 1972 it was purchased by BH MacLachlan and his son HG MacLachlan and developed further under the capable management of Ross Wood. In 1989 the lease came under joint management with Madura which had been purchased by HG MacLachlan to form Madura Plains Station.

Stock water is pumped from underground, generally from depths of around 150 m. There are numerous poly and PVC pipelines which help to water the entire property. Some water is obtained from six or seven dams during good seasons.

One or two families live on the station and there are generally seven or eight employees. They maintain the pipelines and the other watering points and do all the stock work. One employee looks after the dog-proof fence on a full-time basis to make sure it is always dingo-proof.

Rawlinna Station

Hugh MacLachlan

Development of the Rawlinna leases commenced in 1962, by the South Australian pastoral family of BH MacLachlan and his son, Hugh. Development centred on the Rawlinna siding on the Trans-Australian Railway and the homestead site was selected 7 miles west-south-west of the siding. In 1967 an extensive shearing complex, known as Depot Outstation, was built near the middle of the property. Depot Outstation comprises an overseer's house, the 16-stand shearing shed and extensive shearers' accommodation, mess and kitchen for approximately 50 people. Most buildings and stock water tanks are built of local limestone. About 20 people live on the station at any time.

Geographically the property's western boundary is on the western edge of the Nullarbor Plain, the eastern boundary being on the plain proper, with the northern boundary abutting the east–west railway line and extends south to the Eyre Highway either side of Caiguna Roadhouse. Rawlinna Station is an amalgamation of the Pondana, Rawlinna and Vanesk leases, totalling 1 046 600 ha in area. As such, Rawlinna is the largest sheep station in

Western Australia, shearing an average of 60 000 head and producing 1600 bales of wool. The maximum number shorn was 78 417 in 2001, producing a clip of 2177 bales.

To graze sheep successfully on the Nullarbor Plain it was necessary to build a 3 m high dog-proof fence. Marsupial netting with 8 cm mesh and a 60 cm lap on the ground formed the design. The netting covers 370 km and there is a 900 km^2 block adjoining the netting and the Eyre Highway which is dog-proof with a seven-wire solar powered electrical fence. Wethers are mostly run in the south.

Currently 37 bores produce stock water for 87 main paddocks, plus numerous holding paddocks. Bores are up to 140 m deep and water is pumped to the surface and in many cases distributed down an extensive pipeline system by large Comet and, to a lesser extent, Southern Cross windmills. The largest mills have 30 foot diameter wheels. Improvements anticipated for the future are dams to supplement the existing bores.

To help with limited and often unskilled labour, there is a 100 m wide laneway extending the full length of the property, both north and south from the Depot Outstation shed. Rawlinna Station has been very well managed by successive managers since 1967, namely David Seaton, Murray McQuie and Ross Wood who retired in 2007. Michael Simons is the new manager.

Virginia Station

Russell Swann and Eric Swann

Virginia Station was granted as a pastoral lease in the early 1960s. The original lease holder was named Thompson. No work was done on the station until the early 1970s when the lease was taken on by Kelly and Vagg.

The apparent intention was to commence dam construction, though this never eventuated. Following an unsuccessful bore being put down the lease was surrendered without any further development. The lease remained vacant until June 1984, when the Swann family made application to test drill possible dam sites to determine if future development was viable. Permission was granted and as results were promising an application was made for the lease to be made available again. The lease was granted on 30 January 1987 and jointly shared between Ruth and Eric Swann, Russell and Judy Swann, and Malcolm and Susan Sims.

Despite financial restrictions the owners proceeded with development and constructed two dams in an endeavour to get water. Along with this work a comprehensive roaded catchment system was constructed.

With the housing in Rawlinna townsite designated for demolition, the Swanns purchased the old houses and carted seven over 200 km to the homestead site on Virginia. These houses were set up to provide three homes and a couple of sheds.

Virginia had a series of above-average seasons starting in 1992. The initial dams put down into red clay with high gypsum content failed to hold water for any considerable period and were not reliable enough to initiate stocking the station.

With the good seasons dense and tall speargrass grew over most of the station fuelling a severe bushfire in January 1994. After many weeks of fire fighting all except the extreme north-western section of the station had been burnt. With continued good seasons in subsequent years the speargrass regenerated prolifically, each time dominating the regeneration of native herbage and bush. Large fires again occurred in 1995, 1996 and 1997. A notable change caused by the fires during this period was the severe reduction in the coverage of the western myall trees and the bush country associated with it. Trees burned down in one fire year were often burnt completely in the following fire season leaving no sign of having been there and killing off any regeneration. Also greatly affected and reduced was saltbush. Virginia is now one of the most fire-prone stations of the Nullarbor. One lesson learnt from the fires was the need for a system of division lines within the property to provide fire breaks as well as access to help fight fires.

With limited resources remaining for further development and family members wanting to step out of the station the owners applied to sell the lease in 1998. Virginia was sold to new partners trading as Beverly Springs Pastoral Co. In 1999 another bushfire burnt Virginia.

No more work was done on the station until Syd Pond bought the lease in 2001. In 2005 Syd Pond was joined by Russell Swann to

Transporting railway cottages from Rawlinna townsite to Virginia Station. Photo provided by R Swann

continue development work and run the station. Another eight dams were constructed, bringing the number of dams on Virginia to 11. Isolated storms put water in two dams in 2006 and the first cattle were introduced in May of that year. These were Santa–shorthorn cattle which were mated to Murray Grey bulls. Good rain in January 2007 put usable water into six dams and the cow numbers were increased to 280 head by March. Most of these cattle were Santa Gertrudis or Brahman with an infusion of Murray Grey. Seven good quality herd bulls were added, most being Murray Greys bred by Jomel Glen Stud at Toodyay.

The good rain from January 2007 was to be the last for quite a period. With dams slowly drying out, the cattle became restricted to one dam by the end of 2007. This prompted the installation of a 10 km, 2 inch pipeline off the last dam (Syd's Dam) to a new water point to spread the stock. In March 2008 the lack of water forced the destocking of the remaining cattle.

Woorlba Station

Susanne McGrath

Woorlba Station was taken up by James Galloway in 1955. Managers were employed to run the property whilst Mr Galloway managed an engineering business in Midland. In 1978 Alec Robertson purchased the station and then sold it to Doug Grewar in 1988. The title changed hands again in 2003 when James Ferguson bought the property. Greg and Cynthia Stoney acquired Woorlba in 2005.

The property is located approximately 41 km east of the Balladonia Roadhouse on the Eyre Highway and has an area of 315 000 ha.

The homestead was constructed of mainly asbestos sheeting with a corrugated iron roof. Outbuildings are predominantly tin although the fireplace wall in the shearers' quarters is rock. Like many leases in the south-west of the Nullarbor, Woorlba Station relies on rain water, though the scarcity and deteriorated condition of many dams means the lease is poorly watered.

Cattle were run successfully until 1975. Sheep were introduced thereafter when fencing of some dams and waterholes had been completed. Sheep remained until the change to the present day owners. Stocking plans for Woorlba Station involve Droughtmaster cattle.

Reference

Swann, E 2008, *Place in the west. The story of Kanandah*.

Climate

AK Gardner

The Western Nullarbor survey area falls within two bioclimatic regions (Beard 1975). The majority of the survey area is classified as desert: non-seasonal. A small proportion along the south coast is classified as semi-desert: Mediterranean. The desert region is characterised by up to 12 months 'dry' weather and more or less equal rainfall for every month of the year. The irregularity of desert rainfall means that in reality there is an equal chance of rain in any month (Figure 5a). The semi-desert is characterised by 9 to 11 months of dry weather with cool wet winters and hot dry summers. Areas nearer the coast are in this category (Figures 5b and 5c).

Beard (1975) defined 'dry' by analysing the relationship between the mean monthly rainfall and temperature. If the rainfall falls below the temperature then that month is considered dry; precipitation is considered inadequate to sustain plant growth. The number of dry months determines the bioclimatic classification. The distribution of Beard's bioclimatic regions accords well with regional vegetation maps (Beard 1990).

Figure 5a **Relationship between monthly temperature and rainfall at Rawlinna for definition of dryness**

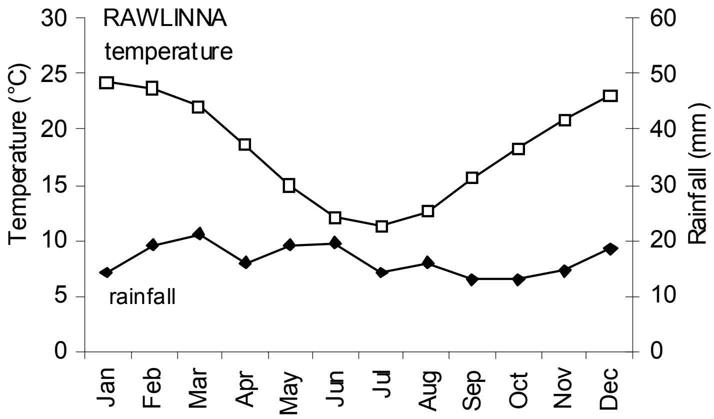


Figure 5b **Relationship between monthly temperature and rainfall at Balladonia for definition of dryness**

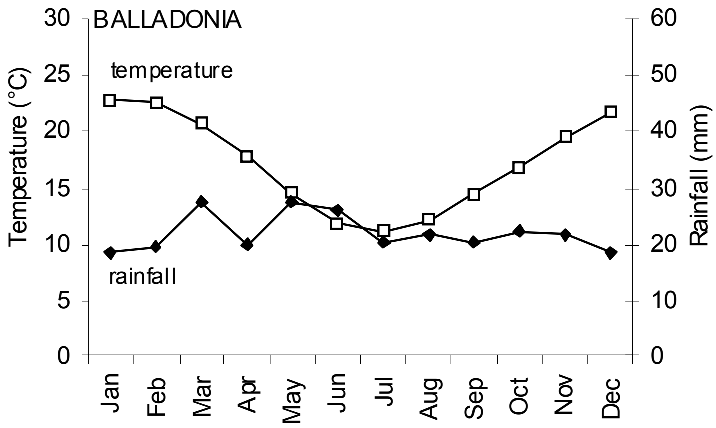
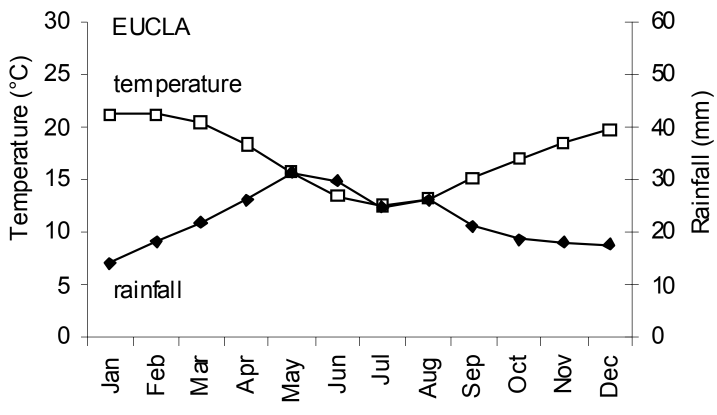


Figure 5c **Relationship between monthly temperature and rainfall at Eucla for definition of dryness**



It is the availability of moisture, together with soil characteristics, that determine plant growth. The presence of moisture is a product of the prevailing climate. The survey area often experiences extended dry periods with associated high temperatures, conditions that are not very conducive to plant growth.

In terms of climatic zones based on temperature and humidity the Bureau of Meteorology (BOM) has classified the Nullarbor Plain into two zones. The majority of the survey area is classified as hot dry summer with a cold winter. A small proportion nearer the coast is classified as warm summer with a cool winter.

Sources of climate data

The Perth office of the BOM is the principal source of weather data for stations in Western Australia. Some of their data is available in comprehensive form from their website (www.bom.gov.au).

Records of meteorological data have been kept at sites along the Trans-Australian Railway and at a number of stations for many years. Some records date back over 90 years. Not all stations record all weather attributes, as some attributes require specialist equipment and a greater commitment from the recorder. Stations that have supplied meteorological data for climate analysis of the Nullarbor are listed in Table 1 and the locations are shown in Figure 6. Figures presented in this chapter consider weather data collected until February 2007, unless otherwise stated in Table 1. Forrest previously housed the BOM Office that serviced the Western Nullarbor District. In 1995 the office was moved to Eucla to improve the amenities provided to staff. At this time an electronic recording station was installed at Forrest.

Major climatic patterns

Throughout this chapter reference will be made to seasonal analysis. The BOM defines the seasons as summer—December to February, autumn—March to May, winter—June to August, and spring—September to November.

Winter/spring patterns (June to November)

The Nullarbor climate is strongly influenced by a band of high pressure, referred to as the subtropical ridge. To the south of this subtropical ridge are moisture laden westerly winds. During winter the ridge moves north to a latitude of between 30°S and 35°S. This allows rain-bearing cold fronts carried by westerly winds to sweep over the Nullarbor (Bureau of Meteorology 2000). Rain events associated with these cold fronts are most significant if disturbances in the westerlies converge with moist, warm air masses from the north. Heavy rainfalls are received at the interface of the two air streams, though the occurrence of these rains is unreliable (Mitchell, McCarthy & Hacker 1979).

Summer/autumn patterns (December to May)

The subtropical ridge reaches its southernmost point in summer to the latitudes between 35°S and 40°S, well south of the State. This allows easterly winds to the north of the subtropical ridge to prevail across the Nullarbor region. One of the main features to influence the climate of the warmer months is the development within the easterly winds of a low pressure trough that extends from the tropics (Bureau of Meteorology 2000). The position of the trough in relation to the subtropical ridge largely determines the weather. The trough

Table 1 **Climate data recording centres used in the text**

Recording centre	Latitude (°S)	Longitude (°E)	Elevation (m)	Years meteorological data recorded	Actual years of rainfall observations	Years temperature recorded	Actual years of temperature observations
Balgair	-31.09	125.66	162	1983–present	24	1983–present	23
Balladonia	-32.46	123.87	148	1891–present	96	1901–present	77
Eucla	-31.68	128.88	93	1876–present	125	1926–present	66
Forrest	-30.84	128.11	159	1930–present	70	1940–present	61
Mundrabilla	-31.84	127.86	20	1901–present	93	1967–present	12
Rawlinna	-31.01	125.33	182	1915–2002	83	1921–1983	60

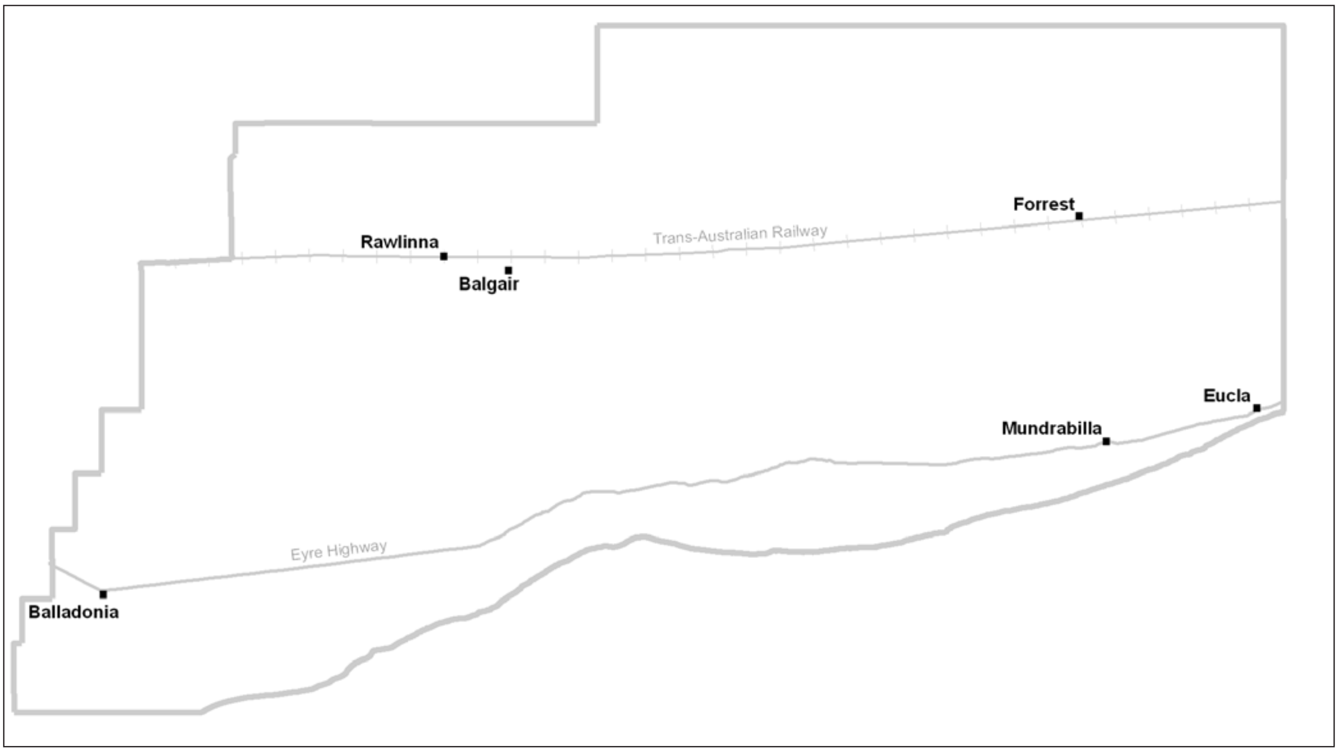


Figure 6 **Meteorological data recording centres**

tends to develop near the west coast and then moves eastwards across the State. As the trough approaches the coast it brings cool conditions influenced by westerly winds from the ocean. However, as it migrates over the landmass it creates hot and dry easterly winds. This results in an alternating pattern of hot and cool periods as the low pressure trough moves across the continent.

Summer rainfall results from the presence of rain-bearing depressions that occasionally pass through the area. The depressions are often remnants of cyclonic activity in northern Australia. These depressions bring heavy and predominantly localised showers. Such events are sporadic and difficult to predict.

Climatic factors

Rainfall

As for most of Australia a 'normal' rainfall year seldom exists within the Nullarbor. Much of the annual precipitation comes from localised heavy falls, so that rainfall may be highly variable across relatively small distances. The sporadic nature of rainfall events means that most places can expect an average rainfall over a period of longer than a year.

Within the Nullarbor survey area BOM were able to supply rainfall data for six recording stations. Of the six recording stations, five are still operating. Records for Rawlinna ceased in 2002 with 83 years of data. Of the stations still operating, all have been recording for over 90 years except Balgair Station which has records for 24 years and Forrest which has records for 70 years.

Median rainfall often provides a better indication of the yearly rainfall than the mean (or average). The median is the middle value in a set of numbers arranged in increasing order. The mean is the arithmetic average of a number set. In calculating the mean annual rainfall for an arid environment a greater proportion of years will be below the mean with only a few years experiencing heavy falls, inflating the mean value. Therefore the median is a better indicator as it is not influenced by extreme rainfall events. Typically the median annual rainfall in the Nullarbor is 10 mm lower then the mean annual rainfall. The mean and median rainfall for the Nullarbor is presented in Table 2.

There are marked differences between coastal and inland areas in terms of average annual rainfall. The majority of the survey area is located inland and experiences very low and erratic rainfall. Along the coastal belt the extremes of aridity are modified by oceanic influences. The median annual rainfall declines northward with increasing distance from the ocean. Eucla, located about a kilometre from

Table 2 **Summary of monthly rainfall data for selected sites**

Balgair	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean monthly rainfall (mm)	21	29	28	20	24	25	17	19	17	16	23	35	274
Median (5th decile) monthly rainfall (mm)	11	18	15	17	22	22	16	15	15	11	14	22	270
Highest monthly rainfall (mm)	102	131	100	60	80	93	43	55	61	50	77	168	
Mean number of rain days	4	5	6	5	7	7	7	6	6	4	5	6	68
Balladonia	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean monthly rainfall (mm)	18	19	27	20	27	26	20	22	20	22	22	18	261
Median (5th decile) monthly rainfall (mm)	10	10	13	16	22	22	18	18	17	14	14	11	234
Highest monthly rainfall (mm)	140	199	168	97	97	125	66	67	90	145	110	96	
Mean number of rain days	3	3	5	5	7	8	8	8	6	5	4	4	66
Eucla	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean monthly rainfall (mm)	15	18	22	26	31	30	25	26	21	19	18	18	269
Median (5th decile) monthly rainfall (mm)	6	9	12	20	28	24	22	21	15	15	14	9	260
Highest monthly rainfall (mm)	121	182	127	205	104	155	83	111	85	74	114	149	
Mean number of rain days	3	4	6	8	10	10	10	10	8	7	6	5	87
Forrest	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean monthly rainfall (mm)	15	17	16	17	15	17	14	16	14	17	15	16	189
Median (5th decile) monthly rainfall (mm)	5	7	7	9	12	10	11	10	10	11	11	12	178
Highest monthly rainfall (mm)	142	143	116	98	73	94	73	80	52	86	64	109	
Mean number of rain days	3	3	4	5	6	7	7	6	5	5	4	4	59
Mundrabilla	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean monthly rainfall (mm)	15	18	18	21	26	25	22	23	18	19	15	18	238
Median (5th decile) monthly rainfall (mm)	7	7	9	12	23	20	19	19	14	13	11	11	227
Highest monthly rainfall (mm)	147	163	151	175	90	111	77	114	64	105	78	165	
Mean number of rain days	2	3	4	5	8	8	7	7	5	4	3	3	59
Rawlinna	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean monthly rainfall (mm)	14	19	21	16	19	20	14	16	13	13	15	19	199
Median (5th decile) monthly rainfall (mm)	6	7	13	8	16	16	10	11	8	9	9	11	189
Highest monthly rainfall (mm)	210	123	104	114	81	131	59	155	85	64	93	137	
Mean number of rain days	3	3	3	3	5	5	5	5	4	3	3	3	45

the shoreline, receives 260 mm of median annual rainfall while Mundrabilla 10 km further inland receives 230 mm. Further to the north, Forrest and Rawlinna receive approximately 180 mm of rain per annum.

In the coastal region, rain falls predominantly in winter and spring, with the chance of rain during these months more reliable then summer. Further inland, rainfall is distributed more uniformly throughout the year (Figures 7 and 8). With increasing distance from the coast the number of days on which rain is recorded decreases at a greater rate than the volume of received. The volume of rain received in a single event is greater on average to the north, however the volume of rain received across an entire year is greater towards the coast. Figure 9 displays annual averages of rainfall isohyets across the survey area from the period 1889–2005.

Much of the winter rainfall is associated with north-west cloud bands. They stretch from the north-west of Australia to the east coast and are narrow in width, typically 5° of longitude wide. Rainfalls occur in areas traversed by the band. North-west cloud band activity peaks during late autumn to early winter (Colls & Whitaker 1995). Winter rain is also received as a result of cold fronts carried by westerly winds (White, Tupper & Mavi 1999). Summer rain events result from thunderstorms or deep rain depressions derived from tropical cyclones. Such events may only take place two or three times per decade (Bureau of Meteorology 2000).

Flooding is infrequent across the Nullarbor as rainfall is low and there are no river systems. Flooding usually takes place from January to March caused by tropical lows often associated with cyclonic activity.

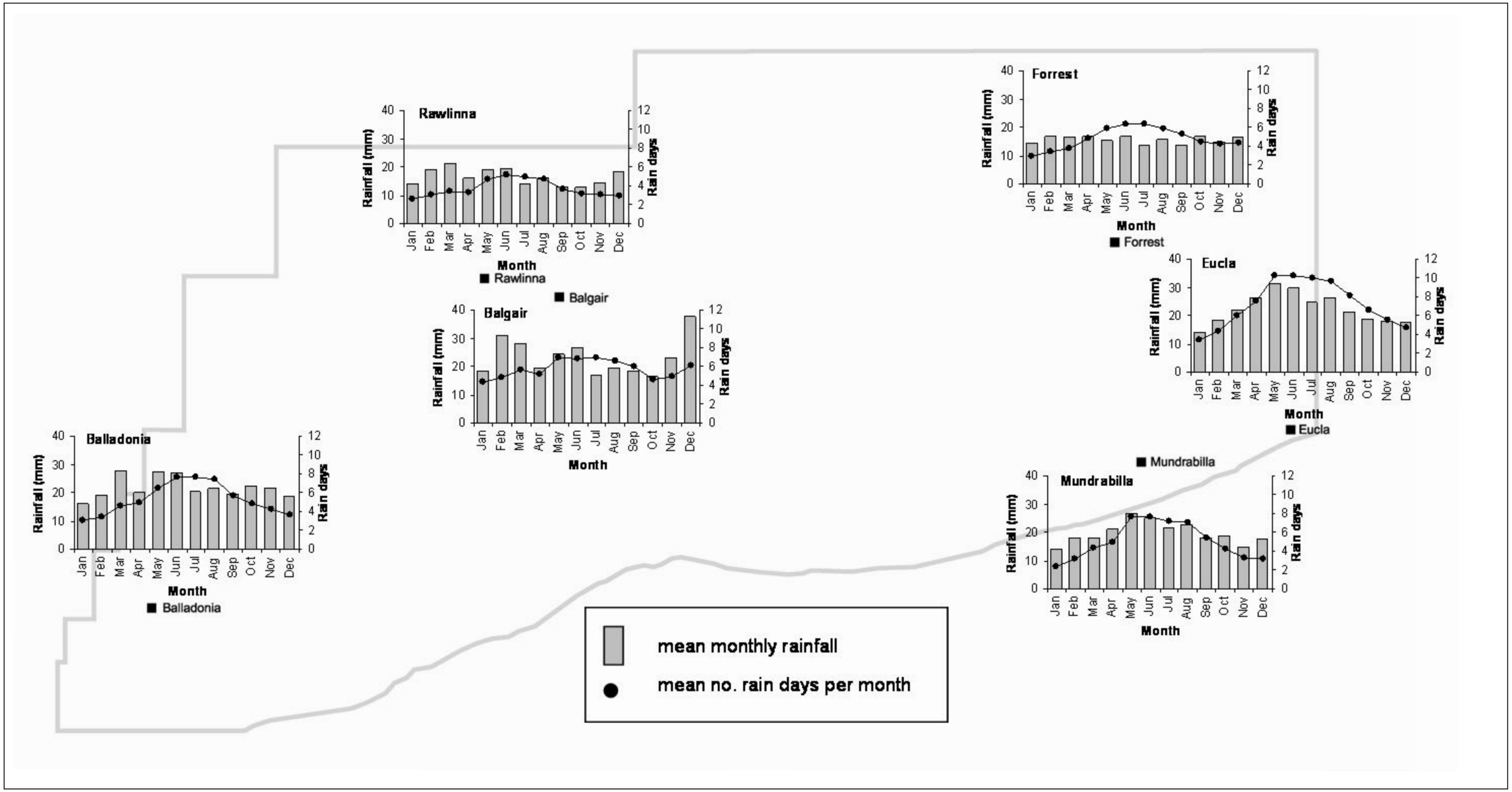


Figure 7 **Mean monthly rainfall and number of rain days**

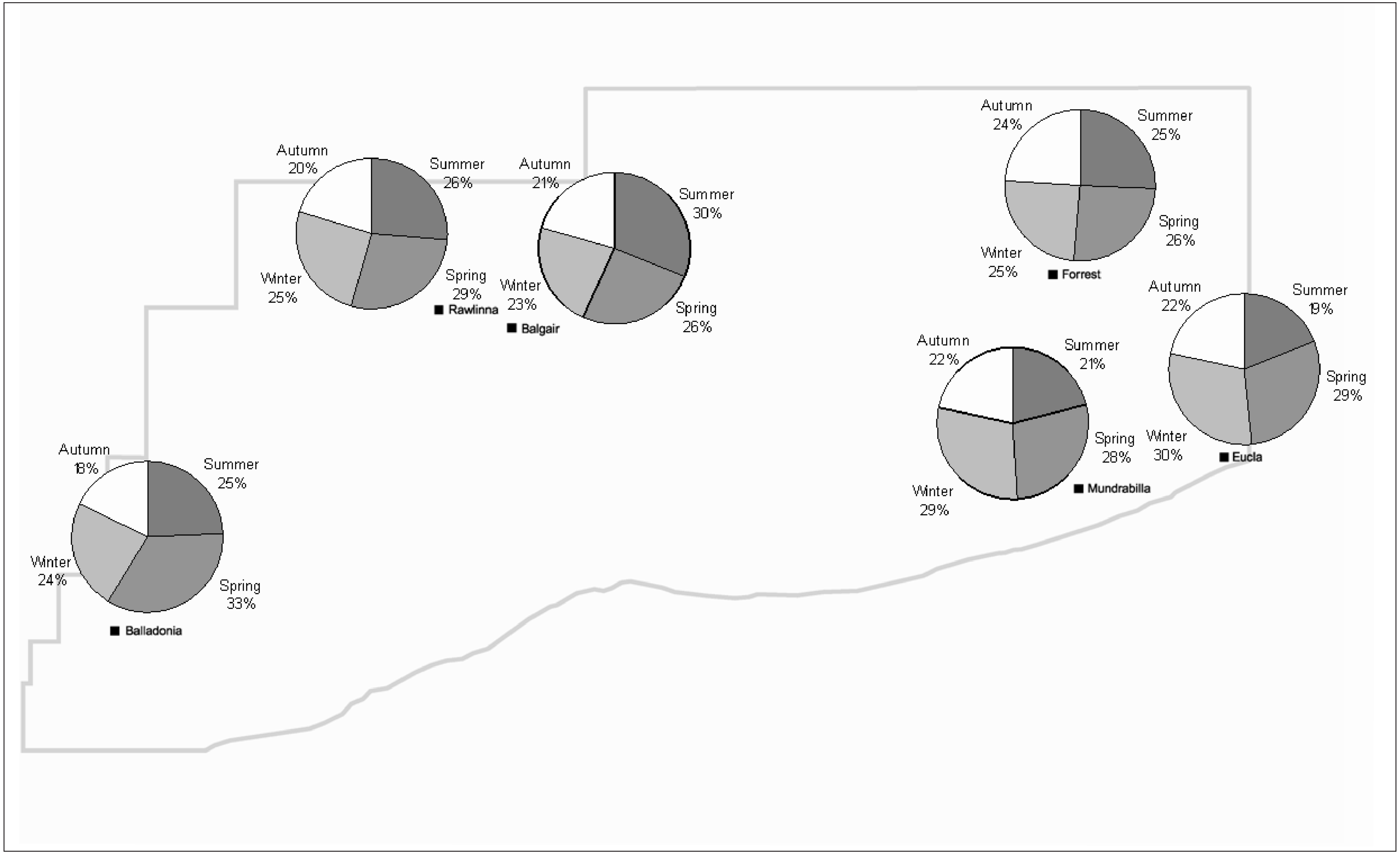


Figure 8 **Proportions of seasonal rainfall**

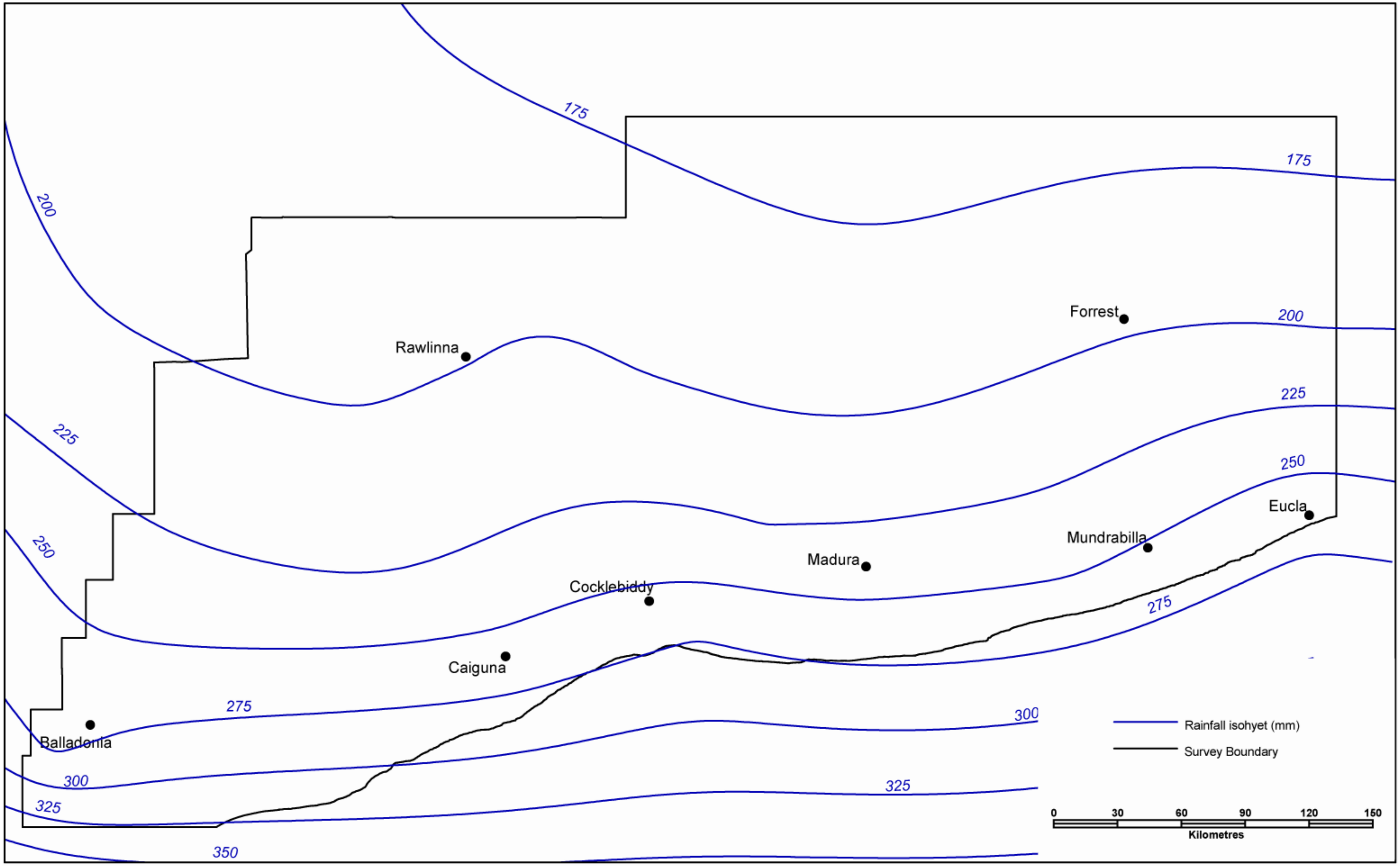


Figure 9 **Annual average rainfall isohyets across the survey area from 1889 to 2005**

In January 1995 Tropical Cyclone Bobby weakened to a rain-bearing depression as it reached the Goldfields dumping large volumes of rain. The resulting run-off filled Lake Boonderoo for the first time since 1975. Tropical Cyclone Vance also caused heavy rainfalls as it passed across the Nullarbor and into the Great Australian Bight as a Category 1 cyclone on 24 March 1999. The resulting floodwaters cut traffic movement on the Eyre Highway and Trans-Australian Railway (Bureau of Meteorology 1999).

Thunderstorms can also produce intense rainfalls in short periods that result in localised flash floods. Localised rainfalls of over 150 mm in early January 2006 resulted in flash flooding across Kybo Station and damaged sections of the railway track near Nurina siding (Bureau of Meteorology 2006).

Drought

The term 'drought' is widely used to describe periods of decreased rainfall. As early as the 1890s drought has been considered a natural characteristic of Australia's variable and changing climate (Hennessy et al. 2008). As the Nullarbor receives on average less than 250 mm per year and loses more water through evaporation than it gains through rainfall it is technically considered a desert. Periods of low rainfall, high temperatures and high evaporation frequently occur and natural pastures and herbage are adapted to such stresses (Reynolds, Watson & Collins 1983).

For a period of low rainfall to be considered a drought by BOM the level of rain received must be within the lowest 10 per cent on record for the specified period of usually three months or longer. However, within arid zones drought should be considered across periods of a year or longer. A severe rainfall deficiency is defined by rainfall during a specified period being within the lowest 5 per cent of recorded rainfalls for the area and a serious rainfall deficiency within the lowest 10 per cent (Reynolds, Watson & Collins 1983). In Figure 10 those years in which the volume of rainfall is less than the dashed line had a serious rainfall deficiency and those that fall below the solid line had a severe rainfall deficiency. As illustrated by the graphs not all areas within the Nullarbor experience serious or severe rainfall deficiencies at the same time. The only years in which all three weather stations recorded a severe or serious deficiency in rainfall were 1928 and 1940.

The Normalised Difference Vegetation Index (NDVI) is closely related to the amount of green vegetation cover and has been widely adopted as a measure of green vegetation in many global monitoring projects (Tucker & Sellers 1986; Cridland et al. 1998). Amongst other uses NDVI is being used to help assess the severity of, and spatial extent of droughts (Cridland et al. 1996). Based on NDVI values the seasonal conditions for some Western Australian Nullarbor pastoral leases were considered to be in drought from 2002 continuing into the survey period in 2006–2007.

The drought risk map (Figure 11) displays the susceptibility of the survey area to drought. The categories are calculated from the percentile variations of the average annual rainfall (Colls & Whitaker 1995). As much of the survey area has a drought risk index of moderate to severe it must be acknowledged that extended dry periods will continue to be a prominent feature of the Nullarbor climate. Climate change scenarios predict reduced annual rainfall averages resulting in fewer exceptionally wet years and an increase in the frequency of exceptionally hot and dry years (Hennessy et al. 2008). Pastoralists must adopt management strategies that will minimise the economic, environmental and social impacts of extended dry periods in the future (Reynolds, Watson & Collins 1983).

Temperature

Across the survey area temperature and rainfall have been recorded at the same six weather stations (Table 1). The availability and installation of thermometers and recording equipment means that fewer stations have routinely recorded temperature over as long a period as rainfall. Balladonia has the greatest length of records at 77 years and Mundrabilla the shortest with only 12 years of data.

A marked increase in maximum summer temperatures takes place with increasing distance from the coast (Figure 12). Eucla, situated only a kilometre from the coast, has a maximum average daily temperature over the three months of summer of only 25.4°C that drops by an average of 9°C to reach the average daily minimum. Further inland,

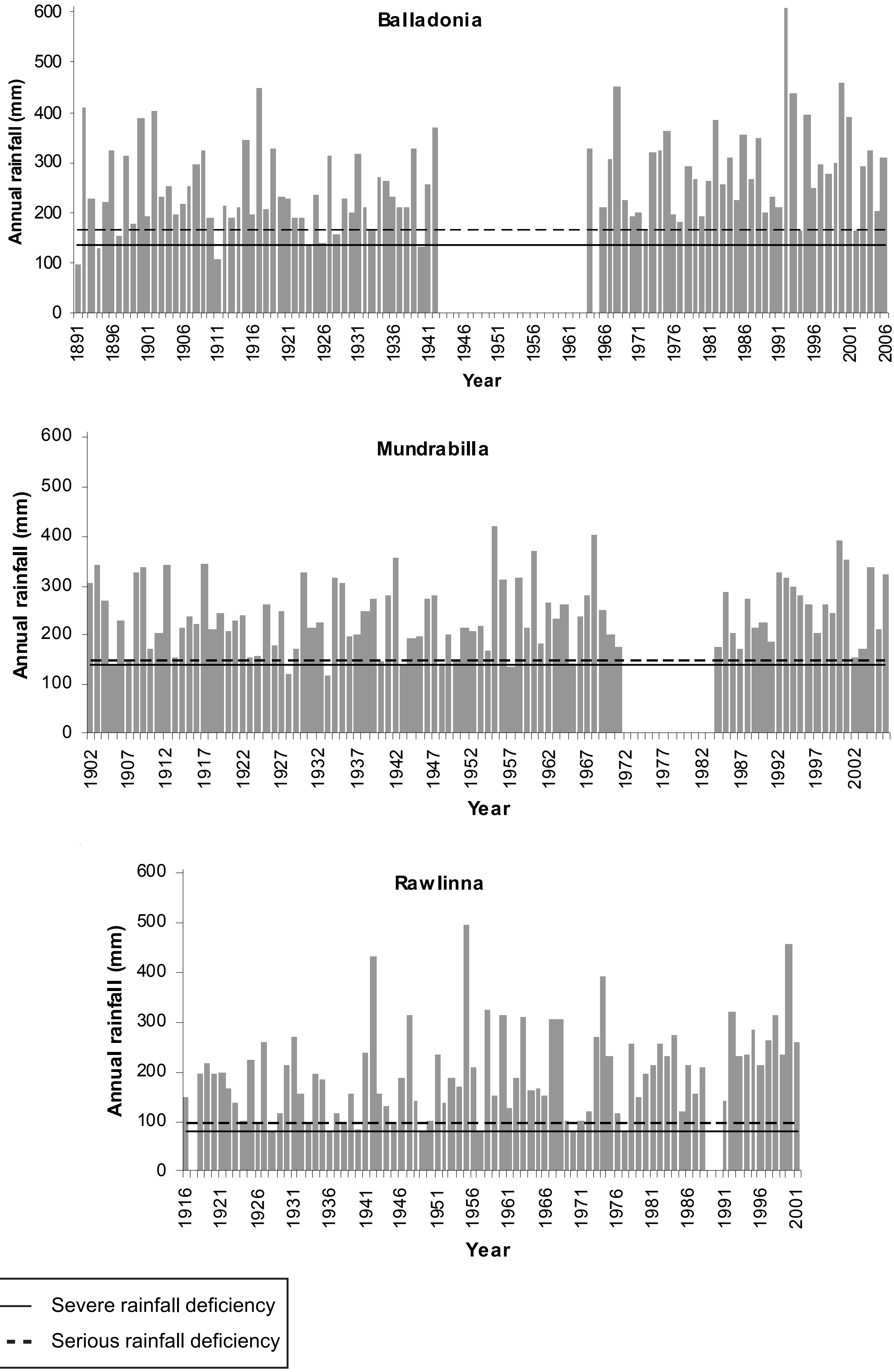


Figure 10 **Annual rainfall and years of serious and severe rainfall deficiencies**

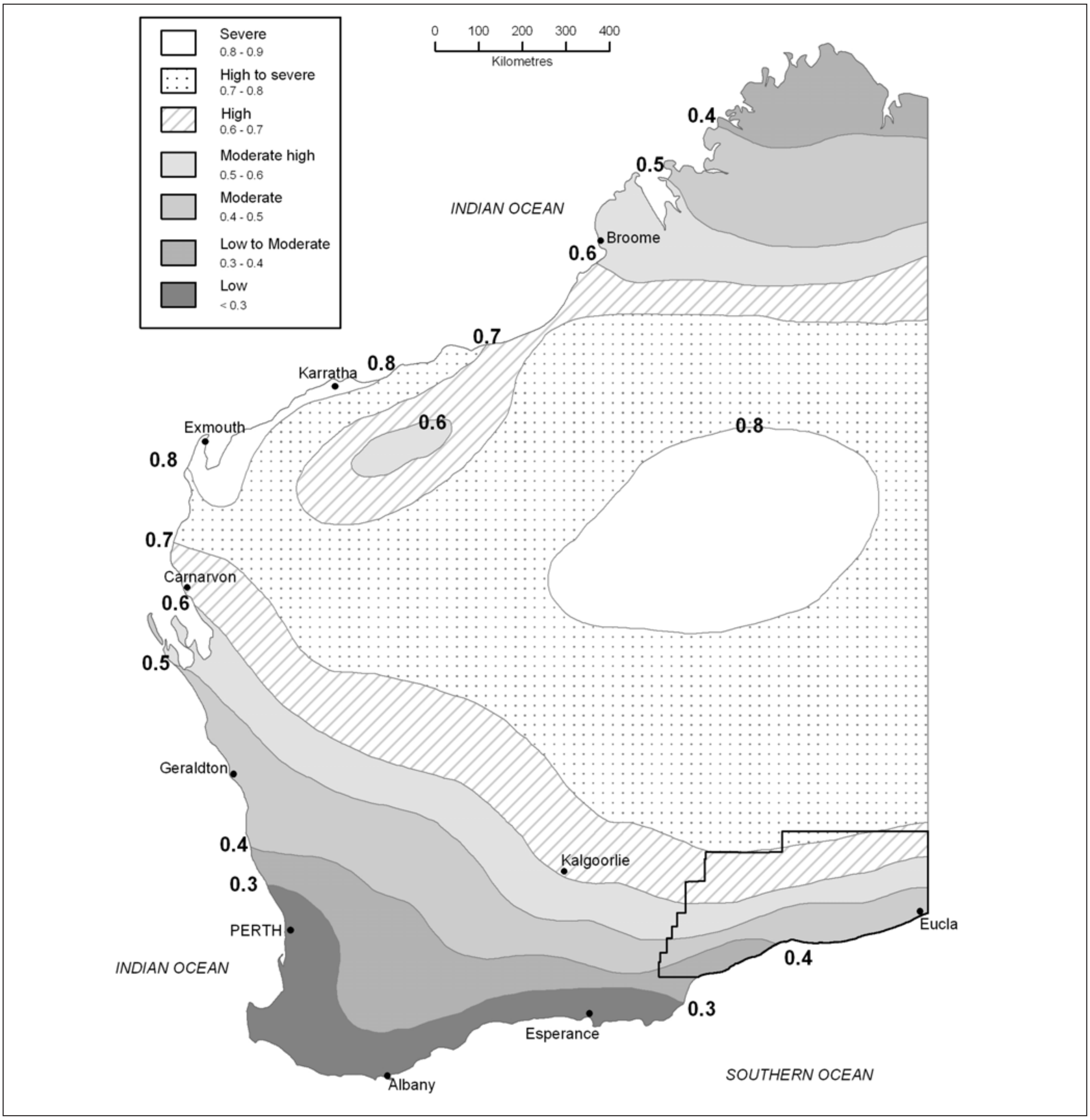


Figure 11 **Drought risk index in Western Australia based on percentiles of annual rainfall (after Colls & Whitaker 1995)**

Rawlinna has a maximum daily temperature of 32.2°C that drops by an average of 17°C to reach the average daily minimum.

Over the three months of summer Rawlinna averages 58.2 days where the temperature exceeds 30°C, whilst Eucla averages 17.6 days (Table 3). Throughout the Nullarbor region January is the hottest month. The highest maximum recorded in the area was 49.8°C at Mundrabilla Station on 3 January 1979.

There is little variation across the study area in the maximum and minimum daily temperature for the three month period of winter (Figure 12). The average maximum daily temperature ranges from 18 to 20°C across the survey area, being greatest at Mundrabilla (19.9°C) and lowest at Balladonia (18.1°C). The minimum varies from 5 to 8°C, being greatest at Mundrabilla and Eucla (7.6°C) and lowest at Forrest (5.1°C).

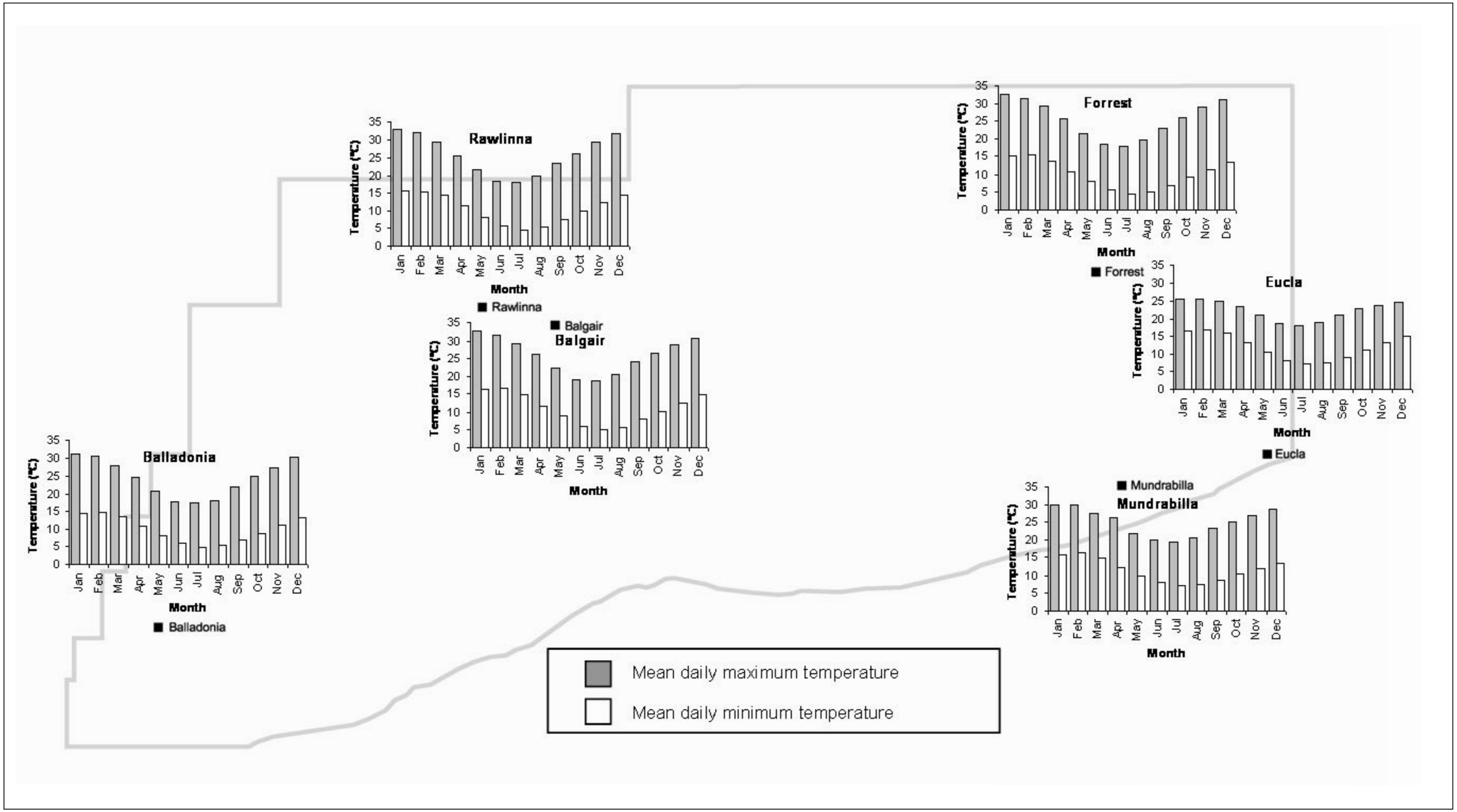


Figure 12 **Mean monthly maximum and minimum daily temperatures**

Table 3 **Summary of monthly temperature data for recording sites**

Balgair	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp. (°C)	33	32	29	26	22	19	19	21	24	27	29	31
Mean daily minimum temp (°C)	16	17	15	12	9	6	5	6	8	11	13	15
Mean number of days temp. > 30°C	21	16	13	7	1	0	0	1	4	8	12	17
Mean number of days temp. < 2°C	0	0	0	0	1	4	6	4	1	0	0	0
Mean daily 9 am relative humidity	50	55	58	61	68	71	70	59	53	47	47	49
Mean daily 3 pm relative humidity	29	34	36	39	43	47	47	37	32	29	30	31
Balladonia	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp. (°C)	31	31	28	25	21	18	17	19	22	25	28	30
Mean daily minimum temp. (°C)	14	15	14	11	8	6	5	5	7	9	11	13
Mean number of days temp. > 30°C	17	14	10	5	1	0	0	0	2	6	10	14
Mean number of days temp. < 2°C	0	0	0	0	1	4	6	5	2	0	0	0
Mean daily 9 am relative humidity	56	60	61	67	71	74	72	67	58	54	53	62
Mean daily 3 pm relative humidity	38	41	42	47	51	53	52	47	43	39	40	38
Eucla	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp. (°C)	26	26	25	24	21	19	18	19	21	23	24	25
Mean daily minimum temp. (°C)	17	17	16	13	11	8	7	8	9	11	13	15
Mean number of days temp. > 30°C	6	5	6	5	1	0	0	1	3	6	6	6
Mean number of days temp. < 2°C	0	0	0	0	0	0	1	1	0	0	0	0
Mean daily 9 am relative humidity	63	65	65	64	67	70	71	65	60	56	58	61
Mean daily 3 pm relative humidity	65	65	65	62	60	59	59	57	57	59	61	63
Forrest	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp. (°C)	33	31	29	26	22	19	18	20	23	26	29	31
Mean daily minimum temp. (°C)	15	16	14	11	8	6	5	5	7	10	12	14
Mean number of days temp. > 30°C	20	16	13	6	1	0	1	1	3	8	12	16
Mean number of days temp. < 2°C	0	0	0	0	1	5	8	5	2	0	0	0
Mean daily 9 am relative humidity	46	52	54	57	64	69	67	60	51	45	43	45
Mean daily 3 pm relative humidity	28	32	33	37	42	46	44	37	32	29	27	29
Mundrabilla	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp. (°C)	30	30	28	26	22	20	19	21	23	25	27	29
Mean daily minimum temp. (°C)	16	16	15	12	10	8	7	7	8	11	12	14
Mean number of days temp. > 30°C	10	9	8	6	2	0	0	1	3	7	9	10
Mean number of days temp. < 2°C	0	0	0	0	0	1	1	1	1	0	0	0
Mean daily 9 am relative humidity	52	56	58	59	65	66	64	61	54	48	47	47
Mean daily 3 pm relative humidity	52	54	55	52	52	52	50	48	48	45	46	47
Rawlinna	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp. (°C)	33	32	30	26	22	19	18	20	24	26	30	32
Mean daily minimum temp. (°C)	16	16	14	12	8	6	5	5	8	10	12	14
Mean number of days temp. > 30°C	22	17	14	8	1	0	0	1	3	9	14	19
Mean number of days temp. < 2°C	0	0	0	0	1	3	7	4	1	0	0	0
Mean daily 9 am relative humidity	47	55	57	61	65	71	69	61	52	46	43	43
Mean daily 3 pm relative humidity	28	34	36	43	47	51	49	41	35	30	27	27

July is the coldest month. Though mean temperatures across the survey area vary little, further inland experiences a greater number of days at lower minimums than further south. Forrest experiences an average of 17.8 days when the temperature drops below 2°C, whilst Eucla experiences only 1.5 days (Table 3). The lowest minimum to be recorded in the survey area was -5°C at Balgair on 15 June 2006.

Frost occurs as a result of water vapour condensing onto surfaces where the temperature is below freezing. Balladonia has the most days of frost, experiencing an average 14 days a year; Eucla has the least at 1.3 days.

The variation in temperature between summer and winter is lowest at Eucla adjacent to the coast where the maximum varies between the two seasons by about 7°C. Further inland it varies by 12–13°C. The variation in the average minimum between summer and winter temperatures varies by 9–10°C. Autumn and spring temperatures fall evenly between the extremes of summer and winter.

Dew and fog

The dew point is the air temperature at which water vapour starts to condense from the air (Bureau of Meteorology 2000). Within the survey area the dew point for the winter months decreases further inland. At Mundrabilla and Eucla near the coast both the 9 am and 3 pm average dew point is about 7°C. Further north at Forrest, Balgair and Rawlinna the average dew point for 9 am is about 5.5°C and the average dew point for 3 pm is about 4.5°C.

At Mundrabilla and Eucla the average minimum temperature in winter is only half a degree above the average dew point. This means there is a high likelihood of dew occurring. Further inland the mean minimum temperature is consistently below the dew point, indicating that dew is common. Dew can be of significant benefit for plant growth in arid environments.

The 9 am and 3 pm average dew points for the summer months at Eucla and Mundrabilla are approximately 13°C. Further inland at Forrest, Balgair and Rawlinna the 9 am dew point is around 11°C dropping to 9°C at 3 pm. The difference between the average dew point and the average minimum temperature is about 2°C nearer the coast and ranges from about 4°C to 7°C further inland. Dew is therefore less likely to occur during the summer months.

If the dew point and air temperature are similar in the late afternoon, as the air cools during the night, fog is likely to develop. Balgair has the greatest number of days with fog, averaging 8.9 days per year and Eucla the least with 5.4 days. Fog events are most likely during May and August.

Relative humidity

Relative humidity expresses the amount of moisture in the air at a given time, compared to the amount of moisture that would be in the air if the air was saturated at the same temperature (Bureau of Meteorology 1971).

Relative humidity is inversely proportional to temperature. Therefore the relative humidity will be greater when the temperature is at a minimum around dawn, and least when the temperature is higher in the afternoon. The 9 am relative humidity varies little between the coast and areas further inland. During the summer months humidity is lowest and ranges from 43 to 57 per cent, whilst in winter it varies from 65 to 73 per cent (Table 3).

Inland the drop in relative humidity from 9 am to 3 pm ranges from 16 to 25 per cent throughout the year, the large drop is due to the higher temperatures during the afternoon in the north. Closer to the coast the drop in relative humidity from 9 am to 3 pm is greater in the winter months at about 13 per cent, whilst during the summer months it varies by only 1 or 2 per cent (Table 3). In the summer the moist air associated with the afternoon sea breeze offsets any decrease in relative humidity resulting from an increase in temperature during the afternoon.

Evaporation

Evaporation is the most important factor contributing to water loss in arid Australia, with the rate of evaporation far exceeding the amount of rainfall. Rainfall in the Nullarbor seldom exceeds 200 mm a year, while annual evaporation exceeds 1500 mm, which is 7.5 times the volume of rainfall. Evaporation ranges across the survey area from 1760 mm at Balladonia to 2870 mm at Balgair.

Evaporation is greater inland throughout the year than along the coast. The difference is more pronounced during the summer months when inland areas experience higher temperatures, decreased cloud cover and lower relative

humidity than coastal areas. During the summer daily evaporation rates range from 7 mm along the coast to 11 mm further inland. The difference between coastal and inland areas is less evident during winter with a rate of about 3 mm per day of evaporation.

Sunshine and cloud

On average the Nullarbor receives more than 8 hours a day of sunshine. The number of daily sunshine hours is at a minimum in June with only 5 to 6 hours and at a maximum in December when the area receives 10 hours of sunshine.

The number of clear days indicates the number of days that are free from cloud, fog or mist. The number of clear days increases with distance inland from the coast. Eucla experiences 97 clear days per year whilst Rawlinna to the north receives 148 clear days. In winter cloud cover increases during the day, with a greater fluctuation in cloud cover occurring further inland than along the coast. During the hotter months there is a decrease in cloud cover during the afternoon (Bureau of Meteorology 2000).

Prevailing winds

In summer winds are generally from the north-east to south-east. During the afternoon further inland there is a slight shift in wind direction from northerly to more southerly. Towards the coast a south-easterly sea breeze commonly develops in the afternoon (Bureau of Meteorology 1971). Winds associated with the sea breeze can be strong, with nearly 50 per cent of wind speeds recorded at 3 pm at Eucla from November to February being greater than 21 km/h (Figure 13).

In winter months winds are generally west to north-west in the mornings, influenced by a greater cooling of the air over the land during the night, than of the air over the ocean (Bureau of Meteorology 2000). The wind direction becomes more southerly during the day. At Eucla approximately half of the winds at 9 am are from the north to north-west, but by 3 pm less than 30 per cent of winds are from this direction as winds become more southerly (Figure 14). Winds are generally weaker during winter, with only 30 per cent of wind speeds recorded at 3 pm at Eucla being greater than 21 km/h.

Climate change

Various organisations and intergovernmental panels (i.e. Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Intergovernmental Panel on Climate Change (IPCC), Indian Ocean Climate Initiative (IOCI)) have been reviewing scientific studies regarding atmospheric change since 1988 and evidence for global warming is scientifically supported (IOCI 2002; IPCC 2007; CSIRO & BOM 2007; Garnaut 2008; Hennessy et al. 2008). The IPCC defines 'climate change' as a change in the state of the climate that can be identified by changes in the mean (and/or the variability), and that persists for an extended period, typically decades or longer (CSIRO & BOM 2007).

In the south-west of Western Australia winter rainfall has substantially decreased since the mid-20th century (IOCI 2002). The IOCI (2002) predict due to natural climate variability the climate of the south-west will continue to exhibit wet and dry periods, though this will be influenced by changes expected from enhanced greenhouse conditions such as continued warming coupled with the probability of a decrease in winter rainfall. This may have implications for Nullarbor production systems that are largely dependent on favourable winter conditions.

Strong winds can wreak havoc on infrastructure exposed out on the open Nullarbor Plain. This mill was damaged by a severe cold frontal wind gust that collapsed the fan onto the mill tower at high speed, the momentum bending the mill tower onto itself.

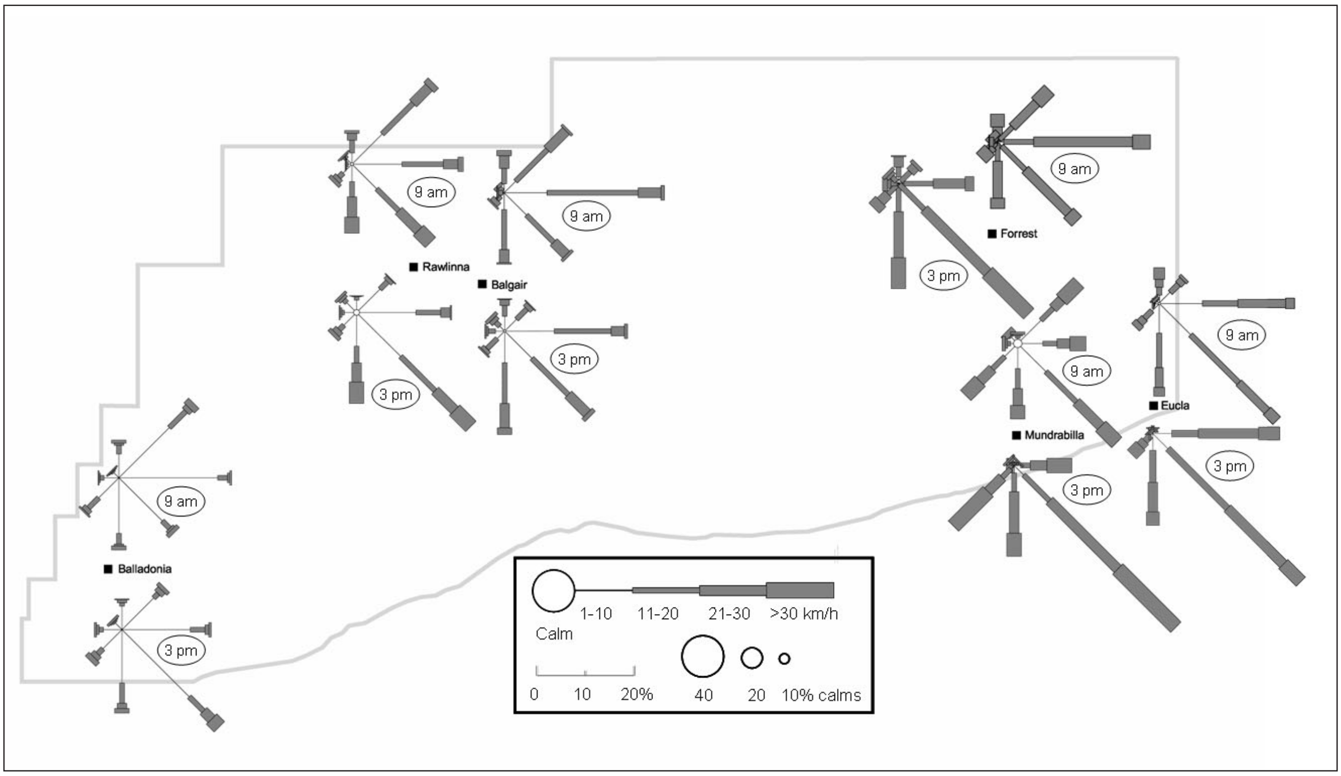


Figure 13 **Summer wind roses for 9 am and 3 pm**

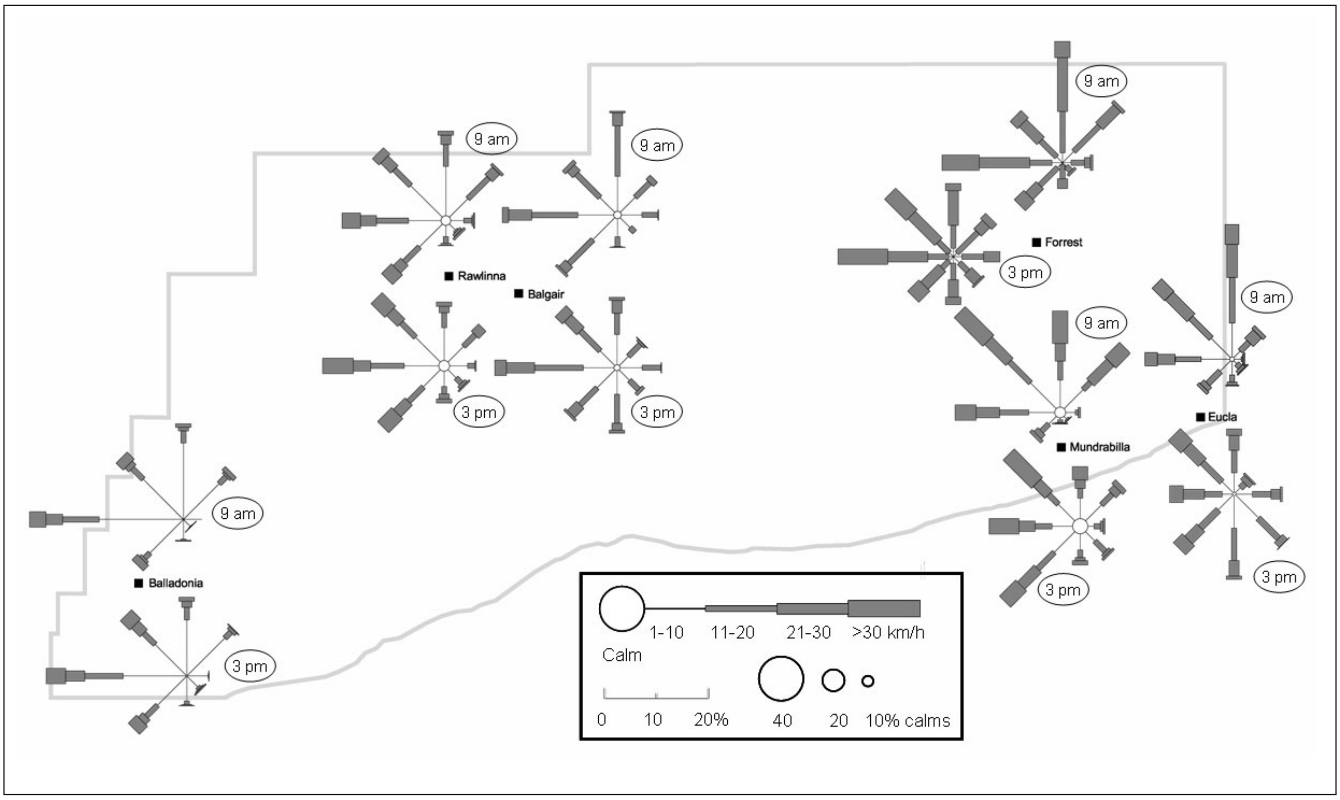


Figure 14 **Winter wind roses for 9 am and 3 pm**

Regional climate projections for the next 20 to 30 years based on simulations using mid-range emission scenarios indicate that across Australia the climate is expected to become warmer and drier. In comparison to 1990, median estimates for 2030 indicate approximately 1°C of warming with temperatures increasing further inland, rainfall to decrease by 3 to 5 per cent with expected larger decreases in the central and south-western areas, and potential evaporation to increase by 2 to 4 per cent (Hennessy et al. 2008).

Hennessy et al. (2008) provide climate change scenarios for Australia, dividing the continent into seven regions, with the physiographic regions associated with the Nullarbor Plain Province occurring within the south-west region. Hennessy et al. (2008) predict the frequency and areal extent of exceptionally hot years and exceptionally dry years are likely to increase in the future. The mean projections indicate that:

- by 2010–2040, exceptionally hot years are likely to affect about 70 per cent of the region, and occur every 1.5 years on average. Simulations based on 1900–2007 figures show about 4.5 per cent of the region had exceptionally hot years. Climatic scenarios for 2010–2040 indicate a mean area increase to 60–80 per cent, with a low scenario of 40–60 per cent and a high scenario of 80–95 per cent. Over recent decades the intensity and frequency of exceptionally hot years have been increasing rapidly and this trend is expected to continue in the future
- by 2010–2040, exceptionally low rainfall years are likely to affect about 8 per cent of the region and occur about once every 14 years on average. Observed and simulated data for 1900–2007 show that previously about 5.5 per cent of the region had exceptionally low rainfall. The projections of reduced annual rainfall averages are likely to result in more exceptionally dry years and fewer exceptionally wet years
- by 2030, exceptionally low soil moisture years are likely to affect about 9 per cent of the region and occur about once every 12 years on average.

The above scenarios are not a forecast; rather they should be considered as a description of possible future climate, based on the best available information.

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Geology

PA Waddell

Introduction

The survey area is confined to the western Nullarbor pastoral district and the Unallocated Crown Land east to the South Australian border. There are twenty pastoral leases presently operating within the western portion of the Nullarbor Plain Province, primarily grazing sheep and cattle. Five roadhouse settlements operate on the Western Australian section of the Eyre Highway (Balladonia, Caiguna, Cocklebiddy, Madura and Eucla). One small scale limestone mining operation is operating north of the Trans-Australian Railway line near Rawlinna rail siding.

The availability of groundwater is extremely important for roadhouse, mining and community water supplies. The pastoral industry depends on groundwater and surface water for sheep and cattle.

This section of the report outlines the geology of the western Nullarbor region.

Previous investigations

A comprehensive description of the geology of the Eucla Basin can be obtained from Bulletin 122 published by the Geological Survey of Western Australia (Lowry 1970). Individual 1:250 000 maps and geological explanatory notes of areas within and immediately adjacent to the Eucla Basin have also been produced by the Geological Survey of Western Australia. The geological map sheets and Explanatory Notes include: Balladonia, Culver, Cundeelee, Eucla–Noonaera, Forrest, Loongana, Madura–Burnabbie, Naretha, Seemore and Zanthus.

Early explorers and surveyors—Matthew Flinders, Edward Eyre, Edmund Delisser and John Forrest gave initial descriptions of the coastal and interior topography of the Eucla Basin. The first descriptive study of the geology and physiography of the area was by Ralph Tate (1879). Soon afterwards the Mines Departments of Western Australia and South Australia released reports on the area and planning for the Trans-Australian Railway line encouraged additional work. Subsequent surveys were primarily concerned with speleological interests (King 1950; Thomson 1950; Jennings 1961, 1963, 1967a, 1967b).

Lowry (1970) provided the first in-depth geological survey of the western two-thirds of the Nullarbor karst and Eucla Basin. Lowry and Jennings (1974) combined geological and geomorphological knowledge to produce a comprehensive description of the attributes characterising the Nullarbor karst.

Physiography

The survey area is situated largely within the physiographic division of the Western Australian portion of the Eucla Basin (Jutson 1950). The majority of the survey area lies within the Nullarbor Plain Province of Jennings and Mabbutt (1977). The westernmost margin of the survey area extends into the Coonana–Ragged Plateau of the Yilgarn Plateau Province. Figure 24 in the geomorphology chapter shows the physiographic regions of the Nullarbor after Jennings and Mabbutt (1977).

The margins correspond with the distribution of sedimentary rocks deposited during the Cretaceous Period. Lowry (1970) identified five main physiographic units: the Bunda Plateau, a scarp (comprising the Wylie Scarp, Baxter Cliffs and Hampton Range), two coastal plains (Israelite Plain and the Roe Plains) and the continental Eucla Shelf, which is not dealt with in this report. Reference to the Nullarbor region includes the onshore Eucla Basin, the Bunda Plateau, the extensive Nullarbor karst, the Nullarbor Plain and associated coastal sections.

Bunda Plateau

Near-horizontal Cainozoic limestones form a vast gently undulating plain, the Bunda Plateau. At about 240 m above sea level in the north-west, the plateau slopes gently southwards terminating at southern sea-cliffs and escarpments. Including the South Australian portion the entire karst region is approximately 250 000 km^2 in area. Only fragments of co-ordinated surface drainage are discernible on the plain. Lowry (1970) explained the perpetuation of the flatness of this uplifted sea floor as the result of extreme regularity in weathering and minimal tectonic activity. The combination of prevailing arid climatic conditions and the high degree of rock solubility of the surface limestones has resulted in uniform weathering across the plateau. However Webb and James (2006) state that the relative lack of surface karst features and the uniform downwasting is

primarily a result of the plain's flat geomorphology. Whilst the onset of aridity restricts karst development through reduced rainfall and high evaporation rates it also causes surface limestones to become indurated by concretisation increasing their resistance to solutional and erosional processes. Surface limestones have been eroded by as much as 30 to 60 m from the southern edge and up to 30 m from the plateau centre (Lowry 1970). The effect of increased rainfall in the southern margins of the plateau has increased solutional and erosional processes progressively towards the south (Lowry & Jennings 1974).

The Bunda Plateau is vast and featureless. Erosion features normally associated with limestone country, such as solution sculptured pits and rock-holes in outcrops, sinkholes, dolines, underground drainage and caves, are scarce in proportion to the total area of the region (Jennings 1963, 1967a, 1967b; Lowry & Jennings 1974; Webb & James 2006). The majority of solution features occur in the southern portions of the plateau where rainfall has usually been higher than further inland. Despite having a long history, this karst region is considered to have remained geomorphically immature, due to a lack of water available to initiate greater solution sculpturing (Jennings 1967a, 1967b). Lowry (1970) supported Jennings (1967b) conclusion that the climate of the area has *never been much more humid than at present for long periods since it emerged from the Miocene sea.* Webb and James (2006) propose that *climate only had a minor role in restricting karst development*, and it is more probable the Nullarbor karst did not develop extensive surface or underground features *due to the flatness of the plain and the particular characteristics of the limestones (primary porosity, lack of jointing and inception horizons).*

Lowry (1970) further divided the Bunda Plateau into physiographic regions based on differences in geological history, topography, soil, vegetation and climate (Figure 15).

Nullarbor Plain

The term 'Nullarbor Plain' is commonly misused when referring to the whole of the Bunda Plateau. The original (Delisser 1867) and true region of the Nullarbor Plain is restricted to the treeless part of the limestone karst in the centre of the Bunda Plateau.

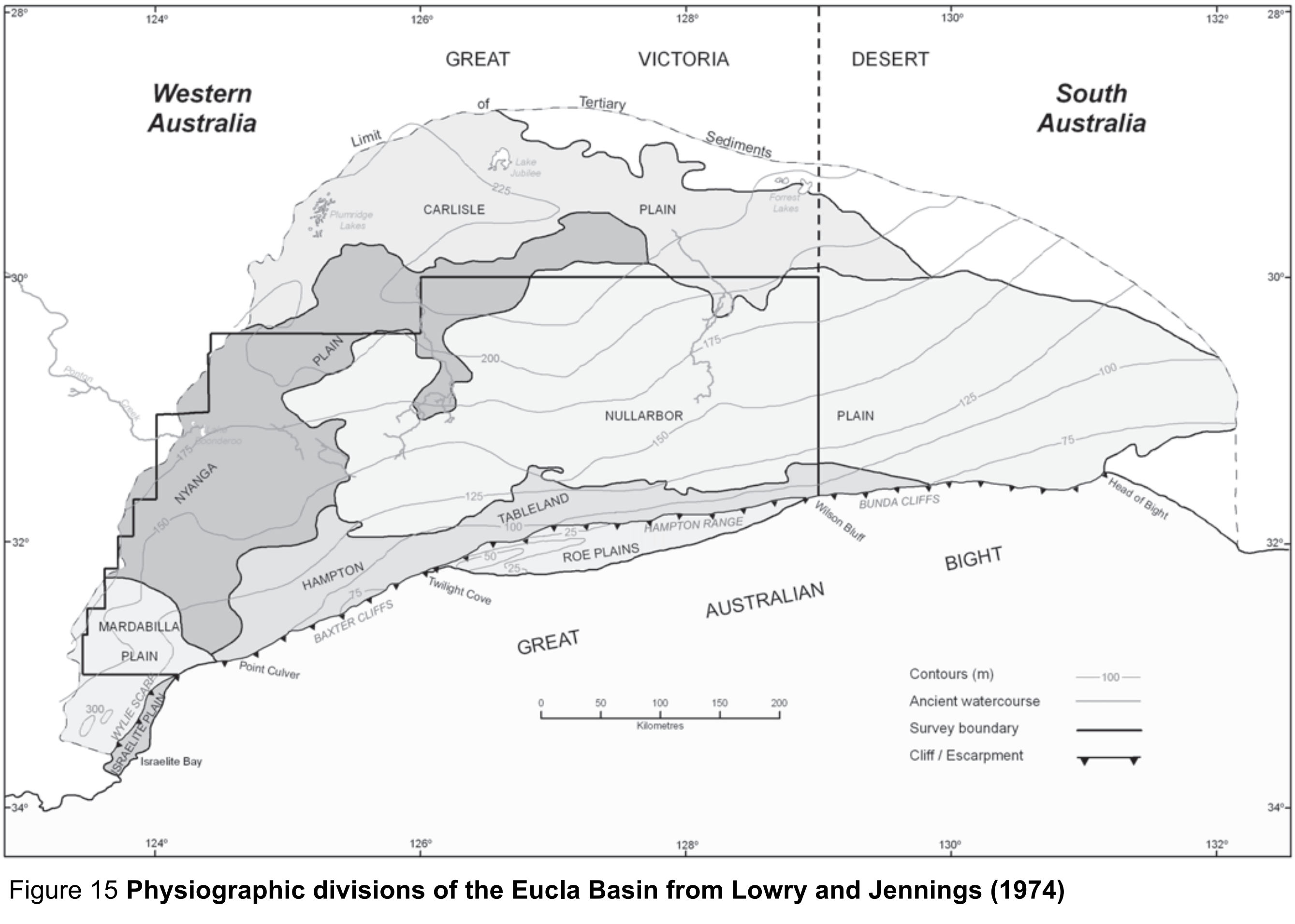

Figure 15 **Physiographic divisions of the Eucla Basin from Lowry and Jennings (1974)**

The landscape is of low relief, generally less than 4 m, and is characterised by different forms of karst depressions, covered by shallow clay loam soils, which form corridors of linear depressions and 'dongas' (locally named rounded depressions or claypans) separated by low rocky limestone ridges or rises. These surface features are described in terms of minor differential surface solution of limestone directed by joint patterns which systematically change throughout the plain (Jennings 1967a, 1967b). Where only one joint set is dominant the undulating relief occurs as parallel low ridges and depressions. Where two major joint sets of equal importance are present, the relief develops into a lattice pattern; ridges shorten to become low compact rises surrounding condensed depressions. Further inland the depressions become enclosed circular, shallow claypans or dongas. These rounded depressions can be arranged in lines parallel with the regular 'wave' pattern of associated ridge and corridor relief or they are randomly scattered (Jennings 1967a). All forms of depression channel water run-off into dolines and blowholes or claypans and dongas to permeate down through colluvial-filled joints.

Hampton Tableland

The Hampton Tableland lies in the south of the Bunda Plateau between the Nullarbor Plain to the north and bordered by the Baxter Cliffs and Hampton Range to the south. The region is characterised by undulating ridge-corridor topography with an average relief greater than elsewhere on the Bunda Plateau, up to 10 m. The higher rainfall closer to the coast has caused greater differential surface solution of the limestones forming the reticulated pattern of stony, tree covered ridges and drainage depressions up to 10 km long and 1 km wide. Donga and gilgai formations are absent.

Nyanga Plain

The Nyanga Plain lies in the west of the Bunda Plateau to the north and west of the Nullarbor Plain and the Hampton Tableland. Broad flat plains of variably thick and continuous residual clay and calcrete overlying Nullarbor Limestone characterise this region. The Nyanga Plain is featureless except for low scarps or 'break-aways' bordering the plain and surrounding occasional closed depressions, 5–15 m, generally deeper than those previously mentioned. The depressions are thought to have formed through surface solution of the limestone in combination with deflation of clay. Evidence of lineation indicative of joint control is much reduced in this part of the Bunda Plateau (Lowry & Jennings 1974).

Mardabilla Plain

The Mardabilla Plain occurs in the south-western part of the Bunda Plateau and is bordered by the Wylie Scarp to the south and the Nyanga Plain to the north-east. The surface of the plain is covered with clay and calcrete. Numerous inliers of crystalline basement rock protrude through the plateau surface. Some granite inliers barely project above the Cainozoic land surface, though others are prominent. Many of the inliers are characteristically surrounded by ringed depressions, 3–10 m deep and 50–150 m wide, caused by water run-off from the crystalline rock concentrating solutional processes on the surrounding calcareous sediments (Lowry & Jennings 1974).

Carlisle Plain

The Carlisle Plain occurs in the north of the Bunda Plateau, north of the Nyanga Plain. The Carlisle Plain is developed on the Colville Sandstone and consists of sparsely vegetated sandy soil. Though not part of the Nullarbor karst the area has many closed depressions, up to 30 m deep and 10 km across, formed possibly by subterraneous drainage, though more likely by deflation of sand and clay.

Scarp

The southern margin of the Bunda Plateau is marked by a continuous line of sea-cliffs and escarpments. These features represent the boundary between the onshore and offshore sections of the Eucla Basin. Only the Baxter Cliffs and Hampton Range sections occur within the survey area. The palaeosea-cliff forming the Hampton Escarpment separates the Bunda Plateau from the coastal Roe Plains below.

Coastal plains

The Western Australian Nullarbor region has two coastal plains: the Roe Plains in the south-east and the Israelite Plain in the south-west, the northern tip occurring in the survey area. The Roe Plains rise gradually from sea level to about 30 m at the base of the Hampton Range and have a maximum width of about 35 km and extend for approximately 300 km east–west.

Regional setting

The Western Australian margins of the Eucla Basin correspond to the limit of the Plumridge Formation and Colville Sandstone in the north and the Nullarbor Limestone and Toolinna Limestone in the west and south-west. The southern extremity of the basin is marked by the 200 m isobath of the continental shelf in the Great Australian Bight.

The South Australian border marks the eastern limit of the Western Australian portion of the Nullarbor Plain Province. Geologically the Bunda Plateau continues east until it becomes completely buried by coastal dune limestone reaching far inland from the coast. Further north of this, the Bunda Plateau's north-eastern margin is defined by the Ooldea Range, behind the Lake Ifould depression (Lowry & Jennings 1974; Benbow 1990a). In the north and north-west the Cretaceous deposits of the Eucla Basin onlap the Permian and older Palaeozoic rocks of the Officer Basin. Along the northern inner margins of the Eucla Basin the Nullarbor Limestone is replaced by the calcareous Colville Sandstone and laterally equivalent Plumridge Formation, both of which are buried beneath longitudinal quartz sand dunes of the Great Victoria Desert (Lowry & Jennings 1974). The western margin occurs where the Bunda Plateau abuts against the rising surface of crystalline basement rocks of the Albany–Fraser Orogen (Doepel & Lowry 1970a; Hocking 1990). Cainozoic deposits extend along wide, ancient valleys into the Yilgarn Craton, with basement inliers cropping out within the Bunda Plateau (Lowry & Jennings 1974).

Stratigraphy and structure

Precambrian

The basement rocks beneath the Eucla Basin consist of Precambrian granite, gneiss, schist and quartzite in the south-west with folded Proterozoic metasedimentary rocks in some northern and eastern areas (Lowry 1970; Lowry & Jennings 1974). Precambrian rocks only occur at the surface as limited outcrops of granite, mainly porphyritic potassium-feldspar granite, and gneiss protruding through the Eucla Basin limestone of the Mardabilla Plain in the south-west of the survey area. Elsewhere along the basin margin, basement is overlain by basin deposits and Quaternary sand.

Mesozoic

The oldest Mesozoic deposit is the Early Cretaceous (probably Neocomian–Aptian) Loongana Sandstone. Accumulated in local depressions on the irregular palaeosurface of Precambrian rocks, this fluvial deposit is typically composed of terrigenous, lenticular, feldspathic and conglomeratic sandstones (Doepel & Lowry 1970a).

Through the Early to Late Cretaceous following Loongana Sandstone deposition relatively continuous and widely distributed marine sediments were deposited. Lying unconformably over Precambrian rocks and conformably over the Loongana Sandstone are marine deposits of glauconitic, carbonaceous, pyritic sandstone, siltstone, claystone and shale. Two formations have been identified consisting of monotonous fine-grained, siliciclastic sequences, with variable contents of glauconite, dominated by siltstone, claystone and sandstone, the Madura and Toondi Formations (Hocking 1990). Deposition of the Madura Formation occurred in the Early to Middle Cretaceous (possibly as early as the Valanginian, Barremian–Aptian). The proportion of sand may be marginally greater in the Madura Formation. In the Middle Cretaceous (Albian–Cenomanian) following a brief depositional hiatus, marine deposition recommenced and the Toondi Formation developed.

In the Late Cretaceous (Santonian–Campanian) the central area of the basin was overlain by glauconitic sandstone, greensand and glauconitic sandy siltstone of the Nurina Formation (Hocking 1990), disconformably overlying the Toondi Formation.

Cainozoic

Eocene

During the Middle Eocene, marine deposition recommenced in the central part of the Eucla Basin with calcareous, limonite-stained lenticular sandstone, the Hampton Sandstone (Lowry 1970), unconformably overlying the Madura Formation. Deposition continued with two related sequences of shallow marine limestones, in cool, quiet waters, forming the Wilson Bluff Limestone (Lowry 1970). In the central part of the basin, the lower part of the Wilson Bluff Limestone consists of Middle Eocene bryozoan glauconitic marl overlying the Hampton Sandstone with probable conformity. The upper part of the Wilson Bluff Limestone

consists of Late Eocene chalky, bryozoan calcarenite and is widely distributed across the basin, conformable with the lower part, but disconformably overlying the Madura Formation and unconformably overlying Precambrian rocks in the north. Outcrop of Wilson Bluff Limestone occurs along the lower sections of the Baxter and Bunda sea-cliffs. In the south-west, the Toolinna Limestone (Lowry 1970), Late Eocene well sorted medium to very coarse-grained bryozoan calcarenite, grades laterally into and overlies the upper part of the Wilson Bluff Limestone. Elsewhere it unconformably overlies Proterozoic rocks at the western edge of the basin and possibly overlies the Madura Formation or Hampton Sandstone in some areas. Toolinna Limestone crops out in the west and south-west of the Bunda Plateau, and at the Baxter Cliffs and Wylie Scarp.

Oligocene – Miocene

In the Late Oligocene to Early Miocene recurring marine transgression resulted in the deposition of porous bryozoan calcarenite and calcirudite in cool, deep (> 70 m) waters under high energy conditions, the Abrakurrie Limestone (Lowry 1970; James & Bone 1991). The Abrakurrie Limestone disconformably overlies the Toolinna Limestone in the west, and the Wilson Bluff Limestone in the centre of the basin (Lowry 1970; James & Bone 1991). Abrakurrie Limestone is exposed in the Baxter Cliffs and on the Hampton Tableland and Range.

Expansion of the marine transgression in the Early to Middle Miocene lead to extensive deposition over the entire Eucla Basin (Lowry 1970). This widespread deposition occurred in warmer waters and commenced with uniform Early Miocene algal-biostrome development, which formed the Mullamullang Limestone Member in the centre of the basin. Outcrop occurs on parts of the Hampton Tableland and Range. The Mullamullang Limestone Member (Lowry 1970) forms the basal unit of the overlying Nullarbor Limestone, an indurated, poorly sorted, medium to coarse-grained, bioclastic (benthic foraminifera and coralline algal) calcarenite of Early to Middle Miocene age. The Nullarbor Limestone including its basal unit overlies the Abrakurrie Limestone disconformably. Elsewhere, the Nullarbor Limestone disconformably overlies Toolinna Limestone in the west and south-west, Wilson Bluff Limestone in the north and unconformably surrounds inliers of Precambrian rocks in the west. The Nullarbor Limestone extensively overlies most of the basin except where it grades laterally, at its northern margins, into the Colville Sandstone (Lowry 1970) and similar equivalents further east (Lowry & Jennings 1974; Benbow 1990b; Hocking 1990). The Colville Sandstone consists of calcareous sandstone, with lesser siltstone, claystone and conglomerate. It disconformably overlies older rocks and grades northwards into the Plumridge Formation (Lowry 1970). The Plumridge Formation consists of fine-grained sandstone and siltstone with lesser claystone and conglomerate and unconformably overlies older rocks. It forms the northern margin of the Eucla Basin (Hocking 1990).

Post-Miocene marine deposits are absent from the Bunda Plateau, except in the southern coastal plains, and it is inferred the onshore portion of the Eucla Basin has been uplifted to become land since the Middle to Late Miocene (Lowry & Jennings 1974). This has resulted in a very shallow dip to the south-south-east in the limestone strata (Webb & James 2006).

Prolonged weathering of Miocene surficial limestones developed a range of cemented calcareous soil profiles containing sheets and nodules of concretionary calcium carbonate, known as calcrete or kankar. Where these soil profiles have become denuded, the limestone has become variably hardened or has weathered irregularly to porous and diagenetically recrystallised to hard microcrystalline calcite. All forms of these surface deposits have since become overlain by an assortment of younger soils, dunes and other Quaternary deposits (Lowry & Jennings 1974).

Pliocene – Pleistocene

After uplift of the portion forming the Bunda Plateau the only deposition to occur was the Roe Calcarenite on the Roe Plains in the Late Pliocene (Hocking 1990; James et al. 2006). The Roe Calcarenite (Lowry 1970) consists of weakly cemented, porous, shelly, molluscan calcarenite and disconformably overlies a planar surface eroded into the Abrakurrie Limestone in the western and central parts of the plain and Wilson Bluff Limestone in the eastern part (Lowry 1970; James et al. 2006). The coastal dunes overlying the Roe Plains are primarily calcareous and on the basis of

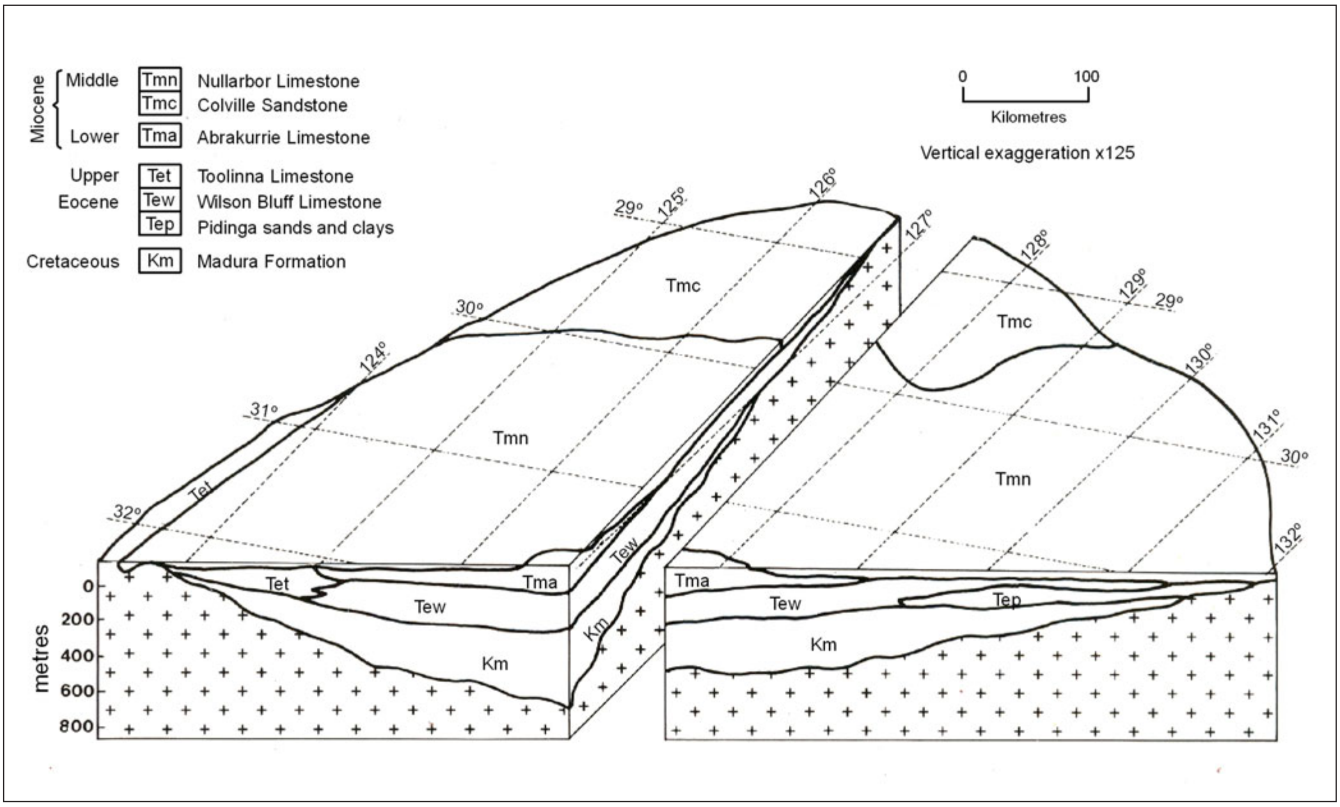

Figure 16 **Principal stratigraphic units of the Eucla Basin from Lowry and Jennings (1974)**

calcrete development three significant stages of dune building can be identified (Jennings 1968; Lowry & Jennings 1974).

The generalised stratigraphy of the rock units in the Eucla Basin is given in Table 4.

Mining and exploration

Early analysis of Eucla Basin limestone showed the Nullarbor Limestone contained up to 97 per cent calcium carbonate combined with 1–2 per cent magnesium carbonate (Lowry 1971). Presently there is only one mining enterprise operating on the Nullarbor where high grade limestone aggregate (< 6 mm) is extracted for use in mineral processing in the mining industry.

There is extensive exploration for a variety of minerals including gold and uranium in the Albany–Fraser Orogen under shallow cover near to and along the western margin and mineral sands around the inland margin of the Eucla Basin. One large gold project has reached mining pre-feasibility stage.

Table 4 **Summary of stratigraphic units in the Eucla Basin (primarily from Hocking 1990 with additional information from Lowry 1970, Benbow 1990a, James & Bone 1991, James et al. 2006)**

Age	Formation	Thickness (m)	Lithology	Stratigraphic relationships	Location
Pleistocene	Dunes of the Great Victoria Desert	5–40	Red-brown, quartz-rich sand, partly calcretised	Recent surficial sediments locally covering older rocks	Northern and north-eastern margins
Late Pliocene	Roe Calcarenite	7	Weakly cemented, poorly bedded, medium to coarse-grained porous, shelly calcarenite; locally dolomitic (Shallow marine above wave base)	Disconformable on older rocks; locally covered by surficial sediments or dunes	Roe Plains
Early–Middle Miocene	Plumridge Formation	9	Fine-grained sandstone, siltstone, claystone, intercalated pebbly sandstone with silcrete clasts (Fluvial to paralic)	Unconformable on older rocks; grades laterally into Colville Sandstone	Around northern margin of Eucla Basin
Early–Middle Miocene	Colville Sandstone	23	Calcareous sandstone; lesser calcarenite, shale, siltstone and granule conglomerate (Marginal marine, coastal)	Disconformable on older rocks; grades laterally into Nullarbor Limestone	Around northern margin of Eucla Basin
Early–Middle Miocene	Nullarbor Limestone	35	Hard foraminiferal and coralline algae skeletal calcarenite; locally shelly; basal algal limestone (Mullamullang Limestone Member) (Warm, shallow marine shelf; low to moderate energy)	Disconformable on older rocks; grades laterally into Colville Sandstone and Plumridge Formation	Widespread: grades into terrigenous facies near Eucla Basin northern margin
Late Oligocene–Early Miocene	Abrakurrie Limestone	90	Yellow, porous bryozoan calcarenite and granule calcirudite; mostly grainstone, some packstone (Cool, deep marine shelf; high-energy)	Disconformable between Nullarbor and Wilson Bluff Limestones	Centre of basin
Late Eocene	Toolinna Limestone	150	Coarse-grained, well sorted, bryozoan calcarenite to granule calcirudite (Cool, shallow marine shelf; high-energy)	Overlies and grades laterally into Wilson Bluff Limestone; grades laterally into Pallinup Siltstone near Israelite Bay	Western and south-western Eucla Basin
Middle–Late Eocene	Wilson Bluff Limestone	300	Chalky white bryozoan calcarenite packstone, containing common chert nodules; basal bryozoan glauconitic marl (Cool, shallow marine shelf; low to moderate energy)	Disconformably on Madura Formation; overlies and grades laterally into Hampton Sandstone; upper part grades laterally into Toolinna Limestone	Widespread, extends below sea level
Middle–Late Eocene	Hampton Sandstone	85	Limonite-stained sandstone, quartzose, variably calcareous and locally unlithified, minor conglomerate (Estuarine–fluvial to marine)	Disconformably on Madura Formation; grades laterally into lower Wilson Bluff Limestone	Basal transgression facies, poorly exposed near margins
Late Cretaceous	Nurina Formation	40	Greensand, glauconitic sandstone and sandy siltstone (Marine)	Disconformably on Toondi Formation	
Middle Cretaceous	Toondi Formation	Max. > 274 onshore	Siltstone, claystone and shale; minor sandstone; commonly pyritic, slightly finer grained than Madura Formation (Marine)	Disconformably on Madura Formation	
Early–Middle Cretaceous	Madura Formation		Carbonaceous sandstone, siltstone, claystone and shale; commonly pyritic (Marine)	Conformable on Loongana Sandstone	
Early Cretaceous	Loongana Sandstone	> 33	Feldspathic sandstone, locally conglomeratic; lithology poorly known (Primarily fluvial)	Unconformable on Precambrian basement rocks	

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Hydrogeology

DP Commander

Introduction

The hydrogeology of the Eucla Basin is not well known because in general groundwater has been developed only for pastoral purposes and the bores do not extend far beneath the water-table. The groundwater is mostly saline, and in the south of the basin stock water supplies exceed a salinity of 10 000 mg/L. The water-table is deep and only in a few places in the coastal dunes is there easily exploited shallow groundwater. The basin is divided between Western Australia and South Australia and is remote from population centres.

Previous investigations

Data on groundwater in the Eucla Basin is relatively sparse, with only about 300 bore records in an area of about 230 000 km^2. Drilling was first carried out for the Trans-Australian Railway, commencing with an artesian bore sunk at Madura (Maitland 1911). Drilling for pastoral supplies commenced in the 1950s, but often with a low success rate. On Kanandah Station for instance, 66 of 77 bores were abandoned (Berliat 1963) owing to the depth to groundwater, high salinity, and drilling problems. Only four petroleum exploration wells have been drilled in the onshore part of the basin.

Lowry (1970) described groundwater conditions in the Western Australian part of the basin, dividing it into six regions with particular characteristics. The hydrogeology of the South Australian part had previously been described by Ward (1946), who drew isopotentials for both the confined and unconfined aquifers, later refined by Shepherd (1978).

Lowry (1970) noted that only four bores in the underlying basement rocks or the basal Cretaceous sediments in the Western Australian part of the basin produced water suitable for stock. However, the area covered by these bores, which are in the centre of the basin, is large. Most drilling appears to have been carried out in the parts of the basin where the salinity is relatively high.

In 1984, compilation of the 1:5 000 000 hydrogeological map of Australia (Lau, Commander & Jacobson 1987) commenced, prompting a reassessment of the hydrogeology of the basin. Coincidentally a new bore was drilled into the confined aquifer at Eucla, which encountered water of 4500 mg/L, significantly better than expected. Following compilation of the 1:2 500 000 scale hydrogeological map of Western Australia (Commander 1989), the hydrogeology of the basin (including previous information from South Australia) was reassessed by Commander (1991b), with the plotting of isopotentials and salinity for both the unconfined and confined aquifers.

In a planning study for the Goldfields–Esperance Region (GEDC 1996), the Eucla Basin was identified as potentially less expensive than a water supply from Esperance, as it had potential to supply less saline water (< 10 000 mg/L) from a closer distance (Allen 1995). The report recommended that the water resource be investigated as a matter of priority. However, Commander (1996) concluded that a large supply of brackish to saline groundwater was only likely to obtained from east of Haig, a distance of over 400 km from Kalgoorlie, and therefore farther than Esperance.

A further more detailed data analysis was done for road construction water along the Eyre Highway and for Aboriginal community water supply in the far north of the basin (Commander 1990, 1991a).

Mineral exploration has generally been limited to the margin of the basin. Drilling for uranium around Lake Boonderoo has provided information on the stratigraphy, but no data on groundwater was collected.

Pastoral bores were visited for this study through 2005 to 2007, and the water salinity measured by electrical conductivity. The resultant groundwater salinity data set is more consistent than previous surveys, allowing a revision of the groundwater salinity distribution in the unconfined aquifer.

Surface drainage

Drainages from the interior of the continent generally terminate in pans or salt lakes around the inland margin of the basin. These palaeo-drainages are remnants of river valleys dating from before the mid-Eocene, some 40 million years ago, which have subsequently been filled

with sediments, and are now occupied by discontinuous chains of salt lakes. The lack of transported sediments in the Eucla Basin younger than 40 million years old suggests these river valleys have been largely inactive since then.

One of the few drainages to reach the basin, Ponton Creek, flowed in 1975 and in 1995. It drains an extensive salt lake system and terminates at the ephemeral Lake Boonderoo on the edge of the Eucla Basin. After the 1975 filling, during which for the first time the Trans-Australian Railway embankment was washed away by the flow, the lake was 15 m deep and persisted for nine years. In late 1995 Lake Boonderoo was reported to be 23 m deep with a salinity of 1800 mg/L. By 2007, the water level was much reduced and the water highly saline with an extensive crust of gypsum crystals developed around the shore.

There are indistinct drainages on the plateau ending in distributary channels which Lowry and Jennings (1974) refer to as relict river courses. After intense rain, surface water ponds for short periods in shallow depressions known as dongas. Otherwise there is an almost total lack of surface water. The limestone of the Bunda Plateau is characterised by karst features, especially by sinkholes and by cave systems formed at the watertable.

Hydrogeology

There are two major aquifers in the basin: an unconfined aquifer system, predominantly limestone, which comprises several different formations, and a sandstone aquifer at the base of the Cretaceous sequence which is confined over most of the basin (Table 5).

The Nullarbor Limestone and Colville Sandstone are unsaturated (Figure 17). The Quaternary sediments on the coastal plains are also part of the unconfined aquifer.

The confined aquifer consists of the Early Cretaceous Loongana Sandstone together with the lower sands of the Madura and Toondi Formations (Lowry 1970; see revised stratigraphy in Cockbain & Hocking 1989, and Hocking 1990), and weathered granitic bedrock. The aquifer is confined by the shale in the Toondi Formation.

Unconfined groundwater

The unconfined aquifer consists of the Wilson Bluff and Abrakurrie Limestones and includes the Hampton Sandstone beneath (Figure 17). The greensands of the Nurina Formation may also be in hydraulic continuity, although these are clayey and have not been exploited by bores (Lowry 1970). The Hampton Sandstone, which is contiguous with the palaeochannel sands of the Lefroy palaeodrainage, is only present around the western margin of the basin and is thin or absent east of Naretha. It has an inter-layered, graduated contact with the Wilson Bluff Limestone.

Around the western edge of the basin the watertable is in the Hampton Sandstone and the uppermost sands of the Nurina Formation, where the confining beds of the Madura Formation are present. However, around Balladonia, the Eocene strata are dry and Lowry (1970) reports dry bores bottoming on granite about 50 m deep on Noondoonia and Woorbla Stations.

East of Naretha the position of the watertable is mostly within the Wilson Bluff Limestone. According to Lowry (1970) the limestone generally has low permeability, except in some beds containing bryozoans, and secondary permeability is rarely encountered in bores despite the presence of caves.

The Abrakurrie Limestone, which occurs in the south, is highly permeable and characterised by low watertable gradient. Drillers report water-bearing beds as consisting of ‘coral’ corresponding to bryozoal horizons, whereas hard massive limestone does not appear to yield water.

The inland limit of saturation is where shale of the Toondi and Madura Formations rises above the elevation of the regional watertable, or where the confining bed is absent allowing drainage into the Loongana Sandstone. In the Naretha area the watertable is 60 m above the potentiometric surface of the Loongana Sandstone confined aquifer (Figure 18).

In the Naretha area, drillers’ logs describe the strata as clayey limestone, which yields low supplies. In the Rawlinna area the watertable is close to the base of the limestone, so potential yields are small.

Table 5 **Hydrostratigraphy**

Age/epoch	Formation	Symbol	Hydrogeology
Quaternary–Pliocene	Roe Calcarenite	Qp	Unconfined aquifer
	Bridgewater Formation	Qp	Unconfined aquifer
--------------------	------*unconformity*-------	------------	---------------------------------
E–M Miocene	Colville Sandstone	Tmc	Unsaturated
	Nullarbor Limestone	Tmn	Unsaturated
	Abrakurrie Limestone	Tma	Unconfined aquifer
--------------------	------*unconformity*-------	------------	---------------------------------
Eocene	Wilson Bluff Limestone (Toolinna Limestone)	Tew	Unconfined aquifer
	Hampton Sandstone	Teh	Unconfined aquifer
	Pidinga Formation	Tep	Aquiclude
--------------------	------*unconformity*-------	------------	---------------------------------
	Nurina Formation	Kn	Unconfined aquifer?
Cretaceous	Toondi Formation	Kt	Aquiclude, confined aquifer
	Madura Formation	Km	Aquiclude, confined aquifer
	Loongana Sandstone	Kl	Confined aquifer
--------------------	------*unconformity*------	------------	---------------------------------
E. Permian	Unnamed claystone	P	Aquiclude

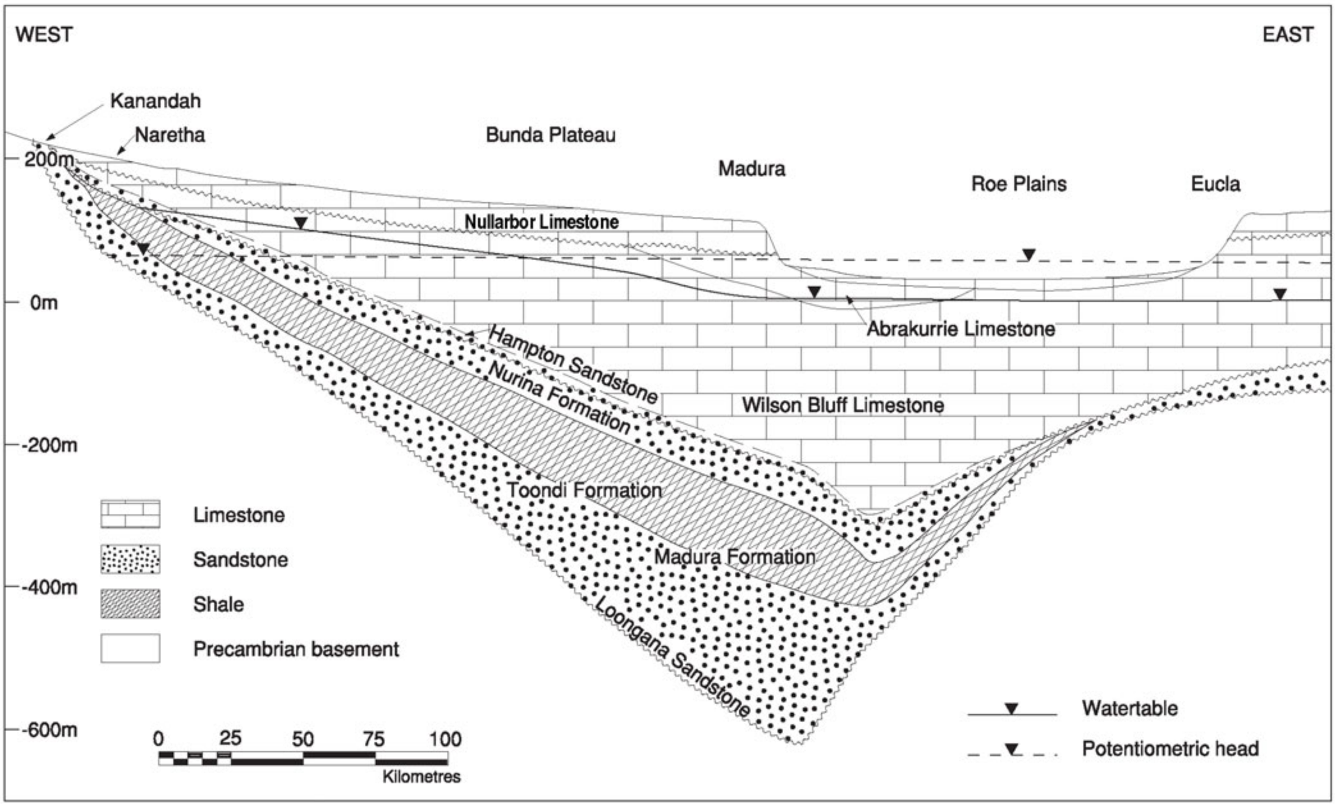

Figure 17 **Hydrogeological cross-section of Nullarbor region**

The watertable is about 40 m below the surface in the Naretha area, increasing eastwards to more than 100 m below the surface north of Cocklebiddy (Figure 19). The watertable is over 120 m below surface east of Balladonia.

Recharge

Lowry (1970) noted that there is only likely to be limited rainfall recharge through the thick clay and calcrete especially around the western margin of the basin, and recharge is generally restricted to depressions known as dongas where surface water ponds after intense rainfall (see photo below). These areas may contain perched water or a thin layer of fresher water at the watertable, especially around the northern margin of the unconfined aquifer north of the Naretha–Rawlinna area.

Recharge from run-off may also occur as sporadic events following rainfall from thunderstorms or from cyclonic activity such as occurred in 1975, when Ponton Creek flowed and damaged the Trans-Australian Railway line, and in 1995 when Lake Boonderoo was filled. Short intermittent streams are also known to flow into some of the dolines and provide recharge (Lowry & Jennings 1974; Wight 1990).

In general, areal recharge directly from rainfall is considered to be extremely low, accounting for the high groundwater salinity.

Groundwater flow

The watertable is about 100 m above sea level in the north-west of the basin and decreases in elevation to the south and east. Near the Hampton Range and beneath the Roe Plains, where there are extensive karst features, the hydraulic gradients are very low: 10 cm/km in the Wilson Bluff Limestone and 2 cm/km in the Abrakurrie Limestone, and reflect the high permeability (Lowry & Jennings 1974).

Salinity

The salinity of the unconfined groundwater, based on measurements in the pastoral bores, increases consistently from north-west to south-east. However, there may be a bias in the data towards successful bores with low groundwater salinity, judging by the success rate on Kanandah Station where 66 out of 77 bores were abandoned (Berliat 1963). The salinity is lower along the northern margin (Figure 20), and in the centre of the basin, where there are poorly defined drainage lines originating within the basin. Fresh water does occur in the unconfined aquifer, but only in a narrow strip along the extreme northern edge of saturation, and these bores may be favourably located near to dongas where recharge is enhanced.

Local ponding in donga after heavy rain in January 2006.
Photo provided by
J Campbell, Kybo Station

The salinity is less than 1000 mg/L in the north-west at Naretha. Fresh water is also locally present beneath dongas and as thin lenses in caves (Lowry & Jennings 1974). Groundwater salinity increases with depth (Lowry 1970), and in a southerly direction where there is a sharp increase along the Hampton Scarp, approaching sea water composition at the edge of the Roe Plains.

Thin lenses of fresh water occur in the sand dunes along the coast on the Israelite and Roe Plains and east of Head of Bight, but have not been evaluated by drilling. Potable water has been obtained from shallow wells in coastal sand dunes at the Eyre telegraph station.

Groundwater in the Hampton Sandstone along the Eyre Highway ranges from 19 000 to 50 000 mg/L (Lowry 1970).

Some caves have halite precipitating, indicating very low recharge rates or a residue of salt in the unsaturated zone. There is also high salt storage in soils of the Roe Plains.

The salinity is less than 2000 mg/L only north-west of Rawlinna, and possibly in the Loongana area, and it appears that around Haig the salinity exceeds 8000 mg/L (Figure 20).

In the north-west, the groundwater salinity appears to reflect influence of the relict drainages, which coincide with areas of more saline groundwater east of Lake Boonderoo and in the Haig area.

Stock quality groundwater occurs locally at the end of gorges in the Hampton Range, but Lowry (1970) states that salinity rises during droughts and documents rises in bores on Mundrabilla Station over 10 to 26 years, suggesting that the low salinity layer can be exhausted by pumping.

Bore yield

There is very little information on bore yields as most bores have been drilled for pastoral supply, where a relatively small quantity is sufficient.

A few bores have been adequately tested, and one at Loongana was test pumped for 21 hours at about 800 m^3/d, demonstrating that relatively high bore yields are obtainable.

Lowry mentions that large supplies are available in the Abrakurrie and Wilson Bluff Limestones in the south of the Bunda Plateau.

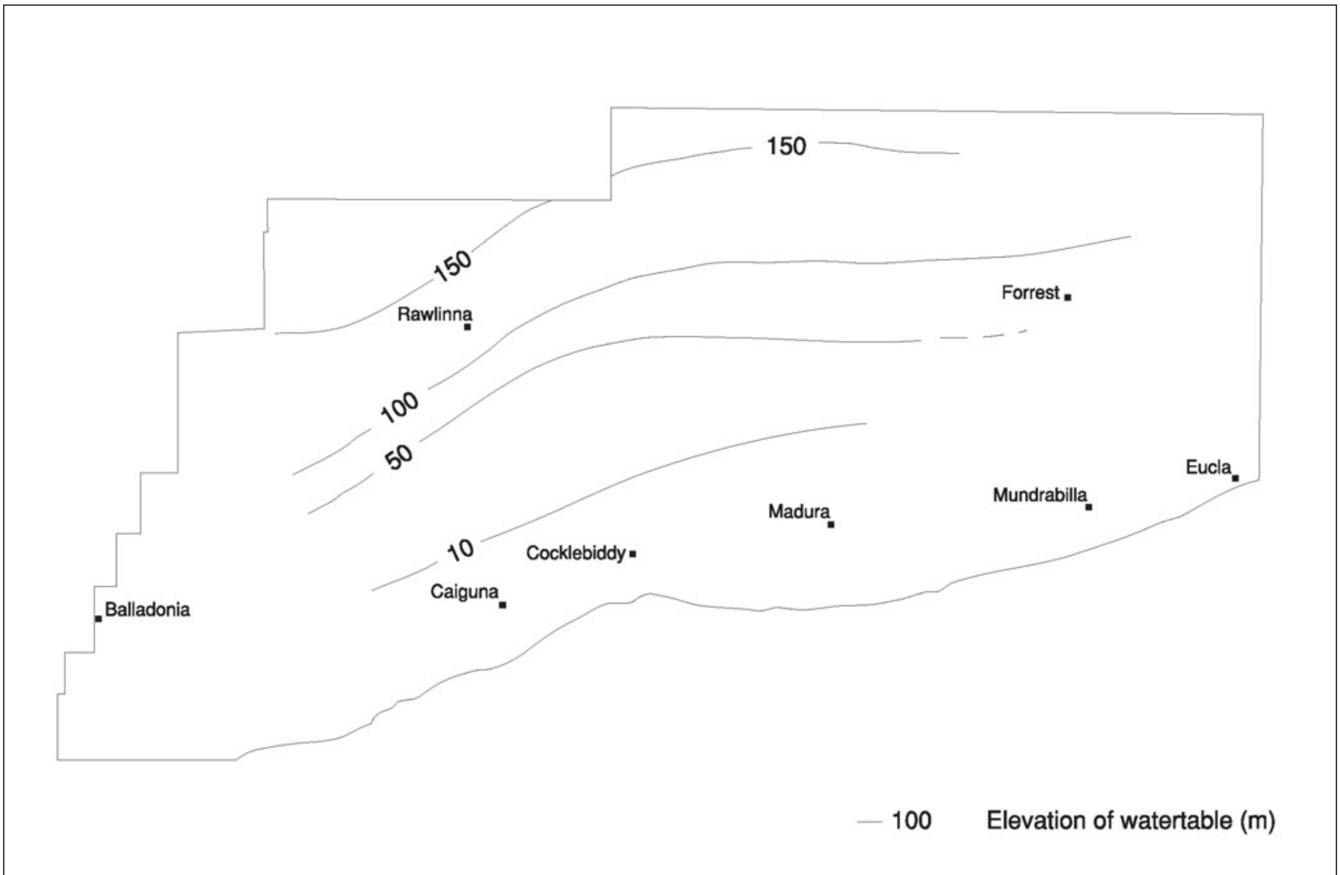

Figure 18 **Unconfined aquifer—watertable elevation**

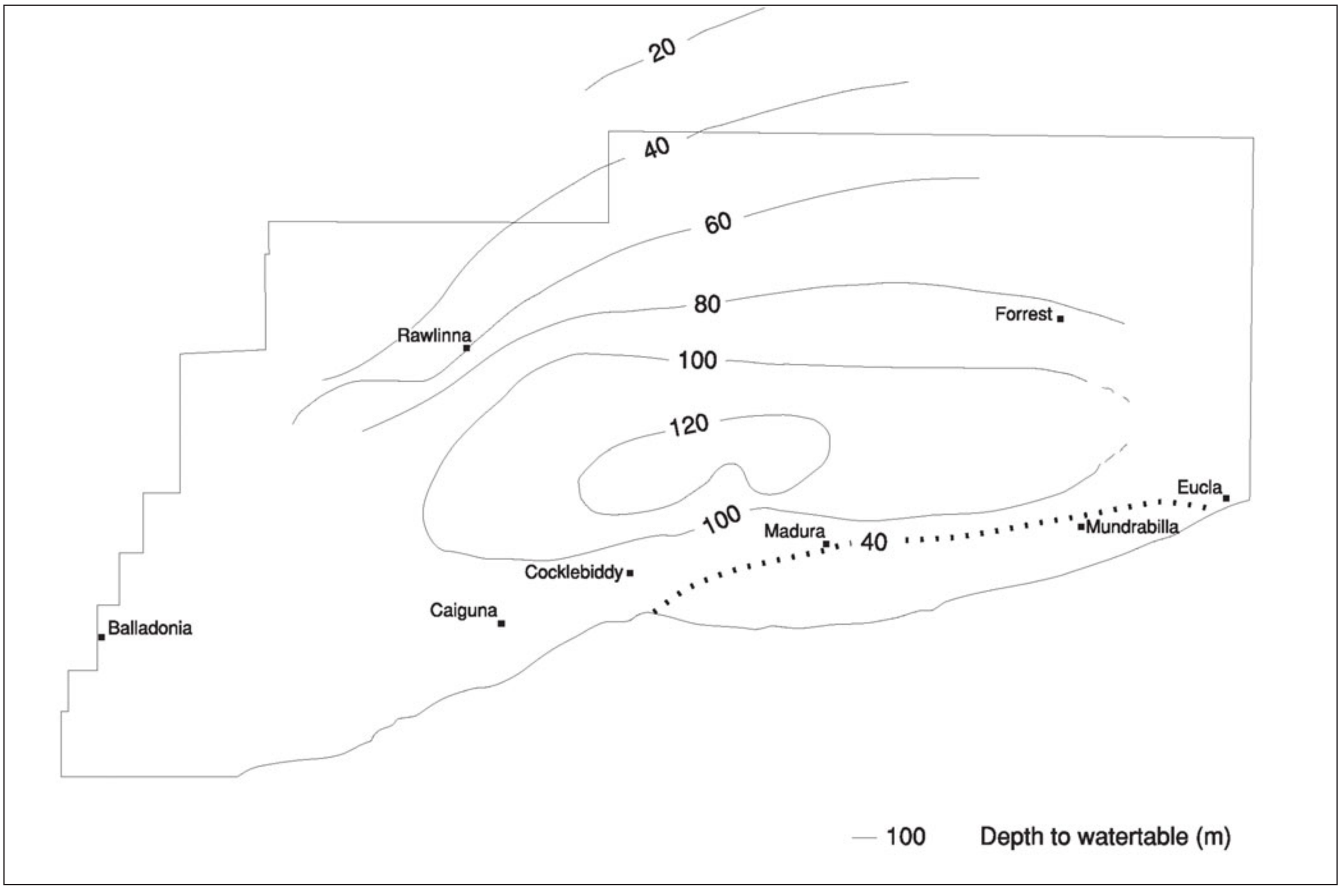

Figure 19 **Unconfined aquifer—depth to watertable**

Limiting factors for bore yield are the lithology, saturated thickness, and pumping head. The limestone strata west of Haig tend to be characterised by clay or marl, therefore low yielding, whereas to the east of Haig limestone is at the watertable, and the saturated thickness is greater. However the pumping head is greater to the east, with the depth to the watertable at Loongana being about 85 m.

Confined groundwater

The confined aquifer consists of the Early Cretaceous Loongana Sandstone together with the lower sands of the Madura Formation, and weathered granitic bedrock (Figure 17). The Loongana Sandstone is generally less than 33 m thick and it is often difficult to differentiate from weathered granite in drillers' logs where the material has been logged as granite sands.

Recharge

Recharge to the Loongana Sandstone is inferred to occur around the inland margin of the basin where the confining Madura Formation is absent, and where direct intake from surface run-off can take place. Lowry (1970) recognised that recharge of highly saline water to the Cretaceous could occur from Ponton Creek. Recharge of saline groundwater can also take place from the concealed Tertiary palaeochannels (Binks & Hooper 1984; Commander, Kern & Smith 1992). The palaeochannels draining the Precambrian shield in the west discharge a significant amount of salt, but in the centre of the basin where palaeodrainages originate in the Officer Basin the salinity is much lower (Commander 1991a). Recharge is presumed not to occur where the Madura Formation oversteps the Loongana Sandstone onto the basement at the edge of the basin.

Groundwater through flow from the Officer Basin is also inferred to recharge the confined aquifer, although through flow is likely to be intercepted and discharged to salt lakes along the northern margin of the Eucla Basin.

Groundwater flow

The potentiometric surface slopes from 50 m above sea level in the north-west of the basin at Kanandah to 30 m at Madura where there are artesian conditions on the Roe Plains (Figure 20).

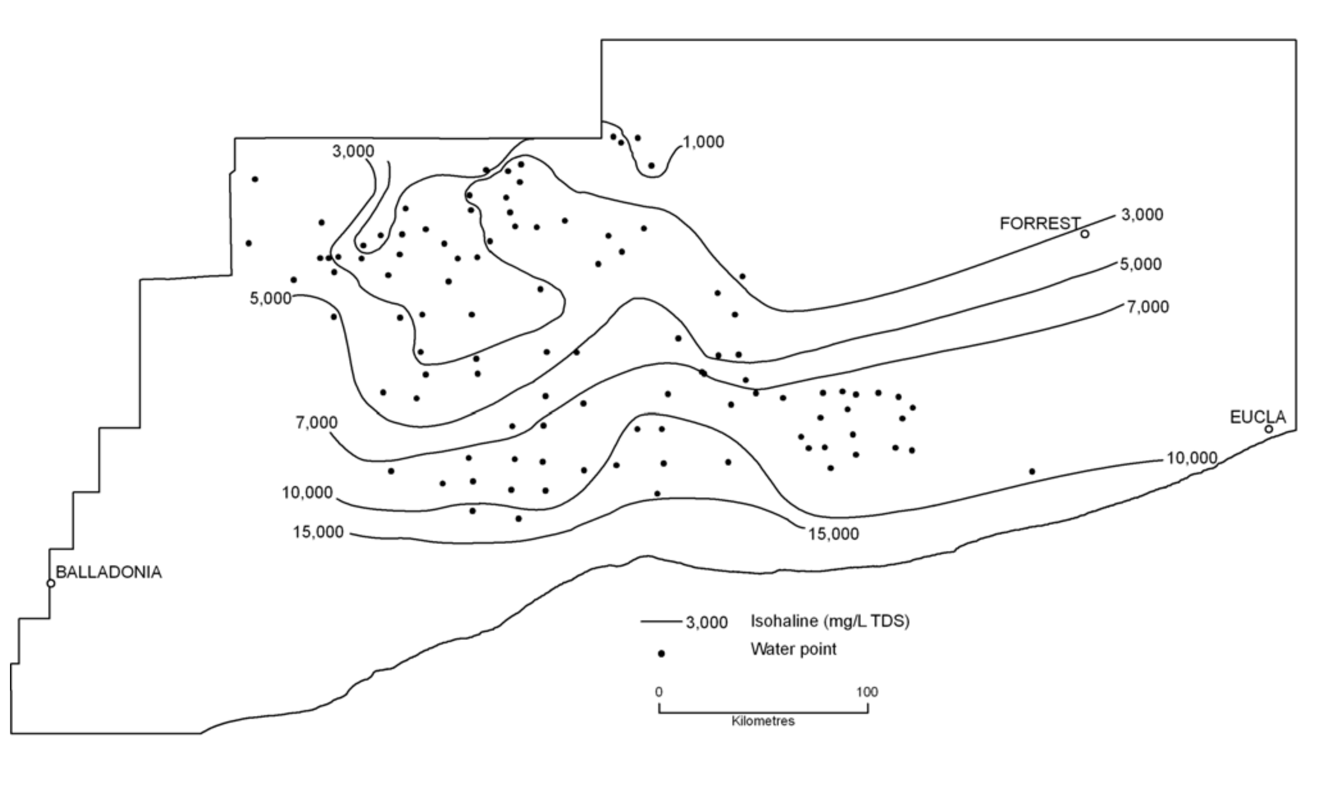

Figure 20 **Unconfined aquifer—groundwater salinity**

The potentiometric head of the aquifer along the Trans-Australian Railway is around 120 m below the land surface.

Discharge

Groundwater discharge from the Loongana Sandstone is likely to occur into the unconfined aquifer in the south of the basin near Eucla where the confining shale is thin or absent, allowing upward groundwater flow into the Wilson Bluff Limestone (Figure 17).

Salinity

In the west of the basin the salinity in the Loongana Sandstone is greater than 19 000 mg/L, reflecting the recharge from palaeodrainages arising on the Yilgarn Craton.

In the centre of the basin the salinity is less than 10 000 mg/L. Around Loongana the salinity is about 3000 mg/L, possibly as a result of recharge from the Officer Basin to the north, and at Eucla a bore obtained groundwater of 4500 mg/L. Little is known about groundwater in the Officer Basin but Birksgate 1 oil exploration well, in South Australia, has fresh water of less than 1500 mg/L extending to at least 170 m in Lower Palaeozoic sandstone (Lau, Commander & Jacobson 1987). Beneath the Roe Plains the groundwater salinity is much higher and is reported to be 51 000 mg/L and 73 900 mg/L respectively in Eyre 1 and Eucla 1 oil exploration wells.

Bore yield

Yields of 400 to 1000 m^3/d are recorded from bores in the Loongana Sandstone along the Trans-Australian Railway at Loongana and 130 km to the east at Reid.

Conclusions

Understanding of hydrogeology has been hampered by the fact that the basin straddles the State border, by poor documentation, and a perception that the groundwater is saline and difficult to obtain. Data on groundwater salinity is not well distributed; most of the bores are in the north-west, the south-east, and along the east–west rail and road routes.

The area of fresh water in the unconfined aquifer is limited to the northern margin of the aquifer, but there may be a substantial area in the middle of the basin where salinity is relatively low. Neither of these areas has been adequately explored. However, fresh groundwater may only be present close to dongas, where rapid recharge can take place. The

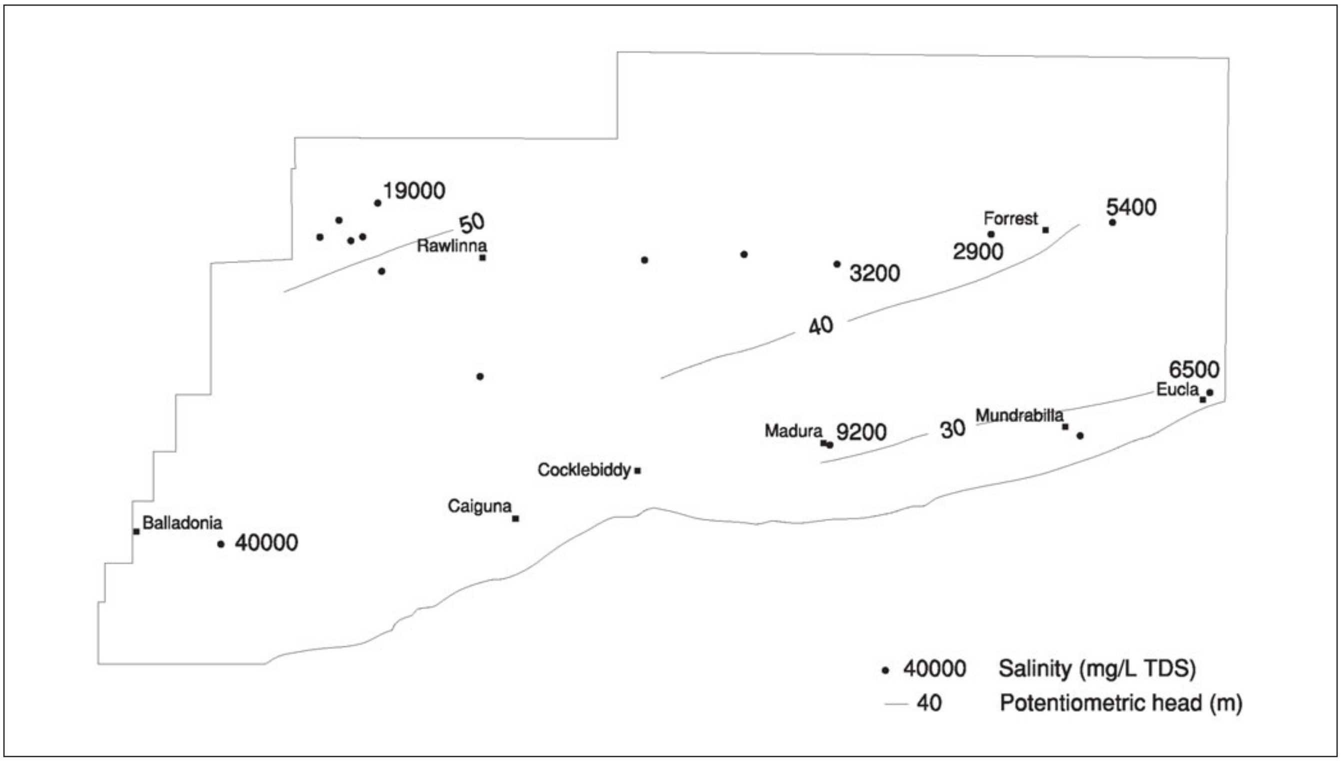

Figure 21 **Confined aquifer—potentiometric head and salinity**

salinity of stock quality groundwater can be predicted from the mapped salinity distribution, though the salinity–depth relationship is not known.

Knowledge of the hydraulic parameters of the aquifers is almost non-existent. It is not even certain how much groundwater flow in the limestone is due to primary permeability and how much is fissure flow.

The only area of the Eucla Basin with potential for supply of large quantities of brackish or saline groundwater lies east of Haig towards Loongana. The unconfined limestone aquifer is too thin and too clayey west of Haig–Rawlinna for major groundwater abstraction. Since recharge is very low, major groundwater abstraction would be from storage.

The Loongana Sandstone is likely to be too thin and discontinuous for major groundwater abstraction in the north-west of the basin. Most bores penetrating the confined aquifer have been in the west where salinity is high, but there is less saline groundwater in the centre of the basin around Loongana.

The observation in 2007 that Lake Boonderoo was highly saline suggests that there is no potential for locating low salinity groundwater associated with recharge from the lake, as had previously been thought.

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Declared plants and animals

AK Gardner

The following plants and animals are present within the survey area, and are declared under the *Agriculture and Related Resources Protection Act 1976.* The Act is administered by the Department of Agriculture and Food. The survey area is serviced by offices at Eucla and Kalgoorlie.

All declared plants and animals are categorised under the *Agriculture and Related Resources Protection Act 1976,* according to the level of control required from eradication through to containment. Declared plants are categorised as follows:

P1 Plants should not be introduced

P2 Plants should be eradicated

P3 Area and/or density of plant infestation should be reduced

P4 Plants should be prevented from spreading beyond the boundaries of the pre-existing infestation

P5 Control is only necessary on public land such as along roads or on reserves.

Nearly all declared plants are P1. Plants are also placed in one of the other categories for the whole or part of the State.

All declared plants in the survey area have been introduced as a result of human activity either as garden plants, contaminants of pasture seed or as seeds entangled in the hair or wool of transported stock. The spread of these plants has been assisted by vehicles, stock, native and feral animals.

Declared animals are categorised as follows:

A1 Animals should not be introduced

A2 Animals should be eradicated in the wild

A3 Animals should not be kept

A4 Animals can only be introduced in accordance to conditions and restrictions

A5 The number of animals should be reduced and kept under restrictions

A6 Animals can only be kept in accordance to conditions and restrictions

A7 Native animals for which there is a management plan to regulate numbers without endangering the species.

The declared animals in the survey area have the potential to reduce the viability of pastoral leases through competition for food and water, increasing land degradation and in some cases direct predation on stock.

Declared plants

Bathurst burr (*Xanthium spinosum*) - P1, P2

Infestations of Bathurst burr are quite common in the survey area, particularly in areas that receive water run-on, including claypans, drainage floors and dongas.

Ecology

Bathurst burr is a hardy, summer-growing annual herb, with small burrs covered in hooked spines. It has dark green leaves with a white underside, and grows to 1.2 m high (Lloyd 2006).

*On the Nullarbor Plain Bathurst burr (*Xanthium spinosum*) commonly occurs in dongas and if uncontrolled can develop into dense infestations. Seeds can remain viable for a number of years with dormancy dependent on the permeability of the seed coat. Staggered germination is common.*

Significance and management

Bathurst burr is believed to have been introduced into Australia from burrs entangled in the tails of horses imported from Chile in the 1840s (Parsons 1973). Seedlings are considered poisonous to stock, but there is little field evidence of this (Everist 1981). The major problem is the contamination of wool by burrs. The difficulty associated with burr removal during processing results in a lower value for contaminated fleeces.

Locations where Bathurst burr is known to grow should be inspected after summer rainfall events and any plants should be either grubbed or treated with recommended herbicides prior to seed set. Seeded plants should be burnt on site to prevent further germination. Infested properties are placed under quarantine with restrictions applied to the movement of livestock.

Horehound (*Marrubium vulgare*) - P1, P4

Small infestations of horehound are found throughout the survey area.

Ecology

Horehound is an erect, perennial herb that originated in Europe and was introduced to Australia as a garden herb and for beer brewing. Horehound has square stems that are densely covered with white hairs. The leaves are also hairy and are aromatic when crushed. The flowers are small and white and form dense clusters. As they dry the flowers become burrs covered with small hooked spines. Horehound is commonly 0.3–0.6 m high and 0.7–0.9 m wide (Weiss, Ainsworth & Faithful 2000).

Significance and management

Horehound leaves contain an alkaloid that makes the plant unpalatable to stock. Heavy grazing encourages growth as competition from palatable plants is reduced. Horehound produces large amounts of seed and can form dense populations in open and disturbed areas (Parsons 1973).

The meat of animals forced to eat horehound has a strong odour and flavour. Affected stock must be fed on clean pasture for seven days before sale to lose this flavour (Weiss, Ainsworth & Faithful 2000). The burrs contaminate wool and reduce the value of fleeces.

Whilst infestations remain small there is the possibility for eradication. Isolated plants should be grubbed before flowering and burnt with the affected areas inspected regularly to ensure new plants are not re-establishing. Spot-spraying is also effective on small populations (Weiss, Ainsworth & Faithful 2000). Properties with horehound infestations are placed under quarantine. Restrictions apply to the movement of livestock depending on the destination.

Saffron thistle (*Carthamus lanatus*) - P1, P4

Saffron thistle is a common troublesome plant and has been recorded in dongas to the north of the survey area.

Ecology

It is an unpalatable winter growing annual, which establishes only from seed. The leaves are rigid, with spiny lobes and the yellow flower heads are surrounded by spiny bracts (Hussey et al. 1997). Seed dormancy can be greater than eight years, which makes control difficult (Fuller 1998).

Significance and management

Saffron thistle is a prolific seed producer with the ability to colonise areas to the exclusion of other plants. The spines may cause injuries to the mouth and eyes of sheep grazing dense infestations. Seed heads and vegetable matter also contaminate wool, making the handling and shearing of contaminated sheep difficult and devaluing the fleece (Department of Primary Industries, Water and Environment 2002).

It is unlikely to become a significant environmental problem or major problem to the pastoral industry. There is regulatory requirement to control it on leasehold land. Eradication is unrealistic, so the main aim should be to contain and control infested areas.

Tamarisk (*Tamarix aphylla*) - P1

Tamarisk or athel pine has commonly been planted as a shade tree near homesteads and water points within the survey area. The plant also occurs on the margins of Lake Boonderoo.

Ecology

Tamarisk is a dense, spreading tree that grows to a height of 10 m. It has a dark grey or black trunk that may reach 1 m in diameter, linear leaves and spikes of small pink flowers (Hussey et al. 1997).

Significance and management

Tamarisk can cause extensive environmental problems by infesting wetlands and waterways, resulting in the alteration of flow and salinisation of water (Hussey et al. 1997). Department of Environment and Conservation employees cut down and sprayed tamarisks within a 70 ha area surrounding Lake Boonderoo in 2006. As it is a P1 plant there is no compulsion to remove plants on leasehold land, however new plants should not be prevented from establishing.

Thornapple (*Datura ferox*) – P1, P4

No large infestations have been found in the survey area, but isolated plants were found to the north.

Ecology

The thornapple was accidentally introduced to Australia as a contaminant of fodder imported from the tropics. It is an erect, bushy annual with white flowers that grows in summer, quickly reaching up to 1.5 m. The leaves are ovate with toothed edges and the egg-shaped fruits are covered with spines of variable lengths (Hussey et al. 1997).

Significance and management

Thornapple is a prolific seed producer and seeds may remain viable for six or seven years. Thornapple contains poisonous alkaloids that are toxic to livestock and humans. However stock rarely graze it due to its unpleasant smell, bitter taste and spiny seedpods (Lloyd 2006).

Infestations of thornapple should be inspected each year and plants grubbed if present. Although thornapple competes with more desirable plants it is unlikely to become a major threat to the pastoral industry.

Declared animals – native species

Dingo (*Canis lupus dingo*) – A4, A5, A6

Dingoes occur throughout the survey area.

Significance

The impact of dingoes is variable and the potential for stock losses can be significant. Dingoes are known to attack and kill sheep and when in packs may harass and kill calves (Thomson 2000).

Status and management

In Western Australia dingoes are 'declared animals' under the *Agriculture and Related Resources Protection Act 1976* and are categorised as A4, A5 and A6. These categories require that populations must be controlled and that dingoes cannot be introduced or kept in captivity except in approved institutions or under a permit which carries special conditions. Dingoes are classified as 'unprotected native fauna' under the Wildlife Conservation Act 1950. The main form of control is through trapping, opportunistic shooting and poisoning, with contract doggers hired to carry out ground control throughout the year.

*Dingo (*Canis lupus dingo*) at a rabbit warren in Unallocated Crown Land. Predation can cause significant stock losses on pastoral properties carrying sheep and may also cause calf losses either by direct attack or by causing mismothering.*

Emu (*Dromaius novaehollandiae*) – A7

Emus occur in low numbers throughout the survey area.

Significance

Emus are not considered to be major forage competitors with livestock (Davies 1978). They are more of a nuisance for the damage they cause to fences.

Status and management

Emus are protected native birds. Numbers are controlled mainly by seasonal conditions and to some extent predation. However they are listed in category A7 so that control may be undertaken when, occasionally, they reach very high numbers during good seasons.

Red kangaroo (*Macropus robustus*) and Western grey kangaroo (*Macropus fuliginosus*) – A7

These two species of kangaroo are found throughout the survey area.

Significance

Kangaroo numbers have increased in many arid and semi-arid rangeland areas since the introduction of artificial watering points with European settlement (Ealey 1967; Oliver 1986). Kangaroos compete directly with stock for food and are sufficiently mobile to respond to local variation in available feed. Station managers generally maintain that kangaroos have the greatest impact on pastoral production during dry periods; this has been confirmed in studies by Wilson (1991a, 1991b). Studies have also shown that kangaroos can adversely affect the regeneration of shrubs and perennial grasses (Gardiner 1986a, 1986b; Wilson 1991b; Norbury & Norbury 1992, 1993; Norbury, Norbury & Hacker 1993). Kangaroo numbers must be considered when setting stocking rates or planning a regeneration program.

Status and management

Kangaroos are classed as A7 under the *Agriculture and Related Resources Protection Act 1976*. They are subject to management programs determined by the Kangaroo Management Advisory Committee and administered by the Department of Environment and Conservation (McNamara & Prince 1986).

Kangaroos are harvested for pet meat by licensed shooters and harvesting levels are revised according to population trends. The aim is to manage the populations so that the species is not endangered while reducing the grazing pressure bought on by high numbers. However, the major control on population numbers is seasonal conditions.

Declared animals – introduced species

Feral camel (*Camelus dromedarius*) – A4, A5, A6

Feral camels occur in varying densities throughout the Nullarbor. Low numbers are found along the coast and centre of the Nullarbor Plain, whilst medium to high numbers are found to the north and on Unallocated Crown Land to the east. Large numbers to the north are a result of close proximity to the Great Victoria Desert which is recognised as an area of high camel abundance (Woolnough et al. 2005).

Significance

Feral camels cause damage to infrastructure, including destroying fences and fouling water points. They may also intimidate stock with aggressive behaviour preventing watering (Vertebrate Pest Services 2000).

Feral camels compete with domestic stock for feed as their preferred diet is succulent herbage. They also damage native trees,

*Camels (*Camelus dromedarius*) occur throughout the survey area becoming more common in the north. Camels may cause damage to infrastructure or compete for sources of browse crucial to maintaining livestock through dry periods such as bullock bush (*Alectryon oleifolius*) and donga groves.*

particularly quandongs (*Santalum acuminatum*) and bullock bush (*Alectryon oleifolius*), as they graze on the fruits, leaves and stems (Vertebrate Pest Services 2000).

Status and management

Control is carried out by opportunistic shooting.

Feral cat (*Felis catus*) – exempt from declaration

Feral cats occur throughout the survey area.

Significance

Whilst feral cats pose no economic threat to the pastoral industry, they are considered partly responsible for the decline and extinction of ground-nesting birds and small to medium-sized ground-dwelling mammals in Australia's arid zone (Dickman 1996).

Status and management

Within the pastoral areas there are no established management programs for feral cats. Pastoralists and kangaroo shooters are known to opportunistically shoot them in an effort to reduce their numbers. Desexing of station cats will minimise the impact of domestic cats turning feral.

Feral horse (*Equus caballus*) – A5

Low to medium numbers of feral horses are present on pastoral stations and adjacent Crown Land in the central east of the survey area (Woolnough et al. 2005).

Significance

Feral horses compete with cattle for feed and water, and also damage fences and water troughs. They also cause significant environmental damage by grazing on native vegetation and trampling causing soil compaction.

Control

Control of feral horses includes mustering and commercial harvesting. The most effective form of control is shooting. A market does exist for some horsemeat, though horses must be transported to South Australia.

Fox (*Vulpes vulpes*) – A4, A5, A6

Foxes are common through the survey area, particularly on pastoral properties where wild dog control programs have reduced dogs.

Significance

Foxes are not considered a major economic threat to the pastoral industry, though occasionally lamb losses are reported. Predation by foxes is a continual threat to many species of native fauna and is thought to have contributed to the extinction of some species (Christensen 1980; Kinnear, Onus & Bromilow 1988). If the disease rabies reached Australia foxes would be a major carrier.

Status and management

Though foxes are a declared animal on pastoral stations, there is no major coordinated control. Some local control occurs through opportunistic shooting by kangaroo shooters or as a result of 1080 baiting programs for wild dogs.

Rabbit (*Oryctolagus cuniculus*) – A1, A3, A5

The number of rabbits has been greatly reduced since the release of rabbit calicivirus in 1995. Small populations continue to survive throughout the survey area.

Significance

Rabbits compete with livestock for pasture and are able to graze plants more closely to the ground than other stock. This may weaken perennial grasses during summer, and possibly eliminate them. As well as grazing juvenile plants, rabbits also cause damage by killing trees and shrubs by stripping bark. Rabbits are

Rabbits are believed to be largely responsible for altering the Nullarbor vegetation communities to the state seen today when they occurred in plague proportions.

responsible for soil erosion by removing plant cover and by exposing the soil through the creation of large warrens.

Status and management

Rabbit calicivirus has been highly successful in reducing numbers. Outbreaks of calicivirus take place whenever there are enough susceptible rabbits within the population to support infection and transmission. As with myxomatosis there is the possibility that rabbit populations will become resistant to the disease. While population numbers are low, rabbit warrens should be ripped (Eldridge & Simpson 2002).

Starling (*Sturnus vulgaris*) – A1, A2, A3

Starlings are a regular occurrence in the south of the survey area following a migratory flight path from South Australia into southern coastal Western Australia (Massam & Woolnough 2004).

Significance

The starling is one of the most successful vertebrate pests. In Australia the bird causes significant damage to horticultural crops including cherries, stone fruit, olives, grapes and blueberries. Starlings also play a large role in the spread of weeds and diseases; they are reported to have been involved in the spread of 25 diseases worldwide including foot and mouth disease (Massam & Woolnough 2004).

Starlings damage cultivated grain, horticulture crops and foul wool, and can damage buildings through their nesting. They also compete with native birds for food and nesting sites, and have the potential to adversely affect the unique biodiversity of Western Australia.

Status and management

Starlings have established populations in eastern Australia and continually threaten to colonise Western Australia through a migratory flight pattern between South Australia and Esperance. Continuing to exclude them is a major protection activity of the Department of Agriculture and Food. This is achieved through ongoing surveillance, trapping and shooting from Eucla along the Roe Plains to Esperance.

Wild dog (*Canis lupus familiaris* and *Canis lupus familiaris* x *Canis lupus dingo*) – A4, A5, A6

Wild dogs (feral domestic dogs and domestic dog x dingo crosses) occur throughout the survey area.

Significance

The impact of wild dogs in some areas has been quite high in the past, particularly on sheep stations. Where stations have changed from sheep to cattle the potential for wild dogs to impact on the pastoral industry has been slightly reduced. However where dog numbers are high and working in packs they may substantially impact upon cattle enterprises through harassing and killing calves.

Status and management

The encroachment of domestic or feral dogs onto pastoral properties is difficult to control. Local government does not generally have the resources to implement the relevant sections of the *Dog Act 1976*. Several properties within the survey area have dog-proof netting boundary fences. These provide a non-lethal means of protecting livestock, though such fences are very expensive to construct and maintain (Thomson 2002). Trapping, shooting and poisoning by pastoralists and contract doggers are the main methods of control.

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The survey

Methodology (PA Waddell)

Geomorphology (PA Waddell)

Soils (P Hennig)

Vegetation (AK Gardner)

Habitat type ecology (PA Waddell and AK Gardner)

Land systems (PA Waddell)

Resource condition (PA Waddell)

Resource management (PA Waddell)

Methodology

PA Waddell

The rangeland resource survey of the Western Australian part of the Nullarbor region was jointly undertaken by the Department of Agriculture and Food (DAFWA) and Landgate (formerly the Department of Land Information). This survey is the thirteenth of its type in a program of rangeland classification, mapping and resource evaluation in the State.

Rangeland surveys have been conducted in Western Australia since the 1950s when they were commenced by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). Rangeland surveys have been widely used in Western Australia by CSIRO (Speck et al. 1960; Mabbutt et al. 1963; Speck et al. 1964; Stewart et al. 1970) and in joint Department of Agriculture, Western Australia (now Department of Agriculture and Food, WA) and Department of Lands and Surveys (now Landgate) rangeland surveys which are commissioned by the Pastoral Lands Board of Western Australia (Wilcox & McKinnon 1972; Payne et al. 1979; Mitchell, McCarthy & Hacker 1979; Payne, Curry, & Spencer 1987; Payne, Mitchell & Holman 1988; Payne & Tille 1992; Curry et al. 1994; Pringle, Van Vreeswyk & Gilligan 1994; Payne et al. 1998; Van Vreeswyk et al. 2004; Cotching 2005; Hennig 2009).

The land system approach to mapping different country types has been used in all of the previous regional rangeland surveys in Western Australia. The concept of land systems was first used by Christian and Stewart in 1953. They define a land system as 'an area with a recurring pattern of topography, soils and vegetation'. These recurring patterns can be seen using aerial photography or other remotely sensed images. It is assumed areas with a similar pattern represent the same land system. The land systems are ground-truthed during field work.

Land system boundaries are mapped from 1:50 000 scale aerial photographs and can be reproduced onto topographical maps or pastoral plans at any required scale. Maps at 1:100 000 scale have been found useful for both paddock and whole station applications (Curry et al. 1994); 1:50 000 scale plans are better suited to the preparation of environmental reviews for mining and engineering projects (e.g. Pringle 1995). Land systems can also be clearly mapped at a 1:250 000 or 1:500 000 scale for regional uses.

The minimum-sized area of land considered mappable at these scales is approximately one square kilometre (1 km^2) in extent. Narrower areas, for example 500 m, can be mapped provided they are 1.5 km long. This allows long sinuous features such as Ponton Creek and the clay depressions of the Woorlba land system to be mapped.

Reconnaissance field work

Black and white aerial photographs at a scale of 1:50 000 were taken between 1997 and 1998, though in some western parts for areas affected by bushfire, aerial photos from 1980 were used. Aerial photographs were used to identify land system boundaries and to plan navigation throughout the survey area.

Reconnaissance trips were initially carried out between April 2000 and September 2001. This included visiting areas mapped during the 1974 Western Australian Nullarbor Plain survey (Mitchell, McCarthy & Hacker 1979). During these trips initial descriptions of the soil and vegetation were collected from 108 inventory sites. The Nullarbor survey was delayed when higher priorities required field work. The survey recommenced in 2005, though due to staffing changes two further reconnaissance trips were required; in May the southern areas were visited and in July northern areas.

To help define land system boundaries other sources of information on the biophysical resources of the survey area were reviewed, including Lowry's geology of the Western Australian part of the Eucla Basin (1970) in conjunction with the 1:250 000 geological map series produced by Geological Survey of Western Australia and Beard's vegetation survey of the Nullarbor (1975).

The aim of the reconnaissance trips was to familiarise survey team members with eastern land systems identified in the 1974 survey (Mitchell, McCarthy & Hacker 1979), major land types and vegetation communities, and to trial and finalise field methods to be used during the survey. Plant species not identified in the field were collected and their locations recorded. These specimens were later identified with the assistance of staff from the Western Australian Herbarium. Due to the large area to be covered in a relatively short period the team mainly

travelled along major tracks, moving through the area relatively quickly and camping in a different location each night.

At Cocklebiddy Roadhouse in June 2005 the Nullarbor Land Conservation District held a meeting where the survey team delivered a session for pastoralists explaining the procedures and intended outcomes for the Nullarbor survey. This provided an opportunity for the team to meet with present day pastoralists and to gain some local knowledge. To assist in the preliminary mapping of land systems pastoralists provided maps of their leases with the land systems they recognised marked out on their properties. Pastoralists' opinions were also sought on such topics as the palatability of major plant species, stocking rates of different pasture types and the susceptibility of different pasture types to fire and grazing. During the reconnaissance period former Nullarbor pastoralists and rangeland practitioners were also sought for advice and opinion.

Participants at the Cocklebiddy meeting held by the Nullarbor Land Conservation District in June 2005.

Main field work

Between September 2005 and November 2007 eleven trips lasting two to three weeks were made to the survey area. The survey team comprised two rangeland advisers and a soil surveyor from the Department of Agriculture and Food and a navigator from Landgate. The staff involved was:

Rangeland advisers	PA Waddell, AK Gardner
Navigator	KA Leighton
Soil surveyor	P Hennig

The area was surveyed on a station by station basis. Prior to each trip traverse routes were planned for the pastoral leases to be visited. Between three and five days were spent on each lease depending on size. Pastoralists were notified when the team would be in their area and encouraged to spend at least one day with the team while they were surveying their property.

Land system identification in previous surveys involved mapping provisional land system boundaries onto aerial photography using a stereoscope prior to each field trip. Once in the field ground-truthing determined the accuracy of provisional boundaries, with amendments made as required. In the land zones other than the Nullarbor Plain proper such as the Hampton Tableland, Mardabilla Plain, Nyanga Plain and the Roe Plains this method was successfully applied, primarily in the west and south of the survey area. The 1:250 000 geological map series produced by the Geological Survey of Western Australia was also used to help determine provisional land system boundaries.

This method, however, proved impractical for the vast and featureless areas of the Nullarbor Plain. Land systems occur over a much broader scale than in previous rangeland surveys and have poorly defined boundaries, tending to transition into adjoining systems over a distance of kilometres. The land systems on the Nullarbor Plain are difficult to distinguish because of the lack of relief in the landform and the similarity in vegetation communities across the same geology. As Mitchell, McCarthy and Hacker (1979) found in the 1974 survey many land systems on the Nullarbor Plain are defined and differentiated by the arrangement of jointing patterns. Differential weathering along these jointing patterns has led to the development of drainage floors of variable form (Lowry 1970). Where jointing patterns differentiate land systems, in most cases no distinct boundary can be discerned, a transitional zone occurs where characteristics from both land systems are evident, sometimes for up to 5 km.

In determining these broad land systems traditional stereoscopic photograph interpretation was supplemented by LANDSAT satellite imagery printed onto A0 sheets at 1:50 000 to correspond with the aerial photographs. This assisted in identifying the vast land systems of

the Nullarbor Plain. Land system boundaries drawn by pastoralists during the Cocklebiddy workshop also provided a valuable method for determining provisional land system boundaries. Aerial photography was still used in the field for these areas and observations regarding the landscape were marked onto the photos to assist in the final determination of a land system boundary.

Problems in navigating through this featureless terrain were largely overcome through the use of LANDSAT imagery and software linked to a Global Positioning System (GPS) unit. This was viewed on a laptop computer in real time and allowed the team to accurately determine its position on the satellite imagery in the field.

During field work the navigator recorded the location of all station infrastructure both on the aerial photographs and into a geo-referenced computer program. Names of bores, dams and paddocks were checked with the pastoralist, and the positions of new watering points, tracks and fences were recorded. This ensured land resource information could later be supplied to land managers on an accurate base map.

Traverses

The navigator followed the predetermined traverse on the aerial photographs and LANDSAT imagery. This allowed land system boundaries to be marked, verified or amended as necessary. At 1 km intervals along the traverse the land system, land unit and habitat type were recorded. In addition, an assessment of range condition was made. The range condition was recorded as a rating of vegetation condition and the extent of accelerated erosion at the site. The 'site' was considered to be an area within a 50 m radius of the vehicle at the kilometre interval point.

The ratings of vegetation condition were subjective visual assessments. They are based on the assessor knowing what type of vegetation is supported on the particular landform/soil association being assessed and an understanding of the natural range in attributes such as species composition, density and cover and the effect unnatural and natural disturbances have on the landscape. A rating of very good, good, fair, poor or very poor was given, based on the extent of induced changes from the 'natural' state of the landscape (Table 6). Pastoralism is the most extensive land use in the survey area, and the changes observed from the 'natural' state are mostly attributed to the development of artificial water points and grazing by introduced stock, native herbivores and feral animals, particularly rabbits.

In conjunction with grazing, fire has a major role in extensively altering much of the Nullarbor landscape. Some vegetation communities have undergone ecological changes so dramatic the original perennial species composition has been replaced by an annual component. Some areas are now considered to be in a state of irreversible transition and therefore were assessed on their present form rather than speculating on their former state.

Table 6 **Criteria for assessment of vegetation condition**

Rating	Condition indicators
1	**Excellent or very good** For the land unit-vegetation type, the composition and cover of shrubs, perennial herbs and grasses is near optimal; free of obvious reductions in palatable species or increases in unpalatable species, or the habitat type supports vegetation which supports vegetation which is predominantly unattractive to herbivores and is thus largely unaltered by grazing.
2	**Good** Perennials present include all or most of the palatable species expected; some less palatable or unpalatable species may have increased, but the total perennial cover is not very different from the optimal.
3	**Fair** Moderate losses of palatable perennials and/or increases in unpalatable shrubs or grasses, but most palatable species and stability desirables still present; foliar cover is less than on comparable sites rated 1 or 2 unless unpalatable species have increased.
4	**Poor** Conspicuous losses of palatable perennials; foliar cover is either decreased through general loss of perennials or is increased by the invasion of unpalatable species.
5	**Very poor** Few palatable perennials remain; cover is either greatly reduced, with much bare ground arising from loss of stability desirables, or has become dominated by a proliferation of unpalatable species.

In assessing range condition past surveys have rated vegetation condition alongside an assessment of accelerated erosion when present. The lack of surface drainage means the Nullarbor has not developed the large scale accelerated water-induced erosion features seen in other southern rangeland regions, particularly those with exoreic drainage now displaying widespread catchment dysfunction (Pringle, Watson & Tinley 2006). The Nullarbor land surface, especially the Nullarbor Plain with its shallow soils, has been extensively shaped through wind erosion (Lowry 1970), as well as by localised natural erosion cells driven by karst processes.

Reconnaissance trips and early traverse ratings recognised a high level of erosion across many habitat types and the dilemma faced in attributing the cause of the erosion. Whilst acknowledging pastoral activities have contributing to overgrazing leading to accelerated erosion at some locations, especially the large piospheres (zones of attenuated impact) radiating out from water points, it is increasingly difficult away from water points to differentiate natural erosion cells, a feature of the karst, against pastoral-induced erosion cells (Gillieson, Cochrane & Murray 1994). Forms of erosion away from water points were assessed on their origin, anthropogenic or karst-induced, and this was taken into account when determining a condition rating. Where erosion was attributed to pastoral activities this contributed to downgrading a site's rating. The criteria for assessment of accelerated erosion are provided in Table 7.

To aid in assessment of each site the presence and abundance of the dominant vegetation species was recorded. As an indicator of the grazing pressure such features as the abundance of stock pads and browse lines was also recorded. If an assessment point was less than 100 m from an area of human-induced disturbance such as a quarry, road works or building then no assessment of range condition was made.

Table 7 **Criteria for assessment of accelerated erosion at sites**

Type – intensity combination
No accelerated erosion present
Slight erosion (< 10% of site affected) Slight accumulation of wind-blown soil around plant bases and other obstacles and/or Removal of finer soil particles evident but soil crust is largely intact and/or Occasional rills (< 300 mm deep evident) and/or A few scalds present, usually < 2 m in diameter
Minor erosion (10–25% of site affected) Accumulation of soil around plant bases with plant mounds noticeably enlarged and/or Evidence of pedestalling but soil loss minor and plant bases not greatly elevated and/or Breaking of surface crust with small erosion faces and some redistribution of soil and/or Rilling evident but no gully development and/or Scalding evident but scalds relatively small and discontinuous
Moderate erosion (25–50%) of site affected Soil piling around plant bases and other obstacles is common but no plants completely covered and/or Pedestalling apparent with plant bases distinctly raised and with obvious soil loss and/or Rilling common or gullying present of parts of site and/or Surface sheeting with erosion faces (and/or microterracing) and active redistribution of soil and/or Wind scalds common
Severe erosion (50–75% of site affected) Extreme hummocking around plants and other obstacles; some plants completely covered and/or Severe pedestalling with plant bases greatly elevated and major soil loss and/or Widespread rilling or major gullying and/or Scalding extensive, smaller scalds have coalesced to form large, more or less continuous scalded areas and/or Surface sheeting with extensive exposure of subsoil or parent material; erosion faces (and/or microterracing) and active redistribution of soil and/or Much of surface generally unstable with ripple mark formation
Extreme erosion (75–100% of site affected) General surface movement, total surface area bare with formation of shifting dunes and/or Surface shifting and or scalding complete with exposure of subsoil or parent material and/or Extensive gullying

Ninety traverse routes, with an average length of 80 km, were completed in the survey area. These are shown in Figure 22. Some 6997 traverse points were recorded in the survey area, 6276 of which had a range condition assessment within pastoral lease boundaries. The geographical locations of the traverse points were stored using a GPS navigation unit linked to a geo-referenced computer program.

In conjunction with inventory sites, at locations representative of major habitat type groups condition sites were sampled determined by distances from permanent water points (0.5, 1, 2, 4 or > 5 km). This allowed investigation of various site attributes which could be used to determine key variables of ecological disturbance and to characterise the patterns of condition states within major habitats.

Inventory and condition sites

Inventory sites were selected to ensure each major land unit within each land system was adequately sampled and to assist in interpreting land system patterns as identified on aerial photos and LANDSAT imagery. Occasionally, when a different land unit/vegetation/soil association was encountered in the field additional sites were selected.

The aim of inventory sites is to collect information at the land unit scale. The site is considered to be an area within a 50 m radius of the survey vehicle. If the land unit was smaller, the assessor would only record information for the area within the selected unit.

Inventory site within a gilgai depression on the Nullarbor Plain.

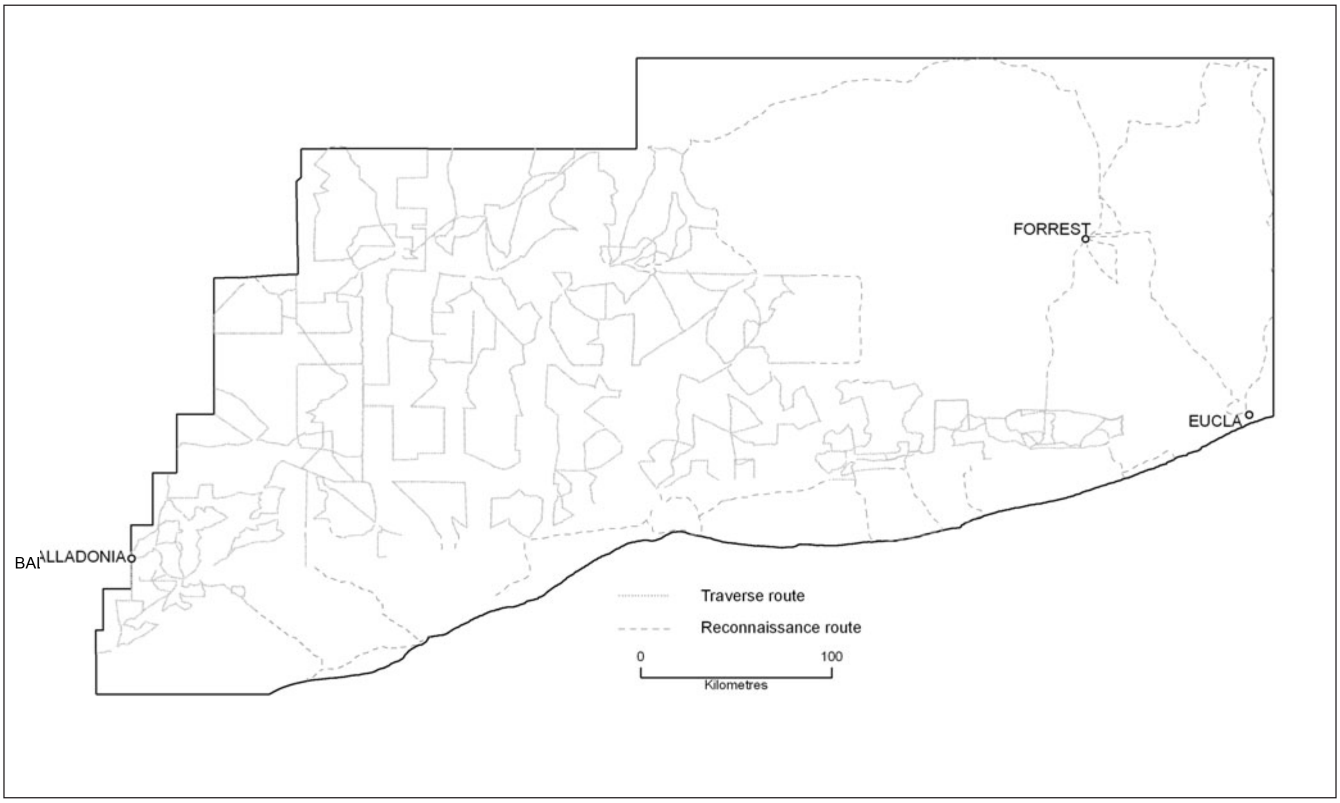

Figure 22 **Traverse and reconnaissance routes in the survey area**

Condition sites provided a means of calibrating visual resource condition assessments. Sampling techniques to interpret perennial plant species density were undertaken using different size classes of quadrats depending on the vegetation type. For bindii–grassland communities the frequency of perennial grass and shrub species was assessed using 0.5 m^2 quadrats. For chenopod shrubland sites perennial species were counted within 100 m^2 quadrats.

At each site information on the landform, vegetation and soil was recorded onto a standard record sheet similar to those used by Curry et al. (1994) in the Murchison regional survey. The attributes recorded at sites were:

General

- site number
- land system
- land unit
- pastoral station
- GPS location
- 1:250 000 map sheet name
- aerial photograph year, run and number
- date
- compass bearing of the site photograph.

Physical environment

- slope (in percentage)
- unit relief
- geology (according to the 1:250 000 Geological Survey series)
- site geology—if different to the mapped geology
- surface mantle abundance, shape, size and type
- outcrop, abundance and type
- type and intensity of accelerated erosion features
- vegetation condition rating
- extent and type of surface crusting
- evidence of fire.

Vegetation

- habitat type
- projected foliar cover (PFC) class of perennial shrubs (Table 8, Curry, Payne & Wilcox 1983)
- the dominant species in each stratum
- the relative dominance of each stratum
- basal cover class for perennial grasses
- height class of tree stratum
- height class of tall shrub stratum
- list of perennial plant species
- list of annual species.

Soil

- Australian Soil Classification class (Isbell 1996)
- total soil depth
- substrate
- soil surface condition
- type and structure of pans
- soil reaction trend
- observation method
- details of soil horizon; horizon designation, depth, texture and texture group, moist colour, soil moisture status, consistence, porosity, fabric, structure, ped shape, boundary distinctness, abundance, shape, size and type of coarse fragments and segregations, effervescence with concentrated hydrochloric acid and field pH.

Notes and landscape sketches were also made on an *ad hoc* basis. At each site a standardised method was used to photograph the site. The photo was taken from the top of the survey vehicle with a board identifying the survey and site number placed about 10 m away.

It usually took between 30 and 60 minutes to complete the description of an inventory and/or a condition site. Over the course of the survey 392 inventory sites were sampled, though eight registered outside the survey area. Figure 23 shows the location of inventory sites, including those sampled from the 1974 survey.

Table 8 **Foliar cover classes for tree and shrub strata (Curry, Payne & Wilcox 1983)**

Foliar cover class	Projected foliar cover (%)	Foliar cover
1	0–2.5	Isolated
2	2.5–5	Very scattered
3	5–10	Very scattered
4	10–15	Scattered
5	15–20	Scattered
6	20–25	Moderately close
7	25–30	Moderately close
8	30–50	Close
9	> 50	Closed

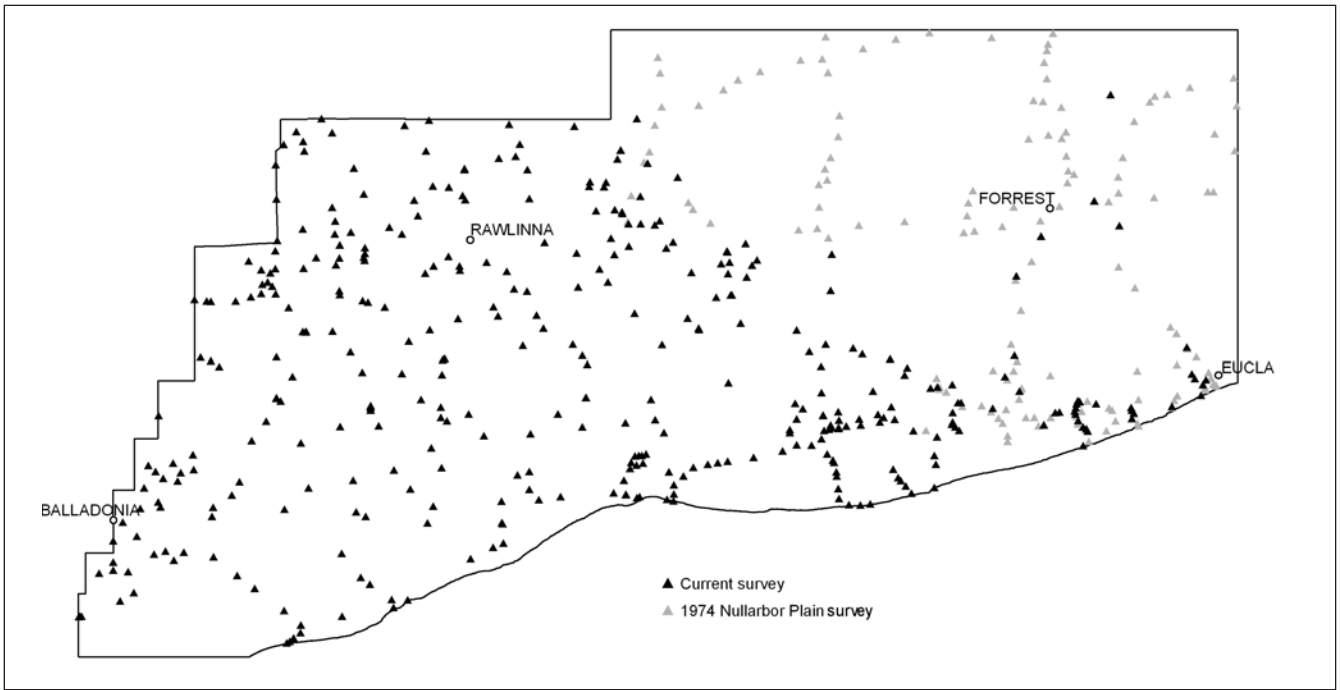

Figure 23 **The distribution of inventory sites in the survey area**

Water point sampling

Information was also gathered on all artificial watering points located adjacent to traverse routes. The water point name, map co-ordinates, type of water body, field pH and salinity were recorded. Whether the watering point was operational and its position in the landscape was also noted.

Analysis of data

Traverse records

Traverse assessment data was recorded in a database. As the assessment points had been recorded using GPS, the points could be referenced on the land system resource maps. This allowed traverse information recorded in the field such as the pastoral lease, paddock name and land system to be cross-referenced with the location of each traverse point on the map and amended if necessary.

Summaries of the traverse assessments were made by sorting the data on the attributes for which information was required. For example: summaries of the land units and habitat types within each land system which assisted in developing land system descriptions; and summaries of the condition of pastoral leases, land systems, land units and habitat types in the survey area. Land system area and condition statements for individual pastoral stations were also prepared.

Inventory and condition site data

The inventory and condition site data was also entered into a database, sorted and analysed to develop detailed descriptions of land systems, land units, soil, vegetation and condition trends. These are presented in the main chapters of this report. The data was then linked to the resource maps, allowing spatial interrogation. Inventory site data from the 1974 survey was also used to provide information to assist with this report.

Map production

In the southern, western and northern parts of the Nullarbor survey area land system boundaries are well defined and could be readily mapped within the confines of 1:50 000 scale aerial photography. For the Nullarbor Plain, through the central and eastern parts of the survey area, the broadscale land systems were mapped onto A0 sheets showing LANDSAT imagery at 1:50 000 to correspond with the aerial photography. Land system boundaries were finalised using the knowledge gained during field work to reinterpret and confirm boundaries drawn on aerial photographs and A0 sheets. The aerial photographs and A0 sheets were scanned and computer software was used to digitise land system boundaries.

First order or discernible land system boundaries were identified by solid lines. On the Nullarbor Plain land systems commonly lack obvious boundaries, tending to have a transitional zone of up to 5 km where characteristics from both land systems are likely to occur. On the map where there is no distinct land system boundary dashed lines indicate an approximate boundary occurring through the transitional zone between the land systems.

With improved aerial photography and the benefit of LANDSAT imagery the land systems identified in the eastern part of the Western Australian Nullarbor Plain during the 1974 survey (Mitchell, McCarthy & Hacker 1979) have been reassessed and in some cases boundaries have been modified. Four land systems from the 1974 survey were extensively modified resulting in one system being renamed and three systems incorporated into others.

Topographical and cultural information covering the survey area was loaded onto the computer system and updated with information collected during the field work. Land system boundaries were overlain on this background information. Maps were edited to make all features and text clear and legends were added.

Resource information has been presented on a land system map which accompanies this report. If clients require more detail, maps can be provided at a smaller scale. Special purpose maps can be produced displaying any combination of information presented on the accompanying map, as data have been captured in a multilayered geographically referenced digital format. Not all the data collected during the field work is presented in this report or on the accompanying map. More detailed information is available from the Department of Agriculture and Food on request.

Station plans at a scale of 1:100 000 have also been produced for each of the pastoral leases within the survey area. These are available to lease holders as full colour maps from the Department of Agriculture and Food.

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Geomorphology

PA Waddell

Introduction

The geomorphology of the survey area is described in terms of its morphotectonic setting at a continental and regional scale. Land surface types are described with reference to their component land systems. Landscape evolution is discussed in terms of Cainozoic alteration of the morphotectonic setting and the interactions between land use and landscape processes are considered.

Physiographic regions of the Nullarbor Plain Province

Physiographically most of the survey area occurs within the Nullarbor Plain Province of Jennings and Mabbutt (1977). The western-most margin of the survey area extends into the Coonana–Ragged Plateau section of the Yilgarn Plateau Province (Figure 24). Within the Nullarbor Plain Province the survey area occupies all or parts of the following component sections of the Province – the Carlisle Plain, the Bunda Plateau, the Israelite Plain, the Roe Plains and supports a low chenopod shrub and *Austrostipa scabra* (speargrass cover over its greater part. The sections occupied by the survey area are described in Table 9.

Table 9 **Brief description of the physiographic regions in the survey area (Jennings & Mabbutt 1977)**

Province	Sections
Nullarbor Plain	Carlisle Plain—sandstone plain with shallow closed depressions
	Bunda Plateau—covered karst plain of flat-lying limestone with closed depressions and caves; continuous cliff margin on south coast
	*Israelite Plain—narrow coastal plain with extensive dunes
	Roe Plains—coastal plain with extensive dunes
Yilgarn Plateau	*Coonana–Ragged Plateau—sandplain and stripped gneissic plains with low hills of granite and metamorphic rocks; calcrete and scattered small salt lakes along shallow valleys

* Only very small parts of these sections fall within the survey area.

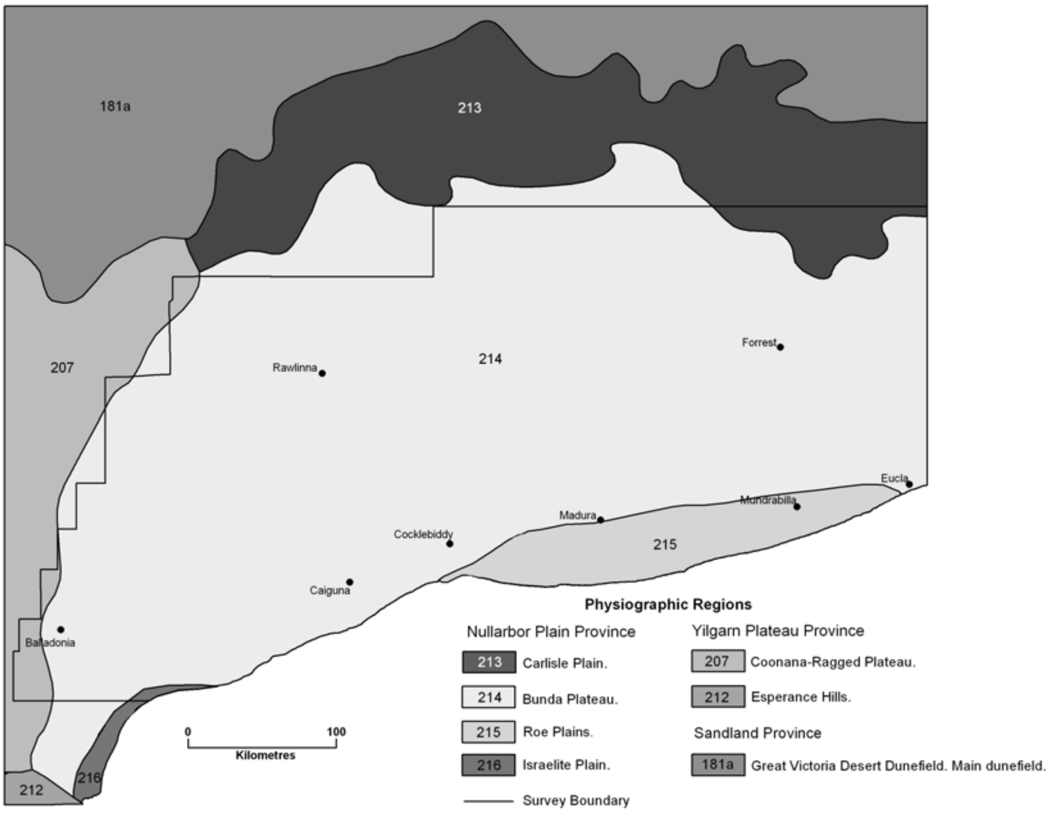

Figure 24 **Physiographic regions of the Nullarbor (after Jennings & Mabbutt 1977)**

Lowry (1970) identified five main physiographic units within the Eucla Basin: a plateau (the Bunda Plateau), a scarp (known in different places as the Hampton Range, Baxter Cliffs and Wylie Scarp), two coastal plains (Roe Plains and Israelite Plain), and a continental shelf (the Eucla Shelf).

Lowry (1970) further divided the Bunda Plateau into physiographic regions based on differences in geological history, topography, soil, vegetation and climate (Figure 25).

- *Nullarbor Plain* – restricted to the treeless part of the limestone karst in the centre of the Bunda Plateau. The landscape is generally of low relief, generally less than 4 m, and is characterised by different forms of karst depressions which form corridors of linear depressions and 'dongas' (locally named rounded depressions or claypans) separated by low rocky limestone ridges or rises.
- *Hampton Tableland* – in the south of the Bunda Plateau between the Nullarbor Plain to the north and bordered by the Baxter Cliffs and Hampton Range to the south. The region is characterised by undulating ridge-corridor topography with an average relief greater than elsewhere on the Bunda Plateau.
- *Nyanga Plain* – in the west of the Bunda Plateau to the north and west of the Nullarbor Plain and the Hampton Tableland. Broad flat plains of variably thick and continuous residual clay loam and calcrete overlying Nullarbor Limestone characterise this region.
- *Mardabilla Plain* – in the south-western part of the Bunda Plateau and is bordered by the Wylie Scarp to the south and the Nyanga Plain to the north-east. The surface of the plain is covered with clay and calcrete. Numerous inliers of crystalline basement rock protrude through the plateau surface.
- *Carlisle Plain* – north of the Nyanga Plain. The Carlisle Plain is developed on the Colville Sandstone and consists of plains with sparsely vegetated sandy soil.

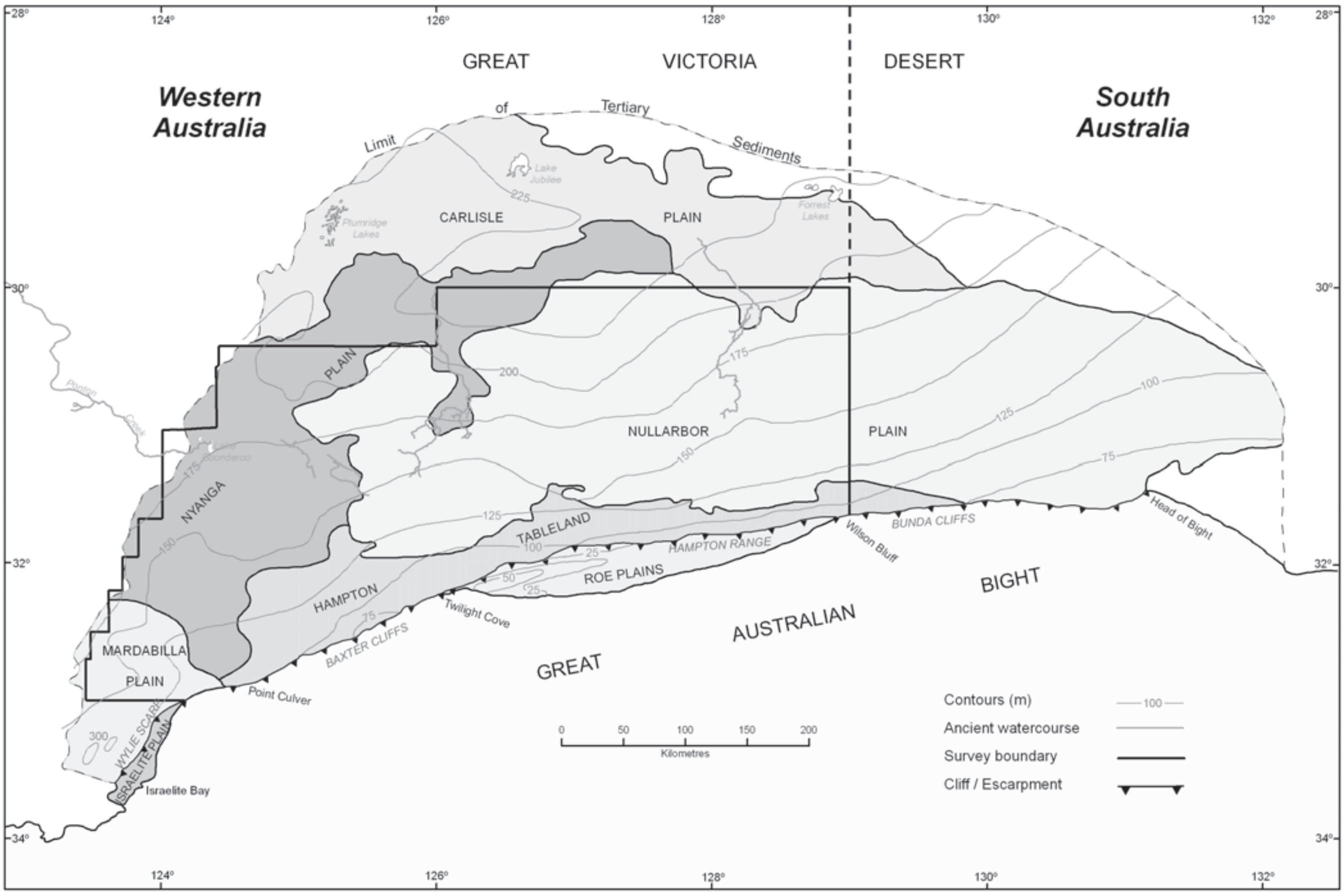

Figure 25 **Physiographic divisions of the Eucla Basin from Lowry and Jennings (1974)**

The regional geology is characterised by near-horizontal sequences of Cainozoic sediments, predominantly limestones and calcrete, over-lying Cretaceous sedimentary rocks of the Eucla Basin on an irregular basement of Precambrian granite and metamorphic rocks. The survey area may be divided into two distinct geological regions within which a number of land zones have been defined. The major geological regions are the Bunda Plateau and the coastal Roe and Israelite plains. The major feature is the Bunda Plateau which also includes Quaternary sandplains on the margins of the Eucla Basin.

The survey area is situated largely within the Western Australian portion of the Eucla Basin (Jutson 1950), the margins corresponding with the limit of the present distribution of the Eucla Group. Lowry (1970), expanding on from Singleton (1954), described the Eucla Group as all sedimentary rocks deposited in the Eucla Basin between the Middle Eocene and the Lower Miocene comprising the Hampton Sandstone, Wilson Bluff Limestone, Toolinna Limestone, Abrakurrie Limestone, Nullarbor Limestone and Colville Sandstone. The upper formations of the Eucla Basin are exposed on cliffs and in caves, but the lower formations are obscured and known only from bores. The Western Australian margins of the Eucla Basin correspond with the limit of the Colville Sandstone and Plumridge Formation in the north and the Nullarbor Limestone and Toolinna Limestone in the west and south-west. The southern extremity of the basin is marked by the 200 m isobath of the continental shelf in the Great Australian Bight.

Lowry (1970) described the surface terrain as having formed as a result of a virtual absence of tectonism and an extreme regularity of karst weathering due in combination to the low rainfall, high permeability and surface solution of limestones forming the plateau surface. However Webb and James (2006) propose that climate only had a minor role in restricting karst development; it is more likely the relative lack of surface and underground karst features are due to the particular characteristics of the limestones (primary porosity, lack of jointing and inception horizons) in combination with the Nullarbor Plain's flat geomorphology and hardening of surface limestones by calcrete, which has increased resistance to solutional and erosional processes.

Morphotectonic setting of the Eucla Basin

By the close of the Late Precambrian the morphotectonic structures largely responsible for determining the future evolution of Western Australian geology were essentially in place (Wyrwoll & Glover 1988). The Western Australian Shield composed of the Yilgarn and Pilbara Blocks, associated orogenic belts and sedimentary basins has essentially remained the dominant morphotectonic element controlling the relative stability of large parts of present day land surfaces.

In the Palaeozoic Australia was part of the super continent Gondwanaland and the area where the Eucla Basin occurs was a stable land mass (Lowry 1970; Wyrwoll & Glover 1988). The basement rocks beneath the Eucla

Toolinna Cove: In the south marine erosion of the Bunda Plateau has formed cliffs exposing limestone beds with uniform structure and lithology.

The centre of the Bunda Plateau is dominated by the vast, level to gently undulating Nullarbor Plain.

Basin comprise Precambrian granite, gneiss, schist and quartzite in the south-west; with folded Proterozoic sedimentary rocks in some northern and eastern areas. When the Eucla Basin developed these Precambrian basement rocks in the south-western part had a high relief and were exposed to erosion (Lowry 1970).

By the Late Jurassic a divergence rift zone parallel to the present south coast had developed as the Gondwanaland sections of Australia and Antarctica began to separate through continental extension (Veevers, Jones & Powell 1982). Active Mesozoic drainage systems of easterly trend were precursors of modern drainage basins (Beard 1975). It is likely these drainage systems were responsible for reducing the topography of the western Precambrian rocks to the low irregular relief similar to the present day condition. Such erosion also stripped the extensive covering of tillite sediments deposited in the southern portions of the Eucla Basin during the Lower Permian (Lowry & Jennings 1974).

In the Early Cretaceous downwarping commenced in the Eucla Basin towards the southern rift (Wyrwoll & Glover 1988). Terrigenous conglomeratic sandstone (Loongana Sandstone) and siltstone and shale (the basal part of the Madura Formation) accumulated over the basins basement rocks (Lowry 1970). In the Early to Middle Cretaceous 120 to 125 million years ago (Ma) the break-up commenced between Australia and Antarctica (Hocking 1990). As subsidence continued the sea entered the Eucla Basin from the south or south-west. Marine deposition occurred across the basin and continued through to the Late Cretaceous. Marine sediments during this period continued to form the Madura Formation and the overlaying Toondi Formation. In the Late Cretaceous the central area of the basin was overlain with glauconitic sandstone and sandy siltstone (Nurina Formation) (Hocking 1990). Towards the end of the Cretaceous the Officer Basin was uplifted to become land, deposition ceased in the Eucla Basin and did not recommence until the Middle Eocene (Lowry 1970).

The Australian continent began its northerly drift away from Antarctica in the Middle Eocene. Stratigraphic and palaeontologic evidence indicates Australia has become increasingly drier as it drifts northward into the arid mid-latitudes between the temperate and tropical latitudes (Jennings 1967; Lowry 1970; Beard 1975; Wasson 1982; Wyrwoll & Glover 1988; Benbow 1990a; Gillieson & Spate 1992).

During the Middle Eocene (45 Ma) downwarping of the Eucla Basin recommenced and was accompanied by marine invasion. Deposition started in the basin's centre with lenticular sandstone (Hampton Sandstone) followed by marl (the lower part of the Wilson Bluff Limestone) until a brief pause in downwarping (Lowry 1970). In the Late Eocene downwarping resumed with the deposition of chalky, bryozoan limestone (the upper part of the Wilson Bluff Limestone) occurring across the basin in areas of calmer water and well sorted bryozoan limestone (Toolinna Limestone) in the south-west under higher energy conditions (Lowry 1970). These processes continued until the end of the Late Eocene when downwarping ceased and the sea regressed past the present shoreline, resulting in weathering and erosion across the surface of the Wilson Bluff Limestone for over 10 million years (Webb & James 2006).

In the Late Oligocene to Early Miocene (25 Ma) the sea returned resulting in the deposition of bryozoan calcarenite and calcirudite (Abrakurrie Limestone) over the centre of the basin. By the Early to Middle Miocene the marine transgression had expanded to cover the entire Eucla Basin (Lowry 1970; Hocking 1990). Widespread deposition of foraminiferal and algal calcarenite followed (Nullarbor Limestone and its basal unit, the Mullamullang Limestone Member). The Nullarbor Limestone extensively overlies most of the basin except where it laterally merges, at its northern margins, into calcareous sandstone (Colville Sandstone) (Lowry 1970) and its equivalents further east (Benbow 1990b). The Colville Sandstone grades northwards into fine-grained sandstone and siltstone with lesser claystone and conglomerate (Plumridge Formation) (Hocking 1990). The limit of the Miocene shoreline is marked by the western and northern margins of the Nullarbor Limestone and Colville Sandstone respectively, a Permian sandstone scarp in the far north and Eocene dunes of the Ooldea Range in the north-eastern margin of the Bunda Plateau, in South Australia (Lowry & Jennings 1974; Benbow 1989, 1990a). Lowry (1970) stated that as there is no evidence that other areas of

southern Western Australia were submerged in the Miocene, the transgression was probably due to downwarping of the Eucla Basin.

Evolution of landforms in the Cainozoic

In the Middle to Late Miocene (about 15–12 Ma) the Australian continent was uplifted. Uplift of the Eucla Basin combined with global eustatic lowering of sea level resulted in the sea finally receding, exposing the Miocene sea floor. From the extent of the uplift and the vast, exposed surface of the Nullarbor Limestone, brought about by the lengthy duration of erosion, Lowry (1970) concluded the Eucla Basin had stopped subsiding. Karst features characteristic of the Bunda Plateau have since developed on and below this surface.

Since the Miocene uplift there has been extensive coastline recession of the carbonate geology where the more durable Precambrian rocks are absent, forming the Great Australian Bight. Aside from the Israelite and Roe coastal plains the land begins at the top of the limestone cliffs forming the southern edge of the Bunda Plateau, 60–100 m above sea level. West of Point Malcolm, in the Esperance District, Precambrian outcrop has reduced the effects of marine erosion along the southern coastline.

Sloping upwards from the southern sea-cliffs, to about 250 m above sea level at the northern perimeters, the majority of the Bunda Plateau's surface is a vast and featureless limestone plain with only minimal evidence of coordinated drainage systems that became inactive during the Pleistocene. The perpetuation of the flatness of this uplifted sea floor is the result of extreme regularity in weathering and minimal tectonic activity (Lowry 1970).

On the Bunda Plateau there are primarily two kinds of surface relief. Both features can be described in terms of minor differential surface solution of limestones directed by joint patterns. Of widespread occurrence is the undulating relief of parallel, low ridges separated most often by open depressions, though closed depressions are common in some systems. The wavelength between undulations is commonly 400–1600 m, though it can be greater, with an amplitude of 1.5–3 m, though nearer the coast it can be up to 10 m. The ridges form regular limestone rises scattered with rocky outcrop whilst the open depressions have clay loam soils. These undulations are straight and parallel but the trend changes throughout the plain reflecting the systematic tectonic control through joint directions (Jennings 1967a, 1967b). In some locations where joint patterns of equal importance converge, the relief pattern develops into a lattice arrangement. Here, shortened ridges occur as compact low rises (limestone hummocks) and are surrounded by smaller depressions.

Further inland there are also circular closed karstic depressions locally termed 'dongas', 400–1600 m or more across and a metre or two deep, commonly clay-floored with or without gilgai micro-relief. In some areas these depressions are arranged in lines parallel with the regular wave pattern of the ridges and corridors, but elsewhere they are randomly scattered (Jennings 1967a). Dongas are considered solution dolines rather than collapsed caves, formed through water ponding in depressions in the limestone plain with solution further dissolving the limestone and deflation later exposing them (Jennings 1963; Lowry 1970).

Erosion features normally associated with limestone country, such as solution sculptured pits and rock-holes in outcrop, sinkholes, dolines, underground drainage and caverns, are scarce in proportion to the regions area (Jennings 1967a, 1967b; Lowry & Jennings 1974; Webb & James 2006). The majority of solution features occur in the south of the Plateau where rainfall has presumably always been higher than further inland. Despite having a long history this karst is considered to have remained immature and retarded, due to a lack of water available to initiate greater solution sculpturing (Jennings 1967a, 1967b). Both Jennings (1967b) and Lowry (1970) state that the climate has never been much more humid than at present for long periods since it emerged from the Miocene sea.

In the Pliocene marine erosion carved sea-cliffs into the uplifted limestones (James et al. 2006). During the Late Pliocene the underlying calcarenite geology for the two coastal plains of the Western Australian portion of the Eucla Basin was deposited (Hocking 1990; James et al. 2006). Several sea level changes associated with Pleistocene climatic fluctuations are marked today by old strand-lines on the Roe Plains. During this period the maximum high sea level stand was about 36 m above the

present sea level (Lowry 1970). The coastal dunes overlying these plains are primarily calcareous and on the basis of calcrete development three significant stages of dune building can be identified (Jennings 1968; Lowry 1970).

From the Late Pliocene through the Pleistocene alternating glacial and interglacial periods influenced and controlled the development of geomorphic features. In the Early Pleistocene, following the onset of arid conditions, erosional periods were responsible for significant deflation of the soils of the central Nullarbor Plain (Jessup 1961; Lowry 1970). Lowry (1970) proposed that the combination of low rainfall and the high permeability of the plateau surface limestones had resulted in the regularity of weathering across the plateau, with up to 100 m of the surface limestone removed. The extent of deflation that occurred during this period exposed the subsurface relief of the joint controlled depression and ridge topography. However Webb and James (2006) state that the combination of the flatness of the plain and the hardening of the surface by calcrete are the features most likely responsible for the uniform denudation and relative lack of surface karst features; climate having only a minor role.

The Roe Plains are backed by the Hampton Range and the Israelite Plain is backed by the Wylie Scarp (Figure 25). The exposed scarp section of the Hampton Range displays Nullarbor Limestone over Abrakurrie Limestone and the Wylie Scarp displays calcrete over Toolinna Limestone (Lowry & Jennings 1974). Both scarps are only slightly degraded by erosion. Alluvial fans have developed below fluvial gullies along the scarp face aligned with structurally controlled joints. The bases of the Hampton Range and Wylie Scarp are overlain by a concave apron of colluvium, consisting mostly of clay with fragments of limestone and calcrete debris washed off the tops of the scarps (Lowry 1970).

There are two sections of presently active sea-cliffs along the southern margin of the Bunda Plateau: the 160 km long Baxter Cliffs in Western Australia and the 200 km long Bunda Cliffs in South Australia. Along the top of the Baxter Cliffs there are sections of weathered sand dunes. These clifftop dunes are wind-blown Pleistocene sand deposits formed when substantial quantities of drift sand accumulated against the cliffs. Sand transported up climbing dunes formed dune ramps to the top of the plateau. Subsequent rises in sea level eroded the ramps re-exposing the cliff face (Jennings 1968). Whilst the wave-cut cliffs and escarpments of the plateau's southern margin were formed during past interglacial stages, wave action today continues to erode the sea-cliffs since the last post-glacial rise in sea level (Davey et al. 1992; James et al. 2006).

The Bunda Plateau is Australia's largest karst area and the world's largest arid karst region (~250 000 km^2). Arid climatic conditions, the high permeability of the plateau surface limestones, concretisation and the geomorphology of the plain have been the major factors responsible for the evolution of the present day relief; a landscape shaped by extreme regularity of weathering and minimal tectonic activity. Since the emergence of the plateau from the Miocene sea karst development has remained restricted, most likely due to the particular characteristics of the limestone and the flatness of the plain. The vast, uniform land surfaces of the Bunda Plateau, and the associated Quaternary coastal plains, have evolved by processes of erosion, weathering and deposition.

Land surface types (groups of land systems)

Eight land surface types were defined within the survey area and grouped primarily on geology, relief and landform, and secondly on genesis and soil (Table 10). Land surfaces have been further subdivided according to vegetation and drainage patterns into 15 land types which provide information at a more regional level than that at the land system scale (refer to land systems chapter).

(i) Calcrete plains

These surfaces are level to gently undulating plains of very low relief formed of cemented calcium carbonate developed as part of the subsoil of an original soil profile. These surfaces are generally underlain by various limestones of the Eucla Group, except in rare instances in the south-west where granite outcrop protrudes through the surface. Predominantly consisting as relict land surfaces with deposits of uncertain origin, some land systems represent stages of transition with

Table 10 **Land surface types of the Western Australian Nullarbor survey area**

Land surface type	Land system	Predominant surface geology	Characteristic landform(s)	Dominant vegetation type	Survey location and distribution
(i) Calcrete plains	Caiguna	Calcrete	Gently undulating plains with residual calcareous low rises	Low eucalypt woodland	South-west, common
	Carlisle	Calcrete	Gently undulating partially deflated stony plains	Bindii grassland with sparse myall	North-east, uncommon
	Colville	Calcrete	Very gently undulating plains overlain by sandy loam	Myall woodland over bindii grassland	North-east, rare
	Culver	Calcrete	Gently undulating stony plains	Low mallee woodland over sedges and hummock grasses	South, common
	Gumbelt	Calcrete	Very gently undulating plains overlain by sandy loam	Eucalypt woodland with mixed scrub understorey	West, common
	Haig	Calcrete	Level loamy plains	Chenopod shrubland or bindii grassland	Central, rare
	Jubilee	Calcrete	Undulating and dissected plains	Bindii grassland with very scattered myall	North-east, uncommon
	Kyarra	Calcrete	Level loamy plains	Bindii grassland with sparse myall	Central and north, common
	Moodini	Calcrete	Level to gently undulating sandy loam plains	Eucalypt or myall woodland	South-east, rare
	Moopina	Calcrete	Level sandy clay plains	Eucalypt and melaleuca woodland; false bluebush shrubland in drainage foci	South-east, rare
	Nyanga	Calcrete	Level loamy plains	Myall or casuarina woodland over chenopod understorey	West and north, very common
	Rabbit	Calcrete	Level loamy plains	Bindii grassland	North-east, rare
	Zanthus	Calcrete	Level sandy loam plains	Mallee woodland over spinifex	West, rare
(ii) Depressions within calcrete plains	Koonjarra	Calcrete	Low breakaways and depressions	Chenopod shrubland or grassland	West, uncommon
	Woorlba	Calcrete	Closed depressions	Chenopod shrubland or grassland	South-west, uncommon
(iii) Granite outcrop in calcrete plains	Balladonia	Granite	Low granite outcrop	Bare granite outcrop with fringing acacia–dodonaea–eremophila shrubland	South-west, rare
(iv) Limestone plains [with deeper soil than (v)]	Kanandah	Recrystallised Limestone	Gently undulating plains	Myall woodland over pearl bluebush shrubland or bindii grassland	North-west, common
	Lowry	Recrystallised Limestone	Undulating rise overlain by sandy loam	Pearl bluebush shrubland	Central, rare
	Thampanna	Abrakurrie Limestone, Mullamullang Member Limestone, Nullarbor Limestone	Undulating joint controlled stony ridges and rises	Eucalypt and myall woodland on ridges; chenopod shrubland and grassland mosaics on drainage floors	South-east, common
	Toolinna	Toolinna Limestone, Abrakurrie Limestone	Undulating stony plains	Low mallee woodland, coastal heath and scrub	South, common
	Virginia	Recrystallised Limestone	Gently undulating plains	Myall woodland on low ridges; halophytic shrubland on saline drainage floors	West, common
	Weebubbie	Nullarbor Limestone	Gently undulating stony plains	Eucalypt and melaleuca woodland on rises; grassland on drainage floors and claypans	South-east, uncommon

Table 10 continued

Land surface type	Land system	Predominant surface geology	Characteristic landform(s)	Dominant vegetation type	Survey location and distribution
(v) Deflated limestone plains	Arubiddy	Nullarbor Limestone	Gently undulating stony plains with irregular joint patterns	Pearl bluebush shrubland; halophytic shrubland on drainage floors	South-central, common
	Balgair	Nullarbor Limestone	Gently undulating stony plains with irregular joint patterns	Pearl bluebush shrubland on broad ridges; bladder saltbush shrubland and grassland mosaics on drainage floors	Central, common
	Bullseye	Nullarbor Limestone	Very gently undulating stony plains, dongas common	Bindii grassland; donga groves	Central north, very common
	Chowilla	Nullarbor Limestone	Gently undulating stony plains with irregular joint patterns	Myall woodland and pearl bluebush shrubland; grassland and halophytic shrubland mosaics on drainage floors	South-east, common
	Gafa	Nullarbor Limestone	Very gently undulating stony plains with irregular joint patterns	Pearl bluebush shrubland or bindii grassland; bladder saltbush and grassland shrubland mosaics on drainage floors	Central, very common
	Kinclaven	Nullarbor Limestone	Level stony plains, dongas common	Mixed shrubs and bindii grassland; donga groves	Central north, common
	Kitchener	Nullarbor Limestone	Gently undulating stony plains	Mixed acacia shrubs and bindii grassland with sparse black oak	North-west, uncommon
	Kybo	Nullarbor Limestone	Undulating stony plains	Pearl bluebush shrubland; grassland and herbland on drainage floors	Central, common
	Moonera	Nullarbor Limestone	Very gently undulating stony plains defined by north-east to south-west trending joint patterns	Pearl bluebush shrubland; bladder saltbush shrubland on drainage floors	Central, very common
	Morris	Nullarbor Limestone	Level to very gently undulating stony plains with irregular joint patterns	Pearl bluebush shrubland; bladder saltbush shrubland and grassland on drainage floors	South-east, common
	Nanambinia	Nullarbor Limestone	Level to gently undulating stony plains	Sugarwood over chenopod shrubland or grassland	South-west, uncommon
	Naretha	Nullarbor Limestone	Gently undulating stony plains	Mixed acacia and pearl bluebush shrubland; bindii grassland	Central west, uncommon
	Nightshade	Nullarbor Limestone	Gently undulating stony plains	Tussock grassland; halophytic shrubs in drainage foci	South, common
	Nurina	Nullarbor Limestone	Stony plains commonly with gilgai patches	Grassland or bladder saltbush shrubland	Central, uncommon
	Oasis	Nullarbor Limestone	Level stony plains, dongas common	Bindii grassland; dongas groves	North-east, common
	Pondana	Nullarbor Limestone	Gently undulating stony plains with large rounded claypan depressions	Pearl bluebush shrubland; bladder saltbush shrubland or annual herbland in claypan depressions	Central west, common
	Reid	Nullarbor Limestone	Level to very gently undulating stony plains defined by north-west to south-east trending joint patterns	Pearl bluebush shrubland; bladder saltbush shrubland on drainage floors	East, common
	Seemore	Nullarbor Limestone	Level stony plains	Pearl bluebush shrubland with sparse myall and black oak	North-east, uncommon
	Shakehole	Nullarbor Limestone	Gently undulating stony plains along regular joint patterns trending north-east to south-west	Pearl bluebush shrubland with sparse myall; grassland and bladder saltbush shrubland mosaics on drainage floors	South-east, common

Table 10 continued

Land surface type		Land system	Predominant surface geology	Characteristic landform(s)	Dominant vegetation type	Survey location and distribution
		Skink	Nullarbor Limestone	Level to very gently undulating stony plains defined by north-east to south-west trending joint patterns	Pearl bluebush shrubland; bladder saltbush shrubland on drainage floors	Central south-east, common
		Vanesk	Nullarbor Limestone	Gently undulating stony plains defined by north-south trending joint patterns	Pearl bluebush shrubland and scattered myall woodland on low ridges; halophytic shrubland on drainage floors	Central west, uncommon
(vi)	Calcarenite plains	Mundrabilla	Colluvium, Roe Calcarenite	Level loamy plains	Myall woodland over false bluebush; open chenopod shrubland and nitre bush	South, Uncommon
		Roe	Colluvium, Roe Calcarenite	Level plains overlain by sandy loam	Eucalyptus and melaleuca woodland	South, Uncommon
(vii)	Coastal plains and dunes	Baxter	Sand, calcrete	Clifftop dunes	Banksia coastal heath and scrubland	South-west, rare
		Bilbunya	Sand	Coastal dunes, beach foredunes, dunefields	Coastal shrubland	South-west, rare
		Delisser	Sand	Coastal dunes, beach foredunes	Coastal shrubland	South, rare
		Wurrengoodyea	Sand, calcrete	Coastal dunes	Eucalypt coastal heath woodland	South, rare
		Wylie	Sand, calcrete	Coastal dunes	Banksia coastal heath and scrubland	South-west, rare
(viii)	Salt lakes	Boonderoo	Alluvium, sand, gypsum	Lake bed, saline alluvial plains, sandy banks	Halophytic and non-halophytic shrubland	North-west, rare
		Damper	Alluvium, clay, gypsum	Lagoonal saline clay flats	Halophytic shrubland	South, rare
		Lefroy	Alluvium, sand, gypsum	Lake beds, saline alluvial plains, sandy plains	Halophytic shrubland	South-west, rare
		Ponton	Alluvium, silt, sand	Concentrated drainage channels	Halophytic and non-halophytic shrubland	North-west, rare

erosional processes dominant as indurated calcrete surfaces become exposed through denudation. This surface type occupies the second largest part of the survey area, occupying almost 29 per cent. The land systems of this surface type are:

Caiguna—Level to gently undulating plains of residual and aeolian loam containing sheet and nodular calcrete, with occasional residual calcareous rises, supporting low eucalypt woodland.

Carlisle—Gently undulating plains of residual clay loam containing sheet and nodular calcrete dissected to expose Nullarbor Limestone supporting bindii grassland with sparse myall; differential surface weathering has formed dongas and drainage floors.

Colville—Very gently undulating plains of residual sandy loam containing sheet and nodular calcrete at or near the surface supporting myall woodland over bindii grassland; dongas and claypans exhibit centripetal drainage.

Culver—Level to gently undulating stony plains of residual and aeolian loam containing sheet and nodular calcrete, irregularly dissected by differential weathering along joint patterns to form closed drainage foci and low rises. Supports low mallee woodland over sedges and hummock grasses.

Gumbelt—Level to very gently undulating plains of shallow aeolian sand over residual loam containing sheet and nodular calcrete supporting eucalypt woodland with mixed scrub understorey.

Haig—Level to gently undulating plains of residual clay loam containing sheet and nodular calcrete supporting chenopod shrubland or bindii grassland; weakly dissected by relic ancient river courses.

Jubilee—Undulating plains of residual clay loam containing sheet and nodular calcrete, dissected by differential weathering along joints and relic ancient river courses to expose Nullarbor Limestone. Supports bindii grassland with very scattered myall. This system is intermediate in form between intact residual loamy calcrete plains of the Nyanga and Rabbit land systems and the completely deflated stony limestone plains of the Bullseye and Oasis land systems.

Kyarra—Level plains of residual clay loam containing sheet and nodular calcrete partially dissected to expose Nullarbor Limestone, supporting bindii grassland with sparse myall. This system is intermediate in form between intact residual loamy calcrete plains of the Kyarra and Nyanga land systems and the completely deflated stony limestone plains of the Bullseye and Oasis land systems.

Moodini—Level to gently undulating plains of undissected residual sandy loam and calcrete, derived from weathered residual aeolian deposits. Supports eucalypt or myall woodland.

Moopina—Level plains of undissected residual sandy clay and calcrete, derived from weathered residual aeolian deposits, supporting dense eucalypt and melaleuca woodland.

Nyanga—Level plains of residual clay loam containing sheet and nodular calcrete, supporting myall or casuarina woodland over chenopod understorey.

Rabbit—Level plains of residual clay loam containing sheet and nodular calcrete, with infrequent small, shallow claypans. Dominated by bindii grassland.

Zanthus—Level plains of residual sandy loam containing nodular calcrete near the surface, overlain by shallow deposits of aeolian sand. Supports mallee woodland over spinifex hummock grassland.

(ii) Depressions within calcrete plains

Within the calcrete plateau forming the Nyanga and Mardabilla plains karstic depressions of variable size occur. Ranging from 5 to 15 m deep, these depressions are bounded by low breakaways or gently inclined slopes. Depression floors are almost level with drainage foci in the lowest positions with various limestones of the Eucla Group exposed at the surface either through deflation or gilgai processes. Solution of the underlying limestone and deflation of clay is believed to be the process responsible for depression formation (Lowry 1970). This surface occupies almost 1.4 per cent of the survey area. The land systems of this surface type are:

Koonjarra—Low breakaways form plateau edges to calcrete plains enclosing large, depressions, supporting chenopod shrubland or grassland, with centripetal drainage patterns to drainage foci with gilgai microrelief.

Woorlba—Level to gently inclined depressions, supporting chenopod shrubland or grassland, forming drainage foci for surrounding plains.

(iii) Granite outcrop in calcrete plains

In the south-west part of the Bunda Plateau inliers of Proterozoic granite protrude through the calcrete plains of the Mardabilla Plain. Fringing surfaces are characterised by gritty-sandy surfaces or moat-like depressions where water run-off is concentrated leading to dissolution of calcareous surroundings. This surface type is a rare occurrence occupying about 0.1 per cent of the survey area. The land system of this surface type is:

Balladonia—Granite low rises and domes protruding through calcrete plains, fringed by gritty, sandy surfaces supporting acacia–dodonaea–eremophila shrubland.

(iv) Limestone plains [with deeper soils than (v)]

These limestone plains differ from the deflated limestone plains primarily by the amount of soil development brought about by weathering. These surfaces are capable of supporting woodland and occupy about 9.3 per cent of the survey area. This surface type can be further subdivided into two groups based on post-depositional limestone weathering processes.

Along the south of the Bunda Plateau surface weathering has created greater land unit relief in the Hampton Tableland than in land units of the Nullarbor Plain. This is considered largely a factor of higher rainfall in southern areas

causing greater solution of the limestones along joint patterns. The plains of the Hampton Tableland consist of undulating stony rises and ridges separated by karstic depressions of various form and length. The land systems of this surface type are:

Thampanna—Undulating irregular low stony rises (limestone hummocks) and ridges supporting eucalypt and myall low open woodland separated by open depressions formed by differential weathering of limestones along predominantly north-east to south-west trending joint patterns which support a mosaic of chenopod shrubland and grassland.

Toolinna—Undulating stony plains with irregular low rises (limestone hummocks) separated by stony marginal slopes and irregular drainage foci in-filled with colluvium. Supports low mallee woodland grading seaward into coastal heath and scrub along clifftops.

Weebubbie—Gently undulating low ridges and stony plains enclosing small drainage foci. Supports eucalypt and melaleuca woodland on rises and grassland on the lower slopes, closed drainage floors and claypans.

Along the west of the Nullarbor Plain weathering of Nullarbor Limestone has resulted in recrystallisation from a hard (indurated) limestone to a soft, porous, rubbly limestone. The land systems of this surface type are:

Kanandah—Gently undulating plains of partially deflated residual loam over recrystallised Nullarbor Limestone, supporting myall woodland over pearl bluebush shrubland or bindii grassland; differential weathering of the surface has formed small dongas and gilgaied depressions.

Lowry—Undulating low rise composed of recrystallised Nullarbor Limestone supporting pearl bluebush shrubland.

Virginia—Gently undulating plains formed through differential weathering of recrystallised Nullarbor Limestone along north-south trending joint patterns have formed parallel, low stony ridges, supporting myall woodland, separated by narrow, saline drainage floors up to 10 km long, dominated by halophytic shrubland.

(v) Deflated stony limestone plains

These surfaces form the Nullarbor Plain and occur in the centre of the Bunda Plateau. This erosional surface is the largest in the survey area occupying approximately 53.2 per cent of the area. Wind erosion in combination with weathering dissolution is the process most responsible for the regularity of weathering across the plain. Extensive deflation over the plateau surface has exposed a level to gently undulating surface with thin soil on the rises and clay to clay loam in the depressions. Deflated stony limestone plains can be further subdivided into two groups based on the genesis of karst landforms.

In the south of the Nullarbor Plain the surface has a gently undulating relief of parallel, low rocky ridges and rises separated by depressions controlled by structural joints in the underlying limestones. The land systems of this surface type are:

Arubiddy—Gently undulating stony plains supporting pearl bluebush shrubland, differentially weathered along irregular joint patterns to form closed drainage depressions, supporting halophytic shrubland.

Balgair—Gently undulating low stony rises with broad stony marginal slopes, supporting pearl bluebush shrubland, separated by drainage floors, containing a mosaic of bladder saltbush shrubland and grassland, along irregular joint patterns with infrequent large claypans and dongas; occasional relic ancient river courses form sinuous, narrow drainage tracts terminating indistinctly into the surrounding plains.

Chowilla—Gently undulating stony plains, supporting scattered myall woodland and pearl bluebush shrubland, separated by open depressions, supporting grassland and halophytic shrubland, along irregular joint patterns forming narrow drainage floors often terminating in oval claypans or as small closed drainage foci randomly distributed throughout the stony plains.

Gafa—Very gently undulating stony plains, supporting pearl bluebush shrubland or bindii grassland, with large claypans, infrequent dongas, lignum swamps and wide drainage floors, supporting a mosaic of grassland and bladder saltbush shrubland; drainage patterns restricted to the ancient river tracts.

Kitchener—Gently undulating stony plains of residual calcareous loam and sheet calcrete dissected to expose Nullarbor Limestone; differential weathering of the surface has formed infrequent dongas. Plains support mixed shrubs and bindii grassland. This system is intermediate in form between the intact residual loamy calcrete plains of the Nyanga land system, the weathered limestone plains of the Kanandah land system and the deflated stony limestone plains of the Naretha land system.

Kybo—A deflated fault scarp, supporting pearl bluebush shrubland, trending north-south for nearly 40 km characterises this system. Elongated clay drainage floors lie to the west of the low scarp, elsewhere superficial weathering of the limestone plain along north-east to south-west trending joint patterns has formed undulating stony ridges separated by broad, level drainage floors, up to 8 km long and < 1 km wide, with infrequent claypans and dongas forming large drainage foci in the lower-lying areas. Drainage floors support grassland and herbland.

Moonera—Very gently undulating stony plains. Defined by north-east to south-west trending joint patterns, which have formed wide drainage floors supporting bladder saltbush shrubland, separated by very gently undulating broad, stony low rises and ridges, supporting pearl bluebush shrubland; large infrequent irregular claypans, < 1 km in extent.

Morris—Level to very gently undulating stony plains, supporting pearl bluebush shrubland, separated by sinuous drainage floors along irregular joint patterns, up to 3 km long, and large, irregular claypans in drainage foci, up to 1.5 km in extent. Drainage floors support bladder saltbush shrubland and grassland.

Nanambinia—Level to gently undulating stony plains and gently inclined depressions subject to very diffuse sheet flow. Supports scattered sugarwood over chenopod shrubland or grassland.

Naretha—Gently undulating stony plains partially overlain by shallow sandy loams, support mixed acacia and pearl bluebush shrubland over bindii grassland. Differential weathering of the surface has formed long, narrow drainage tracts, occasional dongas and very shallow clay depressions. Infrequent relic ancient river courses form sinuous, narrow drainage tracts terminating indistinctly into the surrounding plains.

Nightshade—Gently undulating stony plains differentially weathered along irregular joint patterns to form closed drainage depressions or open drainage floors; saline drainage foci supporting halophytic shrubs occur irregularly throughout the plains. Plains are dominated by tussock grassland.

Pondana—Gently undulating stony plains differentially weathered to form large, closed depressions with level claypan floors characterise this system. Elsewhere the plains are superficially weathered to form dongas or drainage floors along north-south trending joint patterns. Drainage is restricted to relic ancient river courses. Plains support pearl bluebush shrubland; depressions support bladder saltbush shrubland or annual herbland.

Reid—Level to very gently undulating stony plains differentially weathered along predominantly north-west to south-east trending joint patterns to form linked, circular drainage foci along narrow drainage floors, extending up to 5 km. Stony plains support pearl bluebush shrubland; drainage floors support bladder saltbush shrubland.

Seemore—Level plains of partially deflated residual loam exposing Nullarbor Limestone support pearl bluebush shrubland with sparse myall and black oak. Differential weathering of the surface has formed small dongas and gilgaied depressions. This system is intermediate in form between the intact residual loamy calcrete plains of the Nyanga land system, the recrystallised limestone plains of the Kanandah land system and the deflated stony limestone plains of the Kinclaven land system.

Shakehole—Gently undulating stony plains differentially weathered along north-east to south-west trending joint patterns form a series of long, narrow drainage floors, up to 10 km long. Large drainage foci within drainage floors consist of closed, round claypans < 1 km in diameter or open, irregular clay plains up to 3 km in extent. Stony plains support pearl bluebush shrubland with sparse myall on rises and a mosaic of grassland and bladder saltbush shrubland in drainage floors.

Skink—Level to very gently undulating stony plains differentially weathered along predominantly north-east to south-west trending joint patterns to form long, narrow drainage floors, generally up to 10 km long, and large oval claypans in drainage foci, < 1 km in extent. Stony plains support pearl bluebush shrubland; drainage floors support bladder saltbush shrubland.

Vanesk—Gently undulating stony plains defined by north-south trending joint patterns forming marginal slopes to drainage floors, with saline drainage foci. Stony plains and low ridges support pearl bluebush shrubland and scattered myall woodland; saline drainage floors support halophytic shrubland.

In the north of the Nullarbor Plain the surface of the level plain is interrupted by many, rounded shallow, closed karstic depressions locally called 'dongas'. Dongas can be either randomly scattered or aligned parallel with joint patterns in the underlying limestone. The land systems of this surface type are:

Bullseye—Very gently undulating stony limestone plains supporting bindii grassland and drainage floors with frequent large dongas, occasional swamps and small claypans.

Kinclaven—Level stony plains, supporting mixed shrubs and bindii grassland, with frequent dongas, occasional swamps and small gilgai patches randomly distributed through stony plains.

Nurina—Stony plains dissected by broad drainage floors, occasional dongas and infrequent relic ancient river courses. Gilgai patches characterise this system. Plains support grassland or bladder saltbush shrubland.

Oasis—Level stony plains supporting bindii grassland, with numerous small dongas; drainage is restricted to relic ancient river courses.

(vi) Calcarenite plains

These surfaces occur on the Roe Plains below the Bunda Plateau. The coastal plain is underlain by calcarenite deposited after Late Pliocene marine erosion removed the earlier limestones of the Eucla Group and formed the escarpment and cliffs of the Bunda Plateau. They are predominantly level, depositional land surfaces subject to pedogenesis; clay loams and calcrete dominate the soil profile. This surface occupies almost 4 per cent of the survey area. The land systems of this surface type are:

Mundrabilla—Landward section of coastal plain, backed by marine eroded scarp, covered by shallow clay loam containing sheet and nodular calcrete; supporting myall woodland over false bluebush and open shrubland dominated by chenopods and nitre bush.

Roe—Coastal plain, in sections backed by marine eroded scarp, covered by shallow clay loam, with superficial sands, containing calcrete nodules; supporting eucalyptus and melaleuca woodland.

(vii) Coastal plains and dunes

These depositional surfaces form the coastal areas in the south of the survey area. They consist of beaches, foredunes, interdunal swales and saline depressions, partially consolidated to unconsolidated dunefields and colluvial sand ramps against the escarpment of the Bunda Plateau. These coastal surface types occupy about 2.5 per cent of the survey area. The land systems of this surface type are:

Baxter—Clifftop transverse sand dunes trending west-north-west separated by interdunal corridors of indurated calcrete; supporting banksia coastal heath and scrubland.

Bilbunya—Beaches, foredunes, interdunal swales and coastal dunefields with largely unconsolidated parabolic dunes trending approximately north-south, frequently becoming reticulate, occasionally forming star dunes; dune relief up to 90 m. Sparsely vegetated by coastal shrubland.

Delisser—Beaches, unconsolidated to partially consolidated foredunes, dunefields of unconsolidated parabolic dunes trending approximately north-south, swales and interdunal saline depressions. Sparsely vegetated by coastal shrubland.

Wurrengoodyea—Coastal parabolic sand dunes and swales supporting eucalypt coastal heath woodland. Sand dunes partially consolidated by a thin layer of sheet or nodular calcrete close to the surface.

Wylie—Interdunal saline depressions between partially consolidated coastal dunes backed to the escarpment by colluvial sand ramps supporting banksia coastal heath woodland.

(viii) Salt lakes

Salt lakes and their fringing tributary plains have developed as a result of past drainage systems becoming infilled by alluvial deposition and choked by aeolian sediments. They are capable of holding water for extended periods after heavy rainfall. These surface types are the lowest depositional surfaces and occupy about 0.5 per cent of the survey area. The land systems of this surface type are:

Boonderoo—Lake beds and fringing plains on saline alluvium surrounded by sandy banks, gypsiferous and kopi dunes, supporting halophytic and non-halophytic shrubland.

Damper—Lagoonal surfaces of saline, gypsiferous calcareous clay with aeolian deposits forming minor low dunes; supporting halophytic shrubland.

Lefroy—Lake beds and fringing plains on saline alluvium with drainage foci and claypans surrounded by sandy banks, low sand dunes and kopi dunes, supporting halophytic shrubland; only occurs in the far south-west of the survey area.

Ponton—Channels with narrow flanking alluvial plains and sandy banks supporting halophytic and non-halophytic shrubland; only occurs in the far north-west of the survey area.

Erosional landforms and processes

Erosional land surfaces dominate the survey area, occurring extensively across the Nullarbor Plain and where the calcrete plains of the Nyanga Plain are solution weathered, dissected and deflated exposing the underlying Nullarbor Limestone.

The surface of the Nullarbor Plain has been formed through solution, concretisation and deflation by wind erosion resulting in uniform regularity across the plateau. The karst features characteristic of the Bunda Plateau have since developed on and below this surface. The limestone plains can be subdivided into two surface types distinguished by the amount of soil development. Limestone plains with calcareous soils of variable depth occur on the margins of the Nullarbor Plain, whilst the majority of the plain is dominated by deflated surfaces. The extent of deflation has exposed the subsurface relief of the joint controlled depression and ridge topography. Stony limestone plains and infrequent low rises are the predominant features across the Nullarbor Plain's surface, separated by open or closed drainage floors, claypans and dongas. Less common are traditional karst features such as caves, dolines and sinkholes. The limestone plains generally have an abundant mantle of limestone and calcrete fragments, with outcrop more common on the tops of rises and undulations.

Some areas of the Nyanga Plain also exhibit erosional surfaces. Calcrete plains on the margins of the Nullarbor Plain are commonly dissected and the soil surface is shallow with extensive limestone outcrop. These surfaces are considered intermediate in form between intact residual loamy calcrete plains of the Nyanga Plain and the deflated stony limestone Nullarbor Plain. Erosion is the dominant process rather than the formation of soil and calcrete. Similarly some calcrete surfaces within the Hampton Tableland are also dominated by erosional processes. Within the Nyanga Plain the large karstic depressions forming the Koonjarra land system are also considered erosional land surfaces.

The southern edge of the Bunda Plateau represents a major erosional surface. The sea-cliffs and escarpments carved by marine erosion into the uplifted limestones are active zones of erosion with cliff retreat a prominent feature of the present day coastline. Scree and colluvial development against the escarpment on the coastal plains is less dramatic but still an active process.

Of rare occurrence in the south-west of the survey area are the protrusions of granite outcrop through the calcareous plains. The exfoliation observed on low granite domes and rises, as well as the surrounding gritty surface margins, indicate erosional processes. Depressions, 3–10 m deep and 50–150 m wide, characteristically ring most granite outcrop. These moat-like depressions are caused by water run-off from the granite concentrating solutional processes on the surrounding calcareous sediments (Lowry & Jennings 1974).

Relict land surfaces and processes

Relict land surfaces are the second most common surfaces in the survey area. Negligible soil development is the predominant process. The term 'relict' as defined by Hocking et al. (2007) refers to landforms where deposits are of uncertain origin, being either transported or weathered in situ. On such relict land surfaces the processes of denudation operate with minimum intensity and the rate of weathering is often equal to or exceeds the pace of surface erosion (Thomas 1974). The majority of these surface types occur on the Nyanga Plain to the west and north of the Nullarbor Plain. Small isolated areas also exist on the southern edge of the Bunda Plateau on the top of the Hampton Range.

The level to gently undulating surface of the Nyanga Plain is underlain by about 4.5 m of clay loam and calcrete, developed as part of the subsoil of an original soil profile. In most locations the plains support open myall woodland. The calcrete has formed as part of the soil profile through the cementation of calcium carbonate. The thick surfaces of clay loam have developed over an extensive time period with calcrete formation possibly commencing as early as the Pliocene (Lowry 1970).

Residual Late Pleistocene dunes are situated on the top of the Hampton Range. Formerly highly calcareous these have been reduced to sandy clay loams. Calcrete exists at or near the surface as a well developed horizon.

Depositional landforms and processes

Depositional landforms are less common in the Nullarbor region than in other Western Australian physiographic regions. They are the least common surface types in the survey area, largely due to the areic, self-draining nature of the Bunda Plateau. The lack of surface drainage, particularly across the Nullarbor Plain, means the volume of sediment dispersed by alluvial processes is greatly reduced. Aside from deposition processes associated with coastal environments, on the Bunda Plateau areas of deposition are largely restricted to depressions evolved through karst solution processes.

On the Nullarbor Plain karstic depressions within the limestone plains are controlled by structural joints in the underlying limestones. Depression evolution can be described in terms of differential surface solution of limestones. Though their genesis is solutional, depression landforms such as drainage floors and dongas are locally depositional settings accumulating colluvium from the surrounding stony plains and aeolian sediments from further afield. Within depressions soil depth is variable, determined by the degree of limestone solution. However, surfaces can display stony fragments exposed through deflation or brought to the surface through gilgai processes. Within the land system hierarchy they are part of the greater erosional process active on the limestone plains.

Within the Nyanga and Mardabilla plains clay floored depressions form drainage foci for surrounding systems. These depressions form the base unit of the Woorlba land system and are enclosed by gentle slopes draining down from neighbouring land systems. Fine colluvial sediments eroded via sheet flow from surrounding plains accumulate in the depressions.

On the Roe Plains colluvial deposits grade into distal sheetwash deposits in areas proximally associated to the Hampton Range. The majority of the Roe Plains, not overlain by coastal dunes, consist of clay loam underlain by Roe Calcarenite. These surfaces support either open myall woodland and open shrubland or melaleuca and eucalyptus mallee woodland.

Elsewhere coastal dunes have developed on land surfaces adjacent to the coast. Dunes fringe the Roe and Israelite coastal plains as well as locations on top of the Baxter Cliffs. On the coastal plains dune deposition is an ongoing process forming the present day beaches, foredunes and interdunal swales bordering the Southern Ocean. These recent deposits are backed by large dunefields of unconsolidated, mobile dunes forming the Bilbunya Dunes on the Israelite Plain and the Wurrengoodyea Hills and Delisser Sandhills on the Roe Plains. Older, consolidated dunes exist on the landward side of the younger dunes and on top of the Baxter Cliffs. Considered to be of Late Pleistocene age these older dunes have calcrete development close to the surface and are vegetated. At specific locations sand ramps link the Bunda Plateau and the coastal plains. These wind-built ramps formed at the base of the escarpment when the sea exposed coastal areas during a past sea regression.

Along the coast on the Roe and Israelite plains small lagoons have developed in interdunal depressions containing sand, silt, clay and occasionally gypsiferous sediments. On the Roe Plains two larger areas of lagoonal deposits represent Pleistocene lagoons barred from the sea by advancing dunes.

Salt lakes are rare in the survey area occurring in the west at the end of Ponton Creek forming Lake Boonderoo and in the far south-west. Lake sediments consist of recent aeolian and lacustrine deposits of quartz sand, silt and clay, sometimes with halite and gypsum. Lake Boonderoo is intermittently filled by infrequent cyclonic summer rains when Ponton Creek flows after being fed by salt lakes to the west of the Eucla Basin. Due to saline headwaters Lake Boonderoo can be highly saline.

In summary, the majority of the present landforms in the survey area occur on the Bunda Plateau comprising extensive level to gently undulating limestone plains, distinguished by soil development and karst landforms, bordered in the north and west by calcrete plains. In the south the Western Australian portion of the Bunda Plateau is bordered by sea-cliffs and the Roe and Israelite coastal plains fringed by beach and coastal dunes. Relief is greatly subdued and surface drainage is generally absent except in the west where there are rare salt lakes. The areic drainage surface above the Eucla Group limestones results in surface waters permeating through karst landforms into underground drainage systems. Landform patterns are best appreciated in terms of the morphotectonic setting with uplift of the Eucla Basin leading to the exposure of the Miocene sea floor. Minimal tectonic activity since uplift, in combination with the onset of arid conditions, the highly permeable nature of the surface limestones, hardening through concretisation and plain geomorphology has resulted in the regularity of weathering across the plateau surface. Karst features have since developed on and below this surface.

Land use impacts on landscape processes

Until recently there had been little research on the impacts of land use on landscape processes in Western Australian rangelands. Similar surveys to this one (Wilcox & McKinnon 1972; Payne, Curry & Spencer 1987; Payne et al. 1998; Curry et al. 1994; Pringle, Van Vreeswyk & Gilligan 1994) document lands on which natural erosion processes have been accelerated by inappropriate land uses. More recently participatory research and extension projects in the southern rangelands of Western Australia have begun to look at rangeland landscapes across a variety of scales and in doing so are identifying geomorphic determinants responsible for landscape change (Pringle & Tinley 2001, 2003; Pringle, Watson & Tinley 2006).

Calcrete plains

These surfaces are level to gently undulating plains of very low relief generally with clay loam soils of variable depth (e.g. Nyanga land system). When in good condition the moderate covering of vegetation in combination with the flat topography means these surfaces are generally resistant to erosion. However the friable nature of the soil surface makes these plains susceptible to degradation and erosion following disturbance, particularly after preferential grazing fragments vegetation communities or fire completely exposes the ground surface.

Where calcrete plains border the Nullarbor Plain the surfaces are even more susceptible to erosion (e.g. Jubilee and Kyarra land system). Due to landform dissection and slight gradient differences between the calcrete plains over the underlying limestone, soil depth becomes shallower in these intermediate surface types as they merge onto the Nullarbor Plain. The decrease in soil depth reduces the capacity for vegetation formations to offer significant soil surface protection as their coverage is generally scattered. When vegetation is further reduced through disturbance, such as by overgrazing, storm damage and fire, soil loss is further exacerbated.

Depressions within calcrete plains

Low breakaway scarps in the calcrete plain occupy a very small area of the survey (e.g. Koonjarra land system). These land units are inherently unstable and have tributary rills, guttering, gullies and exhibit soil loss downslope. They exhibit some of the most active natural erosion within the survey area as they represent erosional fronts between the topographically higher calcrete plains and the

underlying limestones. Naturally eroding through solution of the underlying limestone and deflation of clay; the degradation of the breakaway scarps is accelerated through loss of perennial shrubs by overgrazing and vehicle tracks. To reduce the track impact on break-away slopes and to protect associated fragile vegetation communities bunds should be constructed to reduce the volume and erosive potential of water flow channelled by the tracks.

Granite outcrop in calcrete plains

The nature of this surface type results in very little infiltration and run-off is concentrated to the margins of the protruding rock outcrop. Erosion of these surfaces is generally not a concern as the surfaces are commonly bare, exposed granite outcrop fringed by gritty-sandy surfaces.

Limestone plains [with deeper soils]

These limestone plains are level to gently undulating and are capable of supporting open woodland primarily due to the amount of soil development improving infiltration. These plains are generally covered by a variable soil layer with a stony mantle. They are generally not susceptible to erosion except when plant cover is reduced and cryptogamic crusts become fragmented through disturbance.

On the Hampton Tableland in the south, where surface weathering has resulted in greater land unit relief, undulating stony rises and ridges are active sites of erosion as sediments are transported to surrounding depressions (e.g. Thampanna land system). Vegetation loss through overgrazing or fire can result in erosion leaving rises (limestone hummocks) completely bare and exposed. In such landforms, particularly when affected by fire, total grazing pressure should be restricted for a period of time set by seasonal conditions which will determine the effectiveness of recovery. Continuous grazing pressure immediately after fire and/or through extended dry periods can result in continual erosion stripping these surfaces to such as extent they become incapable of supporting perennial vegetation communities.

Deflated stony limestone plains

Deflated limestone plains are dominated by level to gently undulating stony surfaces with regular outcrop. Soils on the stony surfaces are shallow and vegetation cover is commonly low and scattered (usually less than 15 per cent projected foliar cover). The stony mantle offers some protection but where loss of perennial shrubs has occurred wind erosion is accelerated.

The lack of surface drainage on the Nullarbor Plain results in water sheet flow having only a restricted and localised role in transporting sediment from the stony plains to surrounding karstic depressions. Wind is also responsible for supplying depression deposits. Deposits form level surfaces in the depressions except where gilgai cause irregular, hummocky patches. The fine clay soil crust of depression floors is readily erodible and any form of disturbance will inevitably lead to accelerated deflation through wind erosion. Installing water points on such fragile landforms has resulted in the extensive piospheres scarring the land-scape through the Nullarbor pastoral areas. The reduction in perennial vegetation to trap wind-blown material exacerbates the extent of piospheres, zones of attenuated impact. Through deflation such areas are losing their ability to provide suitable conditions for germination and establishment of perennial plants. Dust storms on the Nullarbor are a common occurrence, especially during prolonged dry periods.

A piosphere caused by overgrazing at a water point located on the fragile soils of a drainage floor between stony plains.

Deflated surface within a piosphere. Overgrazing has removed perennial shrubs and trampling by stock has disrupted protective soil crusts, exposing the soil to wind erosion.

Older weathered limestone surfaces commonly display pitting, whereas recently exposed surfaces lack weathered features indicating the extent of soil loss.

Calcarenite plains

These surfaces occur on the Roe Plains below the Bunda Plateau (e.g. Mundrabilla and Roe land systems). Underlain by calcarenite these surfaces form level plains subject to pedogenesis with clay loams and calcrete through the soil profile. The flat topography and moderately dense surface cover of vegetation comprising either open myall woodland and open shrubland or melaleuca and eucalyptus mallee woodland means the plains are generally resistant to erosion. Disturbance through overgrazing and fire can expose surfaces making them susceptible to erosion. The colluvial footslopes of the Hampton Range are naturally erodible due to steep gradients. Grazing activity should be minimised on these slopes. Regularly spaced bunds and spoon drains should be constructed on scarp tracks to reduce the volume and erosive potential of water flow channelled by tracks.

Coastal plains and dunes

Unconsolidated coastal beach dunes (e.g. Bilbunya and Delisser land systems) and partially consolidated coastal sand dunes (e.g. Baxter, Wurrengoodyea and Wylie land systems) are subject to strong sea breezes and are susceptible to wind erosion if vegetation is lost. Aside from beach dunes and mobile dunefields, most coastal dunes are stabilised with coastal scrubland and partially consolidated with thin calcrete horizons near or at the surface. Fire and vehicle traffic are the most likely causes of disturbance responsible for reducing vegetation cover and initiating erosion.

Salt lakes and lagoonal flats

Level to very gently inclined saline alluvial plains are found adjacent to salt lakes (e.g. Boonderoo and Lefroy land systems). Soils are duplex types with a sandy surface horizon commonly over gypsiferous sediments. Water infiltration is often enhanced and there are widespread cryptogamic crusts. On the coastal plains lagoonal clay flats occur in interdunal swales or as Pleistocene lagoons (e.g. Damper land system). Generally, lack of slope renders these systems not susceptible to water erosion, though they are subject to inundation. If vegetation cover is reduced and cryptogamic crusts are disturbed (e.g. by overgrazing and trampling) wind erosion can result in scalding.

In summary, the Western Australian part of the Nullarbor region has a number of natural characteristics which help protect the landscape from the impacts of inappropriate land use. The factor most responsible for offering protection to the Nullarbor landscape is its flat topography and calcrete capping of surface limestones in conjunction with prolonged arid to semi-arid climatic conditions, resulting in the nearly level, areic terrain. The lack of distinct coordinated surface drainage means the Nullarbor has not developed the large scale accelerated water-induced erosion features initiated by overgrazing, as seen in other

southern rangeland regions, particularly those with exoreic drainage. Other protective characteristics include the stony surfaces and cryptogamic soil crusts. On the calcrete and coastal plains moderately dense vegetation communities comprising species which are largely unaffected by grazing have also contributed to protecting the landscape.

Fire is a natural feature of the Nullarbor environment spontaneously occurring as a result of lightning strikes during summer thunderstorms. Good seasonal conditions promote an abundance of annual growth and expansion of *Austrostipa scabra* (speargrass). Following dry conditions the potential fuel load from this growth will readily carry fire. Since European settlement the frequency of fires in the Nullarbor region has increased particularly during the period when steam trains used the Trans-Australian Railway and sparks ignited fires adjacent to the railway line.

The areas in which the landscape is most susceptible to inappropriate land use are the Bunda Plateau escarpment footslopes and low breakaway scarps of the calcrete plains which are subject to sheet flow; various forms of karstic depressions (e.g. drainage floors, claypans and dongas) where disturbance accelerates deflation; sand dunes along coastal areas; and sites supporting vegetation which is highly preferred by herbivores. The impact of land use in these areas has not been quantified in terms of soil loss rates, sediment yields, vegetation cover thresholds and other such variables inherently reflective of landscape processes and ecosystem health.

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Soils

P Hennig

Summary

The soils of the study area are dominated by reddish shallow calcareous loams and sands derived from calcareous parent materials.

White, grey and brown deep sands, predominantly calcareous, are associated with coastal margins of the survey area.

Red/brown clayey soils occur sporadically throughout in clay plains and clay, gilgai or donga depressions.

Red sands and red sandy earths are associated with sand banks near Lake Boonderoo in the north-west.

Small areas of saline and gypsiferous soils occur around Lake Boonderoo and variable stony soils, gritty shallow red sands and bare rock are associated with occasional granite outcrop in the south-west.

Previous surveys

The Nullarbor Plain soils were broadly described and mapped at a scale of 1:2 000 000 by Northcote et al. (1960–68) as part of *The Atlas of Australian Soils*, providing a general overview of soil distribution. Laut et al. (1977), Mitchell et al. (1979) and McKenzie et al. (1987) provided more detailed soils information.

Soil classification and description

The Australian Soil Classification (Isbell 2002) is the national system for classifying soils. It replaces previous systems by Stace et al. (1968) and Northcote (1979). The Australian Soil Classification system uses scientific, soil-based nomenclature similar to other classification systems in the world.

In Western Australia a simple system for describing the main soil types—the Soil groups of Western Australia is also used (Schoknecht 2002). Soil groups are a simple method of describing and naming the soils in Western Australia using easily recognisable soil morphological features. In this chapter, the soil types of the Nullarbor are categorised by WA Soil groups with reference to typical Australian Soil Classifications provided within each category.

The basic concept of describing and identifying soils is through the examination of soil layers or horizons. The soil layers have identifiable properties and are described through the concept of pedologic organisation (pedology being the study of soils). Using the principle of soil layering or organisation, soils are described as belonging to three main texture groups: soil with uniform texture throughout the profile, soils that gradually change in texture down the profile; and soils with a texture or permeability contrast (often termed *duplex*) within the profile.

Soils with uniform textures include sands (e.g. deep sandplains inland from the coast or spinifex sandplains in the Zanthus area), loams (e.g. plains of the southern Nullarbor) and clays (e.g. deep clays in dongas). Gradational soils are common on donga margins and areas of common water accumulation. Texture contrast (duplex) soils are uncommon. In many cases the soils are shallow with hardpans or rock within 1 m of the soil surface.

Field sampling methods

Three hundred and twenty soils were described using the criteria of the *Australian Soil and Land Survey Field Handbook* (McDonald et al. 1990).

Sampling was via shallow soil pits and a 50 mm diameter soil auger, to retrieve soil to a depth of 1 m or to the level of the impermeable underlying rock. Samples were laid out on groundsheets to determine different soil layers.

Soil textures were determined for the sieved fine earth fraction (< 2 mm) through moistening the sample and noting the behaviour of the kneaded soil. Field textures provided an indication of the proportions of sand, silt and clay. Soil textures range from sand (< 5 per cent clay) to heavy clay (> 50 per cent clay).

Textures were determined down the profile to separate the major soil layers into A, B, C or K horizons where, the ‘A’ horizon is the topsoil, the ‘B’ horizon is the subsoil, the ‘C’ horizon is weathered rock and the ‘K’ horizon is limestone or calcrete.

Soil colour was determined in the field using a moistened fresh soil aggregate and compared to standard soil colour charts (Munsell 1954).

Consistence (a measure of soil particle bonding) was determined by compressing a 20 mm unit of undisturbed soil. Soil structure and fabric were determined using a hand lens.

The presence or absence, size and shape of soil aggregates (particle clusters held together by forces of inter-particle bonds) were recorded.

The parent material, substrate or underlying rock was determined either from examination of material retrieved via soil auger or from geological maps. Soil pH was measured using a portable pH meter or less commonly a paste calorimetric method described by Raupach and Tucker (1959). Carbonates were detected via drops of hydrochloric acid, effervescence indicating presence of calcium carbonate.

The electrical conductivity (EC) of soil horizons was obtained in the field using a portable EC meter using 10 g of soil in 50 mL of distilled water. This was used to indicate the total soluble salts expressed in milliSiemens per metre (1 mS/m equates to about 5 parts per million). The soil salinity classes are:

Topsoil

Low (non-saline)	1–40 mS/m
Moderate (saline)	41–80 mS/m
High (highly saline)	> 80 mS/m

Subsoil

Low (non-saline)	0–120 mS/m
High (saline)	> 120 mS/m

Other recordings were the shape, size and abundance of coarse fragments, soft segregations or crystals within a profile plus surface features such as mantle, outcrop and cryptogam crusting.

Cryptogams (microbiotic assemblages of mosses, fungi, lichen and liverworts) form thin surface crusts covering many soil surfaces.

The soils were classified using the Australian Soil Classification system in which the soil depth classes are:

< 25 cm	very shallow
25–50 cm	shallow
50–100 cm	moderately deep
> 100 cm	deep

Describing a soil profile at an inventory site.

Soil groups

Eighteen soil groups (Schoknecht 2002) were identified in the survey area and are summarised in Table 11. The soil group concept seeks to summarise and standardise the naming of soils across Western Australia based on easily recognisable soil morphological features. A summary table lists the dominant features of each soil group. Soil types occupying greater than 25 per cent of a land system are listed as major soils. Soils occupying 10–25 per cent of a land system are listed as minor soils.

Table 11 **Soil groups in the survey area**

Soil group (code)	Description	Landscape location
Salt lake soil (102)	Gypsiferous deposits	Lake Boonderoo, lacustrine plains
Bare rock (201) Stony soil (203)	Rock outcrop with very shallow skeletal soils	Granitic outcrop
Red deep sandy duplex soils (405)	Red deep sandy surfaced soils overlying clay subsoils	Floors of depressions with calcrete plain
Calcareous shallow sands (421)	Shallow sands overlying limestone	Hampton and Wylie scarps
Pale shallow sands (422)	Pale shallow sands overlying calcrete	Interdunal swale
Red shallow sands (423)	Red shallow red sands overlying granite or occasionally calcrete	In the west of the survey area near granitic outcrop
Deep sands (440)	Grey and brown deep sands	Beach foredunes and swales
Calcareous deep sands (442)	Calcareous sands over 1 m deep	Beach and foredunes; coastal dunefields and dune ramps
Red deep sands (445)	Red sands over 1 m deep	Sandy banks around Lake Boonderoo
Red sandy earths (463)	Red soils with a sandy surface grading to loam or clay by 80 cm	Sandy banks around Lake Boonderoo; Nyanga Plain
Calcareous shallow loams (521) incorporating Calcareous stony soil (202)	Shallow calcareous loam overlying calcareous rock types	Limestone, calcrete and calcarenite plains
Red shallow loams (522)	Shallow red loam overlying calcrete	Calcrete plains
Calcareous loamy earths (542)	Loamy surfaced soils grading to clay loam subsoils; calcareous throughout	Limestone, calcrete and calcarenite plains
Red loamy earths (544)	Deep red loamy surfaced soils often grading to clay loam	Calcrete plains
Cracking clays (600)	Cracking clays exhibiting surfaces cracks or gilgai mounding	Dongas, swamps and drainage foci
Red/brown non-cracking clays (622)	Red to brown clays (mostly deep) sometimes with cracking clays	Dongas, drainage foci and lacustrine depressions; calcrete plains

Soil group 102—Salt lake soils (Gypsiferous deposits)

This soil type is uncommon and was recorded around the lake bed and saline plains of Lake Boonderoo. These soils also occur on the saline plains, gypsiferous plains and lagoonal low dunes of the Damper land system, or kopi dunes of the Lefroy land system. Gypsum (calcium sulphate) deposits form from saline groundwater or lacustrine accumulations. When dry these deposits are redistributed by wind erosion, often forming dunes on lake or saline plain margins. An accumulation of pure gypsum deposits is in one sense, not a true soil, but rather a growth medium for very specific plants. Gypsum deposits are highly saline and alkaline, providing a harsh growing environment, and as such, support little or no vegetation. When masked by thin layers of sand or clay, gypsum deposits support samphire and other highly salt tolerant plant species. Surface exposures of gypsum are protected from erosion via a thin firm surface crust.

Gypsum deposits forming around margins of Lake Boonderoo.

Gypsiferous deposits summary

Australian Soil Classification	Gypsic Hypersalic Hydrosol
Soil textures	Fine crystals of gypsum throughout the profile or occasionally overlain by thin layers of fine sand or light clay
Land systems	Major soil of the Boonderoo land system, minor with the Damper and Lefroy systems
Land units	Lake bed, saline plain, gypsiferous plain or lagoonal low dunes
Soil colour	Greyish brown (2.5Y 5/2) topsoil to brownish yellow (10YR 6/8) subsoil
Soil depth	Deep (> 100 cm)
Pedality/Fabric/Structure	Apedal, earthy and massive
Soil surface condition	No rock outcrop or mantle
Topsoil slaking	Complete
Subsoil slaking	Complete
Topsoil/subsoil dispersion	Nil
Topsoil/subsoil pH range	Alkaline (9.5) topsoil and subsoil
Topsoil EC range	Highly saline (> 1500 mS/m)
Subsoil EC range	Highly saline (> 200 mS/m)
Soil permeability	Highly permeable
Available water storage	Moderate to high
Unrestricted rooting depth	High
Wind/water erosion hazard	High
Inundation/flooding risk	High

Soil group 201—Bare rock and Soil group 203—Stony soil (Rocky granite soils)

These soil groups are uncommon and occur in the south-west of the survey area on exposed domes of granite. In terms of development, these soils are little more than roughly sorted coarse gritty sands lying on or at the base of granite rock. Granite rock is mainly composed of feldspar, mica and quartz. Feldspar and mica decompose relatively quickly during weathering leaving mainly coarse quartz. In displaying little or no true soil development these soils are classified as Rudosols. Soil depths range from just a few millimetres to about 30–40 cm in localised accumulation zones. As the soil consists of very coarse quartz grains, nutrients and organic matter are leached from the profile relatively quickly resulting in soil with excellent drainage, but with few nutrients and a low water-holding capacity. These soils display an acidic soil reaction trend. These soils have linkages to the red shallow sands (soil group 423). The soil is reddish brown and the surface may have an infrequent to common mantle of granite with abundant rock outcrop.

Rocky granite soils summary

Australian Soil Classification	Paralithic, Lithic, Leptic or Arenic Rudosol
Soil texture	Very coarse sand
Land system	Balladonia land system
Land unit	Low granite rise
Soil colour	Dark reddish brown (2.5YR 3/4 to 5YR 3/4)
Soil depth	Very shallow (< 25 cm)
Pedality/Fabric/Structure	Apedal, sandy and single grain
Soil surface condition	Loose with a common (10–50%) stony mantle of granite and abundant rock outcrop (> 50%)
Substrate	Granite
Topsoil/subsoil pH range	Acidic (5.5–6.0)
Topsoil EC range	Negligible
Subsoil EC range	Negligible
Soil permeability	Highly permeable
Available water storage	Very low
Unrestricted rooting depth	Low
Wind/water erosion hazard	Minor
Inundation/flooding risk	Nil

Soil group 405—Red deep sandy duplex soils

This soil type was only recorded once as a minor occurrence on the marginal slopes to depression floors in the Koonjarra land system. The soil profile comprised thin fine sandy topsoil overlying a deep subsoil of silty clay loam grading to light clay. The topsoil was non-saline, with a neutral soil reaction, and non-dispersive, but did slake. The subsoil was saline with an alkaline soil reaction. The soil surface was stone-free and displayed abundant cryptogams. Soil colour ranged from dark red in the topsoil to red in the subsoil.

Red deep sandy duplex soil summary

Australian Soil Classification	Red Chromosol
Soil textures	Fine sand overlying silty clay grading to light clay
Land system	Minor soil within the Koonjarra land system
Land units	Marginal slope to drainage floor
Soil colour	Dark red (2.5YR 3/6) topsoil to red (2.5YR 5/6) subsoil
Soil depth	Deep (> 100 cm)
Pedality/Fabric/Structure	Apedal, earthy and massive
Soil surface condition	No rock outcrop or mantle; abundant (70%) cryptogam crusting
Substrate	Calcrete
Topsoil slaking	Complete
Subsoil slaking	Nil
Topsoil/subsoil dispersion	Nil
Topsoil/subsoil pH range	Neutral (7.0) topsoil and alkaline (9.5) subsoil
Topsoil EC range	Non-saline (< 5 mS/m)
Subsoil EC range	Saline (200 mS/m)
Soil permeability	Moderately permeable
Available water storage	Moderate to high
Unrestricted rooting depth	Moderate
Wind/water erosion hazard	Low
Inundation/flooding risk	Nil

Soil group 421—Calcareous shallow sands

Calcareous shallow sands are restricted to the scarp face land unit of the Wurrengoodyea land system. These sands are very shallow and overlie limestone. Biological surface crusts are infrequent, but limestone mantles and outcrop are abundant. The soil textures are fine sand with a topsoil colour of light brownish grey overlying dark greyish brown subsurface sand. These soils are highly calcareous, non-saline and have an alkaline soil reaction trend. This soil type is uncommon.

Calcareous shallow sand summary

Australian Soil Classification	Hypercalcic Calcarosol
Soil textures	Fine sand over sand
Land system	Minor soil within Wurrengoodyea land system
Land unit	Scarp face
Soil colour	Topsoil of light brownish grey (10YR 6/2) over subsoil of dark greyish brown (10YR 4/2)
Soil depth	Very shallow (< 25 cm)
Pedality/Fabric/Structure	Apedal, sandy and single grained
Soil surface condition	Infrequent (< 10%) biological surface crusting with an abundant (> 50%) limestone mantle and outcrop
Substrate	Limestone
Topsoil/subsoil slaking	Nil
Topsoil/subsoil dispersion	Nil
Topsoil pH range	Alkaline (9.0)
Subsoil pH range	Alkaline (9.0)
Topsoil EC range	Non-saline (< 5 mS/m)
Subsoil EC range	Non-saline (< 5 mS/m)
Soil permeability	Highly permeable
Available water storage	Very low
Unrestricted rooting depth	Low
Wind erosion hazard	Moderate (due to landscape position)
Water erosion hazard	Low
Inundation/flooding risk	Nil

Soil group 422—Pale shallow sands

These soils are uniform textured fine sands overlying calcrete or calcarenite at very shallow depth. Soil surfaces are soft with no biological surface crusts and have no mantle. The soil is non-calcareous and non-saline with a neutral soil reaction trend. Soil colour ranges from light grey at the surface to dark yellowish brown in the subsoil. This soil type is uncommon and was recorded only once on the interdunal swale land unit of the Wurrengoodyea land system.

Pale shallow sand summary

Australian Soil Classification	Leptic Rudosol
Soil texture	Fine sand
Land system	Minor soil within the Wurrengoodyea land system
Land unit	Interdunal swale
Soil colour	Topsoils of light grey (10YR 7/1) and subsoils of dark yellowish brown (10YR 4/4)
Soil depth	Very shallow (< 25 cm)
Pedality/Fabric/Structure	Apedal sandy and single grained
Soil surface condition	Soft surface with infrequent (< 10%) cryptogam crusting and no mantle
Substrate	Calcarenite
Topsoil/subsoil slaking	Nil
Topsoil dispersion	Nil
Subsoil dispersion	Nil
Topsoil pH range	Neutral (6.0)
Subsoil pH range	Neutral (7.0)
Topsoil EC range	Non-saline (< 5 mS/m)
Subsoil EC range	Non-saline (< 5 mS/m)
Soil permeability	Highly permeable
Available water storage	Very low
Unrestricted rooting depth	Low
Wind erosion hazard	Low to moderate dependant
Water erosion hazard	Nil
Inundation/flooding risk	Nil

Soil group 423—Red shallow sands

These soils are very shallow to shallow, uniform textured loamy sands overlying calcrete. The soils are dark red in colour, non-calcareous and have a neutral to weakly alkaline soil reaction trend. This soil type is uncommon in the survey area and was found in the Balladonia and Zanthus land systems.

Within the gritty-surfaced plains of the Balladonia land system the shallow substrate is granite with an occasional veneer of calcrete. Biological surface crusts are common and a mantle of calcrete/limestone fragments is frequent. The loamy sands associated with granitic land systems tend to be marginally coarse in texture, as the sands are generally developed in situ and are not transported long distances though wind or water erosion.

Within the Zanthus land system red shallow sands occur on the calcareous plains. The sands are also shallow and overlie calcrete and some of these sands contain calcrete nodules. Soil textures tend to be marginally finer than those of the granitic (Balladonia) land system as the Zanthus sands tend to be of aeolian origin. These sands generally lack surface crusting or a mantle.

Red shallow sand summary

Australian Soil Classification	Arenic or Leptic Rudosol
Soil textures	Medium grained loamy sand (occasionally medium to coarse) in the Balladonia land system and medium to fine-grained loamy sand in the Zanthus land system
Land systems	Major soil Balladonia and Zanthus land systems
Land units	Gritty-surfaced plains (Balladonia land system) and calcareous plains (Zanthus land system)
Soil colour	Dark red (2.5YR 3/6)
Soil depth	Very shallow to shallow (< 25–50 cm)
Pedality/Fabric/Structure	Apedal, sandy and single grained or apedal, earthy and massive
Soil surface condition	Common (10–50%) cryptogam crusts with frequent (10–50%) limestone mantle or infrequent mantle and crusting
Substrate	Granite (with or without a calcrete veneer or calcrete)
Topsoil/subsoil slaking	Nil
Topsoil/subsoil dispersion	Nil
Topsoil pH range	Neutral (7.5) to alkaline (8.2)
Subsoil pH range	Mostly alkaline (8.0–8.5)
Topsoil EC range	Non-saline (< 5 mS/m)
Subsoil EC range	Non-saline (< 5 mS/m)
Soil permeability	Highly permeable
Available water storage	Very low
Unrestricted rooting depth	Low
Wind erosion hazard	Low
Water erosion hazard	Low for granitic areas, otherwise nil
Inundation/flooding risk	Nil

Soil group 440—Deep (grey and brown) sands

These sands occur inland from the calcareous deep sands (soil group 442) associated with the beaches. They are more developed than the beach sands and occur as sand dunes and sand sheet swales. Soil textures comprise fine sand and the soils are non-saline. Soil reaction is neutral to alkaline and these soils contain little or no carbonates. These soils trend from grey near the coast progressively showing brown and yellow colours further inland. Sand dune soils have colour ranges from grey-brown in the topsoils to yellowish brown in the deep subsoil. In the swales soil colour ranges from grey to dark yellowish brown.

Deep (brown) sand soil summary

Australian Soil Classification	Arenic Rudosol
Soil textures	Fine sand sometimes grading to weak clayey sand
Land system	Major soil of the Wurrengoodyea land system
Land units	Dunes and swales
Soil colour	Grey (10YR 5/1) to greyish brown (10YR 4/2, 10YR 5/2) grading to dark yellowish brown (10YR 4/6) or yellowish brown (10YR 5/4, 10YR 6/4)
Soil depth	Deep (> 100 cm)
Pedality/Fabric/Structure	Apedal, sandy and single grained
Soil surface condition	Soft with common (30–40%) cryptogam crusting
Topsoil/subsoil slaking	Complete
Topsoil/subsoil dispersion	Nil
Topsoil pH range	Neutral (7.5) to alkaline (8.0)
Subsoil pH range	Alkaline (9.0–9.5)
Topsoil EC range	Non-saline (< 5 mS/m)
Subsoil EC range	Non-saline (< 5 mS/m)
Soil permeability	Highly permeable
Available water storage	Very low
Unrestricted rooting depth	High
Wind erosion hazard	Moderate
Water erosion hazard	Low
Inundation/flooding risk	Nil

Soil group 442—Calcareous deep sands

This soil group comprises deep white, grey and brown calcareous sands of the sandy coastal margins of the survey area. The sands tend to be white to light grey on the beach and foredune zones, trending to brown inland. Soil textures are fine sand and soil colour depends on the vegetative cover. As such, beach sands with little or no vegetation are mostly white or grey. Inland from the beaches, shrubs and stunted trees contribute organic matter to the soil, resulting in different coloured and more stable soils. Calcareous deep sands occur within four land systems: Baxter, Bilbunya, Delisser and Wurrengoodyea. The Bilbunya and Delisser systems front the ocean and consists of beaches, foredunes and inland dunes. The beach sands show no organisation in a soil development sense. They are fine sands continually rearranged by the forces of wind and the ocean. As such they are structureless and support little or no vegetation because of the harsh environment in which they occur. Although faced with regular erosion (and reformation), occasional inundation and influenced by strong salt laden sea breezes, these soils contain very low levels of salt due to their highly porous nature. The colour of the beach sands is white to light grey. Adjoining the beach sands are the beach foredunes, somewhat mobile dunes due to the influence of wind erosion. These foredunes are similar in texture to the beach sands, but are commonly stabilised with pioneer plant species.

Calcareous deep sand soils summary

Australian Soil Classification	Shelly, Arenic or Hypersalic Rudosol
Soil texture	Fine sand
Land systems	Major soil of the Bilbunya, Delisser and Wurrengoodyea land systems
Land units	Beach, inter-dune swale, sand dune
Soil colour	Beaches of white or light grey (10YR 7/1), dunes of light grey to very pale brown (10YR 8/3) to brown (10YR 5/3) or brown (10YR 5/3) to white (10YR 8/2)
Soil depth	Deep (> 100 cm)
Pedality/Fabric/Structure	Apedal, sandy and single grained
Soil surface condition	Loose (on the beach and dunes), otherwise soft to firm with infrequent to common (< 50%) cryptogam crusting
Substrate	Occasionally coastal limestone
Topsoil slaking	Complete
Subsoil slaking	Complete
Topsoil/subsoil dispersion	Nil
Topsoil pH range	Alkaline (> 8.9)
Subsoil pH range	Alkaline (> 8.5)
Topsoil EC range	Non-saline (1–25 mS/m)
Subsoil EC range	Mostly non-saline (1–18 mS/m), some weakly saline (60–135 mS/m)
Soil permeability	Highly permeable
Available water storage	Very low
Unrestricted rooting depth	High
Wind erosion hazard	High
Water erosion hazard	Low (beach and dune land units high)
Inundation/flooding risk	Low (tidal beach land unit high)

Soil group 445—Red deep sands

This soil type is uncommon and occurs on the sandy banks of the Boonderoo land system. These soils are deep and have thin to medium topsoil textures of loamy sand overlying thick subsoils of clayey sand. The soils are red in colour and have an alkaline soil reaction trend due to the association with gypsic elements from Lake Boonderoo. The profiles are free of coarse fragments and the soil surfaces are soft.

These soils may occur adjacent to and among red sandy earths (soil group 463). There may be some intergrading of these soil groups. In many instances the red deep sands and the red sandy earths share similar types of topsoils. Red sandy earths are more clayey with depth.

The red deep sands are very common in the desert areas north of the Bunda Plateau, but have neutral to weakly acidic soil reaction trends.

Red deep sand soils summary

Australian Soil Classification	Arenic Rudosol
Soil textures	Loamy sand to clayey sand
Land system	Minor soil of the Boonderoo land system
Land unit	Sand bank
Soil colour	Red (7.5YR 4/6) to reddish brown (5YR 4/4) and yellowish red (5YR 5/6) subsoils
Soil depth	Deep (> 100 cm)
Pedality/Fabric/Structure	Apedal, sandy, single grained
Soil surface condition	Soft with infrequent (< 10%) cryptogam crusts
Topsoil/subsoil slaking	Nil
Topsoil/subsoil dispersion	Nil
Topsoil pH range	Alkaline (8.5)
Subsoil pH range	Alkaline (9.0)
Topsoil EC range	Non-saline (< 2 mS/m)
Subsoil EC range	Non-saline (< 2 mS/m)
Soil permeability	Highly permeable
Available water storage	Low
Unrestricted rooting depth	High
Wind erosion hazard	Moderate to high
Water erosion hazard	Low
Inundation/flooding risk	Nil

Soil group 463—Red sandy earths

These soils exhibit thin to medium topsoils of loamy sand to sandy loam graduating to medium to thick subsoils of loam or sandy clay loam or clay loam. They are deep soils and may contain calcareous nodules in the lower subsoil or be weakly saline at depth. Soil reaction is alkaline and colour is red throughout. Red sandy earths are uncommon and occur with red deep sands (soil group 445) on the sand bank land unit of the Boonderoo land system. Within the Nyanga land system this soil was recorded infrequently in areas where shallow aeolian sands overlay the calcareous loams.

Red sandy earth soils summary

Australian Soil Classification	Red Kandosol
Soil textures	Loamy sand to sandy loam overlying sandy loam or sandy clay loam; calcareous nodules occasionally present
Land systems	Major soil of the Colville and Zanthus land systems; minor soil of the Nyanga, Ponton and Boonderoo land systems
Land units	Calcareous loamy plain overlain with shallow aeolian sands or sandy banks
Soil colour	Dark reddish brown (2.5YR 3/3) or dark red (2.5YR 4/6) grading to yellowish red (5YR 4/6 and 5/6) to reddish yellow (5YR 6/6)
Soil depth	Deep (> 1 m)
Pedality/Fabric/Structure	Apedal, sandy or earthy (with intergrades); single grain to massive
Soil surface condition	Soft to firm
Substrate	Occasional calcareous nodules in lower subsoil
Topsoil slaking	Complete
Subsoil slaking	Complete
Topsoil dispersion	Nil
Subsoil dispersion	Partial
Topsoil pH range	Alkaline (8.5)
Subsoil pH range	Alkaline (9.0–9.5)
Topsoil EC range	Non-saline (1–5 mS/m)
Subsoil EC range	Non-saline to weakly saline (5–90 mS/m)
Soil permeability	Highly permeable
Available water storage	Moderate
Unrestricted rooting depth	Moderate to high
Wind erosion hazard	Moderate
Water erosion hazard	Low
Inundation risk/flooding risk	Low

Soil group 521—Calcareous shallow loams (incorporating soil group 202—Calcareous stony soil)

Calcareous shallow loams are common on all but coastal and sub-coastal land systems. These soils are divided into three subgroups: sandy loams, loams, and clay loams all over calcareous rock types (i.e. limestone, calcrete, calcarenite). Profiles with more than 50 per cent of rock fragments or calcrete are classified as Calcareous stony soil.

Sandy loams are uncommon and have either uniform textures of fine sandy loam overlying calcrete at very shallow depth or weak gradational textures of sandy loam grading to loam at shallow depth. The fine sandy loam type has only one major horizon whereas the gradational soil type has two primary layers. Soil colour is principally red for the fine sandy loams and reddish brown to brown for the gradational loams. The fine sandy loams are non-saline while the gradational loams may be either non-saline or weakly saline. All of these soils are non-dispersive and do not slake.

Calcareous shallow (sandy) loam soils summary

Australian Soil Classification	Lithocalcic Calcarosol
Soil textures	Fine sandy loam to sandy loam
Land systems	Minor soils of the Lowry, Naretha, Nyanga, Roe and Virginia land systems
Land units	Calcrete plain overlain by loam (KPL), Limestone hummock (low rise) (LHR), Calcareous plain with shallow sands (PKE), Stony limestone plain (SLP)
Soil colour	Mainly dark red (2.5YR 3/6) for fine sand loams and reddish brown (5YR 4/4) to yellowish red (5YR 4/6) or brown (7.5YR 3/4) to strong brown (10YR 5/4) for gradational types
Soil depth	Very shallow (< 25 cm) for fine sandy loams and shallow (25–50 cm) for deeper gradational sandy loam to loam soils
Pedality/Fabric/Structure	Apedal, earthy and massive
Soil surface condition	Mostly to abundant (50–90%) stony mantle of calcareous geology or where below 50% abundant biological (cryptogam) crusting (50–60%)
Substrate	Limestone, calcrete, calcarenite
Topsoil/subsoil slaking	Nil
Topsoil/subsoil dispersion	Nil
Topsoil pH range	Alkaline (9.0)
Subsoil pH range	Alkaline (9.0)
Topsoil EC range	Low (1–5 mS/m) for fine sandy loams, weakly saline (30 mS/m) for some gradational loams
Subsoil EC range	Low (1–10 mS/m) for fine sandy loams, weakly saline (60 mS/m) for some gradational loams
Soil permeability	Highly permeable
Available water storage	Low
Unrestricted rooting depth	Shallow
Wind erosion hazard	Low
Water erosion hazard	Low
Inundation/flooding risk	Low

The loam soil subgroup is very common and consists of mainly one or two loam-textured horizons overlying limestone at very shallow or shallow depth. Soil colour is mainly reddish brown to yellowish red with occasional stronger hues of brown for the more shallow types. The slightly deeper soils have reddish brown topsoils overlying strong brown or dark yellowish brown subsoils. The deeper soils tend to show slightly more saline subsoils than the more shallow types. Soil reaction is alkaline.

Calcareous shallow loam soils summary

Australian Soil Classification	Lithocalcic Calcarosol
Soil texture	Loam
Land systems	Soils of the Balgair, Caiguna, Culver, Haig, Nanambinia, Naretha, Nightshade, Nurina, Nyanga, Thampanna, Roe, Shakehole and Weebubbie land systems
Land units	Calcrete plain overlain by loam (KPL), Calcrete stony plain (KSP), Limestone hummock (low rise) (LHR), Calcareous plain with shallow sands (PKE), Stony limestone plain (SLP)
Soil colour	Mainly dark red (2.5YR 3/6) or brown (7.5YR 3/4) to strong brown (10YR 5/4)
Soil depth	Very shallow (< 25 cm) to shallow (25–50 cm)
Pedality/Fabric/Structure	Apedal, earthy and massive
Soil surface condition	Mostly an abundant (50–90%) stony mantle of calcareous geology, abundant biological (cryptogam) crusting (50–60%)
Substrate	Limestone, calcrete, calcarenite
Topsoil/subsoil slaking	Nil
Topsoil/subsoil dispersion	Nil
Topsoil pH range	Alkaline (9.0)
Subsoil pH range	Alkaline (9.0)
Topsoil EC range	Low (1–30 mS/m)
Subsoil EC range	Low (1–30 mS/m), weakly saline (60 mS/m) for some gradational loams
Soil permeability	Highly permeable
Available water storage	Low
Unrestricted rooting depth	Shallow
Wind erosion hazard	Low
Water erosion hazard	Low
Inundation/flooding risk	Low

A calcareous shallow loam with only 15–20 cm of soil overlying limestone. Soils like this are common throughout much of the Nullarbor Plain proper.

This shallow soil supports speargrass (Austrostipa scabra) *and wallaby grass* (Austrodanthonia caespitosa)*, some shrubs and a few trees. The shrub and tree roots follow fissures in the limestone in search of soil moisture. This is from an area west of Rawlinna Station homestead.*

Calcareous shallow clay loams are very common and have textures ranging from heavy loams at the surface grading into clay loams above the calcareous substrate. The soils may have one to three, mostly thin, horizons. Soil colour ranges from yellowish red in the topsoil to yellowish red and dark brown in the subsoil. Salinity is very low in the topsoil and may range from non-saline to highly saline in the deeper subsoils. These soils are non-dispersive and do not slake. Mantles of calcareous rock types are mostly abundant and surface biological crusting is conversely abundant (i.e. where the mantle is highly abundant, crust abundance is low). Soil reaction is alkaline.

Calcareous shallow clay loam soils summary

Australian Soil Classification	Calcarosol
Soil textures	Heavy loam throughout or grading to clay loam where soil depth is over 30 cm
Land systems	Major soils of the Balladonia, Caiguna, Culver, Damper, Gafa, Gumbelt, Kybo, Mundrabilla, Nanambinia, Nightshade, Nurina, Nyanga, Roe, Thampanna, Toolinna and Zanthus land systems
Land units	Calcrete plain overlain by loam (KPL), Calcrete stony plain (KSP), Low granite rise (LGR), Limestone hummock (low rise) (LHR), Stony limestone plain (SLP)
Soil colour	Mainly yellowish red (5YR 4/6) or brown (7.5YR 4/4) to dark brown (10YR 3/3) for gradational types
Soil depth	Shallow (25–50 cm)
Pedality/Fabric/Structure	Apedal, earthy and massive
Soil surface condition	Mostly abundant (50–90%) stony mantles of limestone or where below 50%, common to abundant biological (cryptogam) crusting (30–50%)
Substrate	Limestone
Topsoil/subsoil slaking	Nil
Topsoil/subsoil dispersion	Nil
Topsoil pH range	Alkaline (8.5–9.0)
Subsoil pH range	Alkaline (9.0)
Topsoil EC range	Low (1–30 mS/m)
Subsoil EC range	Low (1–30 mS/m) to high (50–200 mS/m) for deeper clay loams
Soil permeability	Highly permeable
Available water storage	Low
Unrestricted rooting depth	Shallow
Wind erosion hazard	Low
Water erosion hazard	Low
Inundation/flooding risk	Low

Soil group 522—Red shallow loams

Red shallow loams are uncommon in the survey area. They mostly consist of sandy loams, rarely grading to sandy clay loams and overlie limestone, nodules of limestone or occasionally calcrete. Some soils have a thin veneer of sand on the surface. When overlying granite, soil textures are sandy clay loams.

Generally soil reactions are neutral to weakly alkaline and no coarse or soft calcareous fragments occur through the profile. Soil colour is dark reddish brown to red or dark brown. Soils with sandy veneers have stone-free surfaces. Elsewhere the surfaces have infrequent to common mantles of calcareous fragments commonly with biological crusts.

Red shallow loam soils summary

Australian Soil Classification	Petrocalcic, Lithic or Leptic Rudosol
Soil textures	Sandy loam occasionally grading to sandy clay loam; sandy clay loams when over granite
Land systems	Soils within the Balladonia, Gumbelt, Naretha, Nyanga, and Zanthus land systems
Land units	Drainage floor (DFL), calcrete plain overlain by calcareous loam (KPL), low granite rise (LGR), plain calcareous loam with aeolian sand covering (PKE), stony limestone plain (SLP)
Soil colour	Mainly dark reddish brown (2.5YR 3/4) and red (2.5YR 4/6) to red or dark brown (7.5YR 3/3)
Soil depth	Very shallow (< 25 cm) to shallow (25–50 cm)
Pedality/Fabric/Structure	Apedal, earthy and massive
Soil surface condition	No stony mantle for soils with a thin sand veneer, otherwise few to common (2–50%) stony mantles of limestone and common to abundant biological (cryptogam) crusting (40–80%)
Substrate	Limestone or limestone nodules, occasionally calcrete or granite
Topsoil/subsoil slaking	Nil
Topsoil/subsoil dispersion	Nil
Topsoil pH range	Weakly alkaline to alkaline (7.9–8.6), except where it is neutral (6.5–7.0) in granite areas
Subsoil pH range	Alkaline (8.5–9.0), except in granite areas where it is neutral to weakly alkaline (7.0–8.0)
Topsoil EC range	Low (1–5 mS/m)
Subsoil EC range	Low (1–10 mS/m)
Soil permeability	Highly permeable
Available water storage	Low
Unrestricted rooting depth	Shallow
Wind erosion hazard	Low
Water erosion hazard	Low
Inundation/flooding risk	Low

Soil group 542—Calcareous loamy earths

This group is comprised of soils with textures of loam throughout the profile. It is a complex of various soil types.

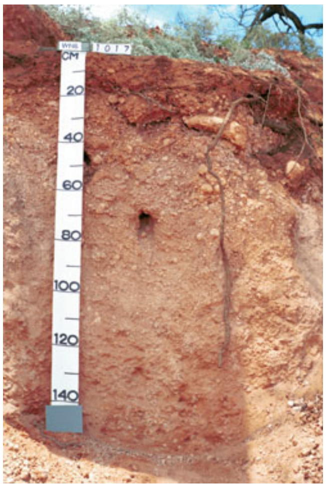
The lightest expression of this Soil group displays topsoils of fine sandy loam or sandy loam overlying subsoils of loam. This soil phase is relatively uncommon, occurring mainly in the Nyanga land system. Most soils within the calcareous loamy earth soil group consist of loam to heavy loam topsoils overlying subsoils of heavy loam to clay loam. This soil phase occurs on almost every land system. A less common soil phase is the heavier textured loam soils being clay loam topsoils grading to light clay subsoils.

Most of the soils within this soil group have thin to medium topsoils overlying moderate to deep subsoils. Limestone or calcrete often underlie these moderate depth soils. Limestone gravels occur within 30 cm of the soil surface and generally increase in abundance and size with depth. Saline subsoils mostly occur in low-lying areas supporting salt tolerant vegetation or where gypsum occurs within the soil. Similarly soils with clayey subsoils are almost always weakly to strongly saline. In lighter textured soils salinity is variable. Soil reaction is alkaline.

Soil colour is generally dark reddish brown to reddish brown near the surface to yellowish red in the subsoil. Within the Thampanna land system the loamy soils tend to be browner in colour. The soil surfaces are generally covered with an abundant mantle of limestone or calcrete with infrequent to common cryptogam crusting.

Calcareous loamy earth summary

Australian Soil Classification	Calcarosol
Soil textures	Fine sandy loam to sandy loam over loam; loam grading to clay loam or clay loam grading to light clay
Land systems	Major soils of the Arubiddy, Caiguna, Damper, Kyarra, Kybo, Mundrabilla, Moonera, Nanambinia, Nightshade, Nyanga, Thampanna, Shakehole and Roe land systems. Minor soils of the Lowry, Naretha, Virginia and Zanthus land systems
Land units	Calcrete plain overlain by loam (KPL), calcrete stony plain (KSP), calcrete rise overlain by calcareous loam (KRL), stony limestone plain (SLP), plain calcareous loam (PKL), Limestone hummock (low rise) (LHR)
Soil colour	Mainly dark red (2.5YR 3/6) and reddish brown (5YR 4/4) to yellowish red (5YR 4/6) or brown (7.5YR 3/4) to strong brown (10YR 5/4)
Soil depth	Moderate to deep (> 80 cm)
Pedality/Fabric/Structure	Apedal, earthy and massive
Soil surface condition	Mostly to abundant (50–90%) stony mantles of limestone, common to abundant biological (cryptogam) crusting (10–50%)
Substrate	Limestone
Topsoil/subsoil slaking	Nil
Topsoil/subsoil dispersion	Nil
Topsoil pH range	Alkaline (9.0)
Subsoil pH range	Alkaline (9.0)
Topsoil EC range	Low (1–10 mS/m) for sandy loams and some loams
Subsoil EC range	Low (1–10 mS/m) for sandy loam and some loams, moderately to highly saline (100–400 mS/m) clay loam or light clay subsoils
Soil permeability	Loamy soils—highly permeable, loams grading to clays moderately permeable
Available water storage	Moderate to high
Unrestricted rooting depth	Moderate to deep
Wind erosion hazard	Low
Water erosion hazard	Low
Inundation/flooding risk	Low



A typical calcareous loamy earth with limestone gravels. Note the ability of tree roots to penetrate deep into the subsoil to get moisture.

Calcareous loamy earths support several different types of vegetation. This area is towards the north of Noondoonia Station.

Soil group 544—Red loamy earths

Red loamy earths are infrequent. They occur as deep soils with sandy clay loam or clay loam topsoils graduating to clay loam or light clay subsoils. The soil surfaces may have a thin sandy veneer or occasionally support a light mantle of stone. The soils are non-saline and only rarely have calcareous deep subsoils. Soil reaction is neutral or occasionally alkaline and the topsoils do not slake or disperse. The soil colour ranges from dark reddish brown to dark brown.

Red loamy earth soils summary

Australian Soil Classification	Red Kandosol
Soil textures	Sandy clay loam to clay loam overlying light clay loam
Land systems	Minor soils of the Gumbelt and Naretha land systems
Land units	Clay depression (CLD) and plain with calcareous loam and thin sand veneer (PKS)
Soil colour	Mainly dark reddish brown (2.5YR 3/6) to dark red (2.5YR 4/6)
Soil depth	Deep (> 100 cm) or moderately deep (> 80 cm)
Pedality/Fabric/Structure	Apedal, earthy and massive
Soil surface condition	Thin sandy veneer on surface or infrequent to common biological (cryptogam) crusting (0–40%)
Substrate	Limestone
Topsoil/subsoil slaking	Nil for topsoil, nil to partial for subsoil
Topsoil/subsoil dispersion	Nil for topsoil, nil to complete for subsoil
Topsoil pH range	Neutral (7.0)
Subsoil pH range	Neutral to alkaline (7.0–8.5)
Topsoil EC range	Low (1–5 mS/m)
Subsoil EC range	Low (5–20 mS/m)
Soil permeability	Highly permeable
Available water storage	Moderate
Unrestricted rooting depth	Deep
Wind erosion hazard	Low
Water erosion hazard	Low
Inundation/flooding risk	Low

Soil group 600—cracking clays

Cracking clay soils are deep with thin to medium light clay (occasionally medium clay) topsoils. Occasionally the topsoils may include a thin layer of clay loam. The thick to very thick subsoils have textures of light or medium to heavy clay. The uppermost layers display large surface cracks or have crumbly (self-mulching) surfaces when dry and often show rough mounded (gilgai) surfaces. Large areas of cracking clays tend to show zonations of varying amounts of surface cracking. Soil colour is mainly dark reddish brown to red, soil reaction is alkaline and many soils contain some carbonates within at least part of the profile. The soil surfaces are generally non-saline with deep subsoils being either non-saline or partially saline. These soils occur in dongas, swamps or areas of surface water accumulation. Cracking clay soils often occur with or adjacent to, red/brown non-cracking clay soils (Soil group 622).

Cracking clay soils summary

Australian Soil Classification	Red Vertosol
Soil textures	Light clay grading to medium or heavy clay
Land systems	Soils of the Haig, Koonjarra, Nurina and Nyanga land systems
Land units	Clay plain (CLP), Gilgai depression (GIL), Calcrete plain overlain by loam (KPL)
Soil colour	Mainly yellowish red (5YR 4/6) or strong brown (7.5YR 4/6 to 7.5YR 5/6)
Soil depth	Deep (> 100 cm)
Pedality/Fabric/Structure	Pedal, moderate to strong polyhedral ped structure
Soil surface condition	Occasional infrequent to common (10–30%) limestone with some soil surface cracks or mounded gilgais
Topsoil/subsoil slaking	Nil, sometimes partial
Topsoil/subsoil dispersion	Nil, sometimes partial or complete
Topsoil pH range	Alkaline (9.0)
Subsoil pH range	Alkaline (9.0)
Topsoil EC range	Low (1–20 mS/m) occasionally high (90 mS/m)
Subsoil EC range	Low (10–20 mS/m) occasionally high (390 mS/m)
Soil permeability	Moderately permeable
Available water storage	High
Unrestricted rooting depth	Moderate to deep
Wind erosion hazard	Low
Water erosion hazard	Low
Inundation/flooding risk	Low

Soil group 622—Red/brown non-cracking clays

Red/brown non-cracking clays are mostly deep soils. Shallow clays occur sporadically throughout the area but rarely dominate.

The deep clays are generally composed of light clay, occasionally grading to medium or heavy clay. Deep clays are mostly non-saline, but saline types tend to occur in areas accumulating overland water flow like clay plains, clay depressions, saline plains and areas with gypsum in the subsoil. Shallow clays overlie limestone.

Deep red/brown non-cracking clays often occur with cracking clay soils and some soils show juvenile features of cracking clays such as weakly developed self-mulching surfaces or minor soil surface cracking. Soil colour is mainly dark reddish brown to dark red or strong brown. The soils are alkaline throughout and may contain calcareous segregations of weathered limestone fragments in the lower subsoils. The topsoils generally do not slake or disperse (unless highly saline) but subsoils commonly partially or completely slake and disperse. The soil surfaces generally have an infrequent mantle of limestone, but display abundant biological cryptogam crusting.

Red/brown non-cracking clay soils summary

Australian Soil Classification	Red Kandosol
Soil textures	Light clay grading to light medium or sometimes heavy clay
Land systems	Commonly found on the Damper, Lefroy, Koonjarra, Kybo, Pondana, Thampanna, Shakehole and Vanesk land systems. Minor soils of the Caiguna, Gafa, Haig, Jubilee, Kanandah, Kitchener, Moonera, Nurina, Skink and Woorbla land systems
Land units	Clay depression (CLA), clay plain (CLP), donga depression (DON), Gilgai depression (GIL), Calcrete plain overlain by loam (KPL)
Soil colour	Mainly dark reddish brown (2.5YR 4/6) to yellowish red (5YR 4/6)or strong brown (7.5YR 5/6)
Soil depth	Deep (> 100 cm), minor shallow soils (50 cm) over limestone
Pedality/Fabric/Structure	Mostly apedal, earthy and massive, or moderately structured with polyhedral ped when occurring among cracking clay soils
Soil surface condition	Hardsetting with mostly abundant biological (cryptogam) crusting (50–90%) and infrequent (< 10%) mantles of limestone
Substrate	Limestone for shallow soils
Topsoil/subsoil slaking	Nil unless saline, then partial
Topsoil/subsoil dispersion	Mostly partial to complete
Topsoil pH range	Alkaline (8.5–9.0)
Subsoil pH range	Alkaline (9.0)
Topsoil EC range	Low for non-saline soils (1–30 mS/m), high for saline soils (100–160 mS/m)
Subsoil EC range	Low for non-saline soils (30–50 mS/m), high for saline soils (200–600 mS/m)
Soil permeability	Highly permeable
Available water storage	High for deep soils, low for shallow soils
Unrestricted rooting depth	Deep, low for shallow soils
Wind erosion hazard	Low
Water erosion hazard	Low
Inundation/flooding risk	Low, but high in clay or gilgai depressions

Biological soil crusts

Most soil surfaces of the Nullarbor have some form of protection from wind and water erosion. This can be in the form of stone, plant or leaf litter cover. Where there is none of this cover, soil crusting mostly exists. Biological soil crusts make up a vital component of the arid or semi-arid ecosystem. Collectively known as cryptogams (from two Greek words 'kryptos' meaning hidden and 'gamos' meaning marriage), they are made up of various lichens, mosses, liverworts, fungi and blue-green algae. The lichen and larger mosses are visible while the microflora of the algae and fungi are difficult to distinguish without the aid of magnification. The lack of soil crusts around some permanent livestock watering points in the Nullarbor pastoral area is notable. Soil surface crusting falls into four scenarios:

- Stone (mantle) free, open low plains surrounded by low rises. The low plains act as micro-sumps collecting some run-off water from the surrounding rises. These low plains primarily have deep clay-based soils and water percolation through the soil is not rapid, taking days rather than hours. The primary vegetation is bladder saltbush (*Atriplex vesicaria*) and may make up to 20 per cent of the soil cover. Plants provide protection to the soil through intercepting rainfall and creating protection from wind erosion. As such biological soil crusting does not grow under the plant canopies. The remaining soil cover is mostly soil crusting.
- Stony open low rises or level to gently undulating plains with a moderate to abundant mantle of limestone rocks and outcrop have shallow soils and water percolation is relatively rapid, within hours. These plains and rises support pearl bluebush (*Maireana sedifolia*) with or without bladder saltbush. In the north, mulga (*Acacia aneura*), tall shrubs or occasional trees provide overstorey. The stony rises and plains have up to 20 per cent vegetation cover protecting the soil surface. The stony mantle may provide up to another 50 per cent of the surface leaving the remaining 30 per cent covered with biological surface crusts.
- Undulating plains with isolated or scattered eucalyptus trees also support low to tall shrubs. Tree and shrub canopies protect the soil surface. Under many trees leaf litter also provides soil protection. Vegetation canopies may cover up to 40 per cent of the soil surface and stone cover may be infrequent to common. The soils are generally free draining with light textured topsoils. Generally cryptogam crust cover ranges from 10 to 20 per cent in these environments.
- Drainage foci on open plains act as local drainage termination zones. Water percolation through the soil profile is slow (weeks rather than days). These foci are mostly stone-free and may support either (non-saline) gilgai soils with grasses or claypans with salt-tolerant vegetation. Soil salinity influences the amount of crusting (in a downward trend) and the surface crust rarely exceeds 70 per cent.

Biological soil crusts often appear somewhat brittle and hard in the dry state, but with the slightest amount of rainfall become soft, pliable and spongy. Soil crusts have not evolved to withstand continuous trampling by hard-hoofed animals and regular vehicle impact. Once broken the crusts re-establish relatively quickly provided they are no longer disturbed. Constant trampling or traffic will destroy the crusts and re-establishment may take many years.

A section of healthy biological soil crust. Note the different colours and types of cryptogams. During dry times much of the crust will appear black and lifeless. Some cryptogams, especially certain mosses, 'green-up' almost immediately after wetting.

A section of scalded soil surface. In this highly degraded state the soil surface has been removed by water and/or wind exposing the clayey subsoil which is relatively impervious to water. In this state water flow is rapid and its erosive capacity significantly increased compared to areas where water flow is obstructed by a rough cryptogam surface.

Biological soil crusts not only protect the underlying soil surface from forces above the ground, but also provide a mulch-effect reducing soil desiccation rates through solar evaporation. There is also anecdotal evidence soil crusts influence surface salinity. In some random tests, salinity levels were measured on the surface of the ruts of vehicle station tracks and healthy intact soil surfaces less than one metre away from the tracks. Soil salinity levels just below the surface of healthy crusted surfaces were so low the salinity could not be measured with a field electrical conductivity (EC) meter. However the salinity of the soil surface (and just below) in the active vehicle tracks was high because there were no binding crusts.

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Vegetation

AK Gardner

This chapter describes aspects of the vegetation. The first part provides a review of the regional vegetation within the survey area based on the Interim Biogeographical Regionalisation of Australia (Environment Australia 2000) and Beard's (1975) vegetation survey of the Nullarbor. The remainder presents the findings of the current survey. A summary of the major taxa recorded during the survey is presented in the second section. Following this the vegetation of the survey area is discussed firstly in terms of plant form and secondly as vegetation formations. Regional patterns of distribution at a plant community and species level are then presented to provide a broader biogeographic perspective. Finally flora conservation is addressed.

This chapter focuses on plants and the communities they comprise. The habitat type ecology chapter looks in more detail at the ecology of vegetation communities.

Regional overview

Most of the survey area lies in the Nullarbor Biogeographic Region of the Interim Biogeographic Regionalisation of Australia. In the south-east is the Hampton Biogeographic Region, and in the south-west some of the survey area is classified within the Coolgardie and Mallee Biogeographic Regions. A small portion in the north-west includes the Great Victoria Desert Biogeographic Region. All of these biogeographic regions are within the Eremaean Botanical Province apart from the Mallee Biogeographic region which is within the South-west Botanical Province (Figure 26).

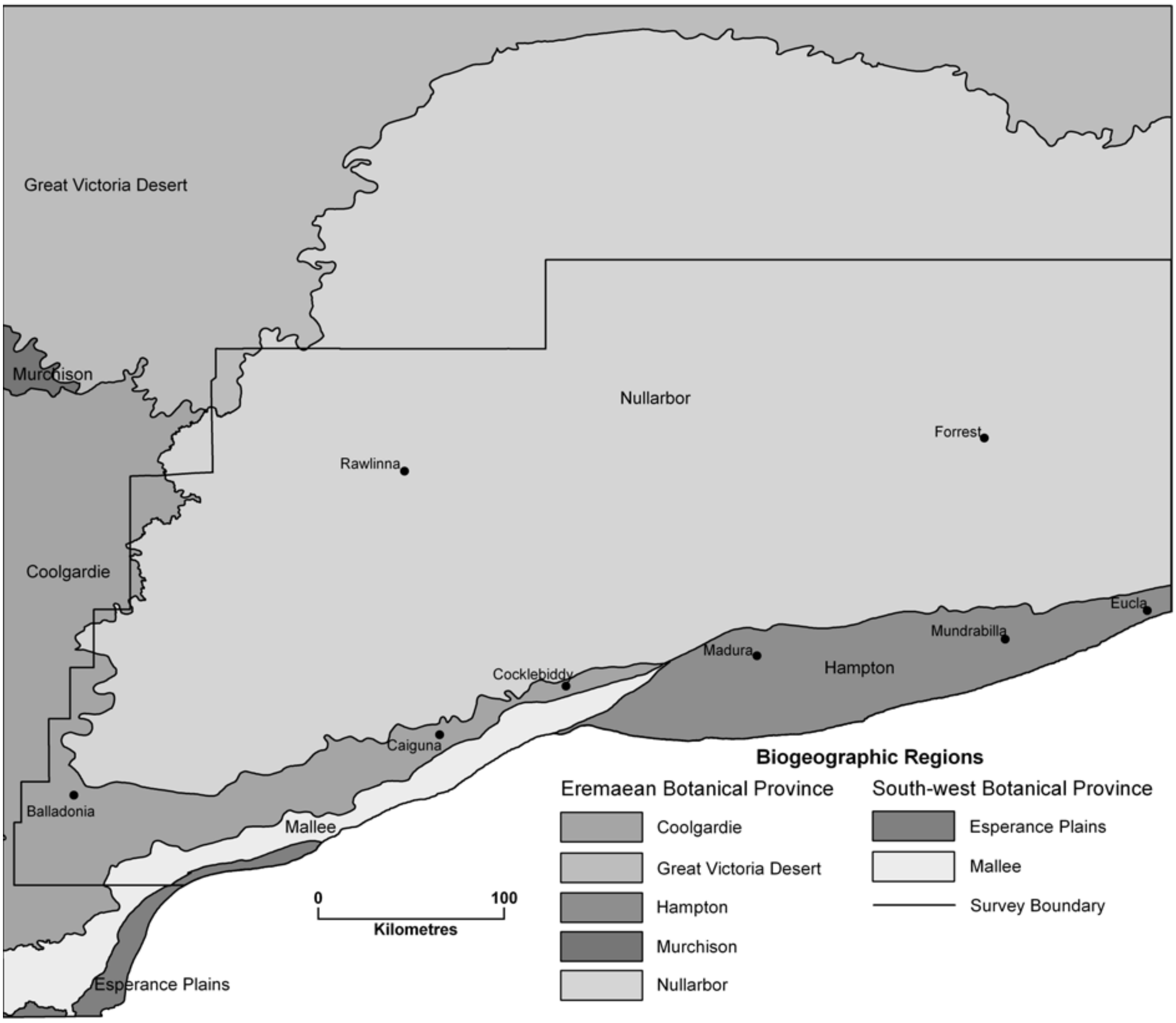

Figure 26 **Biogeographic regions in the survey area (after Environment Australia 2000)**

Beard (1975) mapped the major vegetation communities within Western Australia at a scale of 1:1 000 000. The survey area occurs within Beard's (1975) Nullarbor map sheet 4. Most is located within the Eucla Botanical District of the Eremaean Botanical Province, with smaller areas within the Nanambinia System of the South-Western Interzone and the Culver System of the South-west Botanical Province. Generalised vegetation formations modified from Beard (1975) are displayed in Figure 27.

Eremaean Botanical Province

Nullarbor Biogeographic Region

Broad plains of gently undulating limestone dominate this region. The plains consist of low rises, marginal run-off areas, drainage tracts and claypans. The low rises predominantly support a low shrubland of *Maireana sedifolia,* the marginal slopes support *Atriplex vesicaria* and the drainage tracts and claypans support either a low shrubland of *Atriplex vesicaria* and/or grassland of *Austrostipa scabra* and *Austrodanthonia caespitosa.*

To the north, large circular depressions or dongas become prominent. The dongas support open grassy groves dominated by *Acacia tetragonophylla, Eremophila longifolia, Grevillea nematophylla* and/or *Pittosporum angustifolium*.

Further to the north and west calcrete plains support open woodlands of *Acacia papyrocarpa* (myall) with an understorey of chenopod shrubs (Chapman 2005). The calcrete plains become progressively more wooded towards the northern and western periphery of the Nullarbor province, with myall replaced by *Acacia aneura*, *Casuarina pauper, Myoporum platycarpum* and eucalypts (Beard 1975). Eucalypts and spinifex become increasingly dominant at the perimeter of the north and west of the region, indicative of the transition into the Coolgardie and Great Victoria Biogeographic Regions.

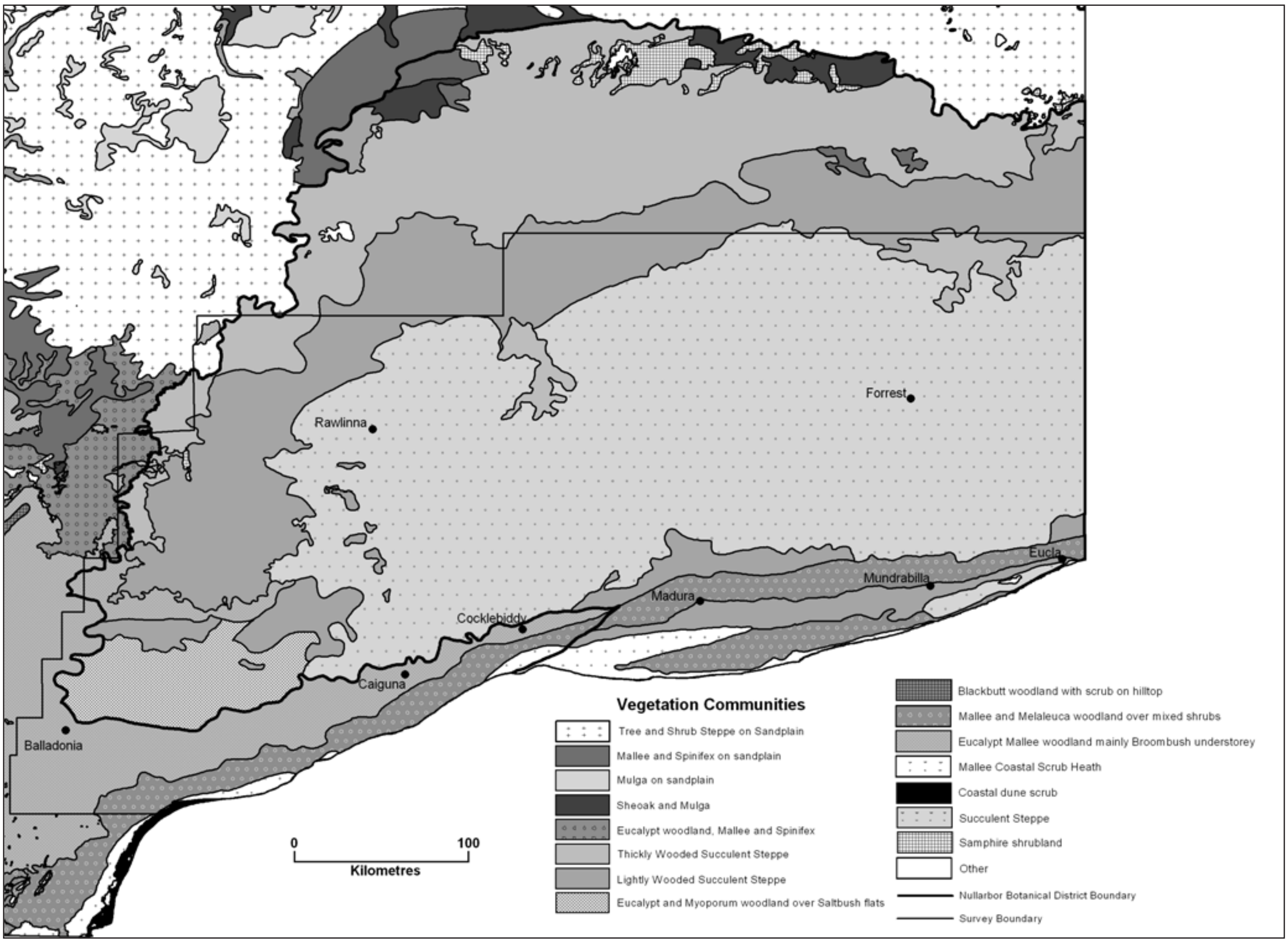

Figure 27 **Generalised vegetation formations within the survey area (modified from Beard 1975)**

Hampton Biogeographic Region

The Hampton tableland supports tall shrubland of eucalypts and melaleucas, with an understorey of sclerophyll and succulent shrubs. The scree slopes of the Hampton Scarp are dominated by open mallee woodland (Chapman 2005).

Below the Hampton Scarp the extensive calcarenite Roe Plains overlies marine limestone. The northern portion of the Roe Plains supports open myall woodland with *Melaleuca lanceolata* and *Myoporum platycarpum* with an understorey of *Atriplex* species, *Cratystylis conocephala* and *Nitraria billardierei*. This vegetation association alternates with open saltbush plains and occasional patches of mallee. The vegetation grades eastwards into mallee woodland with an understorey of *Cratystylis conocephala* (Beard 1975). Soils are calcareous shallow loams and calcareous loamy earths.

The southern portion of the Roe Plains supports stony plains covered with mallee woodland with an understorey of heath and sedge species including *Beaufortia*, *Callitris*, *Spyridium*, *Dianella*, *Lepidosperma* and *Schoenus*. Along the coast is a belt of partially consolidated dunes, poorly vegetated with open mallee woodland with an understorey of coastal species and sedges including *Carpobrotus* spp. and *Dianella revoluta* (Beard 1975). Soils are calcareous shallow loams, loamy earths and deep sands.

Coolgardie Biogeographic Region

Unique to this biogeographic region is scattered granite outcrop. The outcrop is often sparsely vegetated and surrounded by dense stands of *Dodonaea lobulata* and *Eremophila alternifolia.*

This region predominantly supports mallee woodland on calcrete plains of Eocene and Oligocene marine limestone of the Eucla Basin. The understorey is composed of a variety of mixed shrubs including *Atriplex, Cratystylis, Dodonaea, Eremophila, Maireana* and *Senna* (Beard 1975). Soils are calcareous shallow loams, calcareous loamy earths and occasionally red loamy earths.

South-west Botanical Province

Mallee Biogeographic Region

Most of this region comprises mallee woodland with an understorey of scattered mixed shrubs, including *Melaleuca, Eremophila* and *Senna*. A sparse layer of low shrubs including *Atriplex vesicaria, Cratystylis conocephala* and *Maireana sedifolia* is also present. The understorey becomes increasingly dominated by heath species including *Adenanthos, Beaufortia, Callitris* and *Grevillea* towards the coast and the vegetation becomes progressively wind-pruned (Beard 1975). Soils are primarily calcareous loams and sands overlying Eocene and Oligocene marine limestone.

Where sand dunes occur at Point Culver, Toolinna, and Twilight Cove the vegetation is similar to that of the sandplains of Esperance due to the siliceous nature of the sands. Banksias, grevilleas and casuarinas dominate the understorey of sparse mallee woodland (Beard 1975).

Taxonomic summary

The plant taxonomy adopted in this survey is based on the *Census of Western Australia Plants* but also adopts changes on the advice of the Western Australian Herbarium. Scientific names are used with colloquial names of common species provided in the appendices.

Four-hundred-and-twenty-six species of vascular plants representing 198 genera in 61 families were collected during the survey, including 328 perennials and 98 annual species (Appendix 2i). A small number of botanical families contain a large proportion of the species (Table 12).

The largest family is the Chenopodiaceae; the species in this family dominate the survey area, particularly the limestone plains of the treeless portion of the Nullarbor land zone. The Asteraceae family contained the second greatest number of species; species within this family are found in many different landscapes. The Myrtaceae family is predominantly growing at the perimeters of the Nullarbor land zone to the north, south and west, with melaleucas preferring the coastal areas. The grasses of the Poaceae family are found in a wide variety of environments.

Table 12 **Major families and dominant genera in the survey area**

Family	No. of species	Dominant genera
Asteraceae	49	Cratystylis, Olearia, Rhodanthe, Senecio
Chenopodiaceae	47	Atriplex, Chenopodium, Maireana, Rhagodia, Sclerolaena
Poaceae	37	Austrodanthonia, Austrostipa, Enneapogon, Eragrostis
Myrtaceae	35	Eucalyptus, Melaleuca
Mimosaceae	25	Acacia
Myoporaceae	23	Eremophila, Myoporum
Proteaceae	15	Adenanthos, Banksia, Grevillea, Hakea
Brassicaceae	13	Carrichtera, Lepidium, Sisymbrium
Papilionaceae	13	Pultenaea, Swainsona, Templetonia
Solanaceae	12	Lycium, Nicotiana, Solanum

Plant forms

The major plant forms observed within the survey area were trees, mallees, tall shrubs (> 2 m), mid shrubs (1–2 m), low shrubs (< 1 m), subshrubs or perennial herbs (< 0.5 m), perennial grasses, annual herbs and grasses, creepers, sedges, fern and soil cryptogams. These are briefly described below.

Trees

Trees are very scattered throughout the survey area, becoming increasingly abundant away from the Nullarbor land zone. The most common species are *Acacia papyrocarpa, Myoporum platycarpum* and *Pittosporum angustifolium.* Also common are *Alectryon oleifolius, Casuarina pauper* and *Eremophila longifolia*. Other trees which occur occasionally include *Acacia aneura* and *Grevillea nematophylla*. Most common eucalypts recorded in tree form were in the west and north-west of the survey area. *Eucalyptus concinna, E. eremophila, E. fraseri* subsp. *fraseri, E. fraseri* subsp. *melanobasis, E. gracilis, E. melanoxylon, E. salubris* and *E. urna* occur in tree form, though some species also occur in mallee form.

Mallees

Mallees are common towards the west and south of the survey area. Mallees are usually found as open multi-stemmed plants rarely exceeding 6 m high. The most common mallees recorded were the *Eucalyptus oleosa* (group) and *E. yalatensis*. Other mallees recorded include *Eucalyptus brachycalyx, E. conglobata, E. cooperiana, E. discreta, E. diversifolia, E.* sp. *Fraser Range, E. incrassata, E. melanoxylon, E. rigida, E. socialis* and *E. surgens*.

Tall shrubs

Acacias and melaleucas dominate the tall shrubs (> 2 m) throughout the survey area. The most common acacias are *Acacia burkittii, A. oswaldii* and *A. tetragonophylla* and the most common melaleucas are *Melaleuca lanceolata* and *M. quadrifaria.* Other tall shrubs common within the survey area include *Dodonaea lobulata, Eremophila dempsteri, Exocarpos aphyllus, Geijera linearifolia and Myoporum platycarpum.*

Mid shrubs

The most common mid shrub (1–2 m) within the survey area is *Atriplex nummularia. Eremophila* and *Senna* are also commonly represented within this group. Common *Eremophila* include *E. alternifolia, E. decipiens, E. dempsteri, E. deserti* and *E. scoparia.* Common *Senna* includes *S. artemisioides* subsp. x *artemisioides* and *S. artemisioides* subsp. x *coriacea*. Other common mid shrubs include *Dodonaea lobulata, D. stenozyga, Exocarpos aphyllus* and *Nitraria billardierei.*

Low shrubs

The most common growth form is low shrubs (< 1 m). Most are succulent low shrubs belonging to the Chenopodiaceae family. The most common members of this family are *Atriplex vesicaria* and *Maireana sedifolia.* Other common low shrubs from this family include *Chenopodium curvispicatum, Enchylaena*

tomentosa, Maireana erioclada, M. trichoptera, M. turbinata, Rhagodia crassifolia and *Tecticornia* spp.

Common low shrubs not in the Chenopodiaceae family include *Cratystylis conocephala, Lawrencia squamata, Lycium australe, Olearia calcarea, Ptilotus obovatus, Solanum nummularium* and *Westringia rigida.*

Subshrubs or perennial herbs

Subshrubs are seasonally dependent, weakly facultative perennial, generally less than 0.5 m (50 cm) in height. Common subshrubs are *Atriplex acutibractea, Euphorbia drummondii, Sclerolaena diacantha, S. obliquicuspis, S. patenticuspis* and *Sida spodochroma.*

Perennial grasses

The most common perennial grasses are the tussock grasses *Austrodanthonia caespitosa* and *Austrostipa scabra.* Tussock grasses vary from dense, well developed plants to open almost herbaceous forms. Other common tussock grasses include *Austrostipa platychaeta, Enneapogon caerulescens*, *E. cylindricus, Eragrostis dielsii* and *E. setifolia.*

Hummock grasses are a uniquely Australian form of grass in which rigid, pungent involute leaves form large rounded 'hummocks'. Only one species of hummock grass, *Triodia scariosa* (spinifex) is found in the survey area and is restricted to the woodland in the north-western, west and south-western extent where aeolian sand begins to accumulate over calcrete.

Annual herbs and grasses

The survey was conducted in dry seasonal conditions, however, following localised heavy rains that fell predominantly on Kybo Station in the south-east the presence of annuals recorded increased within that localised rainfall zone. The most commonly recorded annuals were *Aristida* sp., *Eriochiton sclerolaenoides, Salsola tragus* and the introduced weed *Carrichtera annua.* Other common annuals include *Atriplex acutibractea, Rhodanthe floribunda* and *Zygophyllum iodocarpum.*

Creepers

Five creepers were recorded within the survey area. The most common was *Marsdenia australis* that produces edible fruits. Others included *Billardiera fusiformis, Cassytha melantha, Comesperma volubile, Glycine rubiginosa* and *Marianthus bicolor* var. *bicolor.*

Sedges

Seven species of the sedge family Cyperaceae occur. The most common of these was *Gahnia lanigera* and *Tetraria capillaris.* Other sedges included *Ficinia nodosa, Isolepis congrua, Lepidosperma* sp. A2 Island Flat, *Mesomelaena stygia, M. stygia* subsp. *stygia, Schoenus caespititius*, *S. lanatus* and *S. subflavus* subsp. hispid culms. Sedges are predominantly found along the south coast.

Ferns

Four species of fern were recorded. *Cheilanthes austrotenuifolia* and *C. lasiophylla* were found in the crevices of granite outcrop. *Marsilea hirsuta* and *Pleurosorus rutifolius* were also recorded.

Soil cryptogams

Soil cryptogams consist of unicellular algae, liverworts, and foliose and crustose lichens. They have an important role in soil ecology in arid zones as they fix nitrogen and stabilise naturally dispersive soils. Particularly in the Nullarbor land zone cryptogams have an especially important role in protecting the soil from wind erosion. Where cryptogams are absent or scarce, generally due to soil disturbance, wind erosion is severe leading to the prominent piospheres seen in satellite imagery around water points. Cryptogams also provide forage for microscopic herbivores, contributing both directly and indirectly to biological activity at the soil surface.

Vegetation formations and their floristic components

The vegetation formations described below have been developed from inventory site data. The dominant stratum at each habitat type was recorded. The vegetation formations are defined as:

Woodland
dominant stratum is trees or mallees (trees have a single stem to 1.3 m high above ground level and mallees are multi-stemmed plants to 6 m)

Tall shrubland
dominant stratum is shrubs over 2 m tall

Mid shrubland
dominant stratum is shrubs 1 to 2 m tall

Low shrubland
dominant stratum is shrubs less than 1 m tall

Tussock grassland
dominant stratum is tussock grasses

Hummock grassland
dominant stratum is hummock grasses

Herbland
dominant stratum is herbs or subshrubs less than 0.5 m tall (herbs may be annual or perennial plants).

These vegetation formations are a simplification of traditional methods of describing vegetation. Muir's (1977) method of classification is referred to in each of the formations described below.

Vegetation was described at 392 inventory sites. Twenty-five had co-dominant strata and one site had no vegetation. The dominant stratum at the remaining 366 sites is shown in Table 13.

Low shrubs were the dominant stratum at the majority of inventory sites, followed by trees, tussock grasses, mid shrubs, tall shrubs, herbs and lastly hummock grasses.

Table 13 **The floristic variability of dominant strata**

Dominant stratum	No. of sites	No. of dominant species
Tree	73	24
Tall shrub	31	21
Mid shrub	30	15
Low shrub	160	26
Tussock grass	42	8
Hummock grass	3	1
Herb/subshrub	27	13
Total	366	108

Low shrubland had the least floristic variability in the dominant strata, considering the large number of sites sampled. In comparison, sites that had a dominant stratum of tall shrubs, mid shrubs and herbs had greater floristic variability.

Woodland

Woodland habitats where trees are the dominant stratum generally had a canopy height of 2–6 m and a canopy cover of 2–20 per cent. These habitats are categorised as 'Open Low Woodland B' or 'Low Woodland B' (Muir 1977).

Woodland habitats where mallees are the dominant stratum generally had a canopy height of 2–12 m and a canopy cover of 15–25 per cent. These habitats are categorised as 'Open Tree Mallee' (Muir 1977).

Of the 20 woodland sites dominated by trees, *Acacia papyrocarpa* dominated six sites, followed by *Eremophila longifolia* and *Myoporum platycarpum* which each dominated three sites. The remaining 52 woodland sites were dominated by 15 species of mallee-form eucalypts. *Eucalyptus gracilis* dominated 22 sites, *E. yalatensis* dominated 16 sites and *E. oleosa* dominated 13 sites.

Sites on calcrete plains in the north-west and west of the survey area were commonly dominated by tree and mallee woodland. *Acacia papyrocarpa* was commonly the dominant species of tree at woodland habitats directly above and below the Hampton Scarp in the south-east, as well as along the northern perimeter. Woodland habitats located on limestone hummocks (low rises), the scree slopes of the Hampton Scarp and along the south coast were primarily dominated by eucalypts. Myall, eucalypt and occasional casuarina woodland alternatively dominated the western perimeter.

Most (66 per cent) of the woodland sites were in very good condition, with 26 per cent in good condition, 5 per cent in fair condition and 3 per cent in poor condition.

Tall shrubland

The projected foliar cover (PFC) of tall shrub-land habitats ranged from 5 to 50 per cent, with over a quarter of the sites having a PFC of 30–50 per cent. The height of the shrubs ranged from 2 to 6 m. According to Muir (1977) tall shrubland with a canopy cover of 10–30 per cent is considered 'Scrub', and those with a cover of greater then 30 per cent are categorised as 'Thickets'.

Acacias and melaleucas were the dominant species at over two-thirds of the 31 tall shrubland sites. Both *Melaleuca lanceolata* and *M. quadrifaria* were the dominant species at six sites, predominantly located along the south coast. *Acacia burkittii* was the most common acacia to dominate tall shrub sites (three sites); these sites were located in the central west of the survey area. However, *Acacia tetragonophylla* and *Acacia oswaldii* were the most common tall shrubs, occurring as very scattered to isolated shrubs, featuring in 30 and 34 inventory sites respectively, especially in the Nullarbor land zone.

Tall shrubland sites on plains overlain by shallow aeolian sands and land units associated with granite outcrops were dominated by *Dodonaea* and *Eremophila*.

Nearly half (49 per cent) of tall shrubland sites were in good condition, 30 per cent in very good condition, 8 per cent in fair condition and 13 per cent in poor condition.

Mid shrubland

The majority of mid shrubland sampled had a PFC of 5 to 20 per cent, which according to Muir's (1977) system of classification are 'Low Scrub A or B' where the PFC is between 10 and 30 per cent and 'Open Low Scrub A or B' where the PFC is less than 10 per cent. *Cratystylis conocephala* and *Maireana sedifolia* which dominated the most sites, reach a maximum height of 1.5 m and fall within group B, whilst species such as *Atriplex nummularia* and *Geijera linearifolia* grow to 2 m and are in group A. Where the PFC was greater than 30 per cent such sites were classified as heathland.

Nine of the 30 mid shrubland sites were dominated by *Maireana sedifolia*. These sites were located throughout the survey area, excluding the coastal region to the south. *Cratystylis conocephala* was the dominant shrub at three sites, a scattered overstorey of *Acacia papyrocarpa* or eucalypts was present at these sites. *Geijera linearifolia* and *Nitraria billardierei* each dominated two sites in the south of the survey area and *Atriplex nummularia* dominated two sites in the west.

The majority (64 per cent) of mid shrubland sites were in good condition, 18 per cent were in very good condition and 18 per cent were in fair condition.

Low shrubland

The PFC for low shrubland sites varied from 5 to 50 per cent. They are categorised as 'Low Heath C' where the PFC is between 30 and 50 per cent, 'Dwarf scrub C' where the PFC is between 10 and 30 per cent and 'Open Dwarf Scrub C' where the PFC is lower than 10 per cent (Muir 1977).

Of the 160 low shrubland sites, 19 were co-dominated by two species of low shrubs and one site by three species. Of the 140 sites dominated by a single species of low shrub, over 75 per cent were dominated by species of the Chenopodiaceae family. *Atriplex vesicaria* dominated 48 of these sites and *Maireana sedifolia* 39 of these sites. Eight other species of Chenopodiaceae dominated the 14 other sites.

Sixteen species of low shrubs not within the Chenopodiaceae family dominated the remaining 32 sites. *Cratystylis conocephala* dominated nine of these sites, *Lawrencia squamata* five sites and *Lycium australe* four sites. Sites dominated by *Lawrencia squamata* commonly occurred on the breakaway slope to drainage floor within the Koonjarra land system. *Ptilotus obovatus* and *Westringia rigida* each occurred at three sites. An overstorey of scattered trees and mallees is often associated with low shrubland dominated by non-chenopodiaceous species. These sites are commonly found towards the northern and western perimeters of the survey area.

Over half (57 per cent) of the sites were in good condition, 21 per cent were in very good condition, 17 per cent in fair condition, 4 per cent in poor condition and 1 per cent in very poor condition.

Tussock grassland

The basal cover of tussock grasses is most commonly 5 to 10 per cent. The PFC was estimated to be between 30 to 70 per cent. The height of grasses that dominate this stratum is predominantly less than 0.5 m. Tussock grassland is classified as 'Low Grasslands' (Muir 1977).

Eight dominant species were recorded at the 42 tussock grassland sites. *Austrostipa scabra* was the dominant species at most grassland sites. *Austrodanthonia caespitosa*, *Eragrostis dielsii* and *Eragrostis setifolia* were each dominant at three sites.

Grassland sites dominated by *Austrostipa scabra* and *Austrodanthonia caespitosa* often represented a transition from degraded shrubland sites. It is likely the shrubs were lost or reduced by fire and overgrazing by rabbits, and secondarily through overgrazing by domestic stock. These sites predominantly occur on limestone plains, with *Austrostipa scabra* dominating sites across the survey area and *Austrodanthonia caespitosa* sites in the north-east. Grassland dominated by *Eragrostis dielsii* and *Eragrostis setifolia* is found in areas where surface drainage accumulates, commonly claypans, dongas and gilgai.

Tussock grassland is difficult to rate as it often dominated an altered vegetation community. As it is assumed that the altered transition is permanent, vegetation communities were rated as found rather than as was perceived to have been once. Over half (56 per cent) of the grassland sites were considered to be in good condition, with 15 per cent in very good condition, 27 per cent in fair condition and 2 per cent in poor condition.

Hummock grasslands

Three hummock grassland sites were recorded; the sites had a PFC of 10 to 40 per cent. According to Muir (1977), a site with a PFC of less than 30 per cent is classified as 'Hummock Grass' and a site with a PFC of greater than 30 per cent, 'Mid Dense Hummock Grass'. Only one species of hummock grass, *Triodia scariosa* was found. Hummock grassland occurs in the north-west, west and south-west of the survey area on calcareous aeolian sandplains.

All sites were rated as being in good condition.

Herbland

The PFC for herbland sites was mostly between 2 and 15 per cent. Herbland sites are therefore classified as 'Very Open Herbs' where the PFC is less than 10 per cent and 'Open Herbs' where the PFC is greater than 10 per cent (Muir 1977).

Thirteen species of herb were recorded at 27 herbland sites. *Sclerolaena obliquicuspis* dominated four sites and *Sclerolaena patenticuspis* dominated seven sites. These sites were commonly located on limestone plains in the north-east of the survey area. *Salsola tragus* was the dominant species at three sites located within areas of drainage focus in the north-east. Herb species that dominated two sites included *Carrichtera annua, Cullen cinereum* and *Zygophyllum iodocarpum.* These species commonly dominate sites in dongas in the north.

Nearly half (52 per cent) of herbland sites were considered to be in fair condition, 15 per cent were very good, 26 per cent were good and 7 per cent were poor.

Regional distribution of plant communities

There is a noticeable geographic variation in the dominant strata at sampling sites across the survey area. Low shrubland is the most common vegetation formation on all 1:250 000 scale map sheets except Burnabbie where woodland dominates. The Cundeelee, Forrest and Noonaera map sheets had too few sites recorded to allow any analysis.

Low shrubland is most common on the Eucla, Madura and Naretha map sheets that fall predominantly within the Nullarbor Plain proper. Woodland is more common on the Balladonia and Burnabbie map sheets that border the survey area in the south-west and south. The majority of woodland on these map sheets is mallee woodland. Tussock grassland grading southwards into tall shrubland is most common on the Culver map sheet. On the Zanthus map sheet mallee woodland and mid shrubland is most common. Herbland is common through the Loongana map sheet, though myall woodland is common along the western border. Similarly herbland is common in the south-east of the Seemore map sheet with woodland in the north-western portion.

Atriplex vesicaria was the most commonly recorded species on the Balladonia, Eucla, Madura and Zanthus map sheets recorded at nearly 90 per cent of the sites on these map sheets, except the Zanthus map sheet where it occurred at 77 per cent of the sites. In the north on the Loongana, Naretha and Seemore map sheets, *Austrostipa scabra* was the most common species recorded at over 70 per cent of the sites.

In the south of the survey area on the Burnabbie and Culver map sheets vegetation associations have more defined boundaries and are confined to smaller areas than further north. This is due to the close coastal proximity and its effect on

Table 14 **The proportion (%) of the plant form of the dominant strata recorded at 366 inventory sites on the 1:250 000 map sheets of the Nullarbor**

Map sheet	Tree	Tall shrub	Mid shrub	Low Shrub	Tussock grass	Hummock grass	Herb	No. of sites
Balladonia	28	9	9	47	7	0	0	32
Burnabbie	47	8	11	24	10	0	0	37
Culver	15	21	9	29	24	2	0	34
*Cundeelee	50	0	0	17	0	0	33	6
Eucla	21	9	3	58	9	0	0	43
Loongana	7	0	7	36	14	0	36	14
*Forrest	0	0	0	67	0	0	33	4
Madura	19	0	1	51	19	0	10	70
Naretha	7	14	9	53	7	0	10	58
*Noonaera	0	50	0	50	0	0	0	2
Seemore	11	8	16	35	14	0	16	37
Zanthus	24	7	21	42	3	3	0	29

* Too few sites recorded to allow for analysis.

the geophysical development of landforms and local weather conditions. As a result, no one species was recorded at more than 55 per cent of the sites on these two map sheets. *Maireana erioclada* (54 per cent) and *Melaleuca lanceolata* (50 per cent) were the most commonly recorded plants on the Burnabbie map sheet and *Austrostipa scabra* (48 per cent) on the Culver map sheet.

The most noticeable geographic variation in individual species is the distribution of trees. The distribution is largely dependent on geomorphology, geology, soils and rainfall gradients across the landscape. The distribution across map sheets of five tree species common on the Nullarbor is shown in Table 15.

Acacia papyrocarpa (myall) is found on all map sheets within the survey area, though is most common on the Eucla, Seemore and Zanthus map sheets. The understorey of myall woodland is primarily composed of *Cratystylis conocephala* and Chenopodiaceae. In the north, dense population recruitment of juvenile myall is occurring. In dry periods myall trees are browsed, whilst sheep and rabbits favour myall seedlings. It is likely the germination is most noticeable in these northern areas as these areas are not stocked with sheep and rabbit numbers have been substantially reduced by rabbit calicivirus. The reduction in the total grazing pressure is providing the opportunity for myall seedlings to survive beyond germination.

Casuarina pauper (black oak) is most common in the south-west, on the Naretha and Zanthus map sheets. It is commonly found on calcrete plains or residual calcrete rises and is often associated with an understorey of *Acacia*, *Eremophila* and Chenopodiaceae.

Table 15 **The number of sites that tree species were recorded at on the 1:250 000 map sheets of the Nullarbor**

Map sheet	*Acacia papyrocarpa*	*Casuarina pauper*	*Eucalyptus gracilis*	*Eucalyptus yalatensis*	*Myoporum platycarpum*	No. of sites
Balladonia	6	3	23	0	48	32
Burnabbie	5	0	3	16	11	37
Culver	9	3	9	15	15	34
Eucla	28	0	35	26	12	43
Loongana	21	0	0	0	21	14
Madura	21	0	7	11	13	70
Naretha	21	21	0	0	14	58
Seemore	38	11	0	0	30	37
Zanthus	30	27	3	0	33	29

Myoporum platycarpum (sugarwood) is mostly found on the Balladonia, Seemore and Zanthus map sheets. Sugarwood often dominates the stony calcrete plains of the Nanambinia land system and the clay depressions of the Woorbla land system. Dense recruitment of sugarwood is often found in these areas, which is considered to be in response to the reduction in rabbit numbers due to rabbit calicivirus.

A variety of eucalypt species is found in the western and southern perimeters of the survey area coinciding with greatest rainfall. *Eucalyptus gracilis, E. oleosa* and *E. yalatensis* were the most common eucalypts recorded. *Eucalyptus gracilis* and *E. oleosa* can survive with less water than *Eucalyptus yalatensis* (Parsons 1970) and therefore have a greater range, being most common on the Balladonia, Zanthus and southern portion of the Eucla map sheets. *Eucalyptus yalatensis* is restricted to the narrow strip along the coast from Balladonia into South Australia. Within the survey area *Eucalyptus yalatensis* is most common on the Balladonia and southern portion of the Eucla map sheets.

Flora conservation

Flora conservation involves maintaining biological diversity at a variety of scales, from genetic diversity within single populations to continental and global species richness. In this section the threats to plant species and communities, and threatened species are discussed.

Threats to native flora

Pastoralism

Pastoralism has extensively modified native plant communities in the rangelands. Where grazing has been excessive, plant species that are palatable to domestic stock, feral animals and kangaroos have been substantially reduced or removed. The vacated niches are then replaced by suites of less palatable plants, with the resulting species richness, density and cover rarely equal to that of the previous vegetation community (Payne et al. 1998). No plants are known to have become extinct in the survey area since pastoralism was introduced, though palatable plant species such as *Maireana georgei* are likely to have been reduced. The prolific germination of *Acacia papyrocarpa* (myall) in areas absent of sheep, coinciding with reduced rabbit numbers, is evidence of the impact sheep have had on suppressing myall populations.

Two key factors affect the susceptibility of plant communities to grazing: first the distance from water and second the palatability of plant species. Cridland and Stafford Smith (1993) demonstrated that the impact of grazing increases as the distance from water decreases. Closer to watering points the concentration of stock is greatest, as all stock from within a paddock congregate in the small area surrounding watering points to drink. This results in increased grazing and trampling of the vegetation and padding of the soil in close proximity to watering points.

The intensity of the piosphere effect surrounding water points depends on the volume of water stock need; this varies depending on the salt content of feed and water, temperature and seasonal conditions. When stock are grazing on saline feed and drinking saline water, as is often the case on the Nullarbor, the volume of water required per day is greatly increased. High temperatures also increase the volume that stock must drink to replace that lost through evaporative cooling mechanisms (Macfarlane & Howard 1974). The greater the volume of water required, the longer stock will spend near watering points and the less distance they will be able to travel away from watering points before needing to return. This increases the level of deterioration of the soil and vegetation surrounding watering points.

Following periods of rainfall, stock are able to graze further from water points due to the increased volume of water ingested as a component of newly germinated herbage. During these times sheep can often fulfil their daily requirements from the water within feed, cattle however will always need access to sources of ‘free’ water (Burnside, Williams & Curry 1990).

Vegetation communities that are highly palatable and accessible to stock are at the greatest risk from overgrazing. Livestock are known to actively seek more desirable plants from pasture, and will range, if necessary, beyond their expected grazing radius to select these plants even when there is abundant feed along the way (Eckersley 1988). Within the Nullarbor, the most palatable feed is often the grasses and herbage that grow between the perennial shrubs. In dry seasons when grasses and

herbage are scarce, the preferred vegetation is often chenopod shrubs, particularly *Atriplex vesicaria,* and browse from *Acacia papyrocarpa, Alectryon oleifolius, Cratystylis conocephala, Eremophila longifolia* and *Pittosporum angustifolium.* These perennial shrubs and trees may be killed by overgrazing, leading to loss of plant cover and increased exposure of soil which increases the susceptibility to all forms of erosion.

A more even distribution of grazing can be achieved if paddocks enclose similar land types (Pringle 1994). All areas within a paddock will be similarly preferred by stock, and so stock will not selectively graze out the most palatable areas. Small areas such as dongas and drainage foci often contain vegetation of high palatability, but also support unique vegetation communities which are important contributors to the heterogeneity of the Nullarbor ecosystem. Excluding dongas and drainage foci from grazing systems is unfeasible, however such areas would benefit from not having water points located directly in them to reduce the degradation that such positioning inevitably causes. This would also encourage more even grazing of the surrounding dominant vegetation types.

Introduced flora species

Forty-three introduced flora species were recorded within the survey area (Table 16). Of the 6997 traverse ratings where range condition was assessed, introduced flora was recorded at 3.3 per cent of traverse points. The most common species was *Carrichtera annua* (Ward's weed) recorded at 3 per cent of traverse points.

Many introduced flora species were commonly recorded in degraded dongas and along the Trans-Australian Railway line and Eyre Highway. Whilst many of the introduced flora species tend to remain restricted to depressions some species have the potential to cause significant ecological problems to Nullarbor communities. *Asphodelus fistulosus* (onion weed) has become established in a number of locations through its ability to dominate disturbed or degraded areas. Another species with the potential to spread on the Nullarbor is *Cenchrus ciliaris* (buffel grass). At the time of the survey buffel grass was observed in the vicinity of the Trans-Australian Railway line, occurring in small but established populations. Other introduced flora increasing in specific localised areas included *Salvia verbenaca* (wild sage), *Schinus molle* var. *areira* (pepper tree) and *Tamarix aphylla* (tamarisk).

Feral herbivores

Historically, rabbits have had a large impact on the Nullarbor. During the 1940s their number was so great it enabled a substantial commercial trade, with 20 000 rabbits a week trapped in the Cocklebiddy area alone (Parsons 1970). Rabbit plagues have had a devastating effect on the landscape. They have reduced the recruitment of trees such as *Acacia papyrocarpa* by grazing on seedlings and juveniles, and ringbarking older trees. Rabbit densities must remain very low in some arid areas to enable plant regeneration. The regeneration of *Acacia papyrocarpa* was found to be affected by rabbit grazing at densities of less than 0.5 rabbits per kilometre (Lange & Graham 1983). Rabbits have also overgrazed palatable herbs and grasses, leading to a reduction in ground cover so that the rate of erosion is increased (Gilfillan 1999). The reduction in perennial plants as well as the soil disturbance caused by burrowing has also led to an increase in populations of unpalatable, short-lived annuals. The release of the viruses (myxomatosis in 1954 and 1966, rabbit calicivirus in 1995) has greatly reduced rabbit numbers across the Nullarbor (Gilfillan 1999).

Feral camels occur in medium to high numbers throughout the pastoral areas, with larger numbers in the Unallocated Crown Land in the north and east of the survey area (Woolnough et al. 2005), feral horses are also present though in lower numbers. Horses and camels graze on the fruits, leaves and stems of trees. They are able to browse higher trees than other animals within the area. The repeated browsing of foliage and bark, breaking of branches and eventually the central trunk can lead to the death of trees. The mustering of feral horses and the shooting of both feral camels and horses is considered the most practical form of control for these animals. Control programs are carried out by pastoralists.

Table 16 **Introduced flora species recorded in the survey area**

Taxon	Common name	Growth form	No. of inventory sites
Anagallis arvensis	Pimpernel	Annual herb	1
Arctotheca populifolia	Dune arctotheca	Perennial herb	-
Asphodelus fistulosus	Onion weed	Annual herb	1
Brassica tournefortii	Wild turnip	Annual herb	-
Cakile maritima	Sea rocket	Annual herb	1
Carduus nutans	Nodding thistle	Annual herb	1
Carrichtera annua	Ward's weed	Annual herb	111
Carthamus lanatus	Saffron thistle	Annual herb	1
Cenchrus ciliaris	Buffel grass	Perennial grass	-
Centaurea melitensis	Maltese cockspur	Annual herb	2
Centaurium erythraea	Common centaury	Annual herb	1
Chenopodium murale	Nettle-leaf goosefoot	Annual herb	2
Chloris gayana	Rhodes grass	Annual herb	-
Citrullus lanatus	Pie melon	Perennial herb	6
Cucumis myriocarpus	Prickly paddy melon	Annual herb	-
Emex australis	Doublegee	Annual herb	1
Erodium aureum	-	Annual herb	21
Erodium cicutarium	Common storksbill	Annual herb	4
Euphorbia paralias	Sea spurge	Perennial herb	2
Heliotropium europaeum	Common heliotrope	Annual herb	-
Gomphocarpus fruticosus	Narrowleaf cottonbush	Perennial herb	-
Hordeum glaucum	Northern barley grass	Annual grass	-
Lepidium africanum	Rubble peppercress	Annual herb	-
Lythrum hyssopifolia	Lesser loosestrife	Annual herb	-
Malva parviflora	Marshmallow	Annual herb	-
Malvastrum americanum	Spiked malvastrum	Perennial herb	6
Marrubium vulgare	Horehound	Perennial herb	-
Mesembryanthemum crystallinum	Iceplant	Annual herb	35
Mesembryanthemum nodiflorum	Slender iceplant	Annual herb	3
Nicotiana glauca	Tree tobacco	Tree	-
Oncosiphon suffruticosum	-	Annual herb	1
Oxalis corniculata	Yellow wood sorrel	Annual herb	5
Pentaschistis airoides	False hairgrass	Annual herb	-
Rostraria pumila	-	Annual herb	1
Salvia verbenaca	Wild sage	Perennial herb	4
Schinus molle var. *areira*	Pepper tree	Tree	-
Schismus barbatus	Kelch grass	Annual grass	-
Sisymbrium erysimoides	Smooth mustard	Perennial herb	10
Sisymbrium irio	London rocket	Annual herb	-
Solanum nigrum	Blackberry nightshade	Perennial herb	2
Sonchus oleraceus	Common sowthistle	Annual herb	17
Tamarix aphylla	Tamarisk	Tree	1
Xanthium spinosum	Bathurst burr	Annual herb	7

Kangaroos

Kangaroo numbers are unnaturally high in pastoral country due to permanent water at artificial watering points (Oliver 1986; Norbury 1992). This results in additional grazing pressure on native plants. Kangaroo grazing is largely uncontrolled due to the ineffectiveness of conventional stock fences in prohibiting kangaroo movement. It has been demonstrated that kangaroos hinder regeneration programs in areas where stock have been excluded to encourage the recovery of native plants (Gardiner 1986a, 1986b; Norbury & Norbury 1991). Commercial shooting is the main method of control of kangaroos.

Fire

Bushfires are a natural feature of the Nullarbor. In years following prolific annual growth the abundant dry matter has the potential to readily catch fire as a result of lightening strikes during thunderstorms. Since European settlement the frequency of fires has increased in the Nullarbor district. Sparks from steam trains on the Trans-Australian Railway are considered responsible for many fires on land adjacent to the railway (Mitchell, McCarthy & Hacker 1979).

The Chenopodiaceae are the most dominant flora type in the survey area. Chenopod shrubland is not adapted to a regular fire regime (Graetz & Wilson 1984). *Maireana sedifolia* (pearl bluebush) can tolerate moderate intensity fires though may be substantially thinned out, whilst *Atriplex vesicaria* (bladder saltbush) may be completely eliminated. Hodgkinson and Griffin (1982) state that as chenopod regeneration after fire is by seed alone, there is a risk of completely exhausting the seed bank if grazing pressure is not relaxed post-fire.

Many of the areas now supporting extensive grasslands once supported a mosaic of chenopod shrubland and grassland. In years of good annual growth these areas have sufficient fuel to burn readily. In combination with increased fire regimes, plague proportions of rabbits grazed on post-fire regrowth limiting the regeneration of chenopod shrubland. The expansion of grassland at the expense of chenopod species has further increased the susceptibility of the area to fire. The increased frequency of burning in combination with grazing of juvenile plants by rabbits has adversely affected the vegetation composition.

Threatened species

The Department of Environment and Conservation maintains a declared rare and priority flora list (Atkins 2005) under the provisions of the Wildlife Conservation Act. Fifteen species from the declared rare and priority flora list occur within the survey area (Table 17). No threatened ecological communities have been identified.

Table 17 **Declared rare and priority flora listings for the survey area (Atkins 2005)**

Taxon	Priority code[1]	No. of inventory sites
Eremophila attenuata	1	-
Grevillea phillipsiana	1	-
Lepidium fasciculatum	1	1
Thysanotus baueri	1	3
Chthonocephalus multiceps	2	-
Eucalyptus fraseri subsp. *melanobasis*	2	1
Eucalyptus surgens	2	-
Goodenia varia	2	-
Harperia eyreana	2	1
Opercularia loganioides	2	1
Phlegmatospermum eremaeum	2	-
Allocasuarina eriochlamys	3	-
Eremophila dendritica	3	-
Eucalyptus histophylla	3	-
Eucalyptus pimpiniana	3	-
Galium migrans	3	-
Eremophila hillii	4	-
Eremophila parviflora subsp. *parviflora*	4	-
Myriophyllum balladoniense	4	-

Priority codes:
1 Taxa with few poorly known populations on threatened lands.
2 Taxa with few poorly known populations on conservation lands.
3 Taxa with several poorly known populations, some on conservation lands.
4 Rare taxa, not currently threatened, but require monitoring.

Of the declared rare and priority species which are known to exist in the Nullarbor area only eight were collected during the survey: *Eremophila dendritica, Eucalyptus fraseri* subsp. *melanobasis, E. surgens, Harperia eyreana, Lepidium fasciculatum, Myriophyllum balladoniense, Opercularia loganioides* and *Thysanotus baueri*.

Eremophila dendritica was collected during traversing through the Nyanga Plain on the Zanthus map sheet. Soils consisted of calcareous loamy soils that contained sheet or nodular calcrete at varying depth.

Eucalyptus fraseri subsp. *melanobasis* was collected on three occasions: at one inventory site and at two traverse locations. All locations occurred in the eucalyptus woodland of the Caiguna and Gumbelt land systems on the Balladonia map sheet. These areas had calcareous loamy soils with sheet or nodular calcrete at varying depths.

Eucalyptus surgens was collected once during a reconnaissance trip on the Culver map sheet. The area consisted of scattered limestone and calcrete outcrop with shallow calcareous loamy soils.

Harperia eyreana was also collected on a reconnaissance trip on the Burnabbie map sheet. It occurred on a calcareous dune overlying a calcarenite plain.

Lepidium fasciculatum was collected at one inventory site. It was collected from a donga in the Kybo land system on the Madura map sheet. The soil was moderately light clay.

Myriophyllum balladoniense was collected during traversing from an ephemeral rock pool on a granite outcrop. It occurs as an aquatic, emergent perennial herb.

Opercularia loganioides was collected at one inventory site. It occurred in drainage foci of the Toolinna land system not far inland from the Baxter Cliffs on the Culver map sheet. The area had calcareous loamy soils.

The rating of *Thysanotus baueri* as Priority 1, taxa with few poorly known populations on threatened lands, is likely due to a lack of sampling in the areas in which it commonly occurs. *Thysanotus baueri* was found within the Balladonia and Culver map sheets in open woodland where the overstorey was dominated by eucalypts and the soil was calcareous loam overlying calcrete.

Conclusion

The vegetation of the Nullarbor is primarily Eremaean; it is adapted to a desert climate without an assured growing season. The majority of the survey area is covered by low shrubland dominated by bluebush and saltbush. Low open myall woodland over chenopod shrubland is present around the perimeter of the Nullarbor Plain. In the west diverse woodland of eucalyptus and sugarwood is also present.

The south-east of the survey area includes the Hampton Range which is dominated by mallee woodland. The calcareous Roe Plains below the Hampton Range supports myall and eucalypt open woodland trending towards coastal heath in the south. The south-west supports mixed eucalypt woodlands trending towards coastal heath in the south before terminating at the Baxter Cliffs.

The effect of European settlement in the Nullarbor has impacted both directly and indirectly on the vegetation communities. The increased fire frequency in combination with plague proportions of rabbits has substantially altered the vegetation. The vegetation has been further modified by the introduction of domestic stock and the development of water points. These have led to an increase in the presence and associated impacts of feral animals and kangaroos.

The vegetation associations dominated by chenopods that cover vast areas of the Nullarbor are relatively resistant to managed grazing. The areas of greatest degradation are those surrounding water points. This is a result of the high salt content of feed and water and the arid climatic conditions that compel stock to drink frequently. Away from the piosphere effects that surround water points, the vegetation is generally considered to be in good condition. However, natural areas of water accumulation such as dongas and drainage areas are prone to degradation due to their often close proximity to water points and because they contain highly palatable vegetation. These areas often support unique flora and fauna communities that are crucial to the health and productivity of the Nullarbor ecosystem.

Land managers have a major contribution to make to regional conservation through the integration of nature conservation and primary production objectives. Pastoralists can make substantial progress towards ecological

sustainability by adopting strategies to manage the total grazing pressure of domestic, feral and native stock and by improved control of stock movement, including the development of infrastructure away from ecologically fragile locations.

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Habitat type ecology

PA Waddell and AK Gardner

Habitats as ecological units

The interrelationships between the physical environment and the plant communities it supports can be described by classifying sampling points (inventory sites) into habitat types. Habitat types are classified in terms of combinations of landforms, soil types and plant communities. They closely resemble the 'ecological site' of the Society for Range Management (1991) and the habitat of Tinley (1991). In previous rangeland surveys of pastoral areas in Western Australia, habitat types have been referred to as 'pasture lands' (Payne, Mitchell & Holman 1988), 'pasture types' (Payne, Curry & Spencer 1987), 'vegetation types' (Curry et al. 1994), 'site types' (Pringle, Van Vreeswyk & Gilligan 1994) and 'habitat types' (Payne et al. 1998). 'Habitat type' was chosen as it most accurately fits the ecological classification below and is relevant to those not familiar with rangeland survey.

Habitat types are generally referred to by their land surface, dominant taxon and dominant vegetation stratum and given an appropriate four letter code (e.g. PXCS—Plain with mixed chenopod shrubland). Many of the habitat types identified on the Nullarbor are distinguished by vegetation, as so much of the survey area occurred on limestone and calcrete plains of similar geomorphic origin.

Habitats types are described within broader habitat groups so as to aggregate ecologically similar habitat types. Habitat types within a habitat type group are generally located in the same position in the landscape as well as having similar vegetation and soils. The broader habitat type groups are categorised in terms of:

- general information (physical environment, distribution patterns, general ecology)
- vegetation physiognomy (Projected Foliar Cover—PFC) and composition (by stratum)
- patterns of variation (including the impact of grazing and fire)
- gradational associations, and
- land system representation (a habitat is defined as being a major type if it occurs on 30 per cent or more of the land system; as common where it occurs on 20–29 per cent of the land system; and as minor where it occurs on < 20 per cent of the land system).

Terminology used in describing habitat composition

Vegetation formations

The following definitions were used to describe the vegetation formations:

Woodland—dominant stratum is trees or mallees (trees have a single stem to a height of 1.3 m above ground level and mallees are multi-stemmed plants to a height of 6 m)

Grove—dominant stratum is trees and tall shrubs confined to small areas

Shrubland—dominant stratum is shrubs; shrub referring to a perennial woody multi-stemmed plant which branches from below or near ground level

Scrub—dominant stratum is collectively composed of stunted trees and shrubs of variable height (< 5 – < 0.5 m), where plants generally have a distinguishable single stem or trunk

Heathland—dominant stratum is perennial low shrubs

Grassland—dominant stratum is tussock grasses

Herbland—dominant stratum is subshrubs and annual herbs.

Where a habitat type is described as a shrub-land or woodland the dominant stratum for locations supporting this habitat type may occur as either shrubs or trees, respectively.

Number of plant species

The survey average is the average number of plant species recorded at each of the 392 inventory sites sampled. This was calculated as 11 perennial species and three annual species.

Dominant and common plant species

The following definitions have been used to categorise the structure of the dominant and common plant species for each habitat type:

Tree—a plant over 2 m high with a single trunk to at least 1.3 m, including single trunk eucalyptus

Mallee—a multi-stemmed eucalypt

Tall shrub—a perennial woody plant over 2 m tall with more than one trunk below 1.3 m

Mid shrub—a perennial woody plant between 1 and 2 m in height

Low shrub—a perennial woody plant less than 1 m in height

Subshrub—a seasonally dependent, weakly facultative perennial, generally less than 0.5 m (50 cm) in height, usually persisting for less than two years

Perennial grass—a grass species usually persisting for at least two years

Annual—a short-lived plant usually persisting for less than one year

Other plant forms—plants such as creepers, mistletoes and sedges.

Dominant species are those which were recorded as dominant in a stratum at a quarter or more of the inventory sites. Common species are subordinate species recorded at a quarter or more sampling sites. Where less than eight inventory sites were sampled for a vegetation unit, dominant and common species were considered those present at two or more sites. Other species refers to uncommon species that were infrequently recorded at less than a quarter of sampling sites.

Taxonomic conventions

The plant taxonomy adopted in this survey is based on advice from the Western Australian Herbarium.

Species conservation status has been assigned according to the declared rare and priority flora list for Western Australia (Atkins 2005).

Declared Rare Flora (R) – Extant—Taxa which have been adequately searched for, and for which populations in the wild are deemed to be rare, in danger of extinction, or otherwise in need of special protection, and have been gazetted as such.

Priority One (P1) – Poorly Known—Taxa which are known from one or a few (generally < 5) populations which are under threat, due to small population size, being on lands under immediate threat (e.g. road verges, urban areas, farmland, active mineral leases) or the plants are under threat (e.g. from disease, grazing by feral animals). It may include taxa with threatened populations on protected lands. Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey.

Priority Two (P2) – Poorly Known—Taxa which are known from one or a few (generally < 5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey.

Priority Three (P3) – Poorly Known—Taxa which are known from several populations, at least some of which are not under immediate threat (i.e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but are in need of further survey.

Priority Four (P4) – Rare—Taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors. These taxa require monitoring every 5–10 years.

Assessment of ecological disturbances

Habitat types are described in terms of common or distinctive characteristics and internal variation; this reduces natural variation into a manageable number of ecological types within which there is strong similarity. This facilitated the assessment of range condition. The validity of assessments has been achieved by comparing the prominence of groups of plant species and soil surface condition at reference inventory (ungrazed or lightly grazed) sites with normally grazed sites.

Influences on internal variation, such as disturbances, are discussed in ecological terms rather than in terms of pastoral impacts on pastoral productivity, though it is common for most changes in productivity to be related to ecological changes.

Ecological disturbances are considered in recognition of their widespread influence on the plants common to each habitat type. Ecological disturbance is discussed in terms of how disturbances, natural or influenced by man, have affected natural resources which may have implications for future land management and nature conservation. Additionally, the patterns discussed may assist present land managers to

better understand and work with the ecological processes operating throughout their leases.

Factors considered responsible for substantially influencing the ecology of Nullarbor habitats include fire, rabbit plagues and grazing impacts, particularly in association with extended dry periods. In many instances more than one disturbance factor was involved. Where a combination of factors had contributed to disturbance it was difficult to determine any one factor as the major cause or to distinguish disturbance from natural variation. This was particularly relevant in areas where there was little prior knowledge of the ecology of the habitat types and their associated communities.

The ecological changes some habitat types have undergone have been so dramatic the original species composition of the perennial vegetation has been significantly replaced by an annual component. The combination of 'drought', fire and rabbit plagues has eliminated large areas of chenopod shrubland throughout the survey area. These areas are now considered to be in a state of irreversible transition (Beard 1975; Davey 1978; Mitchell, McCarthy & Hacker 1979; Westoby, Walker & Noy-Meir 1989). As such, these areas were assessed on their present form rather than considering them as a habitat type of a former state in poor condition.

Plant species indicator values for the grazed situation are defined as:

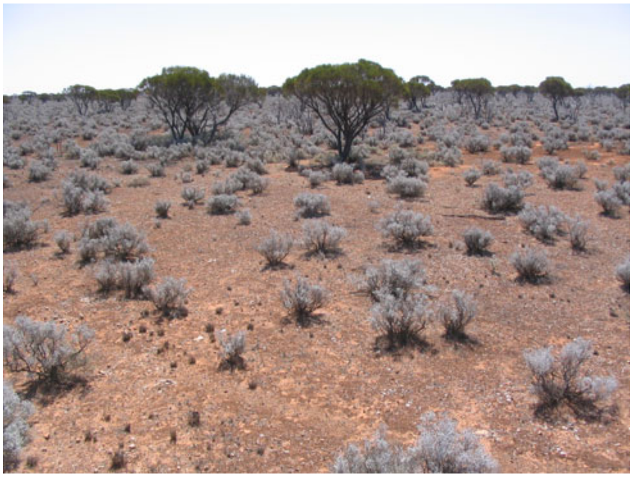
Decreaser—Highly palatable plants whose cover and density decline under excessive grazing pressure. Such plants are often referred to as 'desirables'.

Intermediate—Moderately palatable plants which, under grazing, initially increase in cover and density as they utilise niches vacated by decreasers. Intermediate plants may dominate the stand. They decline under extreme grazing pressure, and may be common in areas regenerating from severe degradation.

Increaser—Generally unpalatable plants which increase in number and cover as decreaser species decline under excessive grazing pressure. They are commonly found in disturbed areas (e.g. burnt patches, water sources). In a grazing context such plants are often referred to as 'undesirables'.

No indicator value—The abundance of these species is not primarily related to grazing history. They usually only decrease after natural disturbances such as fire or hail damage. These species are usually not palatable or only slightly palatable or are out of reach of browsing animals. They have been termed 'stability desirables' in recognition of the role they play in maintaining soil stability and ecosystem function.

Key increaser (KI) and key decreaser (KD) species were identified for most habitat types. The designations of these attributes is based on field observations of reference sites, severely degraded areas and at fence effects. This information is provided to assist in future assessment and monitoring of grazing impacts.



*Scattered myall trees (*Acacia papyrocarpa*) surrounded by pearl bluebush (*Maireana sedifolia*) shrubland. This vegetation community represents a stable state.*

Considered to be in an irreversible transition of myall woodland, this landscape is unlikely to return to its former state as there are no living myall of any age remaining.

In a broadscale survey such as this, it is difficult to establish rigorous scientific linkages between disturbances such as grazing and ecological variation (except where very obvious, such as a recently burnt area). It is therefore important to appreciate that many of the interpretations are based on the experience of survey team members and their ability to recognise and explain the cause of disturbance.

This chapter in context

This chapter focuses on habitat types and plant community descriptions and ecology. At a broader scale landscape characteristics are covered in the Geomorphology and Land System chapters. Summaries of visual traverse assessments of range condition are presented in the Resource Condition chapter.

Description of habitat types within their broader habitat type groups

Fifty-three habitat types split into 10 habitat type groups are described in some detail (Table 18).

Table 18 **Habitat type groups and their component habitat types; structural definitions according to Muir's (1977) classification method are provided in the rightmost column**

A.	Myall shrubland and woodland on calcareous plains		
1.	MSCW	Myall, sugarwood mixed chenopod woodland	Low Woodland A
2.	MFBW	Myall, false bluebush shrubland or woodland	Low Woodland A
3.	MXCS	Myall mixed chenopod shrubland or woodland	Open Low Woodland A / Open Low Scrub B
4.	MSAS	Myall saltbush shrubland or woodland	Low Woodland A
5.	MPBS	Myall, pearl bluebush shrubland	Open Low Woodland A / Low Scrub B
6.	MHXS	Myall mixed halophyte shrubland	Open Low Woodland A / Low Scrub B
7.	MXSS	Myall mixed shrub shrubland	Open Low Woodland A / Low Scrub B
8.	MBIG	Myall bindii grassland	Open Low Woodland A
9.	MSOG	Myall, speargrass open grassland	Open Low Woodland A
B.	Eucalypt shrubland and woodland on calcareous plains		
10.	ESCW	Eucalypt, sugarwood mixed chenopod woodland	Woodland
11.	EXCW	Eucalypt mixed chenopod woodland	Woodland
12.	ESAW	Eucalypt saltbush shrubland or woodland	Woodland
13.	EXSW	Eucalypt mixed scrub woodland	Woodland
14.	EXHS	Eucalypt mixed halophytic shrubland	Open Woodland / Dwarf Scrub C
15.	ESOG	Eucalypt, speargrass open grassland	Open Woodland / Tall Grass
C.	Casuarina shrubland and woodland on calcrete plains		
16.	CXCS	Casuarina mixed chenopod shrubland or woodland	Low Woodland A
17.	CXSS	Casuarina mixed scrub shrubland	Open Low Woodland A / Scrub
18.	CAOS	Casuarina, acacia open shrubland	Open Low Woodland A / Scrub
D.	Shrubland and woodland on calcrete plains overlain by shallow sand		
19.	MHGW	Mallee hummock grass (spinifex) woodland	Tall Mallee / Dense Hummock Grass
20.	MUXW	Mulga mixed shrub woodland	Low Forest A
21.	ACMS	Acacia mixed shrubland	Scrub
E.	Shrubland associated with granitic outcrop		
22.	DEXS	Dodonaea, eremophila mixed shrubland	Scrub
23.	GROS	Granite outcrop shrubland	Low Scrub A / Open Low Scrub A

Table 18 (continued)

F.	Shrubland on calcareous plains		
24.	SWCS	Sugarwood mixed chenopod shrubland	Scrub / Low Scrub B
25.	PBLS	Pearl bluebush low shrubland	Low Scrub B
26.	PBAC	Pearl bluebush, acacia shrubland	Low Scrub B
27.	PXCS	Plain mixed chenopod shrubland	Low Scrub B / Dwarf Scrub C
28.	NXCS	Nitraria mixed chenopod shrubland	Low Scrub B
29.	BSSL	Bladder saltbush shrubland	Dwarf Scrub C
30.	LAWS	Lawrencia squamata shrubland	Dwarf Scrub C
G.	Open shrubland and grassland on calcareous plains		
31.	XAOS	Mixed acacia open shrubland	Scrub / Low Scrub A
32.	XSBG	Mixed shrub bindii grassland	Open Scrub / Very Open Herbs
33.	OBIG	Open bindii grassland	Open Herbs / Very Open Herbs
34.	SWOG	Speargrass and wallaby grass open grassland	Tall Grass / Very Tall Grass
35.	ANNH	Annual herbland	Open Herbs / Very Open Herbs
H.	Drainage foci shrubland		
36.	DOGR	Donga grove	Scrub / Dense Low Grass
37.	DDSS	Drainage depression saltbush shrubland	Open Scrub / Dwarf Scrub C
38.	DDXS	Drainage depression mixed shrub shrubland	Very Open Tree Mallee / Open Scrub
39.	DRAS	Drainage tract acacia shrubland	Open Scrub / Open Low Scrub A
40.	GGSL	Gilgai grassy shrubland	Dense Low Grass
41.	LISW	Lignum swamp	Low Scrub B
42.	PXLS	Plain mixed low shrubland	Low Scrub A / B
I.	Shrubland and woodland on lake margins and saline depressions		
43.	KOPI	Kopi dune woodland	Open Low Woodland / Dwarf Scrub C
44.	SBLS	Sandy bank lake shrubland	Thicket
45.	PXHS	Plain mixed halophytic shrubland	Low Scrub B / Dwarf Scrub C
46.	SAMP	Samphire shrubland	Dwarf Scrub D
J.	Coastal zone heath and woodland		
47.	EMCW	Eucalypt, melaleuca mixed chenopod shrubland or woodland	Open Tree Mallee
48.	EMEW	Eucalypt, melaleuca woodland	Open Tree Mallee
49.	LOMW	Low mallee woodland	Open Tree Mallee
50.	EHEW	Eucalypt heath woodland	Open Tree Mallee
51.	ECHW	Eucalypt coastal heath woodland	Open Tree Mallee
52.	BCHS	Banksia coastal heath and scrubland	Shrub Mallee
53.	COAS	Coastal shrubland	Heath B / Open Dwarf Scrub D

A. MYALL SHRUBLAND AND WOODLAND ON CALCAREOUS PLAINS

This group of habitat types is common throughout the survey area on calcareous plains. The overstorey is dominated by *Acacia papyrocarpa* (myall) and the understorey by low shrubs of the Chenopodiaceae and Asteraceae families. Throughout the survey area the understorey has commonly been reduced or removed, through the combined effects of fire, grazing by rabbits and to a lesser extent domestic stock, replaced by stands of perennial grasses, subshrubs and herbs. The presence of myall is strongly influenced by its growing medium and rainfall. In the south myall corresponds with the location of the Hampton Tableland gradually disappearing as the landscape transitions into the Nullarbor land zone from which it is absent, this may also relate to the gradational decrease of rainfall from the coast. In the north and west myall corresponds with the calcrete and Recrystallised Limestone plains of the Nyanga land zone. With the reduction in rabbit numbers, due to the rabbit calicivirus, recruitment of juvenile myall throughout myall woodland is common. Most frequently observed in the north of the survey area this phenomenon also corresponds with areas destocked of sheep. In the south in the Hampton Tableland juvenile myall is less common and though rabbit numbers are reduced, sheep grazing on juvenile trees is affecting myall recruitment.

1. Myall, sugarwood mixed chenopod woodland (MSCW)

Sampling

1 inventory site, 91 traverse points

General information

MSCW is found on calcrete plains overlain by calcareous loam and on low calcrete rises. Gentle slopes to 4 per cent with an abundant surface covering (50–90 per cent) of calcrete fragments. Soils are calcareous loamy earths. This vegetation association is common in the west of the survey area.

Physiognomy and composition of vegetation

MSCW occurs as a scattered (10–15 per cent PFC) low woodland of *Acacia papyrocarpa* (myall). *Myoporum platycarpum* (sugarwood) dominates the tall shrub stratum and is commonly denser than *Acacia papyrocarpa*. The mid shrub layer is commonly dominated by scattered *Cratystylis conocephala* (false bluebush) (15–20 per cent PFC).

14 perennial species and one annual species were recorded at the inventory site.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—*Acacia papyrocarpa* Common—*Myoporum platycarpum.*
Tall shrubs:	Dominant—*Myoporum platycarpum.*
Mid shrubs:	Dominant—*Cratystylis conocephala* Other—*Atriplex nummularia.*
Low shrubs:	Dominant—Not present as a recognisable stratum Others—*Atriplex vesicaria* (KD), *Chenopodium curvispicatu*m, *Lycium australe*, *Maireana sedifolia*, *Olearia calcarea*, *Solanum nummularium.*
Subshrubs:	Dominant—Not present as a recognisable stratum Others—*Eriochiton sclerolaenoides*, *Maireana trichoptera* (KD), *Sclerolaena diacantha* (KD).
Perennial grasses:	Dominant—Not present as a recognisable stratum Others—*Austrostipa platychaeta.*

Annual species recorded include *Salsola tragus.*

Ecological disturbance

Palatable low shrubs and subshrubs such as *Atriplex vesicaria* (bladder saltbush), *Maireana trichoptera* (pink-seeded bluebush) and *Sclerolaena diacantha* (grey bindii) may be removed through overgrazing. Where this habitat type occurs on low rises crossed by vehicle tracks these areas are prone to water erosion. Prolific *Myoporum platycarpum* regrowth may be a response to a reduction in rabbit numbers due to the rabbit calicivirus. At the time of survey *Myoporum platycarpum* dominated the tall shrub stratum. In future years it may become dominant in the tree strata, though natural competition or fire may also reduce its abundance.

Gradational associations

MSCW commonly grades into *Myall mixed chenopod shrubland or woodland* (MXCW) as *Myoporum platycarpum* becomes less dense through the tall shrub stratum. Where both myall and sugarwood are replaced in dominance by species of eucalyptus MSCW grades into *Eucalypt mixed chenopod woodland* (EXCW)

Land systems

MSCW is a major habitat on Nyanga land system.

2. Myall, false bluebush shrubland or woodland (MFBW)

Sampling

6 inventory sites, 45 traverse points

General information

MFBW is most common in the south-east of the survey area near the Hampton Scarp, either on the calcarenite Roe Plains or on the Bunda Plateau on residual aeolian sand deposits. Coarse (2–6 cm) calcareous fragments, commonly calcrete nodules, are sparsely distributed across 2–10 per cent of the surface. Soils are calcareous loamy earths.

Physiognomy and composition of vegetation

MFBW occurs as a scattered to moderately closed (10–25 per cent PFC) low woodland or shrubland. The tree stratum is dominated by *Acacia papyrocarpa* (myall) and the low to mid shrub stratum by *Cratystylis conocephala* (false bluebush). Very scattered to scattered (2.5–15 per cent PFC) *Geijera linearifolia* (oilbush) occur in the medium to tall shrub stratum.

50 perennial species were recorded at the six inventory sites, with an average of 17 per site, six more than the survey average. Four annual species were recorded, with an average of one per site.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—*Acacia papyrocarpa* Common—*Myoporum platycarpum* Others—*Eremophila longifolia*, *Eucalyptus gracilis* (mallee), *E. oleosa* subsp. *oleosa* (mallee), *E. yalatensis*, *Santalum acuminatum*, *S. lanceolatum.*
Tall shrubs:	Dominant—*Geijera linearifolia* Others—*Eremophila alternifolia, Melaleuca lanceolata.*
Mid shrubs:	Dominant—*Cratystylis conocephala*, *Geijera linearifolia* Common—*Atriplex nummularia* Others—*Nitraria billardierei*, *Senna artemisioides* subsp. *artemisioides.*
Low shrubs:	Dominant—*Atriplex vesicaria* (KD), *Cratystylis conocephala* Common—*Enchylaena tomentosa* (KD), *Eremophila deserti*, *Maireana erioclada*, *Olearia calcarea*, *Westringia rigida* Others—*Eremophila glabra*, *E. latrobei* (KD), *E. parvifolia*, *Gunniopsis calcarea*, *Lycium australe*, *Maireana radiata*, *M. sedifolia*, *Olearia ramosissima*, *Rhagodia crassifolia*, *Solanum lasiophyllum*, *S. nummularium*, *Zygophyllum aurantiacum.*
Subshrubs:	Dominant—*Sclerolaena diacantha* (KD), *S. patenticuspis* (KI) Common—*Maireana trichoptera* (KD) Others—*Maireana tomentosa* (KD), *Ptilotus symonii*, *Sclerolaena obliquicuspis*, *Senecio spanomerus*, *Solanum ellipticum*, *Zygophyllum apiculatum*.
Perennial grasses:	Dominant—Not present as a recognisable stratum Others—*Austrodanthonia caespitosa*, *Austrostipa drummondii*, *A. platychaeta* (KD), *A. scabra*, *Enneapogon caerulescens*, *E. cylindricus*, *Eragrostis dielsii*.

Annual species recorded include *Carrichtera annua* (KI)*, Salsola tragus, Sonchus oleraceus* and *Zygophyllum glaucum.*

Ecological disturbance

The palatable herbs and subshrubs *Maireana tomentosa* (felty bluebush), *M. trichoptera* (pink-seeded bluebush) and *Sclerolaena diacantha* (grey bindii) when abundant in combination with *Atriplex vesicaria* (bladder saltbush), *Enchylaena tomentosa* (ruby saltbush), and *Eremophila latrobei* (warty-leaf eremophila) may

indicate good range condition. Such subshrubs may also indicate seasonal conditions and the level of use of the current season's production. *Cratystylis conocephala* is only occasionally eaten by stock and has no known indicator value (Mitchell & Wilcox 1994). *Cratystylis conocephala* and *Atriplex vesicaria* are fire intolerant and may be removed from areas frequently or intensely burnt.

Gradational associations

MFBW commonly grades into *Myall mixed chenopod shrubland or woodland* (MXCW) as chenopods become increasingly prominent in the understorey or *Plain mixed chenopod shrubland* (PXCS) where myall disappears from the overstorey.

Land systems

MFBW is a common habitat type on Moodini and Mundrabilla land systems, and is a minor habitat type on Nyanga and Roe land systems.

3. Myall mixed chenopod shrubland or woodland (MXCS)

Sampling

22 inventory sites, 625 traverse points

General information

MXCS is predominantly found on calcrete plains in the west and north of the survey area. MXCS commonly has a mantle of small to large pebbles and nodules (6–60 mm), at some locations covering up to 90 per cent of the surface. Soils are calcareous shallow loams and loamy earths. This vegetation association is also located in the south on the limestone hummocks (low rises) of the Thampanna land system and on the Roe Plains in the Mundrabilla land system.

Physiognomy and composition of vegetation

MXCS occurs as a very scattered (10–20 per cent PFC) shrubland or low woodland. The tree stratum is dominated by *Acacia papyrocarpa* (myall) and the lower shrub stratum by *Atriplex vesicaria* (bladder saltbush) and *Maireana sedifolia* (pearl bluebush). The mid shrub stratum commonly comprises very scattered (2.5–10 per cent PFC) *Atriplex nummularia* (old man saltbush); occasionally co-dominated with *Cratystylis conocephala* (false bluebush).

60 perennial species were recorded at the 22 inventory sites, with an average of 14 species per site, three above the survey average. 12 annual species were recorded, with an average of three species per site.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—*Acacia papyrocarpa* Common—*Myoporum platycarpum* Others—*Acacia aneura*, *Alectryon oleifolius*, *Casuarina pauper*, *Eremophila longifolia*, *Eucalyptus yalatensis*, *Pittosporum angustifolium*, *Santalum acuminatum*, *S. spicatum*.
Tall shrubs:	Dominant—Not present as a recognisable stratum Common—*Myoporum platycarpum* Other—*Geijera linearifolia*.
Mid shrubs:	Dominant—*Atriplex nummularia*, *Cratystylis conocephala* Common—*Senna artemisioides* subsp. x *coriacea* Others—*Acacia ancistrophylla* var. *ancistrophylla*, *A. nyssophylla*, *Eremophila decipiens*, *E. latrobei*, *E. scoparia*, *Nitraria billardierei*, *Senna artemisioides* subsp. x *artemisioides*.
Low shrubs:	Dominant—*Atriplex vesicaria* (KD), *Maireana sedifolia* Common—*Chenopodium curvispicatum* (KD), *Enchylaena tomentosa* (KD), *Lycium australe*, *Maireana erioclada*, *M. turbinata*, *Ptilotus obovatus*, *Sida calyxhymenia* Others—*Gunniopsis calcarea*, *Maireana georgei* (KD), *M. pentatropis*, *M. radiata*, *Rhagodia crassifolia*, *Solanum nummularium*, *Zygophyllum aurantiacum*.
Subshrubs:	Dominant—Not recognisable as a dominant stratum Common—*Atriplex acutibractea* (KI), *Eriochiton sclerolaenoides* (KD), *Maireana trichoptera* (KD), *Sclerolaena diacantha* (KD) Others—*Maireana tomentosa* (KD), *Minuria cunninghamii*, *Sclerolaena densiflora* (KI), *S. obliquicuspis* (KI),

	S. patenticuspis (KI), *Senecio spanomerus*, *Sida spodochroma*, *Solanum ellipticum.*
Perennial grasses:	Dominant—Not recognisable as a dominant stratum Common—*Austrodanthonia caespitosa*, *Austrostipa scabra* Others—*Austrostipa platychaeta* (KD), *Enneapogon avenaceus*, *E. caerulescens*, *E. cylindricus*, *Enteropogon acicularis*, *Eragrostis setifolia*, *Eriachne* sp., *Panicum effusum*.
Other plant forms:	Occasional—*Amyema quandang* var. *quandang* (mistletoe).

Annual species recorded include *Angianthus conocephalus, Carrichtera annua* (KI)*, Dysphania melanocarpa* forma *leucocarpa, Erodium cicutarium, Euphorbia drummondii, Nicotiana occidentalis, Rhodanthe floribunda* (KI)*, Salsola tragus* (KI)*, Sonchus oleraceus, Vittadinia humerata, Zygophyllum eremaeum* and *Z. iodocarpum* (KI).

Ecological disturbance

The palatable low shrubs *Atriplex vesicaria* (bladder saltbush), *Chenopodium curvispicatum*, *Enchylaena tomentosa* (ruby saltbush) and *Maireana georgei* (golden bluebush) and subshrubs *Eriochiton sclerolaenoides* (woolly bindii), *Maireana tomentosa* (felty bluebush), *M. trichoptera* (pink-seeded bluebush) and *S. diacantha* (grey bindii) may be reduced through heavy grazing pressure. In areas of poor condition palatable subshrubs are replaced by *Atriplex acutibractea* (toothed saltbush), *Sclerolaena densiflora* (hairy bindii), *S. obliquicuspis* (limestone bindii), *S. patenticuspis* (spear-fruit copperburr) and annuals such as *Carrichtera annua* (Ward's weed), *Rhodanthe floribunda, Salsola tragus* (roly poly) and *Zygophyllum iodocarpum.*

Within myall mixed chenopod woodland tree-based clumps exist as groves around trees such as *Alectryon oleifolius* (mingah bush, bullock bush), *Eremophila longifolia* (berrigan), *Myoporum platycarpum* (sugarwood), *Santalum acuminatum* (quandong) and *S. spicatum* (sandalwood) as well as myall. Browsing pressure is commonly indicated by the condition of these groves and the clump understorey. Browse lines indicate moderate grazing but broken limbs and absent canopies indicate heavy grazing at an unsustainable level. Improving range condition is indicated by the development of dense clumps of palatable shrubs under trees and seedlings or suckers from the palatable trees.

Gradational associations

MXCS commonly grades into *Plain mixed chenopod shrubland* (PXCS) or *Nitraria mixed chenopod shrubland* (NXCS) as the myall tree stratum disappears. As the presence of *Myoporum platycarpum* becomes denser through the tall shrub stratum MXCS commonly grades into *Myall, sugarwood mixed chenopod woodland* (MSCW) or *Sugarwood mixed chenopod shrubland or woodland* (SWCS) where it replaces myall in the tree stratum. In the north-west MXCS grades into *Casuarina mixed chenopod shrubland or woodland* (CXCS) or *Mulga mixed shrub woodland* (MUXW) as casuarina or mulga begins to dominate the tree stratum.

As the low to mid shrub stratum becomes dominated by one species MXCS grades into *Myall, false bluebush shrubland or woodland* (MFBW) or *Myall, pearl bluebush shrubland* (MPBW). As the diversity of chenopod species decreases in the understorey becoming replaced by non-chenopod species MXCS grades into *Myall mixed shrubland or woodland* (MXSS). As the salinity of the soil increases and samphires become more frequent MXCS grades into *Myall mixed halophyte shrubland* (MHXS).

In the north-west MXCS grades into *Acacia mixed shrubland* (ACMS) where aeolian sand patches thinly cover the calcrete plain of the Nyanga land system.

Land systems

MXCS is a dominant habitat type on Mundrabilla and Nyanga land systems, a major habitat type on Thampanna and Virginia land systems and a minor habitat type on Koonjarra and Pondana land systems.

4. Myall saltbush shrubland or woodland (MSAS)

Sampling

5 inventory sites, 176 traverse points

General information

MSAS occurs in the south-east of the survey area on low rises (limestone hummocks) with very gently inclined slopes of up to 2 per cent

and on stony plains. The mantle can have a sparse to moderate covering (2–50 per cent) of limestone fragments with some limestone outcrop (< 10 per cent). Soils are shallow calcareous loams and loamy earths. This vegetation association is also found in the north, though here it is restricted to the Nyanga land system where MSAS occurs on calcrete plains overlain by calcareous loams of varying depth.

Physiognomy and composition of vegetation

MSAS occurs as a scattered (10–20 per cent PFC) low woodland or shrubland. *Acacia papyrocarpa* (myall) dominates the tree stratum and *Atriplex vesicaria* (bladder saltbush) the low shrub stratum. Juvenile *Myoporum platycarpum* (sugarwood), to a height of 3 m, commonly dominate the tall shrub stratum, and *Atriplex nummularia* (old man saltbush) the mid shrub stratum.

23 perennial species were recorded at the five inventory sites, with an average of 10 species per site, one less than the survey average. Eight annual species were recorded with an average of four species per site.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—*Acacia papyrocarpa* Other—*Alectryon oleifolius.*
Tall shrubs:	Dominant—*Myoporum platycarpum* Common—Nil.
Mid shrubs:	Dominant—*Atriplex nummularia* Other—*Eremophila scoparia.*
Low shrubs:	Dominant—*Atriplex vesicaria* (KD) Common—*Chenopodium curvispicatum*, *Enchylaena tomentosa*, *Maireana sedifolia* Others—*Lycium australe*, *Maireana erioclada*, *M. pentatropis*, *Solanum nummularium*, *Zygophyllum aurantiacum.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex acutibractea*, *Eriochiton sclerolaenoides*, *Sclerolaena diacantha* Others—*Maireana trichoptera*, *Sclerolaena obliquicuspis*, *Sida spodochroma.*
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrostipa scabra* Others—*Austrodanthonia caespitosa*, *Enneapogon cylindricus.*

Annual species recorded include *Erodium aureum, Euphorbia drummondii, Lepidium* sp.*, Nicotiana goodspeedii, Rhodanthe floribunda, Salsola tragus, Vittadinia* sp. and *Zygophyllum iodocarpum.*

Ecological disturbance

The density of *Atriplex vesicaria* (bladder saltbush) populations is generally a reliable indicator of range condition. Areas of MSAS with sparse stands of bladder saltbush should be considered as in poor condition. *Atriplex vesicaria* responds to moisture stress by shedding its leaves, but vegetatively responds quickly to rainfall. During this recovery phase it needs protection from grazing to regain vigour and set seed. *Acacia papyrocarpa* (myall) is long-lived with mature trees providing a slightly palatable source of browse. Studies have shown juvenile myall do not survive grazing (Mitchell & Wilcox 1994). However, many juvenile myall were found within this habitat type in the north of the survey area in zones of stock disturbance near water points, formerly used by sheep but now stocked with cattle. In these areas it is possible the destocking of sheep and reduction in rabbit numbers, due to rabbit calicivirus, has allowed *Acacia papyrocarpa* to regenerate prolifically.

Gradational associations

In the south-east MSAS is commonly found on limestone hummocks (low rises) grading downslope into loamy or saline depressions supporting *Bladder saltbush shrubland* (BSSL) or *Plain mixed halophyte shrubland* (PXHS). As eucalypts start to dominate the overstorey MSAS grades into *Eucalypt saltbush shrubland or woodland* (ESAW). In the north in the Nyanga land system MSAS commonly grades into *Bladder saltbush shrubland* (BSSL).

Land systems

MSAS is a major habitat type on Chowilla, Nyanga and Thampanna land systems.

5. Myall, pearl bluebush shrubland (MPBS)

Sampling

6 inventory sites, 155 traverse points

General information

MPBS is commonly found on stony limestone plains with 10–50 per cent of the surface covered by coarse limestone fragments of mixed size. MPBS occurs predominantly in two areas: in the southern portion of the Chowilla and Shakehole land systems merging into the north of the Thampanna land system; and on the Recrystallised Limestone plains of the Kanandah land system and the adjacent Seemore land system which border the Nullarbor Plain in the north-west. The vegetation association is also found in the west and north of the survey area on calcrete plains overlain by calcareous loams within the Nyanga land zone or on adjacent systems on elongated low limestone ridges. Soils are shallow calcareous loams and loamy earths.

Physiognomy and composition of vegetation

MPBS consists of a scattered to moderately closed (10–30 per cent PFC) low to mid shrubland of *Maireana sedifolia* (pearl bluebush). The overstorey is dominated by isolated to very scattered (2.5–10 per cent PFC) *Acacia papyrocarpa* (myall).

34 perennial species were recorded at the six inventory sites, with an average of 13 species per sites, two more than the survey average. 13 annual species were recorded with an average of 6 per site.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—*Acacia papyrocarpa* Others—*Acacia aneura*, *Alectryon oleifolius*, *Myoporum platycarpum*, *Pittosporum angustifolium*, *Santalum acuminatum.*
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex nummularia*, *Senna artemisioides* subsp. x *coriacea* (KI) Others—*Acacia burkittii*, *A. oswaldii*, *Eremophila scoparia*, *Pimelea microcephala.*
Low shrubs:	Dominant—*Maireana sedifolia* Common—*Atriplex vesicaria* (KD), *Chenopodium curvispicatum* (KD), *Lycium australe*, *Solanum lasiophyllum*, *S. nummularium* Others—*Enchylaena tomentosa* (KD), *Eremophila pustulata*, *Lawrencia squamata*, *Ptilotus obovatus*, *Zygophyllum aurantiacum*.
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Maireana trichoptera*, *Sclerolaena diacantha*, *S. obliquicuspis* Others—*Eriochiton sclerolaenoides*, *Erodium aureum*.
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrostipa scabra*, *Enneapogon cylindricus* Others—*Austrodanthonia caespitosa*, *Enneapogon caerulescens*.
Other plant forms:	Occasional—*Amyema quandang* var. *quandang* (mistletoe), *Lysiana* sp. (mistletoe).

Annual species recorded include *Asphodelus fistulosus*, *Brachyscome* sp., *Calandrinia* sp., *Calotis hispidula*, *Carrichtera annua* (KI)*, Euphorbia drummondii*, *Lepidium* sp., *Podolepis canescens*, *Ptilotus exaltatus*, *Rhodanthe floribunda*, *Salsola tragus*, *Sonchus* sp. and *Vittadinia humerata.*

Ecological disturbance

Maireana sedifolia leaves contain up to 10 per cent salt (Mitchell & Wilcox 1994) and may be eaten by stock particularly if fresh water is available. Pastoralists report stock eating only the tips of the plants, particularly when new growth occurs. Pearl bluebush is not a sensitive indicator of range condition on the Nullarbor.

Myall, pearl bluebush shrubland in good condition will support dense clumps of palatable shrubs, such as *Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush). Grazing pressure can be estimated by the structure of bush clumps under trees, the presence of the browse lines and the condition of the tree canopy.

Whilst pearl bluebush can regenerate from low to moderate intensity burns *Acacia papyrocarpa* (myall) and *Atriplex vesicaria* (bladder saltbush)

are fire sensitive (Mitchell, McCarthy & Hacker 1979). However all three species will be removed by frequent fires. Large areas where they have been lost through the combined effects of frequent fires and/or grazing by rabbits and domestic stock are considered to be in poor condition. These areas now support the vegetation association *Myall bindii grassland* (MBIG).

Gradational associations

In the south of the survey area the limestone plains undulate with MPBS on low rises (limestone hummocks) and low ridges grading into *Pearl bluebush low shrubland* (PBLS) on marginal slopes or into *Bladder saltbush shrubland* (BSSL) in the loamy or clay depressions. As soil salinity increases and samphires become common MPBS grades into *Myall mixed halophyte shrubland* (MHXS). In the north as other chenopod species become increasingly common within the understorey MPBS grades into *Myall mixed chenopod shrubland or woodland* (MXCS).

Land systems

MPBS is the dominant habitat type on Kanandah land system and a major type on Chowilla, Nyanga, Seemore, Thampanna and Vanesk land systems and a minor habitat type on Colville, Arubiddy, Jubilee, Kybo and Shakehole land systems.

6. Myall mixed halophyte shrubland (MHXS)

Sampling

3 inventory sites, 38 traverse points

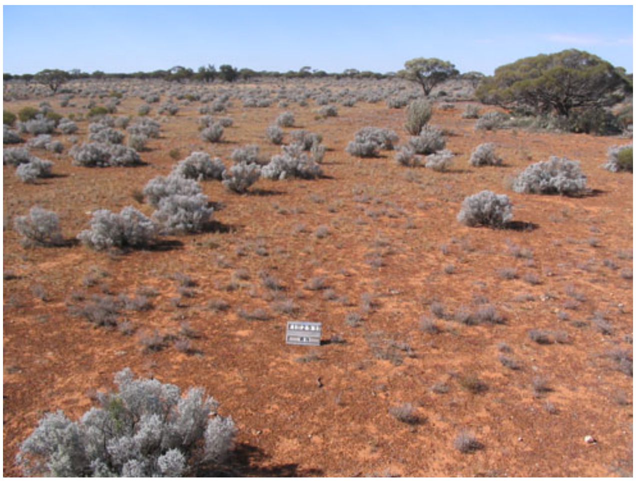
General information

MHXS is predominantly found on the stony limestone plains in the south of the survey area. It commonly has a sparse to common (2–20 per cent) mantle of medium-sized (6–20 mm) limestone fragments. Soils are saline calcareous loamy earths. It occasionally occurs on the calcrete plain of the Nyanga land system on Koonjarra and Virginia pastoral leases.

Physiognomy and composition of vegetation

MHXS consists of a scattered low shrubland (10–20 per cent PFC) of *Atriplex vesicaria* (bladder saltbush) and *Maireana sedifolia* (pearl bluebush). The tree stratum is composed of very scattered (2.5–5 per cent PFC) *Acacia papyrocarpa* (myall). *Myoporum platycarpum* (sugarwood) occasionally dominates these habitats as a tall shrub. The characteristic feature is the presence of *Tecticornia* sp. (samphire) in the lower stratum.

20 perennial species were recorded at the three inventory sites, with an average of 10 per site, one less than the survey average. Three annual species were recorded.



*Scattered myall trees (*Acacia papyrocarpa*) surrounded by pearl bluebush (*Maireana sedifolia*) shrubland. This vegetation community is considered to represent a stable state.*

*Myall trees (*Acacia papyrocarpa*) surrounded by bindii grassland (MBIG). This is considered to be in an irreversible transition from a Myall pearl bluebush shrubland (MPBS).*

The following species (by strata) are dominant and or common:

Trees:	Dominant—*Acacia papyrocarpa* Common—Nil.
Tall shrubs:	Dominant—Occasionally *Myoporum platycarpum* Common—Nil.
Mid shrubs:	Dominant—*Atriplex nummularia* Other—*Nitraria billardierei.*
Low shrubs:	Dominant—*Atriplex vesicaria* (KD), *Maireana sedifolia*, *Tecticornia* sp. Common—*Enchylaena tomentosa*, *Solanum nummularium* Others—*Gunniopsis calcarea*, *Maireana pentatropis*, *M. turbinata*, *Olearia muelleri.*
Subshrubs:	Dominant—Not present as a recognisable stratum Others—*Eriochiton sclerolaenoides*, *Maireana trichoptera*, *Sclerolaena brevifolia*, *S. diacantha* (KD), *S. obliquicuspis* (KI).
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrostipa scabra* Other—*Austrostipa platychaeta* (KD).

Annual species recorded include *Euphorbia drummondii, Nicotiana occidentalis* and *Salsola tragus.*

Ecological disturbance

Species of *Tecticornia* (samphire) are only valuable as forage where fresh water is available, as they may contain up to 24 per cent salt. As fresh water is often uncommon samphire has no indicator value for Nullarbor rangeland condition. *Atriplex vesicaria* (bladder saltbush) is a more reliable indicator. Where *Atriplex vesicaria* populations show a declining abundance rangeland condition is considered to be deteriorating. The higher salt content of feed in the lower stratum may place increased pressure on *Acacia papyrocarpa*. The development of prominent browse lines and trampling of bush clumps also indicates increased grazing pressure.

Gradational associations

As soil salinity decreases and samphires become less frequent, MHXS grades into *Myall mixed chenopod shrubland or woodland* (MXCS) or *Myall pearl bluebush shrubland* (MPBS). Where stony limestone plains grade into saline plains or depressions the taller stratum disappears and MHXS grades into *Plain mixed halophyte shrubland* (PXHS).

Land systems

MXHS is a minor habitat type on Nyanga, Vanesk and Virginia land systems.

7. Myall mixed shrub shrubland (MXSS)

Sampling

1 inventory site, 45 traverse points

General information

MXSS is predominantly found on stony limestone plains commonly with a moderate covering (20–50 per cent) of limestone fragments. MXSS is also located in the north-west of the survey area.

Physiognomy and composition of vegetation

MXSS consists of a moderately closed (20–25 per cent PFC) mid shrubland of variable composition. *Atriplex nummularia* (old man saltbush), *Eremophila scoparia* (broom bush) and *Senna artemisioides* subsp. x *coriacea* (desert cassia) are commonly present within the mid shrub layer. The tree stratum is dominated by very scattered (5–10 per cent PFC) *Acacia papyrocarpa* (myall).

20 perennial species and two annual species were recorded at the one inventory site.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—*Acacia papyrocarpa* Common—*Myoporum platycarpum*.
Tall shrubs:	Dominant—Not present as a recognisable stratum Others—*Acacia oswaldii*, *A. tetragonophylla*, *Senna cardiosperma* (KI).
Mid shrubs:	Dominant—Variable; commonly *Eremophila scoparia* (KI) Common—*Atriplex nummularia*, *Senna artemisioides* subsp. x *coriacea* (KI) Others—*Acacia ancistrophylla* var. *ancistrophylla*, *Eremophila* sp.

Low shrubs:	Dominant—Not present as a recognisable stratum Common—*Chenopodium curvispicatum* (KD), *Enchylaena tomentosa* (KD), *Maireana sedifolia* Other—*Ptilotus obovatus*.
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex acutibractea*, *Eriochiton sclerolaenoides*, *Maireana trichoptera* Others—*Sclerolaena diacantha*, *Sida spodochroma*.
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Enneapogon caerulescens*.

Annual species recorded include *Lepidium* sp. and *Salsola tragus.*

Ecological disturbance

This habitat type was not sampled sufficiently for detailed analysis of patterns of disturbance. However, patterns of disturbance for *Myall mixed chenopod shrubland or woodland* (MXCS) are considered relevant to MXSS. It is likely this vegetation association previously comprised an understorey with a diversity of palatable species now greatly reduced through grazing pressure. This has resulted in unpalatable genera such as eremophila and senna becoming dominant. Sennas are long-lived and difficult to control by grazing or destocking paddocks alone. *Eremophila scoparia* may be grazed when young but once mature it is generally unpalatable. These plants increase in areas of disturbance particularly when competition from palatable lower shrubs has been reduced.

As with *Myall mixed chenopod shrubland or woodland* (MXCS) and *Myall pearl bluebush shrubland* (MPBS), grazing impact may best be judged by the abundance and diversity of palatable low shrubs under the myall overstorey. Palatable shrubs found in MXSS include decreasers such as *Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush) as well as species that respond as much to recent seasonal conditions as to grazing history: *Maireana trichoptera* (pink-seeded bluebush), *Ptilotus obovatus* (cotton bush), *Sclerolaena diacantha* (grey bindii) and *Sida spodochroma* (prostrate sida).

Gradational association

As the diversity of chenopod species increases in the understorey MXSS grades into *Myall mixed chenopod shrubland or woodland* (MXCS).

Land systems

MXSS is a major habitat type on Kanandah land system and a minor habitat type on Kinclaven and Nyanga land systems.

8. Myall bindii grassland (MBIG)

Sampling

2 inventory sites, 44 traverse points

General information

MBIG predominantly occurs on stony Recrystallised Limestone in the north-west or calcrete plains in the north of the survey area. Soils are calcareous shallow loams and loamy earths, with coarse limestone or calcrete fragments covering 20–50 per cent of the surface. MBIG is considered to be a degraded vegetation association. The original understorey is likely to have been reduced by frequent fires and overgrazing, primarily by rabbits. It is unlikely the lower shrub layer will support shrubs in any great density, since the dominance of grasses renders the area susceptible to fire. Stands of juvenile myall were observed between and recorded at several traverse points. This could be because of fewer rabbit numbers due to the calicivirus.

Physiognomy and composition of vegetation

MBIG occurs as a very scattered (2.5–10 per cent PFC) low woodland of *Acacia papyrocarpa* (myall). *Myoporum platycarpum* (sugarwood) can be common to absent; groves of *Alectryon oleifolius* (mingah or bullock bush) and *Eremophila longifolia* (berrigan) occur infrequently. The low shrub stratum is commonly dominated by *Maireana trichoptera* (felty bluebush), *Sclerolaena obliquicuspis* (limestone bindii) and the annuals *Carrichtera annua* (Ward's weed) and *Salsola tragus* (roly poly). The mid and tall shrub strata are often poorly developed.

25 perennial species were recorded at the two inventory sites, with an average of 16 per site, five more than the survey average. Six annual species were recorded.

The following species (by stratum) are dominant and or common:

Trees:	Dominant—*Acacia papyrocarpa* Common—*Alectryon oleifolius*, *Eremophila longifolia* Others—*Acacia aneura* (Colville land system), *Myoporum platycarpum.*
Tall shrubs:	Dominant—Not present as a recognisable stratum Common—*Acacia oswaldii.*
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex nummularia*, *Eremophila scoparia* (KI), Senna artemisioides subsp. x *artemisioides* (KI), *S. artemisioides* subsp. x *coriacea* (KI) Other—*Cratystylis conocephala.*
Low shrubs:	Dominant—Not present as a recognisable stratum Common—*Maireana sedifolia*, *Enchylaena tomentosa* (KD), *Ptilotus obovatus* Other—*Chenopodium curvispicatum* (KD).
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex acutibractea* (KI), *Dissocarpus paradoxus* (KI), *Maireana trichoptera*, *Sclerolaena diacantha* (KD), *S. obliquicuspis* (KI), *S. patenticuspis* (KI), *Sida spodochroma*, *Solanum ellipticum*.
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrostipa scabra*, *Enneapogon caerulescens.*

Common annual species include *Carrichtera annua, Erodium aureum* (KI)*, Euphorbia drummondii, Salsola tragus, Salvia verbenaca* (KI) and *Zygophyllum iodocarpum* (KI).

Ecological disturbance

It is likely an abundance of rabbits and/or heavy grazing pressure from stock during post-fire recovery periods has contributed to the removal of the original understorey of this vegetation association. In the Carlisle, Colville and Kyarra land systems active rabbit warrens are still common. MBIG is commonly found on marginal slopes to drainage areas, such as dongas, and receives considerable use resulting in regular padding and disturbed soil crust. Dry seasonal conditions exacerbate the deterioration as the non-perennial vegetation dies off exposing the soil surface to wind erosion. These factors have reduced the potential for this habitat type to support perennial shrubs in any abundance other than weakly perennial herbs and grasses.

The sparseness of perennial vegetation increases demand on palatable species present. The infrequent groves of *Alectryon oleifolius* (mingah/bullock bush) and *Eremophila longifolia* (berrigan) provide a sought after protein source. Excessive total grazing pressure will kill individuals as plant vigour is eventually reduced to below the point of recovery. The loss of such perennials further reduces the landscape's ability to support herbivores during dry periods.

*Bindii grassland surrounds a berrigan grove (*Eremophila longifolia*) that has been heavily browsed by cattle and camels. Without a reduction in total grazing pressure plant vigour will continue to decline. Groves in this state indicate excessive grazing pressure and deteriorating range condition.*

Gradational association

MBIG commonly grades into *Open bindii grassland* (OBIG) as the Recrystallised Limestone or calcrete of the Nyanga land zone supporting the myall component gives way to the underlying Nullarbor Limestone.

Land systems

MBIG is a major habitat type on Carlisle, Colville, Kanandah and Kyarra land systems and a minor habitat type on Jubilee and Kinclaven land systems.

9. Myall, speargrass open grassland (MSOG)

Sampling

2 inventory sites, 7 traverse points

General information

MSOG predominantly occurs on stony Recrystallised Limestone and calcrete plains in the north of the survey area. MSOG can also infrequently occur wherever populations of myall are present. It commonly has a mantle of coarse (2–6 cm) limestone fragments covering 20–50 per cent of the surface. Soils are calcareous loamy earths. This vegetation association is considered degraded, with the original understorey removed by frequent fires and heavy grazing, particularly by rabbits.

Physiognomy and composition of vegetation

MSOG occurs as dense grassland of *Austrostipa scabra* (speargrass) in good seasonal conditions. In poor seasons only the basal portion of grass butts remains. The tree stratum consists of isolated (0–2.5 per cent PFC) *Acacia papyrocarpa* (myall). All other strata are poorly developed or absent.

17 perennial species were recorded at the two inventory sites, with an average of 12 per site, one greater than the survey average. Seven annual species were recorded.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—*Acacia papyrocarpa* Other—*Myoporum platycarpum*.
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Cratystylis conocephala*, *Nitraria billardierei*.
Low shrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex vesicaria* (KD), *Enchylaena tomentosa*, *Maireana erioclada*, *M. sedifolia* Other—*Lawrencia squamata*.
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex acutibractea*, *Eriochiton*

*This vegetation community of scattered myall trees (*Acacia papyrocarpa*) surrounded by pearl bluebush (*Maireana sedifolia*) shrubland is considered to represent a stable state. Disturbance mechanisms can irreversibly alter this state into Myall speargrass open grassland (MSOG).*

*Sparse myall trees (*Acacia papyrocarpa*) surrounded by grassland. Note at the front right the absence of a burnt stump in the centre of the dead tree; future fires will remove any remaining dead wood promoting the appearance of a grassland. The increase in grass continues to make the area more susceptible to fire.*

	sclerolaenoides, *Maireana tomentosa*, *M. trichoptera*, *Sclerolaena diacantha* (KD), *S. obliquicuspis*.
Perennial grasses:	Dominant—*Austrostipa scabra* Common—*Austrodanthonia caespitosa*.

Annual species recorded include *Brachyscome ciliaris, Carrichtera annua* (KI)*, Euphorbia drummondii, Nicotiana* sp., *Salsola tragus, Senecio spanomerus* and *Zygophyllum ovatum.*

Ecological disturbance

Austrostipa scabra (speargrass) is highly responsive to good seasonal conditions. It is readily eaten when young and green but is not palatable once it has dried off. In dry seasons areas supporting such vegetation communities are susceptible to wind erosion. The lack of a mid or low shrub layer to offer protection further reduces an already declining soil crust. Less than 50 per cent soil crusting was recorded at inventory sites supporting MSOG.

The abundance of speargrass makes this habitat type especially prone to fire. The isolated occurrence of myall also alludes to its sensitivity to fire. Trees killed by earlier fires, rabbit ring-barking or old age are erased from the landscape by fires which burn all evidence that these areas once supported woodland. Stages of this process can be seen throughout the woodlands bordering the Nullarbor Plain. (Photos in the Resource Management chapter show examples of this process.)

Gradational associations

MSOG is commonly found on low rises of Recrystallised Limestone grading down onto Nullarbor Limestone into S*peargrass and wallaby grass open grassland* (SWOG). This gradational association shows the effects of an increased fire frequency in preventing the regrowth of shrubs. As the grasses come to dominate they further increase the susceptibility of the area to future fire.

Land systems

MSOG is a minor habitat type on Chowilla, Kanandah, Kitchener, Kyarra, Shakehole, Thampanna and Virginia land systems.

B. EUCALYPT SHRUBLAND AND WOODLAND ON CALCAREOUS PLAINS

This group consists of habitat types with a variable overstorey of eucalypt species found on calcareous plains. In the west and south-west of the survey area the eucalypts predominantly occur on calcrete plains, whilst in the south-east they are commonly found on limestone hummocks (low rises) within the limestone plains and the Roe Plains. The tree stratum typically contains various species of mallee-form eucalypts. Single-stemmed tree forms are also common, particularly in the Gumbelt land system.

10. Eucalypt, sugarwood mixed chenopod woodland (ESCW)

Sampling

3 inventory sites, 50 traverse points

General information

ESCW is predominantly located on calcrete plains overlain by calcareous loam in the west of the survey area. Medium to coarse (6–60 mm) limestone fragments and calcrete nodules cover up to 30 per cent of the surface. Soils are calcareous shallow loams and loamy earths.

Physiognomy and composition of vegetation

ESCW occurs as a scattered to moderately closed (10–25 per cent PFC) woodland. The tree stratum is composed of mallee-form *Eucalyptus gracilis* (yorrell), *E. oleosa* (giant mallee) and *Myoporum platycarpum* (sugarwood). *Myoporum platycarpum* also dominates the tall shrub stratum. *Cratystylis conocephala* (false bluebush) is common throughout the mid to low shrub stratum.

25 perennial species were recorded at the three inventory sites, with an average of 15 species per site, four greater than the survey average. Three annual species were recorded.

The following species (by strata) were recorded as dominant and/or common:

Trees:	Dominant—*Eucalyptus gracilis* (mallee) Common—*Eucalyptus oleosa*, *Myoporum platycarpum* Other—*Acacia papyrocarpa*.

Tall shrubs:	Dominant—*Myoporum platycarpum* Others—*Acacia oswaldii*, *Eremophila dempsteri*, *Geijera linearifolia*.
Mid shrubs:	Dominant—*Cratystylis conocephala* Common—*Atriplex nummularia*, *Eremophila scoparia* (KI) Other—*Nitraria billardierei*.
Low shrubs:	Dominant—*Atriplex vesicaria* (KD), *Cratystylis conocephala* Common—*Enchylaena tomentosa* (KD), *Maireana erioclada*, *M. radiata*, *M. sedifolia*, *Olearia calcarea*, *Rhagodia crassifolia* Others—*Lycium australe*, *Maireana turbinata*, *Ptilotus symonii*, *Solanum nummularium*.
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Sclerolaena diacantha* (KD).
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrostipa platychaeta* (KD).

Annual species recorded include *Carrichtera annua* (KI), *Salsola tragus* and *Zygophyllum glaucum.*

Ecological disturbance

This is a minor site type and was not sampled for grazing impacts. It is likely that under heavy grazing palatable species will be reduced, particularly *Atriplex vesicaria* (bladder saltbush), *Enchylaena tomentosa* (ruby saltbush) and *Austrostipa platychaeta*. ESCW appears to be largely unaffected by grazing due to the low palatability of many of the shrubs. However, rabbits may have a significant impact on seedling recruitment and therefore floristic diversity influencing the present day species composition. This habitat type typically does not support grasses in great abundance.

Gradational associations

ESCW commonly grades into *Eucalypt mixed chenopod shrubland or woodland* (EXCS) or *Sugarwood chenopod shrubland or woodland* (SWCS).

Land systems

ESCW is a major habitat type on Caiguna and Gumbelt land systems.

11. Eucalypt mixed chenopod woodland (EXCW)

Sampling

5 inventory sites, 305 traverse points

General information

EXCW occurs in the west of the survey area on calcrete plains overlain by calcareous loam of varying depth. Fine to medium calcareous fragments and nodules (2–20 mm) are common. Soils are calcareous loamy earths. It also occasionally occurs on calcrete plains overlain by aeolian sand.

Physiognomy and composition of vegetation

EXCW occurs as a scattered to moderately closed (15–25 per cent PFC) woodland. When located on calcrete plains overlain with loam the tree stratum is dominated by *Eucalyptus gracilis* (yorrell) and *E. oleosa* subsp. *oleosa* (giant mallee). When the surface has a shallow aeolian sand cover *Eucalyptus salubris* (gimlet) is common. The low and mid shrub stratum is dominated by *Atriplex vesicaria* (bladder saltbush) and *Cratystylis conocephala* (false bluebush).

42 perennial species were recorded at the five inventory sites, with an average of 17 species per site, six greater than the survey average. Five annual species were recorded, with an average of two species per site.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—*Eucalyptus gracilis*, *E. oleosa* subsp. *oleosa* (mallee) Common—*Alectryon oleifolius*, *Casuarina pauper*, *Eucalyptus melanoxylon*, *E. salubris*, *Myoporum platycarpum* Other—*Acacia papyrocarpa*.
Tall shrubs:	Dominant—Not present as a recognisable stratum Common—*Geijera linearifolia* Others—*Acacia densiflora* (KI), *A. hemiteles* (KI), *Eremophila dempsteri*, *Senna cardiosperma* (KI), *Exocarpos aphyllus*.
Mid shrubs:	Dominant—*Cratystylis conocephala* Common—*Atriplex nummularia*, *Eremophila decipiens* (KI), *E. scoparia* (KI), *Pimelea microcephala*, *Scaevola*

	spinescens, *Senna artemisioides* subsp. x *coriacea* (KI) Other—*Eremophila glabra*.
Low shrubs:	Dominant—*Atriplex vesicaria* (KD), *Maireana sedifolia* Common—*Eremophila pustulata*, *Frankenia* sp., *Maireana erioclada*, *Olearia calcarea*, *Ptilotus obovatus*, *Rhagodia crassifolia*, *Solanum nummularium*, *Zygophyllum aurantiacum* Others—*Enchylaena tomentosa*, *Maireana radiata*, *Olearia muelleri*, *Westringia rigida*.
Subshrubs:	Dominant—Not recognisable as a dominant stratum Common—*Eriochiton sclerolaenoides*, *Maireana trichoptera*, *Sclerolaena diacantha* (KD) Others—*Sclerolaena obliquicuspis*, *Zygophyllum apiculatum*.
Perennial grasses:	Dominant—Not recognisable as a dominant stratum Other—*Austrostipa platychaeta* (KD).

Annual species recorded include *Nicotiana* sp., *Ptilotus exaltatus, Salsola tragus, Zygophyllum compressum* and *Z. eremaeum.*

Ecological disturbance

The composition of the understorey is the most reliable indicator of grazing impacts. *Austrostipa platychaeta* is sensitive to grazing pressure and may indicate good resource condition when plentiful. In good condition a mix and density of palatable low shrub species would be expected in the open and under trees and tall shrubs. An indication of grazing pressure is a reduction in floristic diversity, firstly in the open areas and then later in the more protected areas under trees and tall shrubs [See tree-based clump condition monitoring photographic guide in the Resource Management chapter.] In poor condition increaser species belonging to the genera Eremophila, Senna and Acacia become abundant.

EXCW appears to be less susceptible to fire than similar eucalypt shrubland or woodland where *Austrostipa scabra* (speargrass) is common through the lower strata. EXCW tends to be more at threat from fire where it borders or is surrounded by grass-dominated habitat types. This can be observed along the northern boundary of the Caiguna land system where it borders the Nightshade land system.

Eucalyptus fraseri subsp. *melanobasis* is a Priority 2 species on the declared rare and priority flora list, and was recorded in this habitat type.

Gradational associations

EXCW grades into *Eucalypt, sugarwood mixed chenopod woodland* (ESCW) or *Sugarwood mixed chenopod shrubland* (SWCS) as *Myoporum platycarpum* increases in the tall shrub and/or tree stratum. Where *Myoporum platycarpum* and *Acacia papyrocarpa* replace eucalypts as the dominant species EXCW grades into *Myall, sugarwood mixed chenopod woodland* (MSCW).

EXCW grades into *Eucalypt mixed halophytic shrubland* (EXHS) where the topsoil becomes more saline. In the west of the survey area EXCW commonly grades into *Eucalypt mixed scrub woodland* (EXSW) forming a woodland mosaic of variable understorey alternating in dominance between chenopod and mixed shrubs. Where the soil becomes sandier EXCW grades into *Mallee hummock grass (spinifex) woodland* (MHGW).

In the Mardabilla land zone where granite outcrop occurs through the calcareous plains EXCW merges into *Dodonaea, eremophila mixed shrubland* (DEXS) or abuts *Granite outcrop shrubland* (GROS).

As the woodland becomes more scattered and open, EXCW commonly grades into *Plain mixed chenopod shrubland* (PXCS).

Land systems

EXCW is the dominant habitat type on Gumbelt land system and a major habitat type on Caiguna and Thampanna land systems.

12. Eucalypt saltbush shrubland or woodland (ESAW)

Sampling

4 inventory sites, 71 traverse points

General information

ESAW predominantly occurs on low rises (limestone hummocks) which are gently inclined with up to 6 per cent slope and stony

limestone plains in the south-east of the survey area. ESAW has a mantle composed of fine to coarse (2–60 mm) limestone fragments covering up to 50 per cent of the surface, with limestone outcrop occurring in up to 50 per cent of habitats. Soils are calcareous loamy earths. This vegetation unit commonly borders the Hampton Scarp.

Physiognomy and composition of vegetation

ESAW occurs as a scattered to moderately closed (10–30 per cent PFC) woodland. The tree stratum is dominated by variable eucalyptus species, though commonly contains *Eucalyptus gracilis* (yorrell) and/or *Eucalyptus yalatensis* (yalata mallee). *Atriplex nummularia* (old man saltbush) is commonly present within the mid shrub stratum and the lower shrub stratum is dominated by *Atriplex vesicaria* (bladder saltbush).

35 perennial species were recorded at the four inventory sites, with an average of 13 species per site, two greater than the survey average. Three annual species were recorded.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—variable; *Eucalyptus diversifolia*, *E. gracilis*, *E. oleosa* subsp. *ampliata*, *E. yalatensis* Others—*Eucalyptus urna*, *Myoporum platycarpum.*
Tall shrubs:	Dominant—Not present as a recognisable stratum Common—*Acacia oswaldii* Others—*Eremophila dempsteri* (KI), *Psydrax suaveolens* (KD).
Mid shrubs:	Dominant—*Atriplex nummularia* Others—*Cratystylis conocephala*, *Scaevola spinescens*, *Senna artemisioides* subsp. x *coriacea* (KI).
Low shrubs:	Dominant—*Atriplex vesicaria* (KD) Common—*Enchylaena tomentosa* (KD), *Maireana pentatropis*, *M. sedifolia*, *Olearia muelleri* Others—*Chenopodium curvispicatum* (KD), *Eremophila oblonga*, *Lawrencia squamata*, *Maireana erioclada*, *Ptilotus obovatus*, *Zygophyllum aurantiacum.*
Subshrubs:	Dominant—Not recognisable as a dominant stratum Common—*Maireana tomentosa* (KD) Others—*Atriplex acutibractea* (KI), *Sclerolaena diacantha* (KD), *S. obliquicuspis*, *Zygophyllum apiculatum.*
Perennial grasses:	Dominant—Not recognisable as a dominant stratum Common—*Austrostipa scabra* Others—*Austrostipa acrociliata*, *A. elegantissima* (KD), *A. platychaeta* (KD).
Other plant forms:	Occasional—*Dianella revoluta* (lily), *Marsdenia australis* (creeper).

Annual species recorded include *Carrichtera annua* (KI), *Euphorbia drummondii* and *Nicotiana goodspeedii*.

Ecological disturbance

The close gradational association to chenopod shrubland in lower-lying areas results in limestone hummocks that support ESAW receiving increased utilisation from herbivores. The trees on these limestone rises provide shelter for both animals and other plants. 'Tree-based clumps' develop under trees and have an important role in arid environments in sustaining other plant species by improving conditions, such as retaining soil moisture and providing protection from desiccation by wind and sun. In good condition a mix and density of palatable shrub and perennial grass species, such as *Atriplex vesicaria, Austrostipa elegantissima* (feather speargrass), *A. platychaeta, Chenopodium curvispicatum, Enchylaena tomentosa* (ruby saltbush), *Maireana tomentosa* (felty bluebush), *Ptilotus obovatus* (cotton bush), *Psydrax suaveolens* and *Scaevola spinescens* (currant bush), would be expected to radiate out from under the canopies into the spaces between tree clumps. An indication of decreasing rangeland condition would be a reduction in floristic diversity, first in the open areas and then later in the more protected areas under the trees [See tree-based clump condition monitoring photographic guide in the Resource Management chapter.]

Gradational associations

ESAW grades downslope into *Plain mixed chenopod shrubland* (PXCS) or *Bladder saltbush shrubland* (BSSL) where colluvial-filled depressions lie adjacent to low rises (limestone

hummocks) within limestone plains. Where myall begins to dominate the overstorey ESAW grades into *Myall saltbush shrubland or woodland* (MSAS).

Land systems

ESAW is a dominant habitat type on Thampanna land system and a minor type on Moodini land system.

13. Eucalypt mixed scrub woodland (EXSW)

Sampling

27 inventory sites, 232 traverse points

General information

EXSW is predominantly found on calcrete plains in the western perimeter of the survey area. Up to 90 per cent of the surface mantle of the plain is covered by medium to large (6–60 mm) calcrete nodules; occasionally a layer of sand is present. Soils are commonly calcareous loams or, occasionally, red loams and sandy earths where the surface is overlain by sand. This vegetation association is also present in the south-east of the survey area on limestone hummocks (low rises) with gentle slopes of up to 3 per cent, on residual depositional surfaces, formerly aeolian calcarenite, behind the Hampton scarp face and along the scarp.

Physiognomy and composition of vegetation

EXSW occurs as a scattered to moderately closed (10–25 per cent PFC) woodland or scrubland. The tree stratum is dominated by eucalypts, commonly *Eucalyptus gracilis* (yorrell) and *E. oleosa* subsp. *oleosa* (giant mallee). Other species are also common but their distribution may be restricted such as *Eucalyptus yalatensis* (yalata mallee) in the south on the Hampton Tableland and *E. diversifolia* (soap mallee) on the scarp of the Hampton Range. The composition of shrubs is variable though the tall shrub stratum is commonly dominated by *Melaleuca lanceolata,* the mid shrub stratum by *Atriplex nummularia* (old man saltbush) and the low shrub stratum by *Westringia rigida.*

104 perennial species were recorded at the 27 inventory sites, including two priority species, with an average of 17 species per site, six greater than the survey average. 11 annual species were recorded, with an average of one species per site.

The following species were dominant and/or common:

Trees:	Dominant—*Eucalyptus gracilis*, *E. oleosa*, *E. yalatensis* (mallee) Common—*Eucalyptus diversifolia* (mallee) Others—*Acacia aneura*, *A. papyrocarpa*, *Alectryon oleifolius*, *Casuarina pauper*, *Eucalyptus conglobata* (mallee), *E. discreta* (mallee), *E. fraseri* subsp. *fraseri*, *E. oleosa* subsp. *oleosa* (mallee), *E. melanoxylon*, *E. salubris*, *E. urna*, *Myoporum platycarpum*, *Pittosporum angustifolium*, *Santalum acuminatum*, *S. lanceolatum*.
Tall shrubs:	Dominant—*Melaleuca lanceolata* Common—*Eremophila dempsteri*, *E. scoparia* (KI), *Geijera linearifolia* Others—*Acacia hemiteles* (KI), *A. oswaldii*, *A. tetragonophylla*, *Dodonaea lobulata* (KI), *Eremophila alternifolia*, *E. longifolia*, *Exocarpos aphyllus*, *Melaleuca quadrifaria*, *Senna cardiosperma* (KI), *Templetonia retusa*, *T. sulcata*.
Mid shrubs:	Dominant—*Atriplex nummularia* Common—*Cratystylis conocephala*, *Dodonaea stenozyga*, *E. scoparia* (KI), *Scaevola spinescens*, *Senna artemisioides* subsp. x *coriacea* (KI) Others—*Acacia anceps*, *A. ancistrophylla* var. *ancistrophylla*, *Alyxia buxifolia*, *Nitraria billardierei*, *Acacia nyssophylla*, *Eremophila decipiens* (KI), *E. deserti* (KI), *E. glabra* (KI), *E. ionantha*, *Leptomeria pachyclada*, *Pomaderris myrtilloides*, *Pultenaea heterochila*, *Senna artemisioides* subsp. x *artemisioides* (KI), *Sida calyxhymenia* (KD).
Low shrubs:	Dominant—*Westringia rigida* Common—*Atriplex vesicaria* (KD), *Enchylaena tomentosa* (KD), *Eremophila weldii*,

	Maireana erioclada, *M. sedifolia*, *Olearia calcarea*, *Ptilotus obovatus* (KD), *Rhagodia crassifolia* Others—*Acacia erinacea*, *Chenopodium curvispicatum* (KD), *Dodonaea caespitosa*, *Eremophila oblonga*, *E. parvifolia* (KD), *Gunniopsis calcarea*, *Halgania andromedifolia*, *Lawrencia squamata*, *Lycium australe*, *Maireana pentatropis*, *M. radiata*, *M. turbinata*, *Microcybe multiflora*, *Olearia muelleri*, *Pomaderris myrtilloides*, *Ptilotus obovatus*, *P. symonii*, *Rhagodia ulicina*, *Solanum lasiophyllum*, *S. nummularium*, *Tecticornia* sp., *Zygophyllum aurantiacum* (KD).
Subshrubs:	Dominant—Not recognisable as a dominant stratum Common—*Goodenia affinis*, *Maireana trichoptera*, *Wurmbea tenella*, *Zygophyllum apiculatum* Others—*Atriplex acutibractea* (KI), *Sclerolaena diacantha* (KD), *S. obliquicuspis* (KI), *S. patenticuspis* (KI), *Sida spodochroma*.
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrostipa scabra* Others—*Austrodanthonia caespitosa*, *Austrostipa elegantissima* (KD), *A. platychaeta* (KD), *Eragrostis leptocarpa*, *Triodia scariosa*.
Other plant forms:	Occasional—*Comesperma volubile* (creeper), *Dianella revoluta* (lily).

Annual species recorded include *Carrichtera annua* (KI)*, Euphorbia drummondii, Podolepis canescens, Salsola tragus* (KI)*, Swainsona formosa, Vittadinia nullarborensis, Zygophyllum compressum, Z. eremaeum, Z. glaucum, Z. iodocarpum* (KI) and *Z. ovatum.*

Ecological disturbance

EXSW is largely unaffected by grazing. The most reliable indication of grazing impact is the diversity and density of palatable low and subshrubs which are often most numerous under trees and sparse in the open. Rabbits are likely to have had an impact on seedling regeneration of many of the palatable species.

The increase in abundance of unpalatable species such as *Acacia hemiteles* (tan wattle), *Dodonaea lobulata* (bead hopbush), *Eremophila scoparia* (broom bush), *Senna artemisioides* subsp. x *artemisioides* (silver cassia) and *Senna artemisioides* subsp. x *coriacea* (desert cassia) may be in response to rabbit grazing during post-fire recovery phases.

The susceptibility of EXSW to fire is largely dependent on the development of the grass strata within the habitat type.

Thysanotus baueri a Priority 1 species, on the declared rare and priority flora list, and *Eucalyptus fraseri* subsp. *melanobasis* a Priority 2 species were recorded among this eucalypt woodland habitat type. *Thysanotus baueri* means the area has a high conservation value.

Gradational associations

EXSW occurring in the south-west of the survey borders poorly developed karst depression land units often supporting *Plain mixed chenopod shrubland* (PXCS). In areas where the topsoil becomes more saline EXSW grades into *Eucalypt mixed halophytic shrubland* (EXHS) or sandier *Mallee hummock grass woodland* (MHGW). In the west of the survey area EXSW commonly grades into *Eucalypt mixed chenopod woodland* (EXCW) forming a woodland mosaic of variable understorey alternating in dominance between chenopod and mixed shrubs. Where *Casuarina pauper* begins to replace eucalypts as the dominant tree EXSW may grade into *Casuarina mixed scrub shrubland* (CXSS).

In specific coastal areas *Banksia coastal heath and scrubland* (BCHS) occurs between EXSW and the Baxter Cliffs. On the Roe Plains as the density of Melaleuca species increases EXSW grades into *Eucalypt, melaleuca woodland* (EMEW).

In the Mardabilla land zone where granite outcrop protrudes EXSW merges into *Dodonaea, eremophila mixed shrubland* (DEXS) or abuts *Granite outcrop shrubland* (GROS).

Land systems

EXSW is a dominant habitat type on Zanthus land system and a major habitat type on Caiguna, Gumbelt, Moodini and Thampanna land systems.

14. Eucalypt mixed halophyte shrubland (EXHS)

Sampling

1 inventory site, 17 traverse points

General information

EXHS predominantly occurs in depressions in calcrete plains in the south of the survey area. Soils are commonly calcareous loamy earths with saline subsoils.

Physiognomy and composition of vegetation

EXHS occurs as a very scattered to moderately closed (5–25 per cent PFC) low shrubland of *Tecticornia* species (samphire) and *Atriplex vesicaria* (bladder saltbush). Very scattered (2.5–5 per cent PFC) eucalypts form the tree stratum.

19 perennial species, including two species of *Tecticornia*, and two annual species were recorded at the one inventory site and 17 traverse points.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—*Eucalyptus gracilis* Others—*Eucalyptus oleosa*, *E. oleosa* subsp. *oleosa* (mallee), *Myoporum platycarpum*.
Tall shrubs:	Dominant—Not present as a recognisable stratum Others—*Eremophila dempsteri*, *Myoporum platycarpum*.
Mid shrubs:	Dominant—*Atriplex nummularia* Other—*Cratystylis conocephala*.
Low shrubs:	Dominant—*Atriplex vesicaria* (KD), *Tecticornia doleiformis*, *Tecticornia* sp. Others—*Gunniopsis calcarea*, *Maireana erioclada*, *M. sedifolia*, *Olearia calcarea*.
Subshrubs:	Dominant—Not present as a recognisable stratum Others—*Maireana trichoptera* (KD), *Sclerolaena diacantha* (KD), *S. obliquicuspis*.
Perennial grasses:	Dominant—Not present as a recognisable stratum Others—*Austrostipa platychaeta* (KD), *A. scabra*.

Annual species recorded include *Brachyscome* sp. and *Salsola tragus.*

Ecological disturbance

This is a minor habitat type and was not sampled for grazing impacts. *Tecticornia* species can be of indicator value when stock water is fresh. If fresh water is available the presence of samphire can indicate good to fair condition. Palatable, less-saline shrubs such as *Atriplex vesicaria, Maireana trichoptera* (pink-seeded bluebush) and *Sclerolaena diacantha* (grey bindii) are likely to be reduced under heavy grazing. In such saline locations rabbits may eat juvenile eucalypts and other plants in preference to halophytes.

Gradational associations

EXHS grades into *Eucalypt mixed scrub woodland* (EXSW) or *Eucalypt mixed chenopod woodland* (EXCW) as the topsoil becomes less saline with increasing soil depth. Where the subsoil remains saline and eucalypts are absent EXHS grades into *Plain mixed halophyte shrubland* (PXHS).

Land systems

EXHS is a minor habitat type on Caiguna, Gumbelt and Thampanna land systems.

15. Eucalypt, speargrass open grassland (ESOG)

Sampling

2 inventory sites, 15 traverse points

General information

ESOG is located in the central south of the survey area. It is considered to be an irreversible state of a former habitat possibly once similar to *Eucalypt mixed chenopod woodland* (EXCW) or *Eucalypt saltbush shrubland or woodland (ESAW).* The lower shrub stratum has likely been removed by rabbit grazing in conjunction with frequent fires. ESOG occurs on gently inclined low rises (limestone hummocks) with up to 2 per cent slope and can extend down onto the edges of adjacent limestone and calcrete plains. Soils are calcareous shallow loams. Small (6–20 mm) fragments of limestone commonly cover up to 90 per cent of the surface and limestone outcrop occurs through up to 10 per cent of these habitats.

Physiognomy and vegetation composition

ESOG occurs as dense grassland of *Austrostipa scabra* (speargrass) under very scattered (2.5–10 per cent PFC) mallee-form *Eucalyptus yalatensis* (yalata mallee) and occasionally *E. gracilis* (yorrell).

21 perennial species were recorded at the two inventory sites, with an average of 13 species per site, two greater than the survey average. Four annual species were recorded.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—*Eucalyptus yalatensis* (mallee) Others—*Eucalyptus gracilis* (mallee), *Myoporum platycarpum*, *Pittosporum angustifolium*.
Tall shrubs:	Dominant—Not present as a recognisable stratum Common—*Geijera linearifolia* Others—*Acacia oswaldii*, *Dodonaea stenozyga*, *Eremophila alternifolia* (KI), *E. dempsteri*.
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Eremophila scoparia* (KI) Others—*Chenopodium curvispicatum* (KD), *Cratystylis conocephala*.
Low shrubs:	Dominant—Not present as a recognisable stratum Common—*Enchylaena tomentosa* (KD), *Maireana erioclada* Others—*Maireana sedifolia*, *Westringia rigida*.
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Maireana trichoptera* Other—*Sclerolaena diacantha* (KD).
Perennial grasses:	Dominant—*Austrostipa scabra* Others—*Austrodanthonia caespitosa*, *Austrostipa platychaeta* (KD).

Annual species recorded include *Carrichtera annua* (KI), *Podolepis canescens, Salsola tragus* and *Zygophyllum glaucum.*

Ecological disturbance

ESOG is an altered vegetation association in an irreversible state of transition. Large mallee roots are capable of upheaving limestone boulders as they grow. Many of these eucalypts and the associated understorey have been killed by increased fires. Holes containing burnt stumps and charcoal surrounded by upheaved limestone boulders are the only evidence for this vegetation association once supporting more eucalypts. The increased fire frequency is a result of activities associated with European settlement. Plant recovery is further hindered by the grazing of juvenile shrubs and tree shoots that germinate or resprout following fire. The dominance of *Austrostipa scabra* further increases the susceptibility of the area to fire. Speargrass is readily eaten when young and green, but has reduced palatability when dry. Dry conditions following good seasons make this a combustible fuel source.

*Remnant yalata mallee (*Eucalyptus yalatensis*) surrounded by grassland. Burnt stumps and charcoal fragments are common through the area indicating it once supported woodland.*

*Intact mallee woodland considered to be the former condition of ESOG prior to an increased fire regime. Mallee-form yorrell (*Eucalyptus gracilis*) and yalata mallee (*Eucalyptus yalatensis*) dominate.*

Gradational associations

ESOG often occurs on low limestone rises, crests and gently undulating ridges grading down into *Speargrass and wallaby grass open grassland* (SWOG) surrounding the rise or ridge. On the land systems where ESOG occurs it is more common along the northern perimeter of the Hampton Tableland where it merges into the vegetation associations of the Nullarbor Plain often dominated by a grass component, maintaining increased fire susceptibility.

Land systems

ESOG is a minor habitat type on Caiguna, Nightshade and Thampanna land systems.

C. CASUARINA SHRUBLAND AND WOODLAND ON CALCRETE PLAINS

This group occurs on calcrete plains in the north-west of the survey area. The vegetation in this group is dominated by an overstorey of *Casuarina pauper* (black oak). Casuarina woodlands commonly occur on low rises or on low fault scarps within the calcrete plain of the Nyanga land zone, as well as on the plain itself. Isolated casuarina shrubland or woodland also occur on residual calcrete low rises overlying Nullarbor Limestone out on the Nullarbor Plain.

16. Casuarina mixed chenopod shrubland or woodland (CXCS)

Sampling

8 inventory sites, 111 traverse points

General information

CXCS is commonly found on calcrete plains and low rises with a common to abundant (20–90 per cent) mantle of fine to large calcrete fragments and nodules (0.6–20 cm) and occasional outcrop (< 10 per cent). Soils are calcareous shallow loams and loamy earths. Very gentle slopes rarely exeed 2 per cent. CXCS may also occur where shallow deposits of sand overlie calcrete plains.

Physiognomy and composition

CXCS occurs as a very scattered to moderately closed (2.5–30 per cent PFC) low woodland. The tree stratum is dominated by *Casuarina pauper* (black oak) and the shrub stratum by *Maireana sedifolia* (pearl bluebush). A very scattered (2.5–10 per cent PFC) mid shrub layer of *Atriplex nummularia* (old man saltbush) and *Cratystylis conocephala* (false bluebush) is commonly present.

39 perennial species were recorded at the eight inventory sites, with an average of 15 species per site, four more than the survey average. 11 annual species were recorded, with an average of three species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant—*Casuarina pauper* Common—*Acacia papyrocarpa*, *Alectryon oleifolius* Others—*Myoporum platycarpum*, *Pittosporum angustifolium*, *Santalum acuminatum*.
Tall shrubs:	Dominant—Not present as a recognisable stratum Others—*Acacia burkittii* (KI), *A. oswaldii*, *A. tetragonophylla*, *Geijera linearifolia*.
Mid shrubs:	Dominant—*Atriplex nummularia*, *Cratystylis conocephala* Common—*Eremophila scoparia* (KI), *Senna artemisioides* subsp. x *coriacea* (KI) Other—*Eremophila glabra* (KI).
Low shrubs:	Dominant—*Maireana sedifolia* Common—*Atriplex vesicaria* (KD), *Chenopodium curvispicatum* (KD), *Enchylaena tomentosa* (KD), *Maireana erioclada*, *Ptilotus obovatus* Others—*Lycium australe*, *Maireana radiata*, *Olearia calcarea*, *Rhagodia crassifolia* (KD), *Solanum lasiophyllum*, *S. nummularium*.
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex acutibractea* (KI), *Maireana trichoptera*, *Sclerolaena diacantha* (KD) Others—*Eriochiton sclerolaenoides*, *Sclerolaena obliquicuspis*.
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrostipa scabra* Others—*Austrodanthonia caespitosa*, *Austrostipa elegantissima* (KD),

	A. platychaeta (KD), *Enneapogon caerulescens*, *E. cylindricus*.
Other plant forms:	Occasional—*Marsdenia australis* (creeper).

Annual species recorded include *Brachyscome ciliaris, Calocephalus knappii, Carrichtera annua* (KI), *Euphorbia drummondii, Mesembryanthemum crystallinum, Ptilotus exaltatus, Salsola tragus, Vittadinia humerata, Zygophyllum eremaeum, Z. iodocarpum* (KI) and *Z. ovatum.*

Ecological disturbance

Palatable perennial species such as *Atriplex vesicaria* (bladder saltbush), *Austrostipa elegantissima* (feather speargrass), *A. platychaeta, Chenopodium curvispicatum, Enchylaena tomentosa* (ruby saltbush), *Enneapogon caerulescens* (limestone grass) *Ptilotus obovatus* (cotton bush) and *Rhagodia crassifolia* may be removed through excessive grazing of the understorey. Browsing pressure is commonly indicated by the condition of *Alectryon oleifolius* (mingah bush, bullock bush) and, to a lesser degree, *Pittosporum angustifolium* (native willow) and *Santalum acuminatum* (quandong). Browse lines indicate moderate grazing but broken limbs and smashed canopies indicate heavy grazing and total grazing pressure at an unsustainable level. [See tree-based clump condition monitoring photographic guide in the Resource Management chapter.] Improving range condition is indicated by the development of clumps of palatable shrubs under trees and dense foliage on *Alectryon oleifolius*. Rabbit warrens were often common. The presence of warrens and/or past fires was often associated with poor condition ratings for CXCS.

Gradational associations

CXCS commonly grades into *Myall mixed chenopod shrubland or woodland* (MXCW), as *Acacia papyrocarpa* becomes increasingly dominant in the overstorey. Where CXCS is located on calcrete rises and faultline low ridges it commonly grades downslope into *Plain mixed chenopod shrubland* (PXCS). In the north-west CXCS grades into *Mulga mixed shrub woodland* (MUXW) as mulga begins to dominate the tree stratum.

Land systems

CXCS is a major habitat type on Nyanga land system and a minor habitat type on Gumbelt, Kanandah, Naretha, Nightshade, Pondana and Vanesk land systems.

17. Casuarina mixed scrub shrubland (CXSS)

Sampling

2 inventory sites, 17 traverse points

General information

CXSS occurs in the north-west of the survey area. It is most common on calcrete plains with a sparse (2–20 per cent) mantle composed of calcrete fragments and nodules. It is also found on calcrete plains overlain by sand. Soils are calcareous loamy earths and shallow loams or red shallow loams where the surface is overlain with sand.

Physiognomy and composition of vegetation

CXSS occurs as a scattered (10–20 per cent PFC) tall shrubland of acacias, eremophilas and sennas. The tree stratum comprises very scattered (2.5–5 per cent PFC) *Casuarina pauper* (black oak). The mid and low shrub stratum is commonly composed of very scattered *Atriplex nummularia* (old man saltbush) and *Maireana sedifolia* (pearl bluebush).

29 perennial species were recorded at the two inventory sites, with an average of 20 species per site, nine greater than the survey average. Two annual species were recorded.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—*Casuarina pauper* Common—*Myoporum platycarpum* Others—*Acacia aneura*, *A. papyrocarpa*, *Alectryon oleifolius*, *Pittosporum angustifolium*.
Tall shrubs:	Dominant—Not present as a recognisable stratum Others—*Acacia burkittii* (KI), *A. tetragonophylla*.
Mid shrubs:	Dominant—*Atriplex nummularia* Common—*Eremophila latrobei* subsp. *latrobei*, *Scaevola spinescens*, *Senna artemisioides* subsp. x *coriacea* (KI) Others—*Eremophila glabra* (KI), *E. scoparia* (KI), *Senna artemisioides* subsp. x *artemisioides* (KI).

Low shrubs:	Dominant—*Maireana sedifolia* Common—*Atriplex vesicaria* (KD), *Chenopodium curvispicatum* (KD), *Ptilotus obovatus* (KD) Others—*Sida calyxhymenia* (KD), *Solanum nummularium*, *Westringia rigida*.
Subshrubs:	Dominant—Not present as a recognisable stratum. Others—*Maireana trichoptera* (KD), *Sclerolaena obliquicuspis*.
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrostipa scabra*, *Enneapogon cylindricus* Others—*Austrodanthonia caespitosa*, *Enneapogon caerulescens*.
Other plant forms:	Occasional—*Marsdenia australis* (creeper).

Annual species recorded include *Eriachne pulchella* subsp. *pulchella* and *Salsola tragus.*

Ecological disturbance

A diverse mix of the following palatable perennials would be indicative of an area in good resource condition: *Atriplex vesicaria* (bladder saltbush), *Chenopodium curvispicatum, Maireana trichoptera* (pink-seeded bluebush), *Ptilotus obovatus* (cotton bush), *Scaevola spinescens* (currant bush) and *Sida calyxhymenia* (tall sida). *Acacia burkittii* (jam), *Senna artemisioides* subsp. x *artemisioides* (silver cassia) and *Senna artemisioides* subsp. x *coriacea* (desert cassia) may increase under heavy grazing or frequent burning.

Gradational associations

CXSS grades into *Mixed acacia open shrubland* (XAOS) and *Mixed shrub bindii grassland* (XSBG) where the underlying Nullarbor Limestone geology is indurated by calcrete. Where soils become increasingly sandier and eucalypts begin to dominate the tree strata CXSS may grade into *Eucalypt mixed scrub woodland* (EXSW).

Land systems

CXSS is a minor habitat type on Gumbelt, Naretha and Nyanga land systems.

18. Casuarina, acacia open shrubland (CAOS)

Sampling

2 inventory sites, 8 traverse points

General information

CAOS is restricted to the mid-west of the survey area, primarily the 1:250 000 Naretha map sheet. It occurs on residual calcrete low rises with gentle slopes to 3 per cent. Large stones (6–20 cm) cover 50–90 per cent of the surface. Soils are calcareous shallow loams and loamy earths.

Physiognomy and composition of vegetation

CAOS occurs as a scattered tall shrubland of *Acacia burkittii* (jam) and *Alectryon oleifolius* (mingah bush, bullock bush) trees (up to 15 per cent PFC) with an overstorey of very scattered *Casuarina pauper* (black oak) to 10 per cent PFC.

19 perennial species were recorded at the two inventory sites, with an average of 11 species per site, the same as the survey average. Two annual species were recorded.

The following species (by strata) are dominant and or common:

Trees:	Dominant—*Casuarina pauper* Common—*Alectryon oleifolius* Others—*Acacia aneura*, *A. papyrocarpa*.
Tall shrubs:	Dominant—*Acacia burkittii* (KI) Other—*Acacia oswaldii*.
Mid shrubs:	Dominant—Not present as a recognisable stratum Other—*Eremophila scoparia* (KI).
Low shrubs:	Dominant—Not present as a recognisable stratum Others—*Chenopodium curvispicatum*, *Enchylaena tomentosa*, *Maireana erioclada*, *Ptilotus obovatus* (KD).
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Eriochiton sclerolaenoides*, *Sclerolaena diacantha* (KD) Others—*Atriplex acutibractea* (KI), *Maireana trichoptera* (KD), *Sclerolaena obliquicuspis* (KI), *S. patenticuspis* (KI).

Perennial grasses: Dominant—Not present as a recognisable stratum
Common—*Enneapogon cylindricus*
Other—*Enneapogon caerulescens*.

Annual species recorded include *Lepidium* sp. and *Salsola tragus.*

Ecological disturbance

The limited structure and composition of the mid and low shrub strata are an indication of the level of animal usage these habitats receive. This is further demonstrated by the presence of rabbit warrens, recent cattle activity and remnant root stumps in deteriorating plant mounds. Commonly the soil surface is poor owing to the high level of animal disturbance, with less than 40 per cent surface crusting. The combination of the landform and associated vegetation mean these low calcrete rises appeal to herbivores. The soil development associated with the calcrete, compared to the surrounding skeletal soils associated with the Nullarbor Limestone, supports trees and provides suitable locations for rabbit warrens. Rabbit piospheres radiating out from warrens are common. Trees provide shelter and browse for large herbivores and many areas have the appearance of livestock 'camps', particularly when favourable browse such as *Alectryon oleifolius* is present. The condition of *Alectryon oleifolius* groves indicates the grazing pressure in an area. [See tree-based clump condition monitoring photographic guide in the Resource Management chapter.] The breakdown of *Alectryon oleifolius* groves is an indication of poor range condition and overgrazing. The development of clumps of palatable shrubs under trees and dense foliage on *Alectryon oleifolius* indicates range condition is improving.

Gradational associations

CAOS grades into *Mixed acacia open shrubland* (XAOS) as residual calcrete low rises give way to the underlying Nullarbor Limestone.

Land systems

CAOS is a minor habitat type of the Nyanga and Kitchener land systems.

D. SHRUBLAND AND WOODLAND ON CALCRETE PLAINS OVERLAIN BY SHALLOW SAND

This group of habitat types commonly occurs on calcrete plains overlain by shallow sheets of aeolian sand. They typically support closed woodland or tall shrubland dominated by acacias or mallee-form eucalypts. This group of habitat types is found in the north-west of the survey area.

19. Mallee hummock grass (spinifex) woodland (MHGW)

Samples

7 inventory sites, 47 traverse points

General information

MHGW occurs on calcrete plains overlain by shallow aeolian sand or calcareous aeolian sandplain. Calcrete nodules are often present at a depth of greater than 30 cm. Fine to coarse calcrete nodules (2–60 mm) may cover up to 2 per cent of the surface. Soils are calcareous loamy earths and red shallow sand and loams. MHGW is located in the north-west and west of the survey area.

Physiognomy and composition of vegetation

MHGW consists of a scattered to closed (15–50 per cent PFC) low woodland of mallee-form eucalypts over an understorey of dense *Triodia scariosa* (spinifex). The most common eucalypt to dominate MHGW is *Eucalyptus oleosa* subsp. *oleosa* (giant mallee).

27 perennial species were recorded at the seven inventory sites, with an average of nine species per site, two less than the survey average. No annual species were recorded.

The following species (by strata) were dominant and/or common:

Trees: Dominant—*Eucalyptus oleosa* subsp. *oleosa*
Common—*Allocasuarina helmsii*, *Eucalyptus concinna*, *E. gracilis*, *E. oleosa*, *Santalum acuminatum*
Other—*Eucalyptus melanoxylon*.

Tall shrubs: Dominant—Not present as a recognisable stratum
Common—*Exocarpos aphyllus*, *Melaleuca eleuterostachya*

	Others—*Acacia densiflora*, *A. hemiteles*, *A. ligulata*, *A. rigens*, *Eremophila caperata*, *E. dempsteri*.
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Scaevola spinescens* Others—*Eremophila decipiens*, *Melaleuca uncinata*, *Rulingia craurophylla*, *Senna artemisioides* subsp. x *coriacea*.
Low shrubs:	Dominant—Not present as a recognisable stratum Common—*Westringia rigida* Others—*Acacia camptoclada*, *A. xerophila*, *Grevillea acuaria*, *Olearia calcarea*.
Subshrubs:	Dominant—Not present as a recognisable stratum Other—*Scaevola collaris*.
Perennial grasses:	Dominant—*Triodia scariosa* Common—Nil.

Ecological disturbance

MHGW is largely unaffected by grazing. Spinifex hummock grass and most shrubs associated with this habitat are not favoured by stock. The grazing value is generally seasonally dependent, with heavy rains promoting new plant growth, particularly after fire.

Gradational associations

MHGW occurs as a component of a broader eucalypt woodland mosaic, grading into *Eucalypt mixed chenopod woodland* (EXCW), *Eucalypt mixed scrub woodland* (EXSW) and *Sugarwood mixed chenopod shrubland or woodland* (SWCS) on calcrete plains. Near Lake Boonderoo MHGW grades downslope into *Sandy bank lake shrubland* (SBLS).

Land systems

MHGW is the dominant habitat type on the Zanthus land system.

20. Mulga mixed shrub woodland (MUXW)

Sampling

1 inventory site, 7 traverse points

General information

This minor vegetation association is found on calcrete plains overlain by sand in the north-west of the survey area. Soils are red loamy earths. This site type is more closely related to mulga vegetation communities more common to the northern Coolgardie and south-western Great Victoria Desert Biogeographic Regions than those of the Nullarbor Biogeographic Region. The presence of MUXW represents the beginning of a transition between the three botanical regions.

Physiognomy and composition of vegetation

MUXW comprises a closed (30–50 per cent PFC) low woodland of *Acacia aneura* (mulga) with an understorey of mixed shrubs. The lower shrub stratum is commonly dominated by scattered (15–20 per cent PFC) *Ptilotus obovatus* (cotton bush).

18 perennial species were recorded at the one inventory site and seven traverse points. No annual species were recorded.

The following species were dominant and/or common:

Trees:	Dominant—*Acacia aneura* Others—*Acacia papyrocarpa*, *Casuarina pauper*.
Tall shrubs:	Dominant—Not present as a recognisable stratum Others—*Acacia tetragonophylla*, *Alectryon oleifolius*, *Dodonaea lobulata* (KI), *Eremophila alternifolia* (KI).
Mid shrubs:	Dominant—Not present as a recognisable stratum Others—*Atriplex nummularia*, *Senna artemisioides* subsp. x *coriacea* (KI).
Low shrubs:	Dominant—*Ptilotus obovatus* (KD) Others—*Enchylaena tomentosa* (KD), *Maireana pentatropis*, *M. sedifolia*, *M. thesioides* (KD), *Solanum lasiophyllum*, *S. nummularium*.
Subshrubs:	Dominant—Not present as a recognisable stratum Other—*Solanum ellipticum*.
Perennial grasses:	Dominant—Not present as a recognisable stratum Other—*Enneapogon caerulescens*.

Ecological disturbance

This site type was not adequately sampled to discuss grazing impacts. However, patterns for similar mulga-dominated woodlands from previous rangeland surveys in the Coolgardie,

Great Victoria Desert and Murchison Biogeographic Regions (Curry et al. 1994; Pringle, Van Vreeswyk & Gilligan 1994; Payne et al. 1998) provide some indication of the likely grazing impacts. In good condition, palatable shrubs such as *Ptilotus obovatus, Enchylaena tomentosa* (ruby saltbush) and *Maireana thesioides* (lax bluebush) would be expected to be common. Conversely, a history of heavy grazing would be indicated by an abundance of *Dodonaea lobulata* (bead hopbush) and *Senna artemisioides* subsp. x *coriacea* (desert cassia) and a noticeable absence of palatable species.

Gradational associations

MUXW grades into *Casuarina mixed chenopod shrubland or woodland* (CXCS) and *Myall mixed chenopod shrubland or woodland* (MXCS) as *Acacia aneura* disappears from the tree strata, replaced by either *Casuarina pauper* or *Acacia papyrocarpa* respectively.

Land systems

MUXW is a minor habitat type on Gumbelt and Nyanga land systems.

21. Acacia mixed shrubland (ACMS)

Sampling

1 inventory site, 9 traverse points

General information

ACMS is a minor habitat type in the Western Nullarbor but has previously been described in the Carnarvon Basin (Payne, Curry & Spencer 1987). In the Western Nullarbor ACMS occurs on calcrete plains overlain by sand and/or calcareous loams in the north-west of the survey area. Soils are calcareous shallow loams or red sandy earths where the surface is overlain by aeolian sand.

Physiognomy and composition of vegetation

ACMS commonly occurs as a scattered to closed (10–50 per cent PFC) tall scrubland of sclerophyllous shrubs, commonly dominated by species of *Acacia*, *Eremophila* and *Senna*. When present *Enneapogon cylindricus* is the dominant perennial grass.

16 perennial species and two annual species were recorded at the one inventory site and nine traverse points.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—Not present as a recognisable stratum Others—*Acacia aneura, A. papyrocarpa, Casuarina pauper.*
Tall shrubs:	Dominant—Variable; *Acacia oswaldii, A. tetragonophylla* (KI) Common—Nil.
Mid shrubs:	Dominant—*Atriplex nummularia* Common—*Eremophila latrobei* (KD), *E.* sp. Others—*Senna artemisioides* subsp. *artemisioides* (KI), *Sida calyxhymenia* (KD).
Low shrubs:	Dominant—Not present as a recognisable stratum Others—*Atriplex vesicaria* (KD), *Chenopodium curvispicatum* (KD), *Maireana sedifolia, Ptilotus obovatus.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex acutibractea* (KI), *Eriochiton sclerolaenoides.*
Perennial grasses:	Dominant—Occasionally *Enneapogon cylindricus* Common—Nil.

Annual species recorded include *Euphorbia drummondii* and *Salsola tragus.*

Ecological disturbance

ACMS was not sampled sufficiently for detailed analysis of grazing impacts. Continuous heavy grazing is likely to result in a reduction in palatable species such as *Atriplex vesicaria* (bladder saltbush), *Enchylaena tomentosa* (ruby saltbush), *Chenopodium curvispicatum, Eremophila latrobei* (warty-leaf eremophila) and *Sida calyxhymenia* (tall sida). With declining condition an increase in unpalatable species such as *Acacia tetragonophylla* (curara) and *Senna artemisioides* subsp. *artemisioides* (silver cassia) may occur.

Gradational associations

ACMS grades into *Myall mixed chenopod shrubland or woodland* (MXCS) as the overlying sand disappears.

Land systems

ACMS is a minor habitat type on Nyanga land system.

E. SHRUBLAND ASSOCIATED WITH GRANITIC OUTCROP

This group of habitat types predominantly occurs within the Mardabilla land zone, where granite outcrop protrudes through limestone and calcrete plains. These habitat types are dominated by sclerophyllous vegetation including *Senna*, *Eremophila* and *Ptilotus*, occurring as scattered to moderately closed, tall and mid shrubland. Sparse trees and grasses are also present. Soils tend to be shallow.

22. Dodonaea, eremophila mixed shrubland (DEXS)

Sampling

2 inventory sites, 11 traverse points.

General information

DEXS is commonly found associated with the slopes of granite domes and outcrop within the Mardabilla land zone. Increased water catchment at the margin of the granite outcrop promotes dense shrubland. Medium to large (6–60 cm) stones of granite mixed with calcrete fragments cover up to 90 per cent of the surface. Granite outcrop occurs through 10 per cent of these habitats. Soils are red shallow sands and calcareous shallow loams. DEXS also occur in the central west of the survey area where sand and calcrete nodules overlie calcrete plains of the Nyanga land zone.

Physiognomy and composition of vegetation

DEXS occurs as a moderately closed (20–25 per cent PFC) tall shrubland of variable composition, mostly dominated by *Eremophila alternifolia* or *Dodonaea lobulata* (bead hopbush).

24 perennial species were recorded at the two inventory sites, with an average of 13 species per site, two greater than the survey average. Two annual species were recorded.

The following species (by strata) were dominant and/or common:

Trees:	Dominant—Not present as a recognisable stratum Common—*Pittosporum angustifolium* Others—*Acacia aneura, Eucalyptus gracilis* (mallee).
Tall shrubs:	Dominant—*Dodonaea lobulata* (KI) Common—*Eremophila alternifolia* Others—*Acacia burkittii* (KI), *A. tetragonophylla, Geijera linearifolia.*
Mid shrubs:	Dominant—Not present as a recognisable stratum Others—*Atriplex nummularia, Eremophila decipiens, E. latrobei* (KD), *Senna artemisioides* subsp. x *artemisioides* (KI).
Low shrubs:	Dominant—*Ptilotus obovatus* (KD) Common—*Solanum nummularium* Others—*Chenopodium curvispicatum, Enchylaena tomentosa, Maireana pentatropis, Olearia axillaris.*
Subshrubs:	Dominant—Not present as a recognisable stratum Others—*Sclerolaena patenticuspis, Sida spodochroma, Solanum ellipticum.*
Perennial grasses:	Dominant—Not present as a recognisable stratum Others—*Austrodanthonia caespitosa, Enneapogon caerulescens, E. cylindricus.*

Annual species recorded include *Brachyscome* sp. and *Salsola tragus.*

Ecological disturbance

This habitat type was not sufficiently sampled to investigate disturbance impacts as the proportion it occupies in the survey area is small. DEXS appeared to be largely unaffected by domestic grazing.

Gradational associations

In the south-west of the survey area DEXS abuts *Granite outcrop shrubland* (GROS) or grades into the *Eucalypt mixed chenopod woodland* (EXCW) or *Eucalypt mixed scrub woodland* (EXSW) surrounding the granite outcrop. In the central west of the survey area DEXS commonly grades into *Mixed acacia open shrubland* (XAOS).

Land system

DEXS is a major habitat type on Balladonia land system and a minor type on Nyanga land system.

23. Granite outcrop shrubland (GROS)

Sampling

4 inventory sites, 9 traverse points

General information

GROS is found in association with granite outcrop and low granite rises in the south-west of the survey area within the Mardabilla land zone. Soils are red shallow loams. Coarse granitic and calcareous fragments (2–20 cm) cover up to 10 per cent of the surface with granite outcrop occurring through up to 50 per cent of the area. The granite outcrop may rise to 5 m.

Physiognomy and composition of vegetation

GROS comprises a very scattered to scattered mid to tall shrubland (5–20 per cent PFC) of variable composition. The lower shrub stratum is commonly dominated by *Ptilotus obovatus* (cotton bush).

32 perennial species were recorded at the four inventory sites, with an average of 13 species per site, two greater than the survey average. 10 annual species were recorded, with an average of four species per site.

The following species (by strata) were dominant and/or common:

Tall shrubs:	Dominant—Variable; *Dodonaea lobulata* (KI) Common—*Acacia ligulata* (KI), *Eremophila alternifolia*, *Myoporum platycarpum.*
Mid shrubs:	Dominant—Variable; *Acacia ligulata* (KI), *Atriplex nummularia* Common—*Sida calyxhymenia* (KD) Others—*Eremophila deserti* (KI), *Pimelea microcephala*
Low shrubs:	Dominant—Variable; *Ptilotus obovatus* (KD) Common—*Atriplex vesicaria*, *Enchylaena tomentosa* (KD), *Rhagodia ulicina* Others—*Atriplex stipitata*, *Chenopodium curvispicatum* (KD), *Maireana erioclada*, *M. georgei* (KD), *M. sedifolia*, *Olearia calcarea*, *Tecticornia* sp.
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Boerhavia repleta*, *Sclerolaena patenticuspis*, *Sida spodochroma*, *Solanum nummularium* Others—*Eriochiton sclerolaenoides*, *Sclerolaena cuneata*, *S. diacantha*, *S. obliquicuspis.*
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrodanthonia caespitosa*, *Austrostipa scabra*.
Other plant forms:	Occasional—*Carpobrotus* sp. (succulent perennial herb), *Cheilanthes lasiophylla* (fern).

Annual species recorded include *Brachyscome* sp., *Calandrinia* sp., *Carrichtera annua* (KI), *Eriachne aristidea, Goodenia* sp., *Mesembryanthemum crystallinum, M. nodiflorum, Salsola tragus, Senecio quadridentatus* and *Vittadinia nullarborensis.*

Ecological disturbance

Different soil chemistries associated with granitic and calcareous rock types are the likely reason for the natural variation in the species composition of this habitat. An abundance of palatable species such as *Austrodanthonia caespitosa* (wallaby grass), *Chenopodium curvispicatum, Enchylaena tomentosa* (ruby saltbush), *Maireana georgei* (golden bluebush), *Ptilotus obovatus* and *Sida calyxhymenia* (tall sida) indicates that GROS is in good condition. Rainwater accumulation in depressions within granite outcrop offers an ephemeral water source. These areas will receive concentrated grazing pressure from native and introduced animals whilst ephemeral pools remain. In such instances palatable flora is likely to be greatly reduced and the immediate area may become dominated by unpalatable species such as *Acacia ligulata, Dodonaea lobulata* (bead hopbush) and *Eremophila deserti.*

Gradational associations

GROS commonly abuts *Dodonaea, eremophila mixed shrubland* (DEXS) or is bordered by *Eucalypt mixed chenopod woodland* (EXCW) or *Eucalypt mixed scrub woodland* (EXSW) with the resumption of the overlying calcareous plains.

Land systems

GROS is a major habitat type on Balladonia land system.

F. SHRUBLAND ON CALCAREOUS PLAINS

This group of habitats consists of 'succulent steppe' according to Beard (1975). It is characterised by a dominant low shrub stratum frequently containing species from the genera *Atriplex* and *Maireana* of the Chenopodiaceae family. These shrubs are well adapted to arid environments. This habitat is common throughout the Nullarbor.

This habitat group occurs from the Nullarbor through to the Pilbara and is considered to have some of the highest pastoral value in the arid southern shrublands. Hacker (1979) researched the ecology and impact of grazing on chenopod shrubland present on depositional landscapes. The research was conducted on Glenorn Station in the north-eastern Goldfields. Hacker concluded excessive grazing pressure reduced shrub cover which in turn led to the extension of naturally present small scalds. Once scalds had extended beyond a certain threshold a reduction in grazing pressure was not enough to reverse the process. Scalded surfaces are less productive and become unsuitable as germination sites for most plants. These findings are reinforced throughout the Nullarbor survey area and are particularly evident from satellite imagery highlighting the piosphere effect around water points, especially within the Nullarbor land zone. The coalescing effect of scalds in heavily utilised areas emphasises the importance of monitoring vegetation, and appropriately responding to deteriorating condition, in order to prevent this process, which leads to reduced landscape function and resilience.

24. Sugarwood mixed chenopod shrubland (SWCS)

Sampling

4 inventory sites, 106 traverse points

General information

SWCS is predominantly found on stony limestone or calcrete plains overlain by calcareous loams in the west of the survey area. Soils are calcareous shallow loams or clay loams.

Physiognomy and composition of vegetation

SWCS comprises a scattered (10–20 per cent PFC) tall shrubland. The tree and/or tall shrub stratum is dominated by *Myoporum platycarpum* (sugarwood) and the shrub stratum by *Maireana sedifolia* (pearl bluebush).

35 perennial species were recorded at the four inventory sites, with an average of 13 species per site, two greater than the survey average. Four annual species were recorded, with an average of two species per site.

The following species (by strata) are dominant and or common:

Trees:	Dominant—*Myoporum platycarpum* Common—Nil.
Tall shrubs:	Dominant—*Myoporum platycarpum* Common—*Geijera linearifolia* Other—*Exocarpos aphyllus.*
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex nummularia*, *Cratystylis conocephala* Others—*Acacia nyssophylla*, *Eremophila decipiens* (KI), *E. deserti* (KI), *E. glabra* (KI), *Nitraria billardierei*, *Scaevola spinescens.*
Low shrubs:	Dominant—*Maireana sedifolia* Common—*Atriplex vesicaria* (KD), *Gunniopsis calcarea*, *Lycium australe*, *Maireana erioclada*, *Rhagodia ulicina* Others—*Chenopodium curvispicatum* (KD), *Enchylaena tomentosa* (KD), *Frankenia* sp., *Maireana turbinata*, *Olearia calcarea*, *Ptilotus symonii*, *Solanum nummularium*, *Zygophyllum aurantiacum.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Maireana trichoptera*, *Sclerolaena diacantha* (KD), *Sida spodochroma* Others—*Atriplex acutibractea* (KI), *Eriochiton sclerolaenoides*, *Sclerolaena patenticuspis* (KI).
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrodanthonia caespitosa*, *Austrostipa scabra* Others—*Austrostipa platychaeta* (KD), *Panicum effusum.*

Annual species recorded include *Brachyscome* sp., *Euphorbia drummondii, Nicotiana goodspeedii* and *Salsola tragus.*

Ecological disturbance

Dense stands of juvenile *Myoporum platycarpum* frequently occur in the south of the survey area. It is thought this is in response to reduced grazing pressure from rabbits due to the rabbit calicivirus. *Myoporum platycarpum* was also observed recolonising some recently burnt areas.

Gradational associations

SWCS often occurs as a transitional habitat type, as shallow calcareous loams marginally deepen, between *Myall mixed chenopod shrubland or woodland* (MXCS), *Eucalypt mixed chenopod woodland* (EXCW) or *Eucalypt, sugarwood mixed chenopod woodland* (ESCW) and *Plain mixed chenopod shrubland* (PXCS), occurring in clay depressions or corridors between low-lying ridges. Where the soil surface becomes sandier SWCS grades into *Mallee hummock grass (spinifex) woodland* (MHGW).

Land systems

SWCS is a major habitat type on Nanambinia land system and a minor habitat type on Woorlba land system.

25. Pearl bluebush low shrubland (PBLS)

Sampling

24 inventory sites, 1202 traverse points

General information

PBLS is the most common vegetation association in the Nullarbor land zone as well as one of the most common communities throughout the entire survey area. It is found on the stony slopes and crests of the undulating limestone plains of the Nullarbor Plain. PBLS occurs on gently undulating stony slopes up to 3 per cent, but often less than 2 per cent, with up to 90 per cent of the surface covered by medium to coarse limestone fragments (6–60 mm). Soils are shallow calcareous loams with limestone outcrop generally occurring through less than 10 per cent of the habitat type. On the calcrete plains of the Nyanga Plain PBLS is less common. The mantle is variably stony.

Physiognomy and composition of vegetation

PBLS comprises a very scattered to scattered (10–15 per cent PFC) low shrubland of *Maireana sedifolia* (pearl bluebush), occasionally moderately closed (< 25 per cent PFC). A sparse mid shrub stratum of mixed shrubs is sometimes present.

47 perennial species were recorded at the 24 inventory sites, with an average of 10 species per site, one less than the survey average. 23 annual species were recorded, with an average of five species per site.

The following species by strata were dominant and/or common:

Trees:	Dominant—Not present as a recognisable stratum Common—*Myoporum platycarpum* (in the south) Others—*Acacia papyrocarpa, Eremophila longifolia, Pittosporum angustifolium.*
Tall shrubs:	Dominant—Not present as a recognisable stratum Common—*Acacia oswaldii.*
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Senna artemisioides* subsp. *artemisioides* (KI) Others—*Atriplex nummularia, Cratystylis conocephala, Eremophila maculata, Senna artemisioides* subsp. x *coriacea* (KI)*, S. artemisioides* subsp. *petiolaris, Sida calyxhymenia.*
Low shrubs:	Dominant—*Maireana sedifolia* Common—*Atriplex vesicaria* (KD)*, Chenopodium curvispicatum* (KD)*, Lawrencia squamata, Lycium australe, Ptilotus obovatus* Others—*Atriplex cryptocarpa, Enchylaena tomentosa, Gunniopsis calcarea, Maireana erioclada, M. radiata, M. turbinata, Solanum nummularium, Tecticornia* sp.*, Zygophyllum aurantiacum.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex acutibractea* (KI)*, Eriochiton sclerolaenoides* (KD)*, Sclerolaena diacantha* (KD)*, S. obliquicuspis* (KI)*, S. patenticuspis* (KI), *Sida spodochroma, Solanum ellipticum, Wurmbea tenella*

	Others—*Desmocladus myriocladus, Maireana trichoptera, Minuria cunninghamii*
Perennial grasses:	Dominant—*Austrostipa scabra* Common—*Austrodanthonia caespitosa, Austrostipa platychaeta* (KD) Others—*Austrostipa nitida, Enneapogon caerulescens, E. cylindricus, Eragrostis setifolia.*
Other plant forms:	Occasional—*Glycine rubiginosa* (creeper), *Marsdenia australis* (creeper).

Annual species recorded include *Angianthus conocephalus, Brachyscome ciliaris, Calandrinia* sp., *Carrichtera annua* (KI), *Dysphania melanocarpa* forma *leucocarpa, Erodium cicutarium, E. cygnorum, Euphorbia drummondii, E. tannensis* subsp. *eremophila, Goodenia pinnatifida, Isoetopsis graminifolia, Lepidium* sp., *Mesembryanthemum crystallinum, Podolepis canescens, Rhodanthe chlorocephala, R. floribunda, Salsola tragus* (KI), *Senecio pinnatifolius, Sonchus oleraceus, Tetragonia eremaea, Vittadinia humerata*, *Zygophyllum iodocarpum* (KI) and *Z. ovatum.*

Ecological disturbance

Maireana sedifolia leaves contain up to 10 per cent salt (Mitchell & Wilcox 1994) and may be eaten by stock if fresh water is available. Pastoralists have observed stock eating only the tips of the plants particularly when there are new shoots. *Maireana sedifolia* is not a sensitive indicator of range condition in the Nullarbor. When in good condition this vegetation association has good diversity, including palatable perennials such as *Atriplex vesicaria* (bladder saltbush) and *Chenopodium curvispicatum,* numerous subshrubs (i.e. *Eriochiton sclerolaenoides, Sclerolaena diacantha*) and palatable grasses such as *Austrodanthonia caespitosa* (wallaby grass) and *Austrostipa platychaeta.* In fair condition these species will be reduced and replaced by less palatable, seasonally dependent facultative perennials *Atriplex acutibractea* (toothed saltbush), *Sclerolaena obliquicuspis* (limestone bindii) and *S. patenticuspis* (spear-fruit copperburr); and in poor condition by unpalatable annuals such as *Carrichtera annua* (Ward's weed), *Salsola tragus* (roly poly) and *Zygophyllum iodocarpum,* with *Austrostipa scabra* (speargrass) dominating the areas between the bluebush mounds. Soils in healthy PBLS communities have well developed cryptogamic crusts of algae, lichens and liverworts, which improve nutrient cycling, soil moisture retention, and provide protection against raindrop impact, sheet flow and wind erosion. The loss of cryptogamic crust is an indicator of deteriorated soil condition.

Following a fire of moderate to low intensity *Maireana sedifolia* can regenerate if not severely grazed during its recovery (Mitchell, McCarthy & Hacker 1979), though it can be eliminated by frequent or intense fires. The ability to regenerate from fire and cope with arid conditions has allowed it to become a dominant climax species throughout the Nullarbor landscape.

*Pearl bluebush (*Maireana sedifolia*) regrowth after a low intensity fire caused by lightning.*

On the Nullarbor Plain *Maireana sedifolia* is immensely important in providing habitat and shelter to animals, including steppe and grassland birds, to other plants and soil protection from wind erosion. Its function in reducing wind speed at ground level is significant, reducing the wind's desiccating effect on inter-mound subshrubs. Whilst not diminishing its ecological importance there is concern the continuous grazing pressure by all herbivores, particularly through dry seasons, is reducing the diversity of PBLS to homogenous communities dominated by *Maireana sedifolia* and *Austrostipa scabra*. In some locations within the landscape PBLS also represents a degraded state of a *Plain mixed chenopod shrubland* (PXCS). The loss of many fire-sensitive and/or palatable species leaves a PBLS community with extensive interpatch areas with only the *Maireana sedifolia* bush mounds remaining.

Gradational associations

PBLS commonly occur on crests and marginal slopes adjacent to depressions dominated by *Plain mixed chenopod shrubland* (PXCS), *Plain mixed halophyte shrubland* (PXHS), *Bladder saltbush shrubland* (BSSL), *Speargrass and wallaby grass open grassland* (SWOG), *Annual herbland* (ANNH), areas prone to water inundation, i.e. *Lignum swamp* (LISW), *Drainage depression saltbush shrubland* (DDSS), donga groves (DOGR) and *Gilgai grassy shrubland* (GGSL). On the Naretha land system as acacia tall shrubs become more common PBLS grades into *Pearl bluebush, Acacia shrubland* (PBAC), elsewhere degraded PBLS is replaced by *Mixed acacia open shrubland* (XAOS).

Land systems

PBLS is the dominant habitat on Balgair, Lowry, Moonera and Morris land systems. PBLS is a major habitat type on Arubiddy, Chowilla, Gafa, Kinclaven, Kybo, Pondana, Reid, Seemore, Shakehole, Skink, Thampanna, and Vanesk land systems and a minor habitat type on Bullseye, Jubilee, Nurina, Oasis and Woorlba land systems.

26. Pearl bluebush, acacia shrubland (PBAC)

Sampling

2 inventory sites, 38 traverse points

General information

PBAC predominantly occurs on stony limestone plains with up to 20 per cent of the surface covered by medium-sized limestone fragments (6–20 mm). Soils are commonly calcareous shallow loams. PBAC occurs in the central west of the survey area.

Physiognomy and composition of vegetation

PBAC occurs as a very scattered to scattered (5–15 per cent PFC) mid to low shrubland. Species of *Acacia* dominate the mid shrub stratum. The lower shrub stratum is commonly co-dominated by *Maireana sedifolia* (pearl bluebush) and *Ptilotus obovatus* (cotton bush).

23 perennial species were recorded at the two inventory sites, with an average of 15 species per site, four greater than the survey average. Six annual species were recorded.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—Not present as a recognisable stratum Other—*Pittosporum angustifolium.*
Tall shrubs:	Dominant—*Acacia burkittii* (KI), *A. tetragonophylla* (KI) Other—*Dodonaea lobulata* (KI).
Mid shrubs:	Dominant—Not present as a recognisable stratum Others—*Scaevola spinescens*, *Senna artemisioides* subsp. x *artemisioides* (KI), *Sida calyxhymenia* (KD).
Low shrubs:	Dominant—*Maireana sedifolia*, *Ptilotus obovatus* (KD) Others—*Chenopodium curvispicatum* (KD), *Enchylaena tomentosa* (KD), *Solanum orbiculatum.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex acutibractea* (KI), *Eriochiton sclerolaenoides* (KD), *Sida spodochroma, Solanum ellipticum* Others—*Maireana trichoptera* (KD), *Sclerolaena diacantha* (KD), *S. obliquicuspis* (KI).
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrodanthonia caespitosa, Austrostipa scabra, Enneapogon cylindricus* Other—*Enneapogon caerulescens.*

Annual species recorded include *Aristida contorta, Carrichtera annua* (KI)*, Erodium aureum, Euphorbia drummondii, Oxalis* sp. and *Salsola tragus.*

Ecological disturbance

Acacia tetragonophylla (curara) is well adapted to arid conditions and may be browsed but generally only during extended dry periods when other species are suffering from water stress (Mitchell & Wilcox 1994). Palatable perennial herbs and grasses, such as *Eriochiton sclerolaenoides* (woolly bindii), *Maireana trichoptera* (pink-seeded bluebush), *Austrodanthonia caespitosa* (wallaby grass) and *Enneapogon caerulescens* (limestone grass) are likely to be preferentially sought when seasonal conditions are favourable.

The vegetation structure and composition of PBAC is unique. Grazing may have altered the floristic composition resulting in an increase of the more dominant, unpalatable species *Acacia burkittii* (jam), *Acacia tetragonophylla* and *Dodonaea lobulata* (bead hopbush). However, the vegetation association may also be influenced by ancient river courses nearby and proximity to the adjacent calcrete plain. These components of the physical geography may have influenced soil characteristics. These factors in combination or individually form a floristic interzone of mixed species composition between the calcrete plain of the Nyanga land zone and the Nullarbor Plain of the Nullarbor land zone.

Gradational associations

PBAC commonly grades into *Pearl bluebush low shrubland* (PBLS) as acacia species become less common. In areas altered by fires and overgrazing PBAC is commonly replaced by *Open bindii grassland* (OBIG) and/or *Mixed acacia open shrubland* (XAOS).

Land systems

PBAC is a major habitat type on Naretha land system and a minor habitat type on Moonera land system.

27. Plain mixed chenopod shrubland (PXCS)

Sampling

16 inventory sites, 705 traverse points

General information

PXCS is common throughout the survey area. On the limestone plains of the Bunda Plateau it can occur on either stony surfaces with fine to coarse calcareous fragments (2–60 mm) covering up to 20 per cent of the surface, on marginal slopes to drainage floors with calcareous loams of varying depth or in the lower-lying depressions. In the west PXCS also occurs on the calcrete plains of the Nyanga Plain which are overlain by calcareous loam of variable depth. Soils are calcareous loamy earths. In the south on the Roe Plains PXCS also occurs on the calcareous loamy earths overlying the Roe Calcarenite.

Physiognomy and composition of vegetation

PXCS exists as a scattered (10–20 per cent PFC) mid to low shrubland, co-dominated by *Maireana sedifolia* (pearl bluebush) and *Atriplex vesicaria* (bladder saltbush).

41 perennial species were recorded at the 16 inventory sites, with an average of 11 species per site, the survey average. 12 annual species were recorded, with an average of three species per site.

The following species (by strata) were dominant and/or common:

Trees:	Dominant—Not present as a recognisable stratum Others—*Myoporum platycarpum, Pittosporum angustifolium.*
Tall shrubs:	Dominant—Not present as a recognisable stratum Others—*Acacia oswaldii, Exocarpos aphyllus.*
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex nummularia, Geijera linearifolia* Others—*Cratystylis conocephala, Eremophila decipiens, E. scoparia, Nitraria billardierei, Pimelea microcephala.*
Low shrubs:	Dominant—*Atriplex vesicaria* (KD)*, Maireana sedifolia*

	Common—*Enchylaena tomentosa* (KD), *Lawrencia squamata* (KI), *Lycium australe, Maireana erioclada* Others—*Chenopodium curvispicatum* (KD), *Gunniopsis calcarea, Maireana radiata, M. turbinata, Olearia calcarea, O. ramosissima, Rhagodia ulicina.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Eriochiton sclerolaenoides, Maireana trichoptera, Sclerolaena obliquicuspis* (KI), *S. patenticuspis* (KI), *Sida spodochroma* Others—*Erodium aureum, Minuria cunninghamii, Sclerolaena densiflora* (KI), *S. diacantha* (KD), *Tecticornia* sp.
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrodanthonia caespitosa* (KD), *A. setacea, Austrostipa platychaeta* (KD), *A. scabra* Others—*Austrodanthonia setacea, Enneapogon cylindricus* (KD).
Other plant forms:	Occasional—*Marsdenia australis* (creeper).

Annual species recorded include *Arabidella trisecta, Brachyscome ciliaris, Carrichtera annua* (KI), *Dysphania melanocarpa* forma *leucocarpa, Euphorbia drummondii, Mesembryanthemum crystallinum, Nicotiana occidentalis, Rhodanthe floribunda* (KI), *Salsola tragus* (KI), *Tetragonia eremaea, Vittadinia* sp. and *Zygophyllum iodocarpum* (KI).

Ecological disturbance

Curry et al. (1994) suggested excessive grazing pressure reduced projected foliar cover (PFC), leaving PXCS habitats susceptible to accelerated soil erosion and/or increases in unpalatable shrubs. Pringle, Van Vreeswyk and Gilligan (1994) found the prominence of key decreaser species was the most sensitive indicator of range condition and to a lesser extent increaser species rather than PFC. Key decreaser shrub species include *Atriplex vesicaria, Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush) and palatable grasses include *Austrodanthonia caespitosa* (wallaby grass), *Austrostipa platychaeta* and *Enneapogon cylindricus*. Increaser species include *Lawrencia squamata* (grey fan leaf), *Sclerolaena densiflora* (hairy bindii), *S. obliquicuspis* (limestone bindii), *S. patenticuspis* (spear-fruit copperburr) and the annuals *Carrichtera annua* (Ward's weed), *Rhodanthe floribunda, Salsola tragus* (roly poly) and *Zygophyllum iodocarpum*. Pringle, Van Vreeswyk and Gilligan (1994) also found the extent of cryptogamic crusting was less in grazed areas, leaving such areas susceptible to soil erosion.

Fire can alter the species composition of these habitats considerably. At graded fencelines and tracks acting as firebreaks, the ability of *Maireana sedifolia* to recover from moderate to low intensity fires is visible, unlike fire-sensitive *Atriplex vesicaria* that is unable to recover, particularly in the presence of high rabbit numbers or continuous grazing. Across some locations with the same geophysical characteristics PXCS has been reduced to a homogenous stand of *Maireana sedifolia* (similar to a *Pearl bluebush low shrubland* PBLS), whilst nearby in fire excluded areas PXCS remains diverse.

Gradational associations

PXCS commonly grades into *Myall mixed chenopod shrubland or woodland* (MXCS), *Myall, false bluebush shrubland or woodland* (MFBW), *Eucalypt mixed chenopod woodland* (EXCW), *Sugarwood mixed chenopod shrubland or woodland* (MXCS) or *Casuarina mixed chenopod shrubland or woodland* (CXCS) as tree species begin to dominate the upper strata. In the south-west of the survey area PXCS is commonly found in the depressions and lower-lying 'corridors' between the undulating patterns of joint controlled limestone ridges supporting *Pearl bluebush low shrubland* (PBLS), *Eucalypt saltbush shrubland or woodland* (ESAW) or *Eucalypt mixed scrub woodland* (EXSW). PXCS can also occur on marginal slopes to drainage floors as a vegetation transition between PBLS-dominated low ridges and lower-lying *Bladder saltbush shrubland* (BSSL) or *Samphire shrubland* (SAMP). On the Roe Plains PXCS grades into *Nitraria mixed chenopod shrubland* (NXCS) as *Nitraria billardierei* begins to dominate the mid shrub layer.

Land systems

PXCS is a dominant habitat type on Koonjarra and Woorlba land systems and a major habitat type on Chowilla, Gafa, Moonera, Morris, Nanambinia, Nyanga, Reid, Shakehole, Thampanna and Vanesk land systems.

28. Nitraria with mixed chenopod shrubland (NXCS)

Sampling

3 inventory sites, 17 traverse points

General information

NXCS is named after the dominance of *Nitraria billardierei* (nitre bush). Soils are calcareous loamy earths overlying the calcarenite Roe Plains. It occurs in the south of the survey area on the north of the Roe Plains, where the soils overlying the Roe Calcarenite remain shallow and are less sandy.

Physiognomy and composition of vegetation

NXCS varies considerably from a very scattered to moderately closed (5–25 per cent PFC) shrubland. *Nitraria billardierei* (nitre bush) dominates the mid shrub stratum with the lower shrub stratum dominated by *Atriplex vesicaria* (bladder saltbush).

21 perennial species were recorded at the three inventory points, with an average of 12 species per site, one greater than the survey average. Eight annual species were recorded, with an average of five species per site.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—Not present as a recognisable stratum Common—*Acacia papyrocarpa.*
Tall shrubs:	Dominant—Not present as a recognisable stratum Other—*Geijera linearifolia.*
Mid shrubs:	Dominant—*Nitraria billardierei* (KI) Common—*Atriplex nummularia.*
Low shrubs:	Dominant—*Atriplex vesicaria* (KD) Common—*Enchylaena tomentosa* (KD), *Gunniopsis calcarea, Lawrencia squamata* (KI), *Maireana erioclada* Others—*Maireana georgei* (KD), *M. sedifolia, Zygophyllum aurantiacum* (KD).
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Eriochiton sclerolaenoides, Sclerolaena patenticuspis* (KI), *Tetragonia implexicoma* Others—*Maireana trichoptera, Sclerolaena diacantha* (KD).
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrodanthonia caespitosa, Austrostipa drummondii, A. scabra* Other—*Austrostipa platychaeta* (KD).

Annual species recorded include *Brachyscome lineariloba, Carrichtera annua* (KI), *Erodium cicutarium, Nicotiana goodspeedii, N. occidentalis, Senecio pinnatifolius, Sonchus oleraceus* and *Trichanthodium skirrophorum.*

Ecological disturbance

Nitraria billardierei is not highly desirable to stock, except for the fruit which is eaten by sheep, and may increase at the expense of palatable low shrubs such as *Atriplex vesicaria*, *Enchylaena tomentosa* (ruby saltbush) and *Maireana georgei* (golden bluebush) which decrease under excessive grazing pressure. In areas of heavy grazing pressure *Nitraria billardierei* shelters palatable grasses such as *Austrostipa platychaeta* within its spreading clump-like form.

Nitraria billardierei can also increase in response to track or roadside disturbances. This is evident along the Eyre Highway and the old Eyre telegraph line where *Nitraria billardierei* has increased due to the combination of disturbance opening the tree canopy and greater accumulation of water at the road or track edge.

Nitraria billardierei is readily dispersed by birds and as a result it commonly occurs under potential perch sites including telegraph poles and fence posts.

Gradational associations

NXCS commonly grades into *Plain mixed chenopod shrubland* (PXCS) or *Myall mixed chenopod shrubland or woodland* (MXCS) as *Nitraria billardierei* becomes less common.

Land systems

NXCS is a major habitat type on Mundrabilla land system and a minor habitat type on Roe land system.

29. Bladder saltbush shrubland (BSSL)

Sampling

31 inventory sites, 578 traverse points

General information

BSSL can occupy a variety of positions within the landscape. It predominantly occurs in the loamy depressions of undulating limestone plains in the south-east of the survey area. In the south-west BSSL occurs in clay depressions with saline subsoils. In the north BSSL occurs on deflated marginal slopes to drainage floors with limestone fragments of mixed size (1–30 cm) generally covering up to 50 per cent of the surface. BSSL also dominates drainage floors and ancient river courses throughout the survey area. Shrub patches are commonly intersected with naturally occurring scalded interbands. Soils are calcareous loamy earths. When present in clay depressions and drainage floors red/brown non-cracking clays dominate.

Physiognomy and composition of vegetation

BSSL comprises a scattered to moderately closed (10–25 per cent PFC) low shrubland of *Atriplex vesicaria* (bladder saltbush).

52 perennial species were recorded at the 31 inventory sites, with an average of eight species per site, three less than the survey average. 23 annual species were recorded, with an average of four species per site.

The following species (by strata) are dominant and/or common:

Tall shrubs:	Dominant—Not present as a recognisable stratum Others—*Acacia tetragonophylla, Geijera linearifolia.*
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex nummularia* Others—*Cratystylis conocephala, Eremophila decipiens* (KI)*, E. deserti, E. glabra* (KI)*, E. scoparia* (KI)*, Pimelea microcephala.*
Low shrubs:	Dominant—*Atriplex vesicaria* Common—*Maireana georgei* (KD)*, M. sedifolia* Others—*Atriplex cryptocarpa, Enchylaena tomentosa, Frankenia densa, Gunniopsis calcarea, Lycium australe, Maireana erioclada, M. pentatropis, M. radiata, M. turbinata, Nitraria billardierei, Rhagodia crassifolia, R. ulicina, Solanum nummularium, Tecticornia doleiformis, Tecticornia* sp.*, Zygophyllum aurantiacum.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Eriochiton sclerolaenoides* (KD)*, Sclerolaena diacantha* (KD)*, S. obliquicuspis* (KI)*, S. patenticuspis* (KI)*, Sida spodochroma* Others—*Atriplex acutibractea* (KI)*, Maireana trichoptera* (KD)*, Sclerolaena brevifolia, Solanum ellipticum.*
Perennial grasses:	Dominant—*Austrostipa scabra* Common—*Austrodanthonia caespitosa* Others—*Austrodanthonia setacea, Austrostipa nitida, A. platychaeta (KD), Enneapogon caerulescens, E. cylindricus, Eragrostis dielsii, Panicum decompositum.*
Other plant forms:	Occasional—*Glycine rubiginosa* (creeper).

Annual species recorded include *Arabidella trisecta, Brachyscome* sp., *Carrichtera annua* (KI)*, Centaurea melitensis, Dysphania melanocarpa* forma *leucocarpa, Erodium aureum, Euphorbia drummondii, Lepidium rotundum, Lotus cruentus, Mesembryanthemum crystallinum, Nicotiana goodspeedii, N. occidentalis, Oxalis corniculata, Podolepis canescens, Rhodanthe floribunda* (KI)*, Salsola tragus* (KI)*, Senecio pinnatifolius, S. quadridentatus, Senecio spanomerus, Swainsona microphylla, Vittadinia humerata, Zygophyllum iodocarpum* and *Zygophyllum ovatum.*

Ecological disturbance

Atriplex vesicaria responds to moisture stress by shedding leaves, but will recover quickly in response to rainfall and soil moisture conditions that stimulate germination. During this recovery phase *Atriplex vesicaria* needs protection from grazing pressure to allow germinant

establishment and for mature plants to regain vigour and set seed. Sustained heavy grazing is likely to reduce perennial vegetation cover as well as reducing other palatable species such as *Eriochiton sclerolaenoides* (woolly bindii), *Maireana georgei* (golden bluebush), *M. trichoptera* (pink-seeded bluebush) and *Sclerolaena diacantha* (grey bindii). This may lead to the expansion of naturally occurring scalded interbands. Further threats to *Atriplex vesicaria* include its lack of tolerance to fire and inability to regenerate after burning.

In BSSL an increase in unpalatable species such as *Eremophila* spp., *Atriplex acutibractea* (toothed saltbush), *Sclerolaena obliquicuspis* (limestone bindii), *S. patenticuspis* (spear-fruit copperburr), *Carrichtera annua* (Ward's weed), *Rhodanthe floribunda* and *Salsola tragus* (roly poly) indicates declining range condition.

Gradational associations

BSSL commonly grades out of depressions and lower-lying areas into *Plain mixed chenopod shrubland* (PXCS), *Pearl bluebush low shrubland* (PBLS) or *Open bindii grassland* (OBIG) occupying the marginal slopes and crests of the gentle undulating Nullarbor Plain. Transitional associations can also occur in the same land unit, usually lower-lying depressions, between BSSL and *Speargrass and wallaby grass open grassland* (SWOG) and, depending on soil salinity, *Plain mixed halophyte shrubland* (PXHS). In ancient river courses BSSL commonly surrounds the drainage foci supporting *Lignum swamp* (LISW).

Due to the common occurrence of BSSL in depressions and low-lying areas, other habitat associations may occur on the surrounding higher slopes of undulating country such as eucalypt and/or myall shrubland or woodland.

Land systems

BSSL is a major habitat type on Arubiddy, Balgair, Chowilla, Gafa, Haig, Moonera, Morris, Reid, Shakehole, Skink, Thampanna and Woorlba land systems and a minor habitat type on Bullseye, Jubilee, Kanandah, Moodini, Nurina, Nyanga, Oasis, Pondana and Vanesk land systems.

30. Lawrencia squamata shrubland (LAWS)

Sampling

3 inventory sites, 16 traverse points

General information

LAWS is a minor vegetation association predominantly occurring on the calcrete breakaway slopes of the Koonjarra land system. Moderately inclined slopes of up to 10 per cent have outcrop occurring through 50 per cent of the area, with 90 per cent of the surface covered by loose calcrete fragments of mixed size. Soils are commonly red/brown non-cracking clays. LAWS are found in the central west of the survey area. LAWS are also found infrequently on stony limestone plains of the Kinclaven and Shakehole land system where it replaces mixed chenopod shrubland.

Physiognomy and composition of vegetation

LAWS comprises scattered (10–15 per cent) low shrubland of *Lawrencia squamata* (grey fan leaf).

16 perennial species were recorded at the three inventory sites, with an average of nine species per site, two less than the survey average. Four annual species were recorded.

The following species (by strata) were dominant and/or common:

Trees:	Dominant—Not present as a recognisable stratum Common—*Acacia papyrocarpa*.
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex nummularia, Nitraria billardierei* Other—*Cratystylis conocephala.*
Low shrubs:	Dominant—*Lawrencia squamata* Common—*Atriplex vesicaria* (KD), *Maireana sedifolia* Others—*Cratystylis subspinescens, Frankenia* sp., *Maireana turbinata, Rhagodia crassifolia.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Maireana trichoptera* (KD), *Sclerolaena diacantha* (KD).

Perennial grasses: Dominant—Not present as a recognisable stratum
Common—*Austrostipa scabra*
Others—*Austrodanthonia caespitosa, Eragrostis dielsii.*

Annual species recorded include *Carrichtera annua* (KI)*, Euphorbia drummondii, Nicotiana occidentalis* and *Salsola tragus.*

Ecological disturbance

Whilst *Lawrencia squamata* is occasionally eaten by stock, in some areas it may be increasing in abundance in response to a loss of more palatable flora. If *Atriplex vesicaria* (bladder saltbush), *Maireana trichoptera* (pink-seeded bluebush) and *Sclerolaena diacantha* (grey bindii) are present in large numbers and with numerous juveniles the area can be assumed to be in good condition. The latter two species are subject to seasonal conditions and caution should be used when selecting them alone to determine range condition.

The breakaway slopes of this habitat are highly susceptible to water erosion. Vehicle tracks have resulted in rilling and gullying. Short spaced bunds across the tracks would divert water flow off the tracks. This would prolong the tracks usefulness, reduce erosion and the deteriorating condition of the breakaway slopes impacted by the tracks.

Gradational associations

In the Koonjarra land system LAWS is commonly found midslope between sparse *Myall mixed chenopod shrubland or woodland* (MXCS) and grading downslope into *Plain mixed chenopod shrubland* (PXCS). Where it is present on limestone plains it often grades into *Open bindii grassland* (OBIG).

Land systems

LAWS is a minor habitat type on Kinclaven, Koonjarra and Shakehole land systems.

G. OPEN SHRUBLAND AND GRASSLAND ON CALCAREOUS PLAINS

This group of habitat types occurs on the limestone and calcrete plains of the Bunda Plateau and is predominantly altered vegetation associations now in an irreversible state of transition. These habitat types are thought to have once supported a low shrub stratum which has since been removed through the combined effects of increased fire frequency and over-grazing, primarily by rabbits. The replacement of perennial shrubs by grasses, particularly *Austrostipa scabra* (speargrass), has increased the susceptibility of these habitats to fire. These irreversibly altered vegetation associations are unlikely to support a low shrub stratum of palatable perennial shrubs in the future. They now carry open grassland and sparse shrubland. Low-lying areas such as claypans, clay plains and drainage areas in some locations may originally have supported these seasonally dependent vegetation associations, but with a more diverse suite of palatable perennials or subshrubs than what is supported by these areas today. In good seasons these habitats support dense stands of perennial and annual grasses and herbs. In dry periods these habitats are susceptible to wind erosion due to the scarcity of plants.

31. Mixed acacia open shrubland (XAOS)

Sampling

4 inventory sites, 66 traverse points

General information

XAOS commonly occurs in the central west of the survey area on stony limestone plains where up to 90 per cent of the surface is covered by coarse (2–20 cm) limestone fragments. It occasionally occurs on calcrete plains overlain by stony calcareous loams. Soils are red shallow loams and calcareous shallow loams.

Physiognomy and composition of vegetation

XAOS occurs as a scattered (10–15 per cent PFC) tall shrubland of acacias. The most dominant acacia is *Acacia burkittii* (jam)*,* though *A. aneura* (mulga) is also common*. Ptilotus obovatus* (cotton bush) commonly dominates the low shrub stratum.

34 perennial species were recorded at the four inventory sites, with an average of 17 species per site, six greater than the survey average. Nine annual species were recorded, with an average of five species per site.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—Not present as a recognisable stratum Occasional—*Acacia aneura, A. papyrocarpa, Alectryon oleifolius, Myoporum platycarpum, Pittosporum angustifolium, Santalum spicatum.*
Tall shrubs:	Dominant—*Acacia burkittii* (KI) Common—*Acacia aneura* Others—*Acacia oswaldii, A. tetragonophylla* (KI), *Dodonaea lobulata* (KI), *Myoporum platycarpum.*
Mid shrubs:	Dominant—Not present as a recognisable stratum Others—*Eremophila latrobei* subsp. *glabra, E. scoparia* (KI), *Scaevola spinescens, Senna artemisioides* subsp. x *artemisioides* (KI), *S. artemisioides* subsp. x *coriacea* (KI), *Sida calyxhymenia* (KD).
Low shrubs:	Dominant—*Ptilotus obovatus* Common—*Atriplex vesicaria, Enchylaena tomentosa, Maireana sedifolia* Other—*Solanum nummularium.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Eriochiton sclerolaenoides* (KD), *Sclerolaena diacantha* (KD), *S. patenticuspis* (KI), *Sida spodochroma*, *Solanum ellipticum* Others—*Maireana trichoptera* (KD), *Minuria cunninghamii, Sclerolaena obliquicuspis* (KI).
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrostipa scabra, Enneapogon caerulescens, E. cylindricus* Other—*Austrodanthonia caespitosa.*
Other plant forms:	Occasional—*Marsdenia australis* (creeper).

Annual species recorded include *Abutilon oxycarpum* subsp. *prostratum, Aristida contorta, Carrichtera annua* (KI), *Dysphania melanocarpa* forma *leucocarpa, Erodium cygnorum, Euphorbia drummondii, Lepidium* sp., *Malvastrum americanum* and *Salsola tragus.*

Ecological disturbance

Acacia burkittii is not grazed by stock and this may have contributed to its dominance through this habitat type. In many areas *Acacia burkittii* was of uniform height and therefore possibly of similar age. This may be a post-fire related response.

XAOS represents a floristic ecotone of mixed species composition between the calcrete plain of the Nyanga land zone and the Nullarbor Plain of the Nullarbor land zone. The occurrence of red shallow loam soils through the XAOS of the Naretha land system indicates the vegetation association may be influenced by the proximity to the calcrete plain and ancient water courses. Alternatively, the soil surface may reflect sand mobility caused through past or present disturbance events.

Ptilotus obovatus is palatable though its condition and presence varies with seasonal conditions. The grasses *Enneapogon caerulescens* (limestone grass) and *Enneapogon cylindricus* are highly palatable to stock, but abundance depends with seasonal conditions. Dense stands of such species may indicate fair to good rangeland condition.

Gradational associations

XAOS commonly grades into low shrubland such as *Pearl bluebush low shrubland* (PBLS) and *Pearl bluebush, acacia shrubland* (PBAC). In the Naretha land system ancient river courses supporting Drainage Acacia shrubland (DRAS) meander through XAOS.

Where residual calcrete rises occur over the Nullarbor Limestone and *Casuarina pauper* (black oak) begins to occur in the overstorey XAOS grades into *Casuarina, acacia open shrubland* (CAOS) or *Casuarina mixed scrub shrubland* (CXSS). Where sand overlies calcrete rises, XAOS grades into *Dodonaea, eremophila mixed shrubland* (DEXS).

Land systems

XAOS is a major habitat type on Kitchener and Naretha land system and a minor habitat type on Nyanga land system.

32. Mixed shrub bindii grassland (XSBG)

Sampling

6 inventory sites, 269 traverse points

General information

XSBG is predominantly found on stony limestone plains. Up to 90 per cent of the stony surface is strewn with limestone fragments of mixed size, and outcrop is common through up to 50 per cent of these habitats. Soils are calcareous loamy earths and shallow loams. XSBG is found in the north-west of the survey area.

Physiognomy and composition of vegetation

XSBG is highly variable and may occur as a very scattered to scattered (2.5–15 per cent PFC) herbland, mid or tall shrubland. The mid and tall shrubland is commonly dominated by sclerophyllous shrubs and the herbland by species of *Sclerolaena* (bindii).

36 perennial species were recorded at the six inventory sites, with an average of 15 species per site, four greater than the survey average. 13 annual species were recorded, with an average of six species per site.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—Not present as a recognisable stratum Common—*Pittosporum angustifolium* Other—*Acacia papyrocarpa.*
Tall shrubs:	Dominant—Variable; occasionally *Eremophila longifolia, A. tetragonophylla* (KI) Common—*Acacia burkittii* (KI), *A. oswaldii.*
Mid shrubs:	Dominant—Variable; occasionally *Senna artemisioides* subsp. x *coriacea* (KI) Common—*Atriplex nummularia* Others—*Eremophila latrobei* subsp. *glabra, Pimelea microcephala, Sida calyxhymenia* (KD).
Low shrubs:	Dominant—Occasionally *Lawrencia squamata* (KI) Common—*Chenopodium curvispicatum, Enchylaena tomentosa* (KD), *Maireana sedifolia* Others—*Atriplex vesicaria* (KD), *Lycium australe, Maireana radiata, Ptilotus obovatus* (KD), *Solanum nummularium.*
Subshrubs:	Dominant—*Sclerolaena obliquicuspis* (KI) Common—*Atriplex acutibractea* (KI), *Eriochiton sclerolaenoides* (KD), *Sclerolaena diacantha* (KD), *S. patenticuspis* (KI), *Sida spodochroma, Solanum ellipticum* Others—*Maireana trichoptera* (KD), *Sclerolaena brevifolia.*
Perennial grasses:	Dominant—*Austrodanthonia caespitosa, Austrostipa scabra* Common—*Enneapogon caerulescens, E. cylindricus* Other—*Eragrostis setifolia.*
Other plant forms:	Occasional—*Glycine rubiginosa* (creeper), *Marsdenia australis* (creeper).

Annual species recorded include *Carrichtera annua* (KI), *Dysphania melanocarpa* forma *leucocarpa, Erodium aureum, E. cygnorum, Euphorbia drummondii, Lepidium* sp., *Malvastrum americanum, Rhodanthe floribunda* (KI), *Salsola tragus* (KI), *Salvia verbenaca* (KI), *Sisymbrium erysimoides, Xanthium spinosum* and *Zygophyllum iodocarpum.*

Ecological disturbance

XSBG is an altered vegetation association. The presence of *Maireana sedifolia* (pearl bluebush) stumps and remnant bush mounds indicates these areas previously supported chenopod shrubland. Many of the shrubs now dominating these areas are unpalatable, including increaser species such as *Acacia burkittii* (jam), *A. tetragonophylla* (curara) and *Senna artemisioides* subsp. x *coriacea* (desert cassia). These shrubs are generally resilient, capable of surviving dry conditions and known to respond in abundance after a fire.

The lower stratum of XSBG is regularly dominated by unpalatable subshrubs and annuals such as *Atriplex acutibractea* (toothed saltbush), *Sclerolaena obliquicuspis* (limestone bindii), *S. patenticuspis* (spear-fruit copperburr), *Carrichtera annua* (Ward's weed), *Rhodanthe floribunda, Salsola tragus* (roly poly) and *Salvia verbenaca* (wild sage). During dry periods these seasonally dependent plants disappear and the area becomes prone to wind erosion. This further reduces the capacity to support

vegetative growth. The extensively stony surface of this habitat is evidence of active erosive processes.

Gradational associations

XSBG is a common component in areas with a record of long-term continuous grazing and a history of fire. This degraded habitat type commonly grades into *Open bindii grassland* (OBIG).

In the northern Nullarbor Plain XSBG commonly surrounds dongas supporting berrigan and curara groves (DBGR and DCGR) as well as small areas of *Gilgai grassy shrubland* (GGSL).

Where Nullarbor Limestone is overlain by thick calcrete and *Casuarina pauper* (black oak) begins to appear in the overstorey XSBG grades into *Casuarina mixed scrub shrubland* (CXSS).

Land systems

XSBG is the dominant habitat on Kinclaven land system, a major type on Kanandah and Kitchener land systems and a minor habitat type on Naretha land system.

33. Open bindii grassland (OBIG)

Sampling

11 inventory sites, 492 traverse points

General information

OBIG predominantly occurs on stony limestone and calcrete plains across the north of the survey area. Coarse gravel and stones (2–20 cm) of limestone may cover up to 90 per cent of the surface. OBIG also commonly occurs on the marginal slopes to drainage floors of clay plains and claypans in the north. Soils are commonly calcareous shallow loams, and where present on clay plains, red/brown non-cracking clays.

Physiognomy and composition of vegetation

OBIG occurs as a very scattered to moderately closed (2.5–25 per cent PFC) grassland with mixed *Sclerolaena* species, most commonly *Sclerolaena patenticuspis* (spear-fruit copperburr).

25 perennial species were recorded at the 11 inventory sites, with an average of six species per site, five less than the survey average. 10 annual species were recorded, with an average of five species per site.

The following species (by strata) are dominant and/or common.

Trees:	Dominant—Not present as a recognisable stratum Occasional—*Acacia papyrocarpa, Casuarina pauper, Eremophila longifolia, Pittosporum angustifolium.*
Mid shrubs:	Dominant—Not present as a recognisable stratum Occasional—*Atriplex nummularia, Scaevola spinescens.*
Low shrubs:	Dominant—Not present as a recognisable stratum Others—*Atriplex cryptocarpa, A. vesicaria, Enchylaena tomentosa, Lycium australe, Maireana sedifolia, Ptilotus obovatus.*
Subshrubs:	Dominant—*Sclerolaena patenticuspis* (KI)*, Eriochiton sclerolaenoides* (KD) Common—*Atriplex acutibractea* (KI)*, Sclerolaena diacantha* (KD)*, S. obliquicuspis* (KI)*, Sida spodochroma* Others—*Maireana trichoptera* (KD)*, Sclerolaena brevifolia, Solanum ellipticum.*
Perennial grasses:	Dominant—*Austrostipa scabra* Common—*Austrodanthonia caespitosa* (KD)*, Enneapogon cylindricus* (KD).
Other plant forms:	Occasional—*Glycine rubiginosa* (creeper).

Annual species recorded include *Carrichtera annua* (KI)*, Erodiophyllum elderi, Euphorbia drummondii, Lepidium* sp., *Mesembryanthemum crystallinum, Nicotiana occidentalis, Rhodanthe floribunda* (KI), *Salsola tragus* (KI)*, Vittadinia* sp. and *Zygophyllum iodocarpum* (KI).

Ecological disturbance

Total grazing pressure has influenced the floristic composition of this habitat type in different locations. In good condition, palatable perennial herbs such as *Eriochiton sclerolaenoides* (woolly bindii), *Maireana trichoptera* (pink-seeded bluebush) and *Sclerolaena diacantha* (grey bindii) and perennial grasses such as *Austrodanthonia caespitosa* (wallaby grass) and *Enneapogon cylindricus* are abundant. In poor condition, unpalatable species dominate. These include *Atriplex acutibractea* (toothed saltbush), *Carrichtera annua* (Ward's weed),

Salsola tragus (roly poly), *Sclerolaena obliquicuspis* (limestone bindii), *S. patenticuspis, Rhodanthe floribunda* and *Zygophyllum iodocarpum.* In dry seasons these areas are prone to erosion and scalding as there is very little protection offered by the seasonally dependent plants.

Gradational associations

OBIG commonly grades into *Myall bindii grassland* (MBIG) as myall begins to appear. In the northern Nullarbor land zone OBIG commonly surround the various forms of donga and small patches of *Gilgai grassy shrubland* (GGSL). Southwards in the Nullarbor land zone, as dongas give way to claypans and clay plains, OBIG surrounds vegetation associations commonly occupying such depressions such as *Bladder saltbush shrubland* (BSSL), *Annual herbland* (ANNH) or *Speargrass and wallaby grass open grassland* (SWOG). As the density of shrubs begins to increase in the mid and tall shrub strata OBIG grades into *Mixed shrub bindii grassland* (XSBG) or *Pearl bluebush, acacia shrubland* (PBAC).

Land systems

OBIG is the dominant habitat on Oasis and Rabbit land systems, a major habitat type on Bullseye, Carlisle, Gafa, Jubilee, Kinclaven, Kitchener, Kyarra, Kybo and Nurina land systems and a minor type on Haig, Moonera, Pondana, Reid, Shakehole and Skink land systems.

34. Speargrass and wallaby grass open grassland (SWOG)

Sampling

29 inventory sites, 635 traverse points

General information

SWOG is considered a fire-induced vegetation association. Patches are likely to have always existed in a mosaic state and transition pattern between saltbush and bluebush low shrubland. The vegetation has become irreversibly altered as a result of increased fire frequency and through grazing by rabbits in plague proportions. SWOG now dominates extensive areas, having replaced other habitat types by increasing the fire susceptibility of much of the Nullarbor.

SWOG occurs across the survey area on limestone plains with up to 50 per cent of the surface overlain by coarse (2–20 cm) limestone fragments. It also occurs in both closed and open depressions on calcareous loamy plains, clay plains and claypans. Soils are calcareous shallow loams and loamy earths, and red/brown non-cracking clays in claypans.

Physiognomy and composition of vegetation

SWOG consists of open grassland of *Austrostipa scabra* (speargrass) and *Austrodanthonia caespitosa* (wallaby grass).

52 perennial species were recorded at the 29 inventory sites, with an average of six species per site, five less than the survey average. 27 annual species were recorded, with an average of four species per site.

The following species (by strata) were dominant and/ or common:

Trees:	Dominant—Not present as a recognisable stratum Occasional—*Acacia papyrocarpa, Eremophila longifolia, Eucalyptus gracilis, E. yalatensis, Myoporum platycarpum.*
Tall shrubs:	Dominant—Not present as a recognisable stratum Occasional—*Acacia burkittii, A. hemiteles, A. oswaldii, Geijera linearifolia.*
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex nummularia* Others—*Acacia nyssophylla, Cratystylis conocephala, Nitraria billardierei, Pimelea microcephala, Scaevola spinescens, Senna artemisioides* subsp. x *coriacea.*
Low shrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex vesicaria, Maireana sedifolia* Others—*Chenopodium curvispicatum, Enchylaena tomentosa, Frankenia densa, Lycium australe, Maireana erioclada, M. pentatropis, M. radiata, Ptilotus obovatus, Rhagodia crassifolia, Solanum nummularium, S. orbiculatum, Tecticornia* sp., *Zygophyllum aurantiacum.*

Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex acutibractea* (KI), *Eriochiton sclerolaenoides, Sclerolaena diacantha, S. obliquicuspis, S. patenticuspis, Sida spodochroma* Others—*Maireana tomentosa, M. trichoptera, Sclerolaena brevifolia, S. densiflora, Solanum ellipticum, Swainsona affinis, Teucrium racemosum, Wurmbea tenella.*
Perennial grasses:	Dominant—*Austrostipa scabra* Common—*Austrodanthonia caespitosa* (KD) Others—*Austrostipa drummondii, Enneapogon cylindricus* (KD), *Eragrostis dielsii, E. setifolia.*
Other plant forms:	Occasional—*Marsdenia australis* (creeper).

Annual species recorded include *Angianthus conocephalus, Arabidella trisecta, Asteridea athrixioides, Brachyscome* sp., *Carrichtera annua* (KI), *Dysphania melanocarpa* forma *leucocarpa, Erodium aureum, Euphorbia drummondii, Goodenia pinnatifida, Isoetopsis graminifolia, Lepidium* sp., *Mesembryanthemum crystallinum, Nicotiana goodspeedii* (KI), *N. occidentalis* (KI), *N. occidentalis* subsp. *obliqua, Oxalis corniculata, Podolepis canescens, Rhodanthe floribunda* (KI), *Salsola tragus* (KI), *Senecio pinnatifolius, Sonchus oleraceus, Tetragonia eremaea, Trichanthodium skirrophorum, Vittadinia nullarborensis, Xanthium spinosum, Zygophyllum iodocarpum* (KI) and *Zygophyllum ovatum.*

Ecological disturbance

In good seasons SWOG is highly productive and during the active growth phase is readily grazed. *Austrostipa scabra* has maximum nutritional value when it has new green shoots, becoming less appealing as it becomes dry and harsh. *Austrodanthonia caespitosa* is highly palatable and is preferentially sought by herbivores. If total grazing pressure is not effectively managed wallaby grass can be eliminated with SWOG becoming dominated by only speargrass and unpalatable species such as *Atriplex acutibractea* (toothed saltbush), *Carrichtera annua* (Ward's weed), *Nicotiana* spp., *Salsola tragus* (roly poly), *Sclerolaena densiflora* (hairy bindii), *S. obliquicuspis* (limestone bindii), *S. patenticuspis* (spear-fruit copperburr), *Rhodanthe floribunda* and *Zygophyllum* spp. reducing the long-term carrying capacity of the grassland.

Gradational association

SWOG is often extensive and grades into *Open bindii grassland* (OBIG), *Pearl bluebush low shrubland* (PBLS) and *Bladder saltbush shrubland* (BSSL). Where soil salinity increases SWOG may grade into *Plain mixed halophytic shrubland* (PXHS) or *Samphire shrubland* (SAMP). As eucalypt mallee or myall begin to occur on ridges and rises SWOG grades into *Eucalypt, speargrass open grassland* (ESOG) or *Myall, speargrass open grassland* (MSOG).

Land systems

SWOG is the dominant habitat type on Nightshade land system, a major type on Bullseye, Carlisle, Chowilla, Gafa, Kybo, Oasis, Nurina, Shakehole and Skink land systems and a minor habitat type on Culver, Jubilee, Kitchener, Kyarra, Moonera, Morris, Nanambinia, Nyanga, Rabbit, Reid, Thampanna and Woorlba land systems.

35. Annual herbland (ANNH)

Sampling

7 inventory sites, 28 traverse points

General information

ANNH is located in areas receiving local drainage such as the claypans and clay plains. Occurring throughout the Nullarbor Plain, such drainage areas are more common in the north, becoming less frequent in the south. Soils are red/brown non-cracking clays.

Physiognomy and composition of vegetation

ANNH occurs as a very scattered to scattered (2.5–15 per cent PFC) herbland of perennial and annual herbs and grasses.

28 perennial species were recorded at the seven inventory sites, with an average of six species per site, five less than the survey average. 20 annual species were recorded, with an average of seven species per site.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant—Not present as a recognisable stratum Occasional—*Eremophila longifolia, Pittosporum angustifolium.*
Tall shrubs:	Dominant—Not present as a recognisable stratum

	Occasional—*Acacia tetragonophylla.*
Low shrubs:	Dominant—Not present as a recognisable stratum Occasional—*Atriplex cryptocarpa, A. vesicaria, Chenopodium curvispicatum, Enchylaena tomentosa, Maireana turbinata, Olearia calcarea, Westringia rigida.*
Subshrubs:	Dominant—*Sclerolaena patenticuspis* (KI) Common—*Atriplex acutibractea* (KI)*, Sclerolaena obliquicuspis* (KI)*, Sida spodochroma* Others—*Cullen cinereum, Eriochiton sclerolaenoides* (KD)*, Maireana trichoptera* (KD)*, Sclerolaena brevifolia, S. diacantha* (KD)*, Solanum ellipticum, Swainsona affinis, S. formosa.*
Perennial grasses:	Dominant—*Austrostipa scabra* Common—*Austrodanthonia caespitosa* (KD) Others—*Austrostipa drummondii, Enneapogon cylindricus* (KD)*, Eragrostis dielsii.*
Other plant forms:	Occasional—*Glycine rubiginosa* (creeper).

Annual species recorded include *Angianthus conocephalus, Asteridea athrixioides, Calotis multicaulis, Carrichtera annua* (KI)*, Cephalipterum drummondii, Dysphania melanocarpa* forma *leucocarpa, Erodiophyllum elderi, Erodium aureum, Euphorbia drummondii, Goodenia pinnatifida, Lotus cruentus, Malvastrum americanum, Mesembryanthemum crystallinum, Nicotiana occidentalis, Podolepis canescens, Rhodanthe floribunda* (KI)*, Salsola tragus* (KI)*, Sisymbrium erysimoides, Sonchus oleraceus* and *Zygophyllum iodocarpum* (KI)*.*

Ecological disturbance

When this vegetation association is in good condition palatable perennial herbs such as *Eriochiton sclerolaenoides* (woolly bindii), *Maireana trichoptera* (pink-seeded bluebush) and *Sclerolaena diacantha* (grey bindii) and perennial grasses such as *Austrodanthonia caespitosa* (wallaby grass) and *Enneapogon cylindricus* are abundant with good cryptogamic crusting. In overgrazed areas palatable species are replaced by *Atriplex acutibractea* (toothed saltbush), *Carrichtera annua* (Ward's weed), *Salsola tragus* (roly poly), *Sclerolaena obliquicuspis* (limestone bindii), *S. patenticuspis* (spear-fruit copperburr), *Rhodanthe floribunda* and *Zygophyllum iodocarpum* and the cryptogamic crust is breaking down or absent. In dry periods these areas are highly susceptible to wind erosion as the annuals and subshrubs die leaving the ground surface exposed.

Gradational associations

ANNH is commonly found in low-lying areas such as claypans grading onto marginal slopes of the surrounding stony plains which support low shrubland such as *Pearl bluebush low shrubland* (PBLS) or their degraded equivalents such as *Open bindii grassland* (OBIG).

Land systems

ANNH is a major habitat type on Kybo land system and a minor habitat on Culver, Kinclaven, Oasis, Pondana, Reid and Vanesk land systems.

H. DRAINAGE FOCI SHRUBLAND

This group of habitat types usually occurs as small localised drainage foci being the lowest parts in the immediate area, commonly vast undulating plains. These drainage sumps are highly fertile and often support unique vegetation associations such as *Donga groves* (DOGR), *Lignum swamp* (LISW) and *Gilgai grassy shrubland* (GGSL). Most of these habitats are uncommon and make up a very small proportion of the survey area, with the exception of Donga groves which are a common habitat through the north of the Nullarbor Plain.

36. Donga groves (DOGR)

Sampling

18 inventory sites, 45 traverse points

General information

Dongas are predominantly found in the north of the survey area. They are rounded, shallow, closed depressions, generally 1.5–3 m below the surrounding stony plain. Donga arrangement can occur randomly or parallel with neighbouring ridge and corridor relief. They commonly have flat clay floors up to several hundred metres across with gently sloped margins. The whole depression may be up to 2 km in diameter, however generally they are significantly smaller. The clay floors often

contain gilgai or crabhole structure with irregular surfaces. Limestone floaters (boulders and slabs) of mixed size have been bought to the surface by alternating wetting and drying cycles associated with gilgai soils. Boulders and slabs can protrude through up to 10 per cent of donga surfaces. Their formation is believed to have occurred by water run-off ponding in depressions in the limestone plain and solution further dissolving the limestone. Dongas are considered solution dolines rather than collapsed caves (Jennings 1963; Lowry 1970). Soils are variable: commonly they consist of deep red/brown non-cracking clays or cracking clays, less commonly of silty-clay loam often with fine aeolian sand deposits.

The donga floors commonly support a sparse tree cover or clumps of small groves over a variety of perennial shrubs, annual herbs and grasses. Dongas are some of the most pastorally productive land units in the survey area. In the pastoral areas water point location is commonly associated with dongas, to the detriment of the associated vegetation. Donga groves serve an important role in 'arid proofing' the northern Nullarbor as a source of browse to be protected for dry periods. The close spacing of water points in dongas and the preferential grazing of the associated vegetation is leading to their deterioration within pastoral boundaries. Mature trees and shrubs are browsed out of reach with no recruitment stages of seedlings or saplings in the lower layers. When these mature trees eventually die, or are killed, there are no younger trees to replace them. The benefits donga groves offer to the local ecosystem, as well as their significant regional ecological value, will be lost.

Donga habitat types were split into four sub-groups according to the dominant genus in the tree or tall shrub strata;

- *Donga berrigan grove* (DBGR) consists of small groves of *Eremophila longifolia* (berrigan) interspersed with perennial shrubs of the low to mid strata and a diverse variety of annuals. DBGR occurs predominantly within dongas in the north-west of the survey area.
- *Donga curara grove* (DCGR) consists of stands of *Acacia tetragonophylla* (curara) that form a sparse perimeter around the centre of a donga. DCGR is commonly found in the north-west and central-north of the survey area.
- *Donga grevillea grove* (DGGR) consists of *Grevillea nematophylla* groves with a low shrub understorey surrounded by dense grass patches. DGGR is predominantly found in the north-east of the survey area.
- *Donga pittosporum grove* (DPGR) consists of scattered stands of *Pittosporum angustifolium* (native willow) surrounded by dense grass patches. DPGR is commonly found in dongas in the north-east of the survey area.

In many instances, dongas contain trees or tall shrub species from all varieties of donga grove habitats. The differences occur in the density within the tall, mid and low shrub strata.

Physiognomy and composition of vegetation

Donga berrigan grove (DBGR) consists of scattered to very scattered (2.5–15 per cent PFC) stands of *Eremophila longifolia* (berrigan) occupying a central location within the donga. Very scattered (5–10 per cent PFC) *Lycium australe* (water bush) or scattered to moderately closed (10–25 per cent PFC) *Atriplex cryptocarpa* commonly surround these berrigan groves. *Austrostipa scabra* (speargrass) commonly dominates the perennial grasses.

Donga curara grove (DCGR) is predominantly vegetated with perennial grasses and annuals in the centre of the donga. The perimeter of these dongas support very scattered to scattered (2.5–15 per cent PFC) stands of *Acacia tetragonophylla* (curara).

Donga grevillea grove (DGGR) consists of a scattered to moderately closed (10–25 per cent PFC) tall shrubland of *Grevillea nematophylla* groves with a low shrub understorey dominated by *Chenopodium curvispicatum* surrounded by dense grass patches of variable composition.

Donga pittosporum grove (DPGR) consists of very scattered to scattered (2.5–15 per cent PFC) stands of *Pittosporum angustifolium* (native willow) with a scattered to moderately closed (10–25 per cent PFC) understorey of *Chenopodium curvispicatum*. The grove is commonly densely surrounded by grasses of variable composition. Very scattered to scattered (2.5–15 per cent PFC) stands of *Acacia tetragonophylla* (curara) commonly occur on the perimeter.

56 perennial species were recorded at the 18 inventory sites, with an average of 10 species

per site, one less than the survey average. 27 annual species were recorded with an average of six species per site.

The following species (by strata) are dominant and/or common:

Trees: Dominant—DBGR: *Eremophila longifolia*

Dominant—DGGR: *Grevillea nematophylla*
Occasional—*Acacia salicina* (north-east only)

Dominant—DPGR: *Pittosporum angustifolium*
Common—*Eremophila longifolia*, *Pittosporum angustifolium*
Others—*Acacia aneura*, *Alectryon oleifolius*, *Santalum spicatum.*

Tall shrubs: Dominant—DCGR: *Acacia tetragonophylla*
Common—*Acacia tetragonophylla* (KI)
Others—*Acacia burkittii* (KI), *A. oswaldii*, *Exocarpos aphyllus.*

Mid shrubs: Dominant—*Lycium australe*
Common—*Pimelea microcephala*, *Scaevola spinescens*
Others—*Atriplex nummularia*, *Eremophila decipiens* (KI), *E. latrobei*, *E. maculata*, *Senna artemisioides* subsp. x *artemisioides* (KI), *S. artemisioides* subsp. x *coriacea* (KI), *Sida calyxhymenia* (KD).

Low shrubs: Dominant—*Chenopodium curvispicatum* (KD), *Enchylaena tomentosa* (KD)
Common—*Atriplex cryptocarpa*, *Lycium australe*
Others—*Atriplex vesicaria*, *Maireana radiata*, *M. sedifolia*, *M. turbinata*, *Ptilotus obovatus*, *Solanum nummularium*, *Zygophyllum aurantiacum.*

Subshrubs: Dominant—*Sclerolaena patenticuspis* (KI)
Common—*Atriplex acutibractea* (KI), *Cullen cinereum*, *Eriochiton sclerolaenoides*, *Erodium aureum*, *Sclerolaena diacantha*, *S. obliquicuspis*, *Sida spodochroma*
Others—*Maireana trichoptera*, *Malvastrum americanum*, *Sclerolaena brevifolia*, Solanum ellipticum, *S. nigrum*, *Teucrium racemosum.*

Perennial grasses: Dominant—Variable; *Austrostipa scabra*, *Eragrostis dielsii*, *E. setifolia*
Common—*Austrodanthonia caespitosa*, *Enneapogon cylindricus*
Others—*Austrostipa platychaeta* (KD), *Enneapogon caerulescens.*

Other plant forms: Occasional—*Amyema quandang* var. *quandang* (mistletoe), *Glycine rubiginosa* (creeper), *Marsdenia australis* (creeper).

Annual species recorded include *Angianthus conocephalus, Calotis hispidula, C. multicaulis, Carrichtera annua* (KI)*, Carthamus lanatus, Citrullus lanatus, Dysphania cristata, Emex australis, Erodium cygnorum, Euphorbia drummondii* (KI)*, E. tannensis* subsp. *eremophila, Goodenia pinnatifida, Lepidium fasciculatum, Lotus cruentus, Malva preissiana, Mesembryanthemum crystallinum* (KI)*, M. nodiflorum, Nicotiana occidentalis* (KI)*, Phlegmatospermum cochlearinum, Rhodanthe floribunda, Salsola tragus* (KI)*, Salvia verbenaca* (KI)*, Sisymbrium erysimoides, Swainsona affinis, Vittadinia* sp., *Xanthium spinosum* and *Zygophyllum iodocarpum* (KI).

Ecological disturbance

The inward drainage of the surrounding landscape results in soil accumulation and improved soil moisture storage. This provides favourable conditions for plant growth. Donga groves offer shelter, a valuable source of browse and support annual plant growth for longer than other areas, typically stony limestone plains. Animals preferentially visit and graze them. The extra soil moisture-holding capacity of dongas means dongas in good condition can support a diverse variety of perennial trees, shrubs and annual herbs.

In the pastoral areas there has been a tendency for water points to be located in dongas leading to the degradation of the vegetation through continuous grazing and the destruction of bush clumps, as herbivores attracted to the water seek browse and shelter. *Eremophila longifolia, Grevillea nematophylla* and *Pittosporum angustifolium* are palatable to stock with foliage that persists during dry periods. They provide an important source of browse during dry conditions. In dongas with water points continuous grazing can eventually lead to the trees' death and reduces the population to only older trees as seedlings and juveniles are eaten.

The dominant genera that differentiate donga habitat types and form the structural nuclei around which donga groves develop are referred to as 'tree-based clumps'. Bush clumps are partly developed by frugivorous birds dispersing the seeds of berry-fruited plants such as *Chenopodium curvispicatum, Enchylaena tomentosa* (ruby saltbush) and *Rhagodia* species. These clumps offer important habitat refuges in these exposed and arid landscapes not only to animals but also to other plants, prolonging the life of annuals and subshrubs, that otherwise do not endure the climatic extremes of the Nullarbor as successfully out in the open. The destruction of nuclei trees and the deterioration of understorey clumps reduces the ecological value of donga groves leading to a reduction in the overall carrying capacity of the landscape as it loses ability to support herbivores during dry periods.

[See tree-based clump condition monitoring photographic guide in the Resource Management chapter.]

The structure and diversity of the tree-based clumps indicates the condition of donga groves. Those in good condition often have an abundance of the palatable grasses *Eragrostis dielsii* (mallee lovegrass) and *E. setifolia* (neverfail) surrounding groves over dense clumps of berry-fruited plants. Dongas near water points are regularly degraded. Degraded donga groves lack tree-based clumps, have no bird dispersed palatable berry plants and have prominent browse lines as a result of herbivorous grazing. The abundance of *Acacia tetragonophylla*-dominated dongas without the development of an understorey through northern pastoral leases indicates the deteriorating condition of donga habitats as a consequence of grazing.

Browsing pressure sequence of dongas dominated by Grevillea nematophylla. *As browsing pressure increases the structure and diversity of the groves deteriorates. If grazing pressure does not ease the forage reserve offered by the donga, which herbivores rely on during dry periods, will be lost.*

In poor condition, donga groves can be reduced to sparse stands of aged trees surrounded by undesirable short-lived species such as *Atriplex acutibractea* (toothed saltbush), *Carrichtera annua* (Ward's weed), *Euphorbia drummondii* (balsam), *Mesembryanthemum crystallinum*, *Nicotiana occidentalis, Salsola tragus* (roly poly), *Salvia verbenaca* (wild sage), *Sclerolaena patenticuspis* (spear-fruit copperburr), *Rhodanthe floribunda* and *Zygophyllum iodocarpum*. Considerable soil loss occurs during dry periods as the donga gradually becomes more open and exposed. The increase in unpalatable species is also compounded by the susceptibility of this vegetation association to invasion by exotic species such as the declared weeds *Carthamus lanatus* (saffron thistle), *Emex australis* (doublegee) and *Xanthium spinosum* (Bathurst burr).

Gradational associations

All forms of donga groves grade upslope from the donga floor into stony plains supporting vegetation associations such as *Mixed shrub bindii grassland* (XSBG), *Open bindii grassland* (OBIG) and/or *Pearl bluebush low shrubland* (PBLS). DBGR and DCGR can also grade upslope from the donga into *Mixed shrub bindii grassland* (XSBG).

Land systems

- DBGR is a minor habitat type on Balgair, Kanandah, Kitchener, Kybo, Nurina and Nyanga land systems.

*Curara (*Acacia tetragonophylla*) dominated donga in poor condition. Trampling and grazing have reduced the soil to a loose, powdery surface that is readily deflated by wind.*

- DCGR is a major habitat type on Kinclaven land systems and a minor habitat type on Balgair, Bullseye, Gafa, Kanandah, Kitchener, Kybo, Naretha, Nyanga and Oasis land systems.
- DGGR a major habitat type on Bullseye and Oasis land systems and is a minor habitat type on Carlisle, Jubilee, Kinclaven, Nyanga, Reid and Seemore land systems.
- DPGR is a major habitat type on Oasis land system and a minor habitat type on Carlisle, Bullseye, Gafa, Jubilee, Kyarra, Reid and Skink land systems.

37. Drainage depression saltbush shrubland (DDSS)

Sampling

1 inventory site, 7 traverse points

General information

DDSS occurs in claypans and clay plains in the west of the survey area. DDSS can also occur in narrow drainage tracts associated with ancient river courses. Soils are red/brown non-cracking clays.

Physiognomy and composition of vegetation

DDSS comprises a moderately closed (20–25 per cent PFC) low shrubland of *Atriplex* species. *Acacia burkittii* (jam) and *Eremophila longifolia* (berrigan) occur as closed stands or as isolated individuals.

11 perennial species and four annual species were present at the one inventory site.

The following species are dominant and/or common:

Trees:	Dominant—Not present as a recognisable stratum Occasional—*Eremophila longifolia, Pittosporum angustifolium.*
Tall shrubs:	Dominant—Not present as a recognisable stratum Common—*Acacia burkittii* (KI) Other—*Acacia oswaldii.*
Low shrubs:	Dominant—Variable; *Atriplex cryptocarpa* (KI) Common—*Chenopodium curvispicatum* (KD), *Enchylaena tomentosa* (KD), *Maireana sedifolia* Other—*Solanum nummularium.*

Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex acutibractea* (KI), *Sclerolaena patenticuspis* (KI) Other—*Swainsona affinis.*

Annual species recorded include *Erodiophyllum elderi, Mesembryanthemum crystallinum, Nicotiana occidentalis* (KI) and *Sisymbrium erysimoides.*

Ecological disturbance

Due to a lack of sampling not much is known of the disturbance mechanisms for DDSS. The low-lying landscape position makes it prone to receiving concentrated flow with potential for greater soil moisture retention. This makes it prone to preferential grazing. Past grazing pressure is likely to have favoured the emergence of more grazing tolerant, less palatable species such as *Atriplex acutibractea* (toothed saltbush), *A. cryptocarpa* and *Sclerolaena patenticuspis* (spear-fruit copperburr).

Tree-based clumps commonly develop around *Acacia burkittii* (jam), *A. oswaldii, Eremophila longifolia* (berrigan) and *Pittosporum angustifolium* (native willow) with bird-dispersed berry-fruited plants common in the understorey. Such palatable shrubs as *Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush) may decrease under continuous grazing pressure.

Gradational associations

DDSS grades upslope into stony plains supporting *Pearl bluebush low shrubland* (PBLS).

Land systems

DDSS is a minor habitat type on Naretha and Pondana land systems.

38. Drainage depression mixed shrub shrubland (DDXS)

Sampling

1 inventory site

General information

DDXS occurs in drainage foci at the base of limestone hummocks (low rises) on the Toolinna and Abrakurrie Limestone towards the coast in the south of the survey area. The surface has a sparse (2 per cent) stony mantle of large (20–60 cm) limestone fragments. Soils are light calcareous loams overlain by dark ‘organic’ loams.

Physiognomy and composition of vegetation

DDXS occurs as a scattered (15–20 per cent PFC) tall shrubland of *Acacia cyclops* (coastal wattle) with very scattered (2.5–5 per cent PFC) *Eucalyptus yalatensis* (yalata mallee) forming the tree stratum. *Acacia cyclops* and *Eucalyptus yalatensis* form bush clumps providing shelter and support for a variety of perennial shrubs.

21 perennial species, including one priority species, and two annual species were recorded at the one inventory site.

The following species (by stratum) were dominant and/or common:

Trees:	Dominant—*Eucalyptus yalatensis* (mallee) Common—*Santalum acuminatum.*
Tall shrubs:	Dominant—*Acacia cyclops* Common—*Templetonia retusa*, *Exocarpos sparteus*.
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Acacia anceps*, *Scaevola spinescens,*
Low shrubs:	Dominant—Not present as a recognisable stratum Common—*Acacia erinacea*, *Enchylaena tomentosa*, *Rhagodia crassifolia* Others—*Acrotriche patula*, *Eremophila decipiens* subsp. *decipiens.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Heliotropium asperrimum*, *Sclerolaena patenticuspis* Other—*Opercularia loganioides.*
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrodanthonia caespitosa.*
Other plant forms:	Common—*Billardiera fusiformis* (creeper), *Cassytha melantha* (creeper), *Lepidosperma* sp. (perennial sedge), *Tetraria capillaris* (perennial sedge),

Annual species recorded include *Euphorbia drummondii* and *Podolepis canescens.*

Ecological disturbance

This habitat occurs outside of pastoral lease boundaries. Insufficient sampling precludes detailed quantitative description of disturbance mechanisms. These areas receive localised water shed from the stony surfaces of the limestone hummocks. In comparison to the surrounding land units these drainage foci have accumulated deeper soils, infrequently being areas with higher soil moisture content supporting subshrubs, *Austrodanthonia caespitosa* (wallaby grass) and annuals. This makes DDXS ecologically important as a preferentially sought after food source for the native herbivores living among the closed low woodland (LOMW) and scrub that dominate the area back from the Baxter Cliffs.

Much of the species diversity in this habitat type is found within the bush clumps under *Acacia cyclops*, *Eucalyptus yalatensis* and tall shrubs. Deterioration in bush clump health is likely to have a significant impact on the floristic diversity of the associated plant community.

Thysanotus baueri, a Priority 1 species on the declared rare and priority flora list, was recorded in this habitat. As such these habitat types are considered areas of high conservation value.

Gradational associations

DDXS is surrounded by irregular limestone hummocks supporting *Low mallee woodland* (LOMW).

Land systems

DDXS is a minor habitat on Toolinna land system.

39. Drainage tract acacia shrubland (DRAS)

Sampling

1 inventory site, 5 traverse points

General information

DRAS was previously described in the north-eastern Goldfields survey (Pringle, Van Vreeswyk & Gilligan 1994) as *Drainage mulga shrubland* (DRMS). It was re-described in the Sandstone–Yalgoo–Paynes Find survey (Payne et al. 1998) as DRAS to recognise the prominence of acacias other than *Acacia aneura* (mulga). On the Nullarbor, DRAS is restricted to Rawlinna Station and occurs in both narrow and wide drainage tracts. Some of these shallow drainage lines may represent ancient river courses draining from the north-west. Some drainage tracts feature fine well-worked quartz grains in the soil profile. Soils are calcareous loamy earths.

Physiognomy and composition of vegetation

DRAS occurs as a very scattered (2.5–5 per cent PFC) shrubland of acacias and *Ptilotus obovatus* (cotton bush).

13 perennial species and four annual species were recorded at the one inventory site.

The following species (by strata) were dominant and/or common:

Trees:	Dominant—Not present as a recognisable stratum Common—*Acacia aneura, Myoporum platycarpum* Other—*Santalum spicatum.*
Tall shrubs:	Dominant—*Acacia burkittii* (KI)*, A. tetragonophylla* Common—Nil.
Low shrubs:	Dominant—*Ptilotus obovatus* (KD) Common—*Enchylaena tomentosa* (KD)*, Sida calyxhymenia* (KD).
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Sclerolaena patenticuspis* (KI)*, Sida spodochroma.*
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrostipa scabra, Enneapogon caerulescens, E. cylindricus.*

Annual species recorded include *Carrichtera annua* (KI)*, Nicotiana occidentalis, Salsola tragus* (KI) and *Sisymbrium erysimoides.*

Ecological disturbance

Insufficient information was obtained for a detailed report on disturbance. From similar occurrences of DRAS from other surveys, overgrazing will cause decline in rangeland condition, resulting in the reduction of palatable perennial shrubs and grasses such as *Enchylaena tomentosa* (ruby saltbush), *Sida calyxhymenia* (tall sida), *Ptilotus obovatus* (cotton bush) and *Enneapogon* species may result. *Santalum spicatum* (sandalwood) is a

common source of browse; the presence of juveniles indicates improving range condition. Unpalatable species such as *Carrichtera annua* (Ward's weed), *Sclerolaena patenticuspis* (spear-fruit copperburr) and *Salsola tragus* (roly poly) may increase under continuous grazing pressure.

Gradational associations

DRAS grades out of the drainage line into the surrounding *Mixed acacia open shrubland* (XAOS).

Land systems

DRAS is a minor habitat type on Naretha land system.

40. Gilgai grassy shrubland (GGSL)

Sampling

11 inventory sites, 24 traverse points

General information

Gilgai formations result from the wetting and drying of clays with high montmorillonite content. Areas with gilgai soils are commonly found in the north of the survey area. Gilgai structures often occur in dongas or at the base of depressions on the limestone plain. In the west of the survey area gilgai structures also occur on the drainage floors of the large depressions within the calcrete Nyanga Plain. Soil heaving associated with wetting and drying cycles of gilgai soils bring limestone rocks to the surface. Limestone debris ranging from coarse fragments to boulders (6–200 cm in diameter) can cover up to 20 per cent of the surface. Soils are cracking clays.

Physiognomy and composition of vegetation

GGSL commonly occurs as low shrubs of very scattered (5–10 per cent PFC) *Lycium australe* (water bush) among dense patches of perennial grass of variable composition. Occasionally, isolated *Eremophila longifolia* (berrigan) or *Pittosporum angustifolium* (native willow) trees are present.

41 perennial species were recorded at the 11 inventory sites, with an average of 13 species per site, two greater than the survey average. 25 annual species were recorded, with an average of nine species per site.

The following species are dominant and/or common:

Trees:	Dominant—Nil Common—Occasionally; *Eremophila longifolia, Pittosporum angustifolium* Other—*Acacia papyrocarpa.*
Tall shrubs:	Dominant—Not present as a recognisable stratum Common—*Acacia oswaldii, A. tetragonophylla* (KI).
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex nummularia, Eremophila maculata, Nitraria billardierei* Others—*Pimelea microcephala, Scaevola spinescens, Senna artemisioides* subsp. x *artemisioides* (KI), *S. artemisioides* subsp. x *coriacea* (KI).
Low shrubs:	Dominant—*Lycium australe* Common—*Atriplex vesicaria, Chenopodium curvispicatum, Enchylaena tomentosa, Maireana radiata, M. sedifolia* Others—*Atriplex cryptocarpa, Zygophyllum aurantiacum*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex acutibractea* (KI), *Cullen cinereum, Eriochiton sclerolaenoides, Sclerolaena diacantha, S. obliquicuspis, S. patenticuspis, Sida spodochroma, Solanum ellipticum* Others—*Erodium aureum, Maireana trichoptera, Sida intricata, Swainsona affinis.*
Perennial grasses:	Dominant—Variable; *Austrostipa scabra, Eragrostis dielsii* (KD), *E. setifolia* (KD). Common—*Austrodanthonia caespitosa* (KD) Others—*Enneapogon caerulescens, E. cylindricus, Panicum decompositum.*
Other plant forms:	Occasional—*Glycine rubiginosa* (creeper), *Marsdenia australis* (creeper).

Annual species recorded include *Angianthus conocephala, Brachyscome* sp., *Calotis multicaulis, Carrichtera annua* (KI), *Centaurium erythraea, Chenopodium murale, Citrullus lanatus, Dysphania*

melanocarpa forma *leucocarpa, Erodium cygnorum, Euphorbia drummondii, Goodenia pinnatifida, Lepidium* sp., *Lotus cruentus, Malva preissiana, Mesembryanthemum crystallinum* (KI), *M. nodiflorum, Nicotiana goodspeedii, N. occidentalis* (KI), *Oxalis corniculata, Podolepis canescens, Rhodanthe floribunda* (KI), *Salsola tragus* (KI), *Sisymbrium erysimoides, Vittadinia* sp. and *Zygophyllum iodocarpum* (KI).

Ecological disturbance

Due to the landscape position of GGSL as drainage foci and the potential to retain soil moisture for longer periods than the surrounding stony plains, this vegetation association supports an abundance of short-lived species. GGSL is preferentially grazed due to the abundance of palatable grasses it supports, particularly *Eragrostis* species. Under continuous heavy grazing the palatable grasses *Austrodanthonia caespitosa* (wallaby grass), *Eragrostis dielsii* (mallee lovegrass) and *E. setifolia* (neverfail) decline and are replaced by less palatable grasses and annuals. GGSL is also susceptible to invasion by exotic species.

Gradational associations

GGSL grades into *Open bindii grassland* (OBIG), *Mixed shrub bindii grassland* (XSBG) and *Pearl bluebush low shrubland* (PBLS) on the surrounding stony limestone plains.

Land systems

GGSL is a major habitat type on Nurina land system and a minor habitat type on Balgair, Jubilee, Kanandah, Kinclaven, Koonjarra, Nyanga and Seemore land systems.

41. Lignum swamp (LISW)

Sampling

4 inventory sites

General information

LISW was previously described as a minor habitat type in the Sandstone–Yalgoo–Paynes Find survey area (Payne et al. 1998). LISW occurs within areas where water inundation occurs periodically such as in claypans, low-lying areas of karst depressions (‘corridors’ and dongas) and in ancient river courses. These areas sometimes have gilgai structure with *Muehlenbeckia florulenta* (lignum) distributed according to the micro-relief, preferring the raised areas. Soils are calcareous loamy earths and cracking clays where gilgai are present.

LISW occurs occasionally and is found randomly through the survey area dependent on local topography in areas subject to inundation.

Physiognomy and composition of vegetation

LISW is dominated by a very scattered to scattered (5–20 per cent PFC) shrubland of *Muehlenbeckia florulenta*. Species that can cope with temporary inundation such as *Marsilea hirsuta* (Nardoo) and *Rhagodia ulicina* are common. *Muehlenbeckia florulenta* grows in closed communities with few other plants.

22 perennial species were recorded at the four inventory sites, with an average of seven species per site, four less than the survey average. 15 annual species were recorded, with an average of six species per site.

The following species (by strata) were dominant and/or common:

Mid shrubs:	Dominant—*Muehlenbeckia florulenta* Other—*Nitraria billardierei.*
Low shrubs:	Dominant—Not present as a recognisable stratum Common—*Rhagodia ulicina* Others—*Atriplex vesicaria*, *Enchylaena tomentosa*, *Lycium australe*, *Maireana sedifolia*, *Rhagodia crassifolia.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex acutibractea* Others—*Cullen cinereum*, *Maireana trichoptera*, *Sclerolaena obliquicuspis*, *S. patenticuspis*, *Solanum ellipticum*, *S. nigrum*, *Swainsona affinis.*
Perennial grasses:	Dominant—*Eragrostis setifolia* (KD) Common—*Eragrostis dielsii* (KD) Others—*Enneapogon caerulescens*, *Enteropogon ramosus* (KD), *Eragrostis australasica.*
Other plant forms:	Common—*Marsilea hirsuta* (fern).

Annual species recorded include *Carrichtera annua* (KI), *Centaurea melitensis, Chenopodium murale, Citrullus lanatus, Eriachne* sp., *Goodenia pinnatifida, Isolepis congrua, Medicago* sp., *Menkea* sp., *Mesembryanthemum crystallinum* (KI), *Nicotiana occidentalis* (KI), *Rhodanthe floribunda, Senecio* sp., *Sonchus oleraceus* and *Zygophyllum iodocarpum* (KI).

Ecological disturbance

Muehlenbeckia florulenta is rarely eaten and has very low forage value. The palatable grasses *Eragrostis dielsii* (mallee lovegrass) and *E. setifolia* (neverfail) may decline under continuous grazing pressure.

Gradational association

LISW has defined boundaries dependent on local topography being confined to areas subject to periodic inundation. It is commonly surrounded by *Pearl bluebush low shrubland* (PBLS) or *Bladder saltbush shrubland* (BSSL).

Land systems

LISW is a minor habitat type on Bullseye, Gafa, Kinclaven, Koonjarra and Nyanga land systems.

42. Plain mixed low shrubland (PXLS)

Sampling

2 inventory sites, 3 traverse points

General information

PXLS occurs in clay depressions to the south of the survey area. Soils are calcareous loamy earths and red/brown non-cracking clays.

Physiognomy and composition of vegetation

PXLS comprises scattered (10–15 per cent PFC) mid shrubland dominated by *Eremophila* species.

30 perennial species were recorded at the two inventory sites, with an average of 17 species per site, six greater than the survey average. Six annual species were recorded with an average of three species per site.

The following species (by strata) were dominant and/or common:

Tall shrubs:	Dominant—Not present as a recognisable stratum Common—*Acacia cyclops, Geijera linearifolia* Other—*Exocarpos aphyllus.*
Mid shrubs:	Dominant—*Eremophila decipiens* (KI)*, E. deserti* Common—*Atriplex nummularia, Nitraria billardierei* Others—*Leptomeria pachyclada, Solanum symonii.*
Low shrubs:	Dominant—Occasionally; *Lawrencia squamata* (KI) Common—*Enchylaena tomentosa* (KD), *Eremophila parvifolia* (KD)*, Lycium australe, Maireana sedifolia, Olearia calcarea, O. muelleri, Tecticornia* sp.
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Sclerolaena diacantha* (KD)*, Sida spodochroma* Others—*Hypoxis glabella* var. *glabella, Minuria cunninghamii, Senecio quadridentatus, Solanum nigrum, Wahlenbergia communis, Wurmbea tenella.*
Perennial grasses:	Dominant—*Austrodanthonia caespitosa* (KD)*, Austrostipa scabra* Common—*Austrostipa elegantissima* (KD), *A. platychaeta* (KD).
Other plant forms:	Occasional—*Cassytha melantha* (creeper).

Annual species recorded include *Anagallis arvensis, Carduus nutans, Erodium cicutarium, Nicotiana goodspeedii, Sonchus oleraceus* and *Xanthium spinosum.*

Ecological disturbance

This vegetation association was insufficiently sampled to obtain detailed quantitative information regarding disturbance characteristics. Overgrazing of PXLS is likely to result in a decline in palatable shrubs such as *Enchylaena tomentosa* (ruby saltbush) and *Sclerolaena diacantha* (grey bindii), and the perennial grasses *Austrodanthonia caespitosa* (wallaby grass), *Austrostipa elegantissima* (feather speargrass) and *A. platychaeta*.

Gradational associations

PXLS changes abruptly into the surrounding *Low mallee woodland* (LOMW) and *Eucalypt mixed scrub woodland* (EXSW) at the boundary of the karst depression and the resumption of the stony calcrete plain.

Land system

PXLS is a minor habitat type on Caiguna and Culver land systems.

I. SHRUBLAND AND WOODLAND ON LAKE MARGINS AND SALINE DEPRESSIONS

This group of habitat types is generally confined to the margins of lake beds or occurs in saline low-lying closed or open depressions within undulating plains. Occurring on saline and gypsiferous soils, these habitat types characteristically support halophytic plants, such as species of *Tecticornia* (samphire) and *Frankenia* (frankenia). They make up a small proportion of the survey area.

43. Kopi dune woodland (KOPI)

Sampling

2 inventory sites, 8 traverse points

General information

KOPI has previously been described in the north-eastern Goldfields (Pringle, Van Vreeswyk & Gilligan 1994) and the Sandstone–Yalgoo–Paynes Find (Payne et al. 1998) survey areas. KOPI occurs on the kopi dunes surrounding Lake Boonderoo, fringing Ponton Creek and salt lakes in the very south-west of the survey area. Kopi dunes form by prevailing winds deflating lake beds and building up powdery dunes of gypsum around the lake margins. The dunes have gently inclined slopes of up to 3 per cent and coarse (2–6 cm) limestone fragments are common on the surface. Soils are calcareous loamy earths.

Physiognomy and composition of vegetation

KOPI occurs as a scattered (10–20 per cent PFC) low shrubland of *Tecticornia* species (samphire) and *Chenopodium curvispicatum.* The overstorey consists of very scattered (2.5–5 per cent PFC) *Casuarina pauper* (black oak). In the south-west of the survey area *Eucalyptus* species are also present on kopi dunes alongside *Casuarina pauper*. Around Lake Boonderoo many trees are dead as a result of inundation when the water level increased following Cyclone Bobby in 1995. Areas supporting this vegetation around Lake Boonderoo are now in a state of ecological transition as water level subsides.

31 perennial species were recorded at the two inventory sites, with an average of 16 species per site, five greater than the survey average. Three annual species were recorded at one site.

The following species (by strata) were dominant and/or common:

Trees:	Dominant—*Casuarina pauper* Common—*Myoporum platycarpum*, *Eucalyptus concinna, E. conglobata.*
Tall shrubs:	Dominant—Not present as a recognisable stratum Common—*Senna artemisioides* subsp. x *coriacea* Others—*Acacia ligulata*, *Geijera linearifolia.*
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex nummularia*, *Cratystylis conocephala*, *Eremophila scoparia* Others—*Acacia nyssophylla*, *Dodonaea lobulata.*
Low shrubs:	Dominant—*Chenopodium curvispicatum* (KD), *Tecticornia doleiformis*, *Tecticornia sp*. Common—*Atriplex vesicaria* (KD), *Disphyma crassifolium*, *Enchylaena tomentosa* (KD), *Frankenia densa*, *Lycium australe*, *Maireana erioclada*, *Olearia ramosissima*, *Rhagodia crassifolia* (KD), *Zygophyllum aurantiacum.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Maireana trichoptera*, *Sclerolaena diacantha* (KD), *S. obliquicuspis*, *S. patenticuspis.*
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrodanthonia caespitosa*, *Austrostipa scabra.*
Other plant forms:	Occasional—*Dianella revoluta* (lily).

Annual species recorded include *Carrichtera annua, Eriachne* sp. and *Zygophyllum glaucum.*

Ecological disturbance

Inundation due to the associated effects of Cyclone Bobby in 1995 dramatically altered the composition and structure of Lake Boonderoo KOPI. Much of the casuarina woodland surrounding the lake has died and is now in a state of transition as water levels subside. The high soil salinity is influencing the vegetation colonisation sequence.

After infrequent periods of inundation Lake Boonderoo is known to contain fresh water, however during the survey period the water was highly saline due to the concentration of salts through evaporation. Grazing impact will be determined by the quality of nearby drinking water. If the quality of drinking water is fresh then continuous grazing may result and a decline in the palatable shrubs *Atriplex vesicaria* (bladder saltbush), *Chenopodium curvispicatum, Enchylaena tomentosa* (ruby saltbush), *Maireana trichoptera* (pink-seeded bluebush), *Rhagodia crassifolia* and *Sclerolaena diacantha* (grey bindii) could be expected. However the absence of these species from an area may be natural rather than as a result of grazing.

Gradational association

Sloping down to the margin of Lake Boonderoo, KOPI grades into *Samphire shrubland* (SAMP) and/or *Plain mixed halophyte shrubland* (PXHS) dominated by *Atriplex* and *Tecticornia* species.

Land systems

KOPI is a minor habitat type on Boonderoo, Lefroy and Ponton land systems.

44. Sandy bank lake shrubland (SBLS)

Sampling

2 inventory sites

General information

SBLS has been previously described in the north-eastern Goldfields (Pringle, Van Vreeswyk and Gilligan 1994) and the Sandstone–Yalgoo–Paynes Find (Payne et al. 1998) survey areas. It occurs on sandy banks adjacent to bare lake beds. The formation of the sandy banks is due to a combination of transported sandy sediment via prevailing winds, infrequent lake inundation and by high energy sheet flow from landforms adjacent to and above the sandy slopes. Soils are generally deep red sands.

The banks support two different floristic components: non-halophytic species such as *Acacia* spp., *Casuarina pauper* (black oak), *Eucalyptus* spp. and *Triodia scariosa* (spinifex); and chenopod species such as *Atriplex vesicaria* (bladder saltbush), *Chenopodium curvispicatum*, *Enchylaena tomentosa* (ruby saltbush), *Maireana sedifolia* (pearl bluebush) and *Rhagodia* spp. The morphology of the sandy banks appears to influence the proportion of non-halophytic shrubs to halophytic shrubs occurring adjacent to SBLS on the Boonderoo lake bed. These red, deep sandy soils provide the associated vegetation with increased water availability through enhanced infiltration, deeper storage and reduced evaporation rates.

Physiognomy and composition of vegetation

SBLS consists of a non-halophytic component which generally is more prominent on the upper banks. Chenopods become more abundant on the lower banks and bank margins, possibly due to the development of duplex soils and increasing soil salinity associated with the proximity to Lake Boonderoo. This variability is observed in the range of composition and form of this vegetation type.

SBLS occurs as a closed (30–50 per cent PFC) tall shrubland, commonly dominated by species of acacia, such as *Acacia ligulata* (umbrella bush). The tree component is variable, the species composition often reflecting a transition from adjacent habitats. Low shrubs are prominent and perennial grasses such as *Triodia scariosa* (spinifex) vary from common to absent.

21 perennial species were recorded at the two inventory sites.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—Not present as a recognisable stratum Common—*Casuarina pauper, Eucalyptus concinna, E.* sp. *Fraser Range* Others—*Myoporum platycarpum, Psydrax attenuata.*
Tall shrubs:	Dominant—*Acacia ligulata* Common—*Eremophila dempsteri.*
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Eremophila latrobei* subsp. *glabra* Others—*Grevillea* sp., *Rhagodia preissii* subsp. *preissii* (KD), *Senna* sp.
Low shrubs:	Dominant—Not present as a recognisable stratum Common—*Atriplex vesicaria* (KD), *Chenopodium curvispicatum* (KD), *Enchylaena tomentosa* (KD), *Maireana sedifolia, Ptilotus obovatus,*

	Rhagodia ulicina (KD), *Solanum nummularium.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Maireana trichoptera.*
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Triodia scariosa.*
Other plant forms:	Occasional—*Marsdenia australis* (creeper).

Only one annual (*Eriachne* sp.) was observed at the time of sampling, however it should be noted that the area was in a dry period.

Ecological disturbance

Insufficient information was obtained for a qualitative assessment of disturbance mechanisms. The most noticeable indicators of grazing impact in SBLS would be in the palatable low shrub component where pastures become more saline. Under heavy grazing the palatable shrubs *Atriplex vesicaria* (bladder saltbush), *Chenopodium curvispicatum*, *Enchylaena tomentosa* (ruby saltbush), *Maireana trichoptera* (pink-seeded bluebush) and *Rhagodia* spp. may decline. However, the absence of these species may not be as a result of grazing and may reflect natural variability in species composition.

Gradational associations

SBLS grades upslope on to calcrete plains overlain by sand supporting *Mallee hummock grass (spinifex) woodland* (MHGW). The lower slopes of sandy banks are usually clearly defined as the adjacent halophytic plant communities, *Plain mixed halophyte shrubland* (PXHS), associated with Lake Boonderoo replace the non-halophytic species.

Land systems

SBLS is a minor habitat type on Boonderoo and Ponton land systems.

45. Plain mixed halophyte shrubland (PXHS)

Sampling

27 inventory sites, 316 traverse points

General information

PXHS has previously been described in the north-eastern Goldfields (Pringle, Van Vreeswyk & Gilligan 1994), Sandstone–Yalgoo–Paynes Find (Payne et al. 1998) and Pilbara (Van Vreeswyk et al. 2004) survey areas. It was also described in the Murchison survey area (Curry et al. 1994) as Mixed halophyte shrubland (MXHS). PXHS commonly occurs in saline depressions on marginal slopes or within drainage floors and in clay depressions between gently undulating plains. It also occurs on lake beds and margins. Soils are calcareous loamy earths or red/brown non-cracking clays. Where present at lake bed margins soils may be saline wet soils or red deep sands. It is found throughout the survey area.

Physiognomy and composition of vegetation

PXHS exists as a scattered to moderately closed (10–25 per cent PFC) low shrubland of *Atriplex vesicaria* (bladder saltbush), *Maireana sedifolia* (pearl bluebush) and *Tecticornia* species (samphire).

68 perennial species were recorded at the 27 inventory sites, with an average of 11 species per site, the survey average. 22 annual species were recorded, with an average of three species per site.

The following species (by strata) were dominant and/or common:

Trees:	Dominant—Not present as a recognisable stratum Others—*Acacia papyrocarpa, Eucalyptus gracilis, Melaleuca quadrifaria, Myoporum platycarpum, Pittosporum angustifolium, Santalum acuminatum, Tamarix aphylla.*
Tall shrubs:	Dominant—Not present as a recognisable stratum Others—*Exocarpos aphyllus, Geijera linearifolia.*
Mid shrubs:	Dominant—Occasionally: *Atriplex nummularia* Common—*Cratystylis conocephala, Nitraria billardierei* Others—*Eremophila decipiens* (KI), *E. deserti, E. scoparia* (KI), *Scaevola spinescens, Senna artemisioides* subsp. x *artemisioides* (KI), *S. artemisioides* subsp. x *coriacea* (KI).
Low shrubs:	Dominant—*Atriplex vesicaria* (KD), *Maireana sedifolia, Tecticornia doleiformis, Tecticornia* sp. Common—*Atriplex cryptocarpa,*

A. stipitata, Enchylaena tomentosa (KD)*, Frankenia densa*, *Gunniopsis calcarea, Lawrencia squamata, Lycium australe, Maireana erioclada, M. georgei* (KD)*, M. oppositifolia, M. turbinata, Nitraria billardierei*
Others—*Chenopodium curvispicatum* (KD)*, Cratystylis subspinescens* (KD)*, Disphyma crassifolium, Gunniopsis quadrifida, Olearia calcarea, O. muelleri, Rhagodia crassifolia, R. ulicina, Solanum nummularium, Westringia rigida.*

Subshrubs: Dominant—Not present as a recognisable stratum
Common—*Cullen cinereum, Eriochiton sclerolaenoides* (KD)*, Maireana tomentosa* (KD)*, M. trichoptera* (KD)*, Sclerolaena diacantha* (KD)*, S. obliquicuspis* (KI)*, S. patenticuspis* (KI)
Others—*Atriplex acutibractea* (KI)*, Lawrencia spicata, Minuria cunninghamii, Sclerolaena densiflora* (KI)*, Senecio spanomerus, Sida spodochroma, Wurmbea tenella, Zygophyllum billardierei.*

Perennial grasses: Dominant—Not present as a recognisable stratum
Common—*Austrodanthonia caespitosa, Austrostipa scabra*
Others—*Austrodanthonia setacea, Austrostipa drummondii, A. platychaeta* (KD)*, Enneapogon caerulescens, Enteropogon ramosus.*

Other plant forms: Occasional—*Carpobrotus virescens* (succulent perennial herb), *Dianella revoluta* (lily).

Annual species recorded include *Angianthus conocephalus, Atriplex codonocarpa, Brachyscome ciliaris, Calandrinia* sp., *Calotis* sp., *Carrichtera annua* (KI)*, Eriachne* sp., *Erodium* sp., *Euphorbia drummondii, Lepidium* sp., *Nicotiana occidentalis* (KI)*, Oxalis corniculata, Podolepis canescens, Rhodanthe chlorocephala, Salsola tragus* (KI)*, Senecio pinnatifolius, Sonchus oleraceus, Trichanthodium skirrophorum, Vittadinia humerata, Xanthium spinosum, Zygophyllum iodocarpum* (KI) and *Z. ovatum.*

Ecological disturbance

The low-lying landscape position can improve growing conditions for plants by providing areas with longer higher soil moisture retention. This can lead to an abundance in subshrubs and annuals, which in turn can lead to preferential grazing by herbivores. If good quality water is available grazing pressure can lead to reductions in palatable plants. Where PXHS has previously been described (Curry et al. 1994; Pringle, Van Vreeswyk & Gilligan 1994; Payne et al. 1998; Van Vreeswyk et al. 2004) it was found that the most sensitive indicator of grazing impact was the prominence of key decreaser species and, to a lesser extent, increaser species. Under heavy grazing pressure palatable shrubs that tend to decrease include *Atriplex vesicaria*, *Chenopodium curvispicatum, Enchylaena tomentosa* (ruby saltbush), *Eriochiton sclerolaenoides* (woolly bindii), *Maireana tomentosa* (felty bluebush), *M. trichoptera* (pink-seeded bluebush) and *Sclerolaena diacantha* (grey bindii). With the loss of palatable species *Tecticornia* spp. (samphire) can become dominant. Other increaser plants include species of *Senna* and *Eremophila*. If unpalatable subshrubs such as *Atriplex acutibractea* (toothed saltbush), *Sclerolaena densiflora* (hairy bindii), *S. obliquicuspis* (limestone bindii) and *S. patenticuspis* (spear-fruit copperburr) occur in abundance repeatedly each year then an area is also considered to be in poor condition.

The saline nature of the subsoil makes it susceptible to scald development. As scalds begin to coalesce the capacity of the area to support plant growth is reduced. Loss of perennial species and scald development can result in accelerated soil loss through wind erosion.

The declared weeds *Tamarix aphylla* (athel pine) and *Xanthium spinosum* (Bathurst burr) were recorded at this habitat type.

Gradational associations

As the subsoil becomes less saline PXHS commonly grades into *Bladder saltbush shrubland* (BSSL) and *Speargrass and wallaby grass open grassland* (SWOG). Where kopi or sandy dunes surround Lake Boonderoo and the salt lakes of the Lefroy land system or fringe Ponton Creek, PXHS is bordered by *Kopi dune woodland* (KOPI) or *Sandy bank lake shrubland* (SBLS). As eucalypt or myall species start to appear but soils remain saline PXHS grades

into *Eucalypt mixed halophyte shrubland* (EXHS) or *Myall mixed halophyte shrubland* (MHXS). PXHS depressions are commonly surrounded by *Pearl bluebush low shrubland* (PBLS) or less commonly in the south-east by *Myall saltbush shrubland or woodland* (MSAS).

Land systems

PXHS is a major habitat type on Boonderoo, Damper, Vanesk and Virginia land systems and a minor habitat on Arubiddy, Caiguna, Chowilla, Nanambinia, Nightshade, Ponton, Reid, Shakehole, Thampanna and Woorlba land systems.

46. Samphire shrubland (SAMP)

Sampling

5 inventory sites, 29 traverse points

General information

SAMP was previously described in the Carnarvon Basin (Payne, Curry & Spencer 1987), north-eastern Goldfields (Pringle, Van Vreeswyk & Gilligan 1994), Murchison River catchment (Curry et al. 1994) and Sandstone–Yalgoo–Paynes Find (Payne et al. 1998) surveys. SAMP is associated with highly saline, gypsiferous soils fringing the lake beds in the south-west of the survey area. It is also found on the Roe Plains on the Damper land system and in saline depressions between gentle undulations in the south on the Bunda Plateau. Soils are calcareous shallow loams and loamy earths, and red/brown non-cracking clays.

Physiognomy and composition of vegetation

SAMP comprises a low shrubland of very scattered to scattered (5–20 per cent PFC) *Tecticornia* species (samphire).

15 perennial species were recorded at the five inventory sites, with an average of five species per site, six less than the survey average. Five annual species were recorded, with an average of two species per site.

The following species (by strata) are dominant and/or common:

Mid shrubs:	Dominant—Not present as a recognisable stratum Other—*Nitraria billardierei.*
Low shrubs:	Dominant—*Tecticornia disarticulata, T. doleiformis* Common—*Atriplex vesicaria* (KD)*, Lawrencia squamata, Maireana erioclada, M. oppositifolia* Others—*Frankenia densa, Gunniopsis calcarea, Kippistia suaedifolia.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Sclerolaena diacantha* (KD) Other—*Lawrencia spicata.*
Perennial grasses:	Dominant—Not present as a recognisable stratum Others—*Austrostipa scabra.*
Other plant forms:	Occasional—*Carpobrotus modestus* (succulent perennial herb), *C. virescens* (succulent perennial herb).

Annual species recorded include *Brachyscome ciliaris, Lepidium* sp., *Senecio pinnatifolius, Sonchus oleraceus* and *Trichanthodium skirrophorum.*

Ecological disturbance

Due to the high salt content of most plants, predominantly samphires, the habitat type is resilient to grazing. Pringle, Van Vreeswyk and Gilligan (1994) noted stock preferred other less saline pastures where available, unless nearby water supplies are fresh and there is little else to eat. Some of the more palatable species such as *Atriplex vesicaria* (bladder saltbush) and *Sclerolaena diacantha* (grey bindii), comprising a minor component of this vegetation association, may be removed through grazing, though this is not a reliable indicator of condition as such species can be absent from ungrazed areas.

Gradational associations

SAMP populations associated with lake systems in the south-west of the survey area are commonly surrounded by *Kopi dune woodland* (KOPI) or *Sandy bank lake shrubland* (SBLS). Elsewhere SAMP commonly grades upslope to *Speargrass and wallaby grass open grassland* (SWOG) or *Plain mixed chenopod shrubland* (PXCS).

Land systems

SAMP is the dominant habitat type on Damper land system and a minor habitat type on Boonderoo, Lefroy and Ponton land systems.

J. COASTAL ZONE SCRUBLAND AND WOODLAND

The habitat types in this group predominantly occur on aeolian sand sheets and dunes, in various stages of stabilisation, along the coastline of the Great Australian Bight in the south of the survey area. These coastal habitats tend to grade inland coastward from eucalyptus–melaleuca woodland into eucalypt mallee woodland and finally develop into scrubland and coastal heath at the coast. This gradational pattern corresponds with increasing depth of sand associated with dune development and structural modifications and adaptations related to coastal influences.

47. Eucalypt, melaleuca mixed chenopod shrubland or woodland (EMCW)

Sampling

9 inventory sites, 8 traverse points

General information

EMCW commonly occurs on the steep stony slope (up to 30 per cent) of the Hampton Scarp. Limestone colluvial debris (2–60 cm) covers up to 90 per cent of the scree slope; up to 50 per cent of the area can have scarp outcrop protruding through it. EMCW also occurs on the Roe Plains where a scattered mantle of mixed-sized calcareous gravel (0.2–6 cm) can cover up to 10 per cent of the surface. Soils are calcareous loamy earths and shallow loams.

Physiognomy and composition of vegetation

EMCW consists of a scattered (10–20 per cent PFC) low woodland or shrubland. The tree stratum is composed of mallee-form eucalypts of variable species but *Eucalyptus brachycalyx* (gilja), *E. gracilis* (yorrell) and *E. oleosa* subsp. *ampliata* dominate. The tall shrub stratum is dominated by *Melaleuca lanceolata* (Rottnest tea-tree), the mid shrub stratum by *Cratystylis conocephala* (false bluebush) and the low shrub stratum by *Atriplex vesicaria* (bladder saltbush) and/or *Maireana erioclada*.

58 perennial species were recorded at the nine inventory sites, with an average of 16 perennial species per site, five greater than the survey average. 11 annual species were recorded, with an average of three species per site.

The following species (by stratum) were dominant and/or common:

Trees:	Dominant—Variable; *Eucalyptus brachycalyx* (mallee), *E. gracilis* (mallee), *E. oleosa* subsp. *ampliata* (mallee) Common—*Eucalyptus conglobata* (mallee), *E. oleosa* subsp. *oleosa* (mallee), *E. yalatensis* (mallee), *Myoporum platycarpum* Others—*Acacia papyrocarpa*, *Eucalyptus discreta* (mallee), *E. diversifolia* (mallee), *Pittosporum angustifolium*, *Santalum spicatum.*
Tall shrubs:	Dominant—*Melaleuca lanceolata* Common—*Melaleuca quadrifaria*, *Exocarpos aphyllus*, *Geijera linearifolia* Others—*Eremophila alternifolia*, *Templetonia retusa.*
Mid shrubs:	Dominant—*Cratystylis conocephala* Common—*Atriplex nummularia*, *Eremophila glabra*, *Nitraria billardierei* Others—*Dodonaea stenozyga*, *Eremophila deserti*, *E. glabra.*
Low shrubs:	Dominant—*Atriplex vesicaria* (KD), *Maireana erioclada* Common—*Enchylaena tomentosa*, *Lycium australe*, *Olearia calcarea*, *Rhagodia crassifolia*, *Zygophyllum aurantiacum* Others—*Eremophila weldii*, *Frankenia sessilis*, *Maireana georgei* (KD), *M. radiata*, *M. sedifolia*, *Olearia ramosissima*, *Ptilotus obovatus*, *P. symonii*, *Tecticornia* sp., *Westringia rigida.*
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Maireana tomentosa* (KD), *Sclerolaena diacantha* (KD), *S. obliquicuspis*, *S. patenticuspis*, *Tetragonia implexicoma* Others—*Eriochiton sclerolaenoides* (KD), *Maireana trichoptera* (KD), *Sclerolaena densiflora*, *Zygophyllum apiculatum.*

Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrostipa platychaeta* (KD), *A. scabra* Others—*Austrodanthonia caespitosa* (KD), *Austrostipa drummondii*, *A. elegantissima* (KD).
Other plant forms:	Occasional—*Carpobrotus modestus* (succulent perennial herb), *Dianella revoluta* (lily).

Annual species recorded include *Asteridea athrixioides, Aristida* sp., *Brachyscome ciliaris, B. lineariloba, Carrichtera annua, Erodium* sp., *Euphorbia drummondii, Rostraria pumila, Sonchus oleraceus, Zygophyllum glaucum* and *Z. ovatum.*

Ecological disturbance

EMCW commonly occurs adjacent to areas that are actively grazed and are not preferentially sought after. However, heavy grazing will result in a reduction of palatable low shrubs and grasses such as *Atriplex vesicaria, Austrostipa platychaeta, A. elegantissima, Austrodanthonia caespitosa, Enchylaena tomentosa, Eriochiton sclerolaenoides, Maireana trichoptera, M. tomentosa* and *Sclerolaena diacantha.*

Gradational associations

EMCW grades into *Eucalypt melaleuca woodland* (EMEW) where the chenopod component becomes sparse and the tree stratum becomes denser and closed. In other areas EMCW tends to have a defined boundary such as where these woodland areas lie adjacent to chenopod shrubland, commonly *Plain mixed chenopod shrubland* (PXCS), or where stabilised dunes support a heath understorey such as *Eucalypt heath woodland* (EHEW) or *Eucalypt coastal heath woodland* (ECHW).

Land systems

EMCW is a major habitat type on Roe land system and a minor habitat type on Thampanna and Wurrengoodyea land systems.

48. Eucalypt, melaleuca woodland (EMEW)

Sampling

20 inventory sites, 81 traverse points

General information

EMEW predominantly occurs on the calcarenite Roe Plains. Soils are calcareous loamy earths and calcareous shallow sands. A variable mantle of fine calcareous fragments (2–6 mm) commonly covers less than 10 per cent of the surface, but can cover up to 90 per cent. EMEW is also present in interdune swales of stabilised sand dunes. In the south-east of the survey area EMEW also occurs on residual old dunes now altered to sandy clay and calcrete on the southern edge of the Hampton Tableland behind the Hampton Scarp.

Physiognomy and composition of vegetation

EMEW occurs as a scattered to moderately closed (10–30 per cent PFC) low woodland or tall scrubland. The tree stratum is dominated by mallee-form eucalypts of various species and by melaleucas through the tall shrub stratum.

67 perennial species were recorded at the 20 inventory sites, with an average of 11 species per site, the same as the survey average. Seven annual species were recorded with an average of one species per site.

The following species (by strata) were dominant and/or common:

Trees:	Dominant—Variable; *Eucalyptus brachycalyx* (mallee), *E. gracilis* (mallee), *E. oleosa* (mallee), *E. oleosa* subsp. *oleosa* (mallee) Common—*Eucalyptus conglobata* (mallee), *E. discreta* (mallee), *E. diversifolia* (mallee), *E. oleosa* subsp. *ampliata* (mallee), *E. urna* Others—*Allocasuarina helmsii*, *Eucalyptus yalatensis* (mallee), *Myoporum platycarpum*, *Santalum acuminatum.*
Tall shrubs:	Dominant—*Melaleuca lanceolata*, *M. quadrifaria* Common—*Eremophila dempsteri*, *Exocarpos aphyllus*, *Geijera linearifolia* Others—*Acacia oswaldii*, *Templetonia sulcata*.
Mid shrubs:	Dominant—Occasionally; *Cratystylis conocephala* Common—*Atriplex nummularia*, *Eremophila deserti* Others—*Acacia anceps*, *A. merrallii*, *Alyxia buxifolia*, *Dodonaea bursariifolia*,

	D. stenozyga, *Eremophila decipiens*, *Nitraria billardierei*, *Scaevola spinescens*.
Low shrubs:	Dominant—*Olearia calcarea* Common—*Atriplex vesicaria*, *Enchylaena tomentosa*, *Eremophila weldii*, *Maireana erioclada*, *Rhagodia crassifolia*, *Westringia rigida*, *Zygophyllum aurantiacum* Others—*Acacia erinacea*, *Atriplex isatidea*, *Eremophila oblonga*, *E. parvifolia*, *Frankenia densa*, *Gunniopsis calcarea*, *Lawrencia squamata*, *Maireana pentatropis*, *Microcybe pauciflora* subsp. *pauciflora*, *Olearia muelleri*, *O. ramosissima*, *Pultenaea elachista*, *Scaevola bursariifolia*, *Sclerolaena brevifolia*, *Tecticornia* sp.
Subshrubs:	Dominant—Not present as a recognisable stratum Common—*Sclerolaena diacantha* Others—*Eriochiton sclerolaenoides*, *Maireana tomentosa*, *Sclerolaena obliquicuspis*, *S. patenticuspis*, *Threlkeldia diffusa*.
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Austrostipa scabra* Other—*Austrostipa platychaeta*.
Other plant forms:	Occasional—*Carpobrotus modestus* (succulent perennial herb), *Cassytha melantha* (creeper), *Comesperma volubile* (creeper), *Dianella revoluta* (lily), *Gahnia lanigera* (perennial sedge).

Annual species recorded include *Asteridea athrixioides, Euphorbia drummondii, Oncosiphon suffruticosum, Trichanthodium skirrophorum, Zygophyllum glaucum, Z. iodocarpum* and *Z. ovatum.*

Ecological disturbance

Little is known about the disturbance mechanisms in EMEW in the Nullarbor region. This habitat has limited occurrence within the pastoral leases and is generally unfavoured for grazing owing to the lack of grasses and dominance of unpalatable eucalypts and melaleucas. Where low shrubs and subshrubs occur in any abundance it would be expected palatable species would decline under continuous grazing pressure.

Gradational associations

EMEW commonly grades into *Eucalypt, melaleuca mixed chenopod shrubland or woodland* (EMCW) or *Eucalypt mixed scrub woodland* (EXSW) as the tree stratum becomes scattered and the density of the melaleuca component reduces as chenopods or mixed shrubs begin to dominate the lower shrub stratum. EMEW also grades into *Eucalypt heath woodland* (EHEW) on stabilised dunes or *Coastal shrubland* (COAS) as dunes become more mobile. *Low mallee woodland* (LOMW) replaces EMEW when outcrop starts to occur as calcareous shallow sands disappear and calcareous loamy earths become shallower.

Land systems

EMEW is a major habitat type on Moopina and Roe land systems and a minor habitat type on Caiguna, Culver, Toolinna and Wurrengoodyea land systems.

49. Low mallee woodland (LOMW)

Sampling

11 inventory sites, 80 traverse points

General information

LOMW occurs on limestone and calcrete plains in the south of the survey area. The mantle is variable, becoming stonier coastward. Medium-sized (6–20 mm) angular, calcareous fragments can cover up to 50 per cent of the surface. Indurated calcareous outcrop occurs through 10–50 per cent of habitats depending on the variability of the overlying calcareous shallow loam. On limestone hummocks the outcrop is greater and the surface is commonly pitted due to weathering.

Physiognomy and composition of vegetation

LOMW occurs as scattered (10–20 per cent PFC) low mallee woodland of variable eucalypt species over scattered to moderately closed mixed scrub, sedges and occasionally hummock grasses.

65 perennial species were recorded at the 11 inventory sites, including one priority species, with an average of 13 species per site, two greater than the survey average. One annual species was recorded.

The following species (by strata) are dominant and/or common:

Trees: Dominant—*Eucalyptus oleosa* subsp. *oleosa* (mallee) Variable; *Eucalyptus brachycalyx* (mallee), *E. conglobata* (mallee), *E. cooperiana* (mallee), *E. gracilis*, *E. yalatensis* (mallee)
Common—*Allocasuarina helmsii*, *Eucalyptus diversifolia* (mallee)
Other—*Santalum acuminatum*.

Tall shrubs: Dominant—*Allocasuarina helmsii*, *Melaleuca lanceolata*
Common—*Dodonaea stenozyga*, *Templetonia retusa*, *Eremophila dempsteri*
Others—*Acacia cyclops*, *Allocasuarina scleroclada*, *Exocarpos aphyllus*, *E. sparteus*, *Geijera linearifolia*.

Mid shrubs: Dominant—Not present as a recognisable stratum
Others—*Acacia cupularis*, *A. sulcata* var. *platyphylla*, *Beyeria lechenaultii*, *Dodonaea bursariifolia*, *D. stenozyga*, *Grevillea sparsiflora*, *Kunzea pulchella*, *Lasiopetalum compactum*, *Leptomeria pachyclada*, *Melaleuca pentagona* var. *latifolia*, *Pultenaea heterochila*, *Scaevola spinescens*, *Senna artemisioides* subsp. x *artemisioides*, *S. artemisioides* subsp. x *coriacea*.

Low shrubs: Dominant—Not present as a recognisable stratum
Common—*Acacia erinacea*, *Halgania andromedifolia*, *Olearia calcarea*, *O. muelleri*, *Pomaderris myrtilloides*, *Prostanthera serpyllifolia* subsp. *serpyllifolia*, *Pultenaea elachista*, *Spyridium tricolor*, *Westringia rigida*
Others—*Acacia excentrica*, *Acrotriche cordata*, *A. patula*, *Calytrix tetragona*, *Conostephium drummondii*, *Eremophila weldii*, *Hibbertia nutans*, *Microcybe multiflora*, *Olearia picridifolia*, *Philotheca fitzgeraldii*, *Pimelea serpyllifolia*, *Scaevola bursariifolia*.

Subshrubs: Dominant—Not present as a recognisable stratum
Others—*Goodenia affinis*, *G. concinna*, *Lomandra* sp., *Wahlenbergia communis*.

Perennial grasses: Dominant—Not present as a recognisable stratum
Common—*Triodia scariosa* (hummock grass)
Other—*Austrostipa platychaeta*.

Other plant forms: Dominant—*Gahnia lanigera* (perennial sedge)
Common—*Dianella revoluta* (lily), *Tetraria capillaris* (perennial sedge)
Others—*Cassytha melantha* (creeper), *Lepidosperma* sp. (perennial sedge), *Schoenus subflavus* subsp. hispid culms (perennial sedge).

Annual species recorded include *Calandrinia* sp.

Ecological disturbance

This habitat type generally occurs outside of pastoral lease boundaries and little is known about the grazing ecology or other disturbance mechanisms.

Thysanotus baueri, a Priority 1 species on the declared rare and priority flora list, was recorded in this habitat and as such the area is of high conservation value.

Gradational associations

LOMW commonly grades into *Eucalypt melaleuca woodland* (EMEW) as calcareous loamy earths deepen and calcareous shallow sands cover outcrop. LOMW has a defined boundary against aeolian sand dunes supporting *Banksia coastal heath and scrubland* (BCHS) behind cliff faces. Also occurring randomly through the LOMW are karst depressions supporting *Plain mixed low shrubland* (PXLS) or *Drainage depression mixed shrub shrubland* (DDXS) within the indurated stony calcareous plains and between limestone hummocks.

Land systems

LOMW is the dominant habitat type on Toolinna and Culver land systems.

50. Eucalypt heath woodland (EHEW)

Sampling

7 inventory sites, 15 traverse points

General information

EHEW occurs on partially consolidated, aeolian sand dunes stabilised by vegetation, along the top of the Baxter Cliffs and on the landward side of younger mobile dunes fringing the coastal Israelite and Roe Plains. The dunes generally have gently inclined slopes, though near the Wurrengoodyea Hills they can be steep and up to 90 m. Soils are calcareous deep sands or pale deep sands with a calcrete horizon developed at or near the surface.

Physiognomy and composition of vegetation

EHEW comprises scattered to closed (15–50 per cent PFC) low woodland of various eucalypt species in mallee-form over scattered to closed low shrubland of variable heath species.

48 perennial species were recorded at the seven inventory sites with an average of 10 species per site, one less than the survey average. No annual species were recorded.

The following species (by strata) are dominant and/or common:

Trees:	Dominant—*Eucalyptus discreta* (mallee), *E. diversifolia* (mallee), *E. incrassata* (mallee) Common—*Callitris preissii*, *Eucalyptus brachycalyx* (mallee), *E. conglobata* (mallee) Others—*Allocasuarina helmsii*, *Eucalyptus yalatensis* (mallee).
Tall shrubs:	Dominant—Not present as a recognisable stratum Common—*Exocarpos aphyllus*, *Melaleuca lanceolata* Others—*Acacia oswaldii*, *Exocarpos sparteus*, *Templetonia retusa*.
Mid shrubs:	Dominant—Not present as a recognisable stratum Common—*Pultenaea heterochila* Others—*Beaufortia empetrifolia*, *Dodonaea stenozyga*, *Grevillea sparsiflora*, *Hakea nitida*.
Low shrubs:	Dominant—*Adenanthos forrestii* Common—*Acacia cochlearis*, *Beaufortia micrantha*, *Bossiaea leptacantha*, *Conostephium drummondii*, *Pomaderris myrtilloides* Others—*Acacia mutabilis* subsp. *angustifolia*, *Acrotriche cordata*, *Boronia crassifolia*, *Cryptandra* sp., *Enchylaena tomentosa*, *Hibbertia nutans*, *Lechenaultia formosa*, *Leucopogon* sp., *Lysinema ciliatum*, *Microcybe pauciflora* subsp. *pauciflora*, *Olearia muelleri*, *Pultenaea elachista*, *Spyridium tricolor*, *Synaphea oligantha*.
Subshrubs:	Dominant—Not present as a recognisable stratum Other—*Desmocladus myriocladus*.
Perennial grasses:	Dominant—Not present as a recognisable stratum Other—*Austrostipa platychaeta*.
Other plant forms:	Common—*Carpobrotus modestus* (succulent perennial herb), *Comesperma volubile* (creeper), *Dianella revoluta* (lily), *Lepidosperma* sp. A2 Island Flat (perennial sedge), *Marianthus bicolor* (creeper) Others—*Gahnia deusta* (perennial sedge), *G. lanigera* (perennial sedge), *Schoenus lanatus* (perennial sedge).

Ecological disturbance

This habitat type generally occurs outside of pastoral lease boundaries and little is known about the grazing ecology. Burnt areas show a mosaic pattern, often confined to this habitat type, indicating this woodland is more susceptible to fire than the vegetation associations adjacent to it.

Gradational associations

EHEW commonly grades into *Eucalypt, melaleuca woodland* (EMEW) on stabilised dunes and *Eucalypt, melaleuca mixed chenopod/woodland* (EMCW) where calcareous loamy earths and shallow loams become overlain by sandy soils.

Land systems

EHEW is a major habitat type on Wurrengoodyea land system.

51. Eucalypt coastal heath woodland (ECHW)

Sampling

3 inventory sites

General information

ECHW occurs where coastal aeolian sand dunes have accumulated. This predominantly occurs on the Roe Plains but there are also aeolian sand deposits at the edge of the Hampton Range and Baxter Cliffs. These sandy deposits occur as sand sheets and coastal dunes in the south of the survey area near the coast. Where dunes occur they are gently sloping (up to 6 per cent). Soils vary from calcareous deep sands to pale deep sands.

Physiognomy and composition of vegetation

ECHW consists of a scattered to moderately closed (15–30 per cent PFC) low woodland of mallee-form eucalypts. Scattered (10–15 per cent PFC) mixed shrubs form the understorey.

38 species were recorded at the three inventory sites, with an average of 15 species per site, four greater than the survey average. No annual species were recorded.

The following species were dominant and/or common:

Trees:	Dominant—Variable; *Eucalyptus discreta* (mallee), *E. gracilis*, *E. incrassata* (mallee) Common—*Callitris preissii* Other—*Eucalyptus cooperiana* (mallee).
Tall shrubs:	Dominant—Variable; *Melaleuca lanceolata* Common—*Callitris preissii* Others—*Exocarpos aphyllus*, *Rhagodia preissii*, *Templetonia retusa.*
Mid shrubs:	Dominant—Variable; *Beaufortia empetrifolia*, *Hakea nitida* Others—*Adenanthos cuneatus*, *Dodonaea amblyophylla*, *Pultenaea heterochila*, *Styphelia hainesii.*
Low shrubs:	Dominant—Not present as a recognisable stratum Common—*Pimelea serpyllifolia* Others—*Acrotriche cordata*, *Bossiaea leptacantha*, *Conostephium drummondii*, *Grevillea pauciflora*, *Hibbertia nutans*, *Lysinema ciliatum*, *Pomaderris myrtilloides*, *Pultenaea elachista*, *Spyridium microcephalum*, *Synaphea oligantha.*
Subshrubs:	Dominant—Not present as a recognisable stratum Others—*Harperia eyreana*, *Lomandra* sp.
Other plant forms:	Others—*Amyema melaleucae* (mistletoe), *Carpobrotus* sp. (succulent perennial herb), *Cassytha melantha* (creeper), *Dianella revoluta* (lily), *Lepidosperma* sp. A2 Island Flat (perennial sedge), *Marianthus bicolour* var. *bicolour* (creeper), *Mesomelaena stygia* (perennial sedge), *Schoenus caespititius* (perennial sedge), *S. lanatus* (perennial sedge), *S. subflavus* subsp. hispid culms (perennial sedge).

Ecological disturbance

The disturbance mechanisms of this habitat have not been investigated in any significant detail in this region. Disturbance by vehicles and/or fire may result in wind erosion of the dunes.

Gradational associations

ECHW commonly grades into *Coastal shrubland* (COAS) as dune development becomes unconsolidated. ECHW has a defined boundary where the stabilised sand dunes overlie calcareous loamy earths and shallow loams that support *Eucalypt, melaleuca mixed chenopod shrubland or woodland* (EMCW).

Land systems

ECHW is a minor habitat type of Toolinna and Wurrengoodyea land systems.

52. Banksia coastal heath and scrubland (BCHS)

Sampling

3 inventory sites

General information

BCHS is a unique vegetation association. It occurs on stabilised sand dune deposits on the Israelite Plain, above the Baxter Cliffs and Wylie Scarp. Sand dunes have developed between the Wylie Scarp and the landward side of mobile coastal dunes on the Israelite Plain.

These older dunes are likely to have formed during a sea regression, forming beaches at the base of the cliff. Winds built sand ramps and transported large amounts of sand to the clifftops (Jennings 1968). Later sea level increases have removed some dune ramps but aeolian clifftop deposits have remained above the Baxter Cliffs and Wylie Scarp. BCHS is largely restricted to these aeolian sand deposits.

Along the edge of the Baxter Cliffs the BCHS vegetation association is present in a dwarfed form due to wind exposure causing high evapo-transpiration and wind-borne salt spray causing leaf tip necrosis and asymmetric growth forms (Parsons 1970). The banksia population found above Toolinna Cove is the most easterly population of a Western Australian banksia species (Nelson 1974).

Physiognomy and composition of vegetation

BCHS comprises closed (30–50 per cent) thickets of banksia, eucalyptus and melaleuca, except along the cliff edge where BCHS is a dwarfed closed low heathland. The lower shrub stratum is variable and can be dominated by *Beaufortia micrantha* or *Pomaderris forrestiana.*

36 perennial species were recorded at the three inventory sites, with an average of 10 species per site, one less than the survey average. No annual species were recorded.

The following species were dominant and/or common:

Tall shrubs:	Dominant—*Banksia media*, *Eucalyptus incrassata*, *Melaleuca pentagona* var. *latifolia* Others—*Allocasuarina helmsii*, *Banksia speciosa*, *Calothamnus gracilis*, *Eucalyptus diversifolia*, *Melaleuca lanceolata*.
Mid shrubs:	Dominant—Occasionally *Melaleuca quadrifaria* Common—*Pultenaea heterochila* Others—*Adenanthos cuneatus*, *Grevillea sparsiflora*, *Hakea cinerea*, *H. nitida*, *Isopogon trilobus*, *Melaleuca pulchella*, *Petrophile teretifolia*.
Low shrubs:	Dominant—Occasionally *Beaufortia micrantha*, *Pomaderris forrestiana* Common—*Adenanthos forrestii*, *Boronia crassifolia*, *Conostephium drummondii* Others—*Acrotriche patula*, *Bossiaea leptacantha*, *Grevillea nudiflora*, *Hibbertia nutans*, *Stirlingia anethifolia*, *Verticordia sieberi*.
Subshrubs:	Dominant—Not present as a recognisable stratum Others—*Desmocladus myriocladus*, *Euphorbia* sp.
Other plant forms:	Occasional—*Cassytha melantha* (creeper), *Dianella revoluta* (lily), *Lepidosperma* sp. A2 Island Flat (perennial sedge), *Schoenus caespititius* (perennial sedge), *S. lanatus* (perennial sedge), *Tetraria capillaris* (perennial sedge).

Ecological disturbance

The mechanisms of disturbance in BCHS have not been investigated in any significant detail. Dune erosion has resulted when disturbance caused by vehicles and/or fire has damaged or removed stabilising vegetation.

Gradational associations

BCHS commonly grades into scattered *Low mallee woodland* (LOMW) or *Eucalypt mixed scrub woodland* (EXSW). Coastward as the stabilised colluvial dune apron becomes less consolidated and foredunes and swales develop BCHS is replaced by *Coastal shrubland* (COAS).

Land systems

BCHS is the dominant habitat type on the Baxter and Wylie land systems.

53. Coastal shrubland (COAS)

Sampling

7 inventory sites, 2 traverse points

General information

COAS occurs on recently mobile or fixed dunes fringing the Israelite and Roe coastal plains. In places dunes form large masses such as the Bilbunya Dunes near Point Culver and the Delisser Sandhills near Eucla. Foredunes are usually 3–10 m high with gently inclined slopes to 8 per cent, though at the Bilbunya Dunes they are more steeply inclined, with relief up to 90 m. Soils are deep calcareous sands.

Physiognomy and composition of vegetation

COAS commonly occurs as a mid to low shrubland of varying composition. It ranges from supporting isolated shrubs (0–2.5 per cent PFC) to closed (30–50 per cent PFC) shrubland. Vegetation characteristic to coastal areas such as *Euphorbia paralias* (sea spurge), *Ficinia nodosa* (knotted club rush), *Leucophyta brownii* and *Scaevola crassifolia* (thick-leaved fan-flower) are common.

29 perennial species were recorded at the seven inventory sites with an average of seven species per site, four less than the survey average. Two annual species were recorded.

The following species were dominant and/or common to this vegetation association:

Tall shrubs:	Dominant—Occasionally: *Acacia cyclops*, *Eucalyptus conglobata* (mallee), *Melaleuca lanceolata* Others—*Myoporum platycarpum*, *Olearia axillaris*.
Mid shrubs:	Dominant—*Acacia anceps* Others—*Atriplex isatidea*, *Nitraria billardierei*, *Pultenaea heterochila*.
Low shrubs:	Dominant—Occasionally: *Leucophyta brownii*, *Scaevola crassifolia* Common—*Olearia axillaris*, *Rhagodia crassifolia*, *Frankenia sessilis*, *Westringia rigida* Others—*Acacia cochlearis*, *Atriplex cinerea*, *Darwinia diosmoides*, *Pimelea ferruginea*, *Tecticornia* sp.
Subshrubs:	Dominant—*Threlkeldia diffusa* Others—*Euphorbia paralias*, *Senecio spanomerus*, *Tetragonia implexicoma*, *Zygophyllum apiculatum*, *Z. billardierei*.
Perennial grasses:	Dominant—Not present as a recognisable stratum Common—*Spinifex hirsutus*.
Other plant forms:	Common—*Carpobrotus modestus* (succulent perennial herb), *C. virescens* (succulent perennial herb), *Ficinia nodosa* (perennial sedge).

Annual species recorded include *Cakile maritima* and *Senecio pinnatifolius.*

Ecological disturbance

This habitat is susceptible to dune erosion when coastal vegetation is damaged or removed. Common disturbance mechanisms causing dune instability include vehicle impact and fire.

Gradational associations

COAS commonly grades into *Samphire shrubland* (SAMP) growing in lagoonal habitats immediately between or behind recent coastal dunes. As unconsolidated dunes become increasingly stabilised COAS grades into *Banksia coastal heath and scrubland* (BCHS), *Eucalypt coastal heath woodland* (ECHW) or *Eucalypt, melaleuca woodland* (EMEW).

Land systems

COAS is the dominant habitat type on the Bilbunya and Delisser land systems.

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Land systems

PA Waddell

Within the survey area 54 land systems have been identified, 34 of which are described for the first time and the other 20 previously described in adjacent surveys. The land systems are derived from aerial photography and descriptions are built up using field data collected during traversing and at inventory sites. With improved aerial photography and the benefit of LANDSAT imagery the land systems identified in the eastern part of the Western Australian Nullarbor Plain during the 1974 survey (Mitchell, McCarthy & Hacker 1979) have been reassessed and in some cases boundaries have been modified. Four land systems from the 1974 survey were extensively modified resulting in one system being renamed and three systems incorporated into others.

Land systems are grouped into land types according to a combination of landforms, soils, vegetation and drainage patterns. Table 19 shows the land types and their component land systems. This amalgamation of the 54 land systems into 15 land types provides information at a more appropriate level for use when considering a regional scale, and provides a simpler way to colour code regional scale maps.

The location of each inventory site, with the site number and a code for the land unit on which it occurred, is shown on pastoral lease maps. Table 20 provides a list of land units with the codes used on the maps.

Land systems are described in alphabetical order in this chapter. A summary description of each system's major features is followed by more detailed accounts of the units that comprise each system. The format used for the summary description is:

- land system name, area and percentage of the survey area
- reference to any previous description
- brief descriptive statement of dominant landform(s) and vegetation
- land type (refer to Table 19)
- major geological formation or land surface types
- geomorphology overview
- brief description of land management considerations such as susceptibility to soil erosion
- traverse condition summary
- locality map showing the distribution of the land system
- plan showing the physical features of the system, and with each land unit identified
- list of land units, normally in order of highest to lowest position in the landscape, with the number of sampling points. Not all units in each land system are shown in diagrams or described in tables. Minor units that were encountered very occasionally whilst traversing the land system are listed as 'other' in the summary table.

On each opposing page a summary of the biophysical components for each land unit provides additional detail:

- unit area, estimated from aerial photograph interpretation and field observation, is presented as a percentage of the total land system area
- landform—lists each land unit with a description of the landform
- soils—generalised description with reference to the appropriate soil groupings (refer to the Soils chapter)
- vegetation—the vegetation is described in three parts: foliar cover (refer to Table 8 of the Methodology chapter); formation (refer to the Vegetation chapter) and dominant species, e.g. 'Pearl bluebush low shrubland (PBLS)'. The four-letter code for the habitat type (refer to the Habitat type ecology chapter) is also listed.

Table 19 **Land types and their land systems**

Land type	Description and land systems
1	1 – **Calcrete plains overlain by aeolian sandy loam with eucalypt woodland and spinifex grasses** Land system—Zanthus
2	2 – **Calcrete plains with eucalypt woodland and mixed scrub understorey** Land systems—Caiguna and Gumbelt
3	3 – **Calcrete plains with myall woodland and mixed shrubland** Land systems—Colville and Nyanga
4	4 – **Calcrete plains with sparse myall and bindii grassland or chenopod shrubland** Land systems—Carlisle, Haig, Jubilee, Kyarra and Rabbit
5	5 – **Large depressions within calcrete plains with chenopod shrubland or bindii grassland** Land systems—Koonjarra and Woorlba
6	6 – **Low granite outcrop protruding through calcrete plains with fringing acacia–dodonaea–eremophila shrubland** Land system—Balladonia
7	7 – **Level to gently undulating calcareous plains with eucalypt–melaleuca–myall woodland and chenopod shrubland** Land systems—Moodini, Moopina, Thampanna and Weebubbie
8	8 – **Undulating calcareous plains with eucalypt woodland, mixed scrub and heathland** Land systems—Culver and Toolinna
9	9 – **Recrystallised (weathered) limestone plains with myall woodland and bluebush shrubland or bindii grassland** Land systems—Kanandah, Lowry and Virginia
10	10 – **Deflated limestone plains with myall woodland and chenopod shrubland or bindii grassland** Land systems—Chowilla, Seemore, Shakehole and Vanesk
11	11 – **Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland** Land systems—Arubiddy, Balgair, Gafa, Kitchener, Kybo, Moonera, Morris, Nanambinia, Naretha, Nightshade, Pondana, Reid and Skink
12	12 – **Deflated limestone plains with regular karst drainage depressions (dongas) surrounded by bindii grassland** Land systems—Bullseye, Kinclaven, Nurina and Oasis
13	13 – **Level calcarenite coastal plains with eucalypt–melaleuca–myall woodland and mixed shrubland** Land systems—Mundrabilla and Roe
14	14 – **Coastal plains, cliffs, dunes, lagoonal deposits and beaches; varied vegetation** Land systems—Baxter, Bilbunya, Delisser, Wurrengoodyea and Wylie
15	15 – **Salt lakes and fringing saline plains with halophytic shrubland** Land systems—Boonderoo, Damper, Lefroy and Ponton

These are modified land types taken from the Department of Agriculture and Food, WA State Land Type list.

Table 20 **Land units and their codes**

Code	Land unit
BAS	Sandy bank
BEA	Beach
BRX	Breakaway
CLA	Claypan
CLD	Clay depression
CLP	Clay plain
DFL	Drainage floor
DON	Donga (karst depression)
DRF	Drainage focus
DRN	Narrow drainage floor (< 0.5 km)
DRT	Drainage tract (ancient river course)
DUN	Dune
FOL	Lower footslope – concave
FOR	Foredune
GIL	Gilgaied depression
KOP	Kopi dune
KPL	Calcrete plain overlain by calcareous loam of varying depth
KRL	Calcrete (residual) rise overlain by calcareous loam of varying depth
KSP	Calcrete stony plain
LAK	Lake bed including playa lake
LAM	Lake margin
LGR	Low granite rise
MDF	Marginal slope to drainage floor
PCL	Calcarenite plain overlain by calcareous loam
PGR	Gritty-surfaced plain with shallow soil on granite
PGY	Gypsiferous plain
PKE	Calcareous loam plain overlain by shallow aeolian sand
PLS	Highly saline depression
LHR	Limestone hummock (low rise)
SCF	Scarp face
SLP	Stony limestone plain
SWA	Swale
SWP	Swamp

Sampling intensity

Table 21 indicates the area and intensity of sampling on each system in the survey area.

Table 21 **Land system areas and sampling intensity**

Land system	Area (km^2)	% of total survey area	No. of inventory sites	Traverse sampling intensity		
				No. of assessments	km^2 per rating	Density index*
Arubiddy	2 046	1.7	5	210	10	1.74
Balgair	1 937	1.6	4	195	10	1.70
Balladonia	145	0.1	5	31	5	3.63
Baxter	285	0.2	1	0		
Bilbunya	47	< 0.1	1	0		
Boonderoo	83	0.1	5	14	6	2.85
Bullseye	8 817	7.4	15	15	588	0.03
Caiguna	7 066	6.0	16	201	35	0.48
Carlisle	2 066	1.7	0	0		
Chowilla	1 532	1.3	1	21	73	0.23
Colville	421	0.4	0	0		
Culver	1 707	1.4	9	48	36	0.48
Damper	390	0.3	7	35	11	1.52
Delisser	150	0.1	6	2	75	0.23
Gafa	8 501	7.2	5	138	62	0.27
Gumbelt	5 053	4.3	12	381	13	1.28
Haig	552	0.5	7	115	5	3.53
Jubilee	934	0.8	1	8	117	0.14
Kanandah	1 641	1.4	10	223	7	2.30
Kinclaven	4 790	4.0	14	542	9	1.91
Kitchener	405	0.3	8	56	7	2.34
Koonjarra	1 067	0.9	14	186	6	2.95
Kyarra	2 099	1.8	4	62	34	0.50
Kybo	1 289	1.1	12	174	7	2.28
Lefroy	9	< 0.1	3	3	3	5.94
Lowry	65	0.1	1	16	4	4.14
Moodini	123	0.1	7	51	2	7.04
Moonera	4 234	3.6	10	319	13	1.27
Moopina	107	0.1	2	7	15	1.11
Morris	3 323	2.8	0	49	68	0.25
Mundrabilla	1 688	1.4	19	127	13	1.27
Nanambinia	570	0.5	5	114	5	3.38
Naretha	1 547	1.3	7	139	11	1.52
Nightshade	3 373	2.8	7	286	12	1.43
Nurina	2 247	1.9	9	204	11	1.54
Nyanga	12 990	11.0	38	1 045	12	1.36
Oasis	4 180	3.5	1	0		
Pondana	1 649	1.4	6	188	9	1.93
Ponton	23	< 0.1	0	0		
Rabbit	350	0.3	0	0		
Reid	3 998	3.4	1	38	105	0.16
Roe	2 853	2.4	20	64	45	0.38
Seemore	415	0.4	2	15	28	0.61
Shakehole	4 045	3.4	11	355	11	1.48
Skink	4 000	3.4	2	85	47	0.36
Thampanna	5 284	4.5	36	723	7	2.31
Toolinna	1 879	1.6	9	55	34	0.50
Vanesk	1 107	0.9	6	64	17	0.98
Virginia	1 689	1.4	4	144	12	1.44
Weebubbie	416	0.4	2	14	30	0.57
Woorlba	554	0.5	10	163	3	4.97
Wurrengoodyea	1 946	1.6	14	23	85	0.20
Wylie	52	< 0.1	1	0		
Zanthus	619	0.5	6	49	13	1.34
	118 358		401	6 997		

* Density index: measure of sampling intensity relative to the mean of the survey area (16.9 km^2 per assessment)

ARUBIDDY LAND SYSTEM (2046 km^2, 1.7% of the survey area)

Gently undulating stony limestone plains supporting pearl bluebush shrubland with saline drainage floors along irregular joint patterns supporting halophytic shrubland.

Land zone: Nullarbor Plain.

Land type: 11

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

Geomorphology: Erosional surfaces; differential weathering along irregular joint patterns through the deflated Nullarbor Limestone has formed broad stony plains with up to 3 m relief separated by closed drainage depressions.

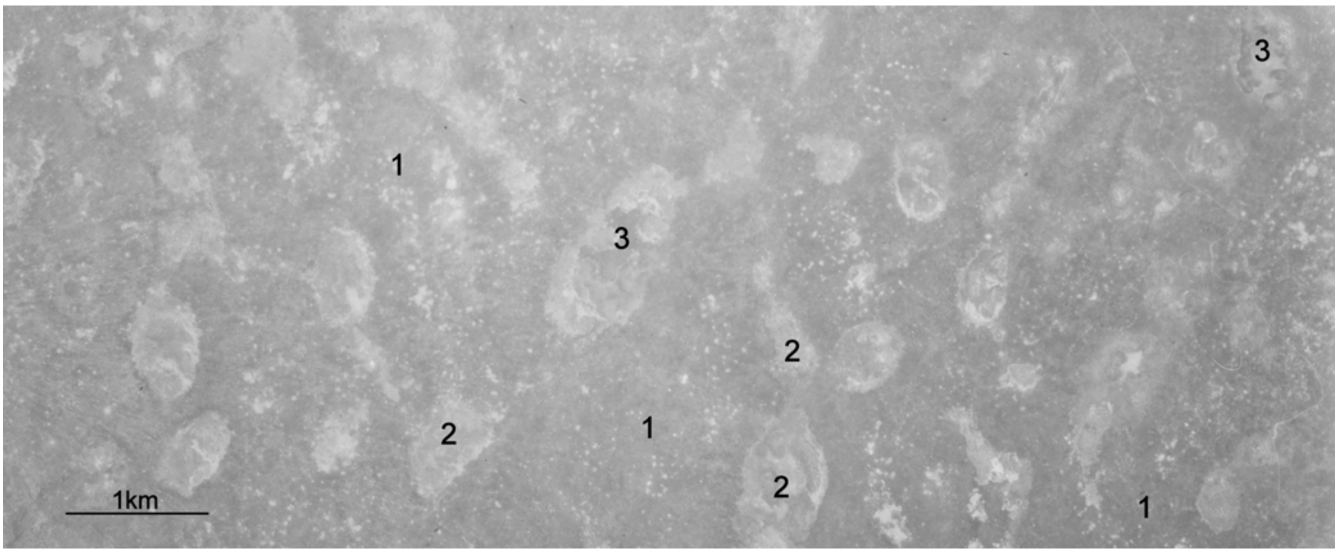
Land management: The grasses and subshrubs that grow between the mid to low shrubs are preferentially grazed by herbivores. Subshrubs are important sources of protein and are key indicators for the production systems in the seasonally dependent Nullarbor landscape. Uncontrolled grazing can reduce the floristic diversity and cover of the area, making it susceptible to wind erosion. The expansion of naturally occurring scalded interbands is also accelerated by increased animal activity. Loss of heterogeneity reduces the ability of the landscape to offer any significant pastoral value during dry periods.

Chenopod shrubland needs to be protected from fire, particularly where expanses of grassland surround zones of chenopod shrubs. *Maireana sedifolia* (pearl bluebush) can regenerate from moderately intense fire if it is not severely grazed during its recovery. *Atriplex vesicaria* (bladder saltbush) is very fire sensitive and its potential for post-fire recovery is seriously impeded under grazing pressure.

Traverse condition summary:
(210 assessments)

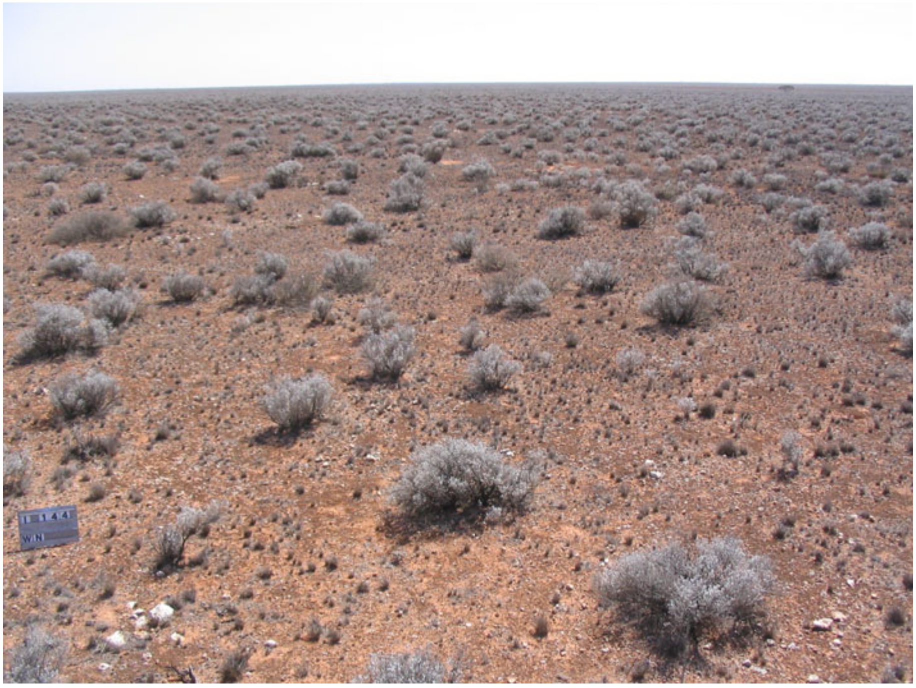
Vegetation—very good 1%, good 67%, fair 27%, poor 4%, very poor 1%.

No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	130	3
2.	Marginal slope to drainage floor	68	1
3.	Saline depression	12	1
	Total	210	5



Arubiddy land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	65%	**Stony limestone plains**—gently undulating limestone plains with extensive mantle of limestone fragments and outcrop.	Calcareous shallow loams (521).	Very scattered to scattered low shrubland of *Maireana sedifolia* (pearl bluebush) (PBLS), occasionally with a sparse mid shrub stratum. Isolated stands of *Acacia papyrocarpa* (myall) occur infrequently (MPBS). Areas of open grassland dominated by *Austrostipa scabra* (speargrass) and *Austrodanthonia caespitosa* (wallaby grass) become more common in the south (SWOG).
2.	25%	**Marginal slope to drainage floors**—very gently inclined gradual slopes draining to extensive closed depressions defined by irregular joint patterns.	Calcareous loamy earths (542) with saline subsoils.	Scattered low to mid shrubland co-dominated by *Maireana sedifolia* and *Atriplex vesicaria* (bladder saltbush) (PXCS) tending to grade downwards into moderately closed *Atriplex vesicaria* shrubland (BSSL).
3.	10%	**Saline depressions**—closed depressions, up to 1 km diameter, occurring on marginal slopes or often in the lowest position within the drainage floor.	Calcareous loamy earths (542) with saline subsoils.	Scattered to moderately closed low shrubland of *Atriplex vesicaria*, *Frankenia* sp. (*frankenia*), *Gunniopsis calcarea*, *Lycium australe* (water bush), *Maireana* spp. (bluebushes) and *Tecticornia* spp. (samphires) (PXHS).



***Arubiddy land system:** Stony limestone plain supporting pearl bluebush and speargrass.*

BALGAIR LAND SYSTEM (1937 km², 1.6% of the survey area)

Gently undulating stony limestone plains with broad low ridges supporting pearl bluebush shrubland and a mosaic of bladder saltbush shrubland and grassland in drainage floors and claypans following irregular joint patterns.

Land zone: Nullarbor Plain.

Land type: 11

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

Geomorphology: Erosional surfaces; differential weathering of the deflated Nullarbor Limestone along irregular joint patterns has formed gently undulating low stony rises with broad stony marginal slopes separated by drainage floors with infrequent large claypans and dongas; infrequent relic ancient river courses form sinuous, narrow drainage tracts that terminate indistinctly into the surrounding plains.

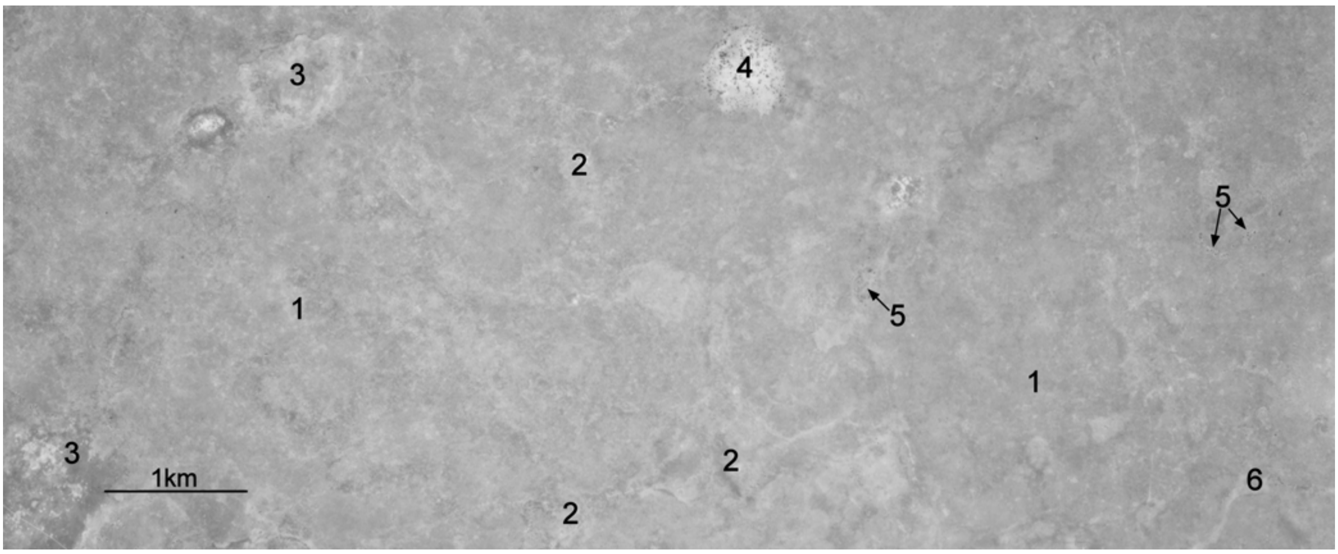
Land management: The grasses and subshrubs that grow between the mid to low shrubs are preferentially grazed by herbivores. Subshrubs are important sources of protein and are important indicators for the production systems in the seasonally dependent Nullarbor landscape. Uncontrolled grazing can reduce the floristic diversity and cover of the area, making it susceptible to wind erosion. The expansion of naturally occurring scalded interbands is accelerated by increased animal activity. Loss of heterogeneity reduces the ability of the landscape to offer any significant pastoral value during dry periods.

Dongas offer a valuable source of browse during dry periods and are favoured habitats for many Nullarbor animals due to the benefits they offer in comparison to the surrounding vast, open stony plains.

Traverse condition summary:
(195 assessments)

Vegetation—good 66%, fair 29%, poor 5%.

No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	137	–
2.	Marginal slope to drainage floor	50	2
3.	Claypan	6	–
4.	Donga	2	1
5.	Drainage focus (gilgai)	–	1
6.	Drainage tract (ancient river course)	–	–
	Total	195	4



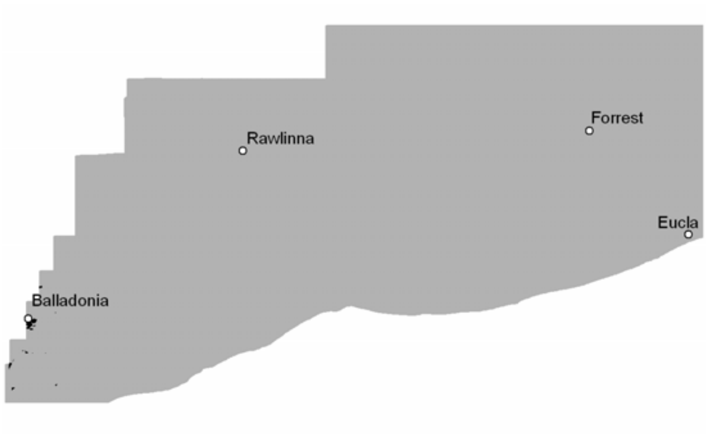
Balgair land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	70%	**Stony limestone plains**—gently undulating plains with extensive mantle of Nullarbor Limestone fragments and outcrop.	Calcareous shallow loams (521).	Very scattered to scattered low shrubland of *Maireana sedifolia* (pearl bluebush) (PBLS).
2.	20%	**Marginal slope to drainage floors**—gently inclined stony slopes, with mantle of mixed limestone fragments, draining to open depressions defined by irregular joint patterns.	Calcareous shallow loams (521).	Scattered low shrubland of *Maireana sedifolia*, occasionally with a sparse mid shrub stratum (PBLS), grading downwards into moderately closed *Atriplex vesicaria* (bladder saltbush) shrubland (BSSL) and/or *Austrodanthonia caespitosa* (wallaby grass) and *Austrostipa scabra* (speargrass) (SWOG).
3.	5%	**Claypans**—large oval claypans up to 1.5 km in diameter.	Calcareous loamy earths (542).	Vegetated either by a mosaic of mixed low shrubs or solely dominated by: moderately closed *Atriplex vesicaria* shrubland (BSSL) or very scattered to moderately closed grassland varying in composition of *Sclerolaena* species (bindiis), *Sida spodochroma, Austrodanthonia caespitosa* and *Austrostipa scabra* (OBIG, SWOG).
4.	5%	**Dongas**—rounded, closed depressions, generally 1.5–3 m below the surrounding limestone plain and up to 0.6 km in diameter.	Moderate to deep red/brown non-cracking clays (622) and/or cracking clays (600).	Scattered to very scattered stands of *Acacia tetragonophylla* (curara) or *Eremophila longifolia* (berrigan) surrounded by *Pittosporum angustifolium* (native willow) with an understorey of very scattered mid shrubs of *Lycium australe* (water bush) and moderately closed low shrubland of *Atriplex cryptocarpa, Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush) (DBGR, DCGR).
5.	< 1%	**Drainage foci (gilgai)**—gilgai at claypan edges or within dongas (unit 4).	Cracking clays (600).	Dense patches of perennial grasses; *Austrodanthonia caespitosa*, *Austrostipa scabra*, *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) surround very scattered low shrubs of *Lycium australe* with occasional *Eremophila longifolia* or *Pittosporum angustifolium* trees (GGSL). More frequent in the north where it transitions into the Nurina system.
6.	< 1%	**Drainage tracts (ancient river courses)**—level to gently inclined, sinuous, narrow (< 0.1 km wide), drainage tracts between stony plains (unit 1).	Calcareous loamy earths (542) interspersed with cracking clays (600), occasionally gypsiferous.	Scattered to moderately closed mid to low chenopod shrubland, commonly dominated by *Atriplex vesicaria* (BSSL) or *Sclerolaena* species (OBIG).

***Balgair land system:** Gently undulating stony limestone plains supporting pearl bluebush shrubland sloping down into a mosaic of bladder saltbush shrubland and grassland in drainage floors.*

BALLADONIA LAND SYSTEM (145 km², 0.1% of the survey area)

Gritty-surfaced calcrete plains surrounding bare granite outcrop with fringing acacia–dodonaea–eremophila shrubland.



Land zone: Mardabilla Plain.

Land type: 6

Geology: Proterozoic granite and Quaternary (Pleistocene) sheet and nodular calcrete overlain by residual and aeolian loam.

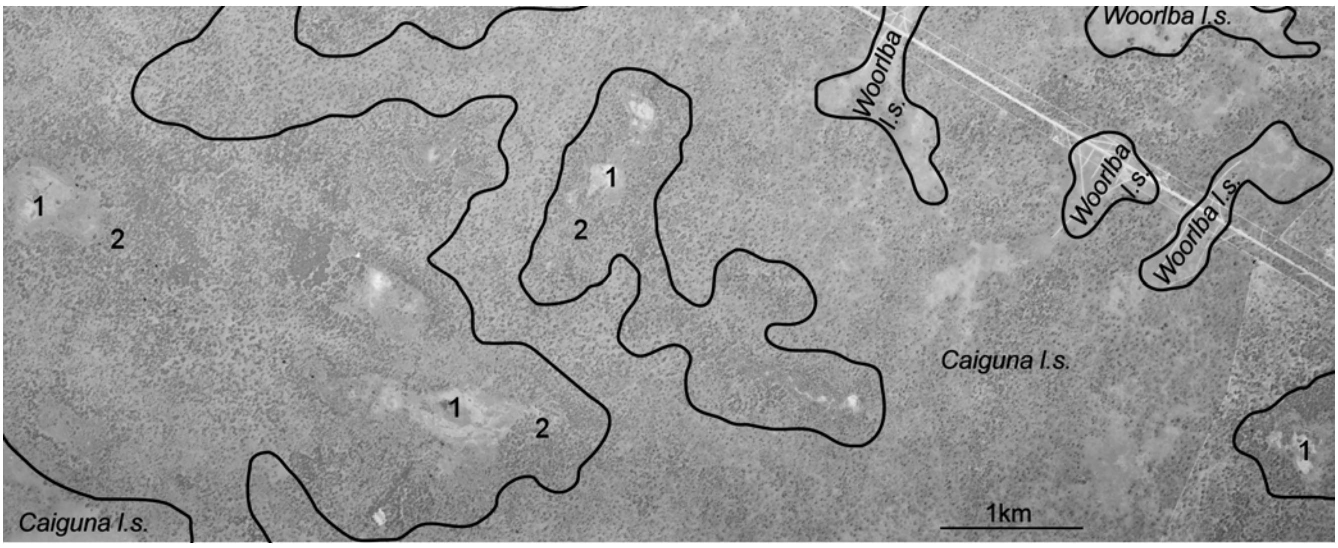
Geomorphology: Erosional surfaces; granite low rises and domes protruding through calcrete plains, fringed by gritty, sandy surfaces. Granitic outcrop is often ringed by moat-like depressions, 3–10 m deep and 50–150 m across, where water run-off is concentrated dissolving calcareous surroundings.

Land management: This land system is generally not susceptible to soil erosion, partly as a consequence of the protective stony mantle. Overgrazing of palatable species can occur near rock holes when ephemeral water pools for significant periods.

Traverse condition summary:
(31 assessments)

Vegetation—very good 13%, good 45%, fair 29%, poor 10%, very poor 3%.

No.	Landform	Traverse recordings	Inventory sites
1.	Low granite rise	3	2
2.	Gritty-surfaced margin	28	3
	Total	31	5



Balladonia land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	50%	**Low granite rises**—Granite outcrop occurring as low rises or domes, generally less than 5 m relief (occasionally up to 10 m relief).	Very shallow red sands (423) or loams (522) on granite; rocky granite soils (201).	Unvegetated to very scattered mixed shrubland commonly *Acacia ligulata* and *Dodonaea lobulata* with *Ptilotus obovatus* (cotton bush) understorey (GROS).
2.	50%	**Gritty surfaced margins**—generally narrow gritty, sandy surfaces fringing granite outcrop (unit 1) merging into surrounding calcrete plains.	Red shallow sands (423) or loams (522) over granite or occasionally calcrete.	Moderately closed mid to tall shrubland dominated by *Eremophila* and *Dodonaea* species (DEXS) or low shrubland of mixed shrubs including *Atriplex* species, *Enchylaena tomentosa*, *Ptilotus obovatus* and *Rhagodia ulicina* (GROS). A scattered overstorey of eucalypts is occasionally present (EXCW, EXSW).

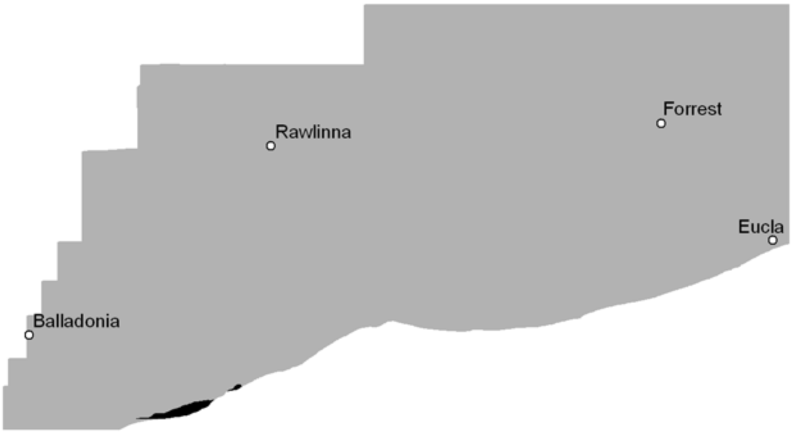
Balladonia land system: *Low granite rises surrounded by calcrete plains supporting eucalypt woodland.*

BAXTER LAND SYSTEM (285 km², 0.2% of the survey area)

Clifftop dunes supporting banksia coastal heath and scrubland.

Land zone: Hampton Tableland.

Land type: 14



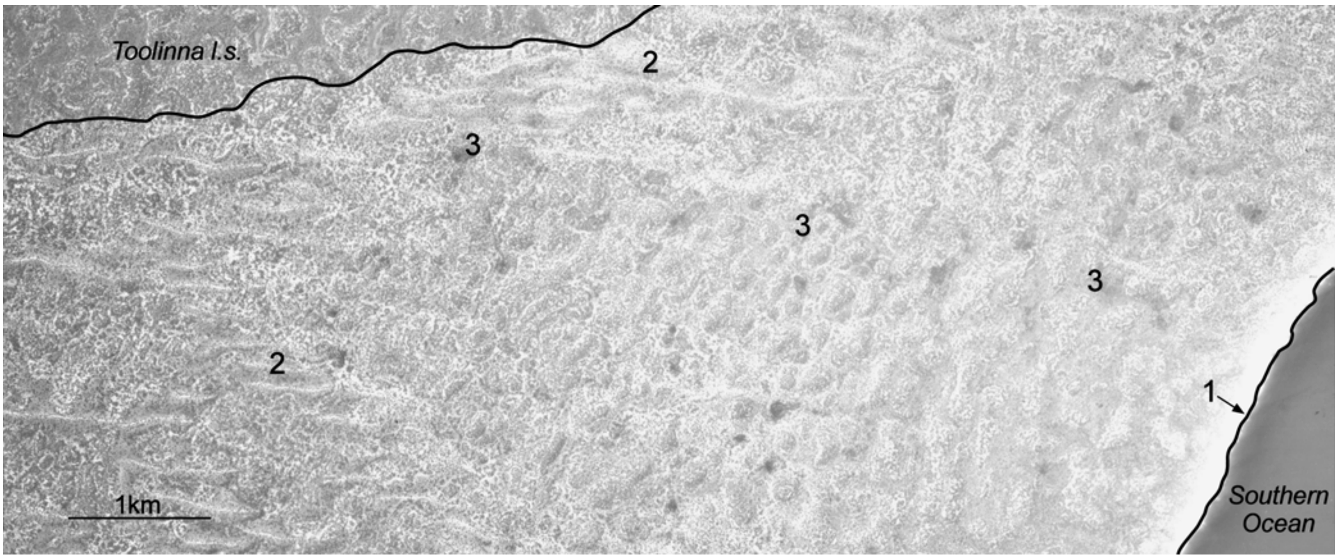
Geology: Quaternary (Pleistocene) aeolian siliceous sands containing sheet and nodular calcrete, over Eocene Toolinna Limestone.

Geomorphology: Depositional surfaces; transverse sand dunes trending west to north-west partially consolidated with a calcrete horizon developed close to the surface. Commonly in sets of low parallel ridges separated by interdunal corridors of calcrete and consolidated aeolian calcarenite, occasionally indurated Toolinna Limestone, with no organised drainage; marine-eroded scarp and cliff forms the southern edge of Bunda Plateau.

Land management: Dunes are stable when vegetated but are susceptible to wind erosion if vegetation is reduced due to disturbance through fire or vehicle-induced track erosion.

Traverse condition summary:
(not traversed)

No.	Landform	Traverse recordings	Inventory sites
1.	Scarp/Cliff	–	–
2.	Dune	–	1
3.	Interdunal swale	–	–
	Total	–	1



Baxter land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Scarp/Cliff**—marine-eroded cliff face.	Shallow aeolian siliceous sands (421), weakly bioclastic.	Dwarfed closed heathland of *Adenanthos forrestii, Banksia media*, *Beaufortia micrantha, Boronia crassifolia, Conostephium drummondii, Eucalyptus incrassata*, *Melaleuca quadrifaria* and *Pultenaea heterochila* (BCHS).
2.	40%	**Dunes**—partially consolidated parallel transverse dunes with gentle to moderately inclined slopes with a calcrete horizon developed close to the surface.	Deep aeolian siliceous sands (442), weakly bioclastic.	Moderately closed tall scrubland dominated by *Banksia media*, *Eucalyptus incrassata* and *Melaleuca* species with closed heathland of *Adenanthos forrestii, Beaufortia micrantha, Boronia crassifolia, Conostephium drummondii* and *Pultenaea heterochila* (BCHS).
3.	59%	**Interdunal swales**—weathered outcrop of calcrete sheets or occasional Toolinna Limestone, commonly with a mantle of calcarenite and calcrete nodules and fragments.	Shallow aeolian siliceous sands (421), weakly bioclastic.	Thickets of *Banksia media*, *Eucalyptus incrassata* and *Melaleuca* species among closed heathland of *Adenanthos forrestii, Beaufortia micrantha, Boronia crassifolia, Conostephium drummondii* and *Pultenaea heterochila* (BCHS).

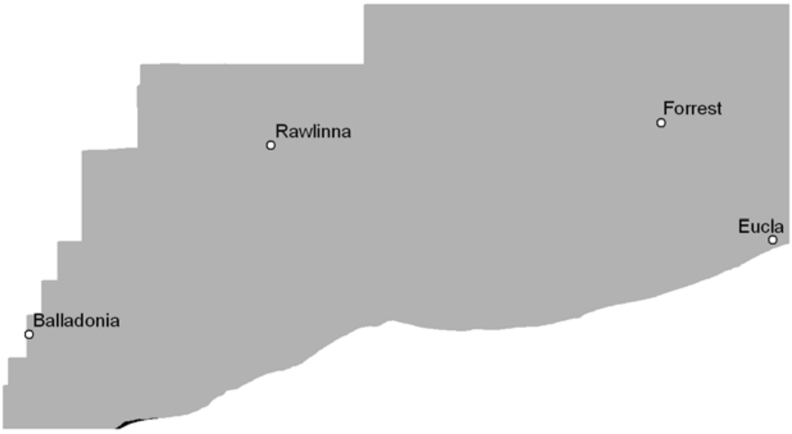
Baxter land system: *Dune supporting banksia coastal heath and scrubland.*

BILBUNYA LAND SYSTEM (47 km², < 0.1% of the survey area)

Seaward side of narrow coastal plain composed of beach, foredunes, interdunal swales and coastal dunefields supporting coastal shrubland, with areas of sparsely vegetated exposed calcarenite.

Land zone: Israelite Plain.

Land type: 14



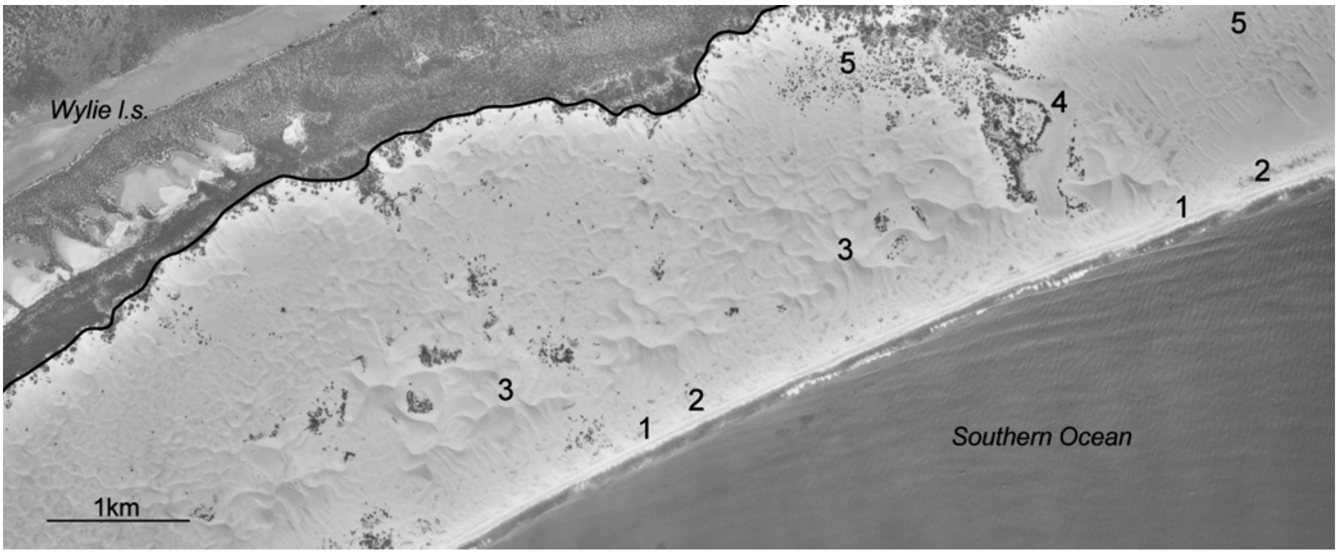
Geology: Quaternary (Recent) aeolian calcareous and siliceous sand, overlying aeolian calcarenite.

Geomorphology: Depositional surfaces; beaches, unconsolidated to partially consolidated foredunes and swales with narrow drainage zones receiving more concentrated flow; broad dunefields with largely unconsolidated parabolic dunes trending approximately north-south, frequently becoming reticulate, occasionally forming star dunes; swales of variable width with depressions of calcareous silt, clay or lagoonal deposits; aeolian calcarenite is exposed in some areas; interdunal chains of old coastal lagoons with saline, gypsiferous soils. Dune relief up to 90 m.

Land management: Most land units are highly susceptible to wind erosion if vegetative cover is reduced resulting in large blow-outs and sand drifts.

Traverse condition summary:
(not traversed)

No.	Landform	Traverse recordings	Inventory sites
1.	Beach	–	–
2.	Foredune	–	1
3.	Dunefield	–	–
4.	Interdunal lagoonal depression	–	–
5.	Calcarenite platform	–	–
	Total	–	1



Bilbunya land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	5%	**Beaches**—narrow calcareous sand beaches on seaward side of foredunes.	Calcareous deep sands (442).	No vegetation.
2.	4%	**Foredunes**—unconsolidated to partially consolidated dunes inland from beaches with gently to moderately inclined slopes and hummocky, uneven crests; relief up to 10 m.	Calcareous deep sands (442).	Infrequent clumps and thickets of *Eucalyptus conglobata*, *Acacia anceps* and *A. cyclops* (coastal wattle) with scattered shrubs of *Scaevola crassifolia* (thick-leaved fan-flower), *Threlkeldia diffusa, Leucophyta brownii, Euphorbia paralias, Olearia ramosissima* (much-branched daisy bush) and sedges such as *Ficinia nodosa* (knotted club rush) (COAS).
3.	80%	**Dunefields**—unconsolidated parabolic and star dunes with gentle to steeply inclined dune slopes. Variable-sized swales between dune crests. Dunes up to 90 m high.	Deep calcareous and siliceous aeolian sands (442).	Generally no vegetation though coastal shrubland (COAS) species do occur in varying abundance. *Acacia anceps*, *A. cyclops* and other plants adapted to sand inundation occur as isolated clumps and thickets.
4.	1%	**Interdunal lagoonal depressions**—level narrow saline flats of variable length. Subject to occasional inundation.	Shallow to moderate depth clay loams (542, 544) or clays (622). Saline and gypsiferous.	Commonly poorly vegetated with very scattered low shrubland of *Carpobrotus virescens* (coastal pigface) and *Tecticornia* spp. (samphires) (SAMP) or with no vegetation.
5.	10%	**Calcarenite platform**—very gently inclined to level stony platform with an abundant mantle of angular calcarenite and calcrete fragments.	Skeletal calcareous aeolian sands (421).	Sparsely vegetated with isolated shrubs of *Acacia anceps*, *Darwinia diosmoides* and *Pimelea ferruginea*.

Bilbunya land system: *Bilbunya dunefield in background. Foreground banksia coastal heath and scrubland of Wylie land system.*

BOONDEROO LAND SYSTEM (83 km^2, 0.1% of the survey area)

Salt lakes and fringing saline plains, surrounded by sand and kopi dunes supporting halophytic and non-halophytic shrubland.

Land zone: Nyanga Plain.

Land type: 15

Geology: Quaternary (Pleistocene)—Recent aeolian and lacustrine deposits of quartz sand, silt and clay, sometimes with halite and gypsum.

Geomorphology: Depositional surfaces; lake beds and fringing level to very gently inclined plains of saline alluvium, sandy banks and gypsiferous dunes at margins of surrounding saline plains, undulating kopi dunes; alluvial plains on margin of system subject to sheet flow and inundation.

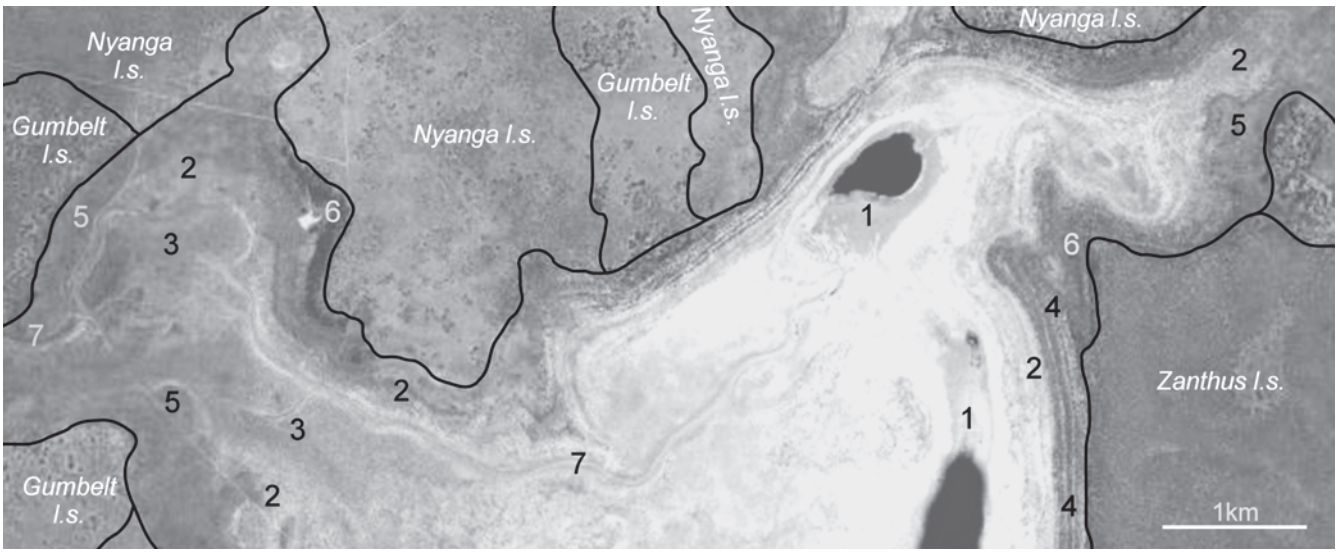
Lake Boonderoo is intermittently filled by cyclonic summer rains that cause its main tributary, Ponton Creek, to flow after being fed by major salt lakes to the west of the Eucla Basin. Due to its saline headwaters Lake Boonderoo can be highly saline.

Land management: After flooding water quality can be suitable for animals prior to it becoming more saline as water level declines. Lake Boonderoo has sub-regional significance for its role in maintaining ecological processes and its importance to migratory birds. As a valuable habitat it provides feeding and breeding grounds unique in their importance in this arid landscape. In recognition of the uniqueness of the habitats associated with Lake Boonderoo land management should include conservative stocking rates in the vicinity of the lake and regular control measures for feral animals and weeds. At the time of survey *Tamarix aphylla* (tamarisk, athel pine) was observed on the lake margins, where it had become established due to its tolerance to dry and saline conditions. A control program had been instigated. Tamarisk is highly invasive and is listed as a weed of national significance, capable of causing considerable environmental and economic problems by competing with native vegetation, altering arid zone watercourses and consuming water resources.

No.	Landform	Traverse recordings	Inventory sites
1.	Lake bed	3	–
2.	Lake margin	3	2
3.	Saline plain	1	–
4.	Sandy bank	1	2
5.	Kopi dune	5	1
6.	Dune	–	–
7.	Drainage zone	1	–
	Total	14	5

Traverse condition summary:
(14 assessments)

Vegetation—good 100%.



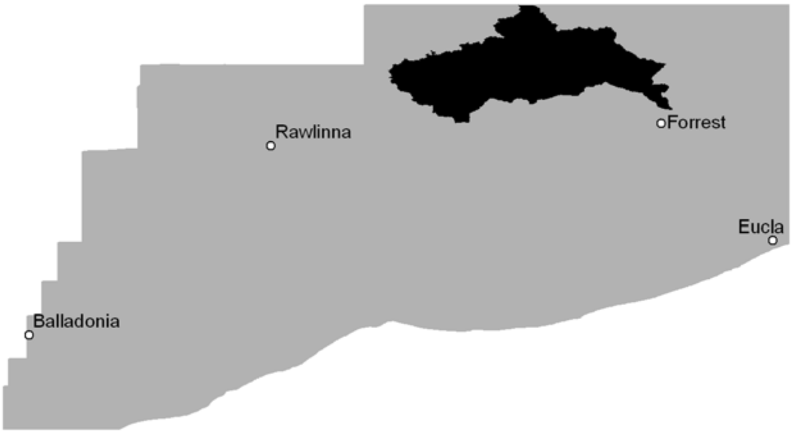
Boonderoo land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	40%	**Lake bed**—lake floors.	Highly saline, gypsiferous sediments (102).	Unvegetated.
2.	20%	**Lake margins**—level to very gently inclined plains marginal to lake bed (unit 1).	Gypsiferous and calcareous gravels. Thin layer of clay on surface (102).	Former *Casuarina pauper* (black oak) open woodland drowned by inundation associated with Cyclone Bobby (1995), now moderately closed halophytic low shrubland dominated by *Atriplex* spp. (saltbush), other common plants include: *Frankenia* (frankenia), *Maireana* (bluebush), *Senna* and *Tecticornia* (samphire) species (PXHS).
3.	20%	**Saline plains**—level, highly saline lower plains often adjacent to lake bed (unit 1).	Red loams and clays over saline gypsiferous deposits (542).	Scattered to moderately closed halophytic low shrubland consisting of *Atriplex*, *Frankenia* and *Maireana* species (PXHS) or dominated by scattered *Tecticornia* spp. (SAMP).
4.	10%	**Sandy banks**—banks and low rises with uneven surfaces, up to 10 m above surrounding plains and lake margin.	Red deep sands (445).	Closed tall shrubland with very variable composition of halophytic and non-halophytic shrubs (SBLS).
5.	5%	**Kopi dunes**—low dunes with gently undulating crests and uneven surfaces, gentle side slopes above units 1 and 3.	Encrusted gypsiferous sediments with shallow red sands in pockets (703).	Scattered woodland *Casuarina pauper* over moderately closed low halophytic shrubs belonging to the genera *Atriplex*, *Cratystylis, Frankenia*, *Maireana, Rhagodia* and *Tecticornia* (KOPI).
6.	4%	**Dunes**—aeolian deposits up to 20 m high fringing units 1 and 5.	Deep red gypsiferous sands (445).	Scattered woodland of *Eucalyptus* species and *Casuarina pauper* over closed tall shrubland of *Acacia* species, occasionally with hummock (spinifex) grass *Triodia scariosa* (SBLS).
7.	1%	**Drainage zones**—narrow drainage lines and drainage foci.	Red clays (622) or shallow red sands (423) and gypsiferous deposits in pockets.	Halophytic low shrubland in drainage lines (PXHS, SAMP). Drainage foci with variable halophytic and non-halophytic communities.

Boonderoo land system: *Gypsiferous encrusted lake margin, background of dunes and sandy banks.*

BULLSEYE LAND SYSTEM (8817 km^2, 7.4% of the survey area)

(modified and incorporating the land system formerly known as Loongana from Mitchell, McCarthy and Hacker 1979)



Very gently undulating stony limestone plains supporting bindii grassland and drainage floors with frequent large dongas, occasional swamps and small claypans.

Land zone: Nullarbor Plain.

Land type: 12

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

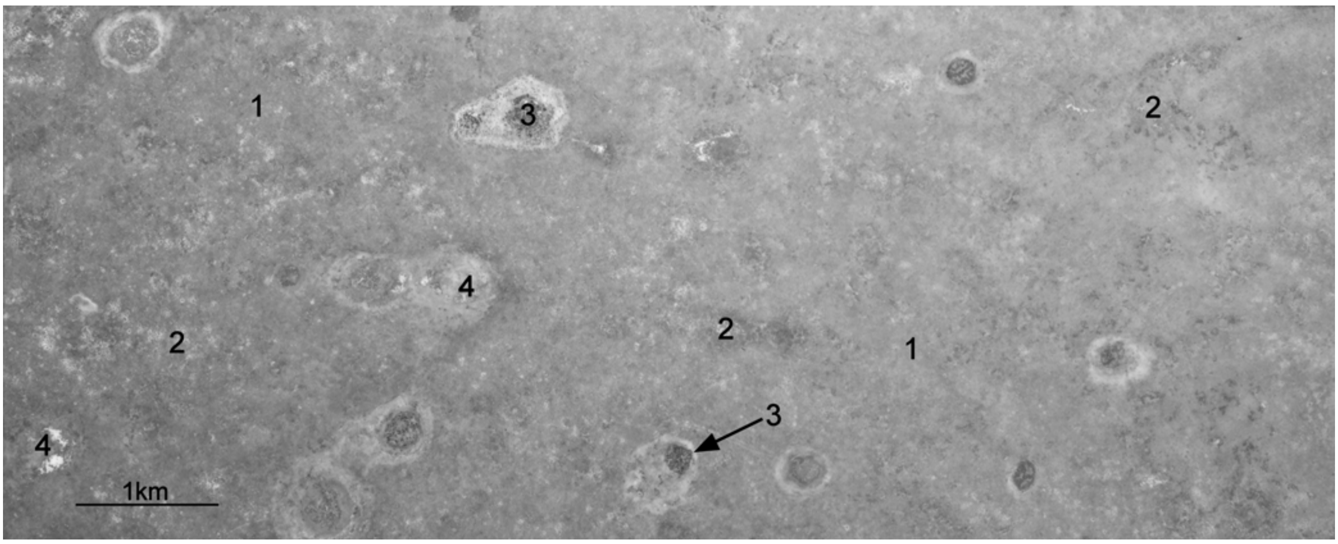
Geomorphology: Erosional surfaces; differential weathering of the deflated Nullarbor Limestone has formed drainage floors along irregular to east-west trending rectilinear joint patterns draining into large circular drainage foci: swamps or dongas with gilgai micro-relief and often with prominent lightly vegetated annuli, or small claypans. Dongas are considered solution dolines rather than collapsed caves, formed through water ponding in depressions in the limestone plain and solution further dissolving the limestone.

Land management: In comparison to the surrounding open stony plains donga vegetation communities have an important role in providing sheltered habitats to animals and plants, as well as significant production value in providing a crucial source of browse during dry periods. Vegetation communities associated with dongas need to be preserved to ensure the heterogeneity of the northern Nullarbor Plain. Water points in dongas leads to deterioration of the vegetation communities as animals frequent the area causing overgrazing, depletion of the seed store as juvenile plants are continually eaten, and breaking down of bush clumps for forage and shelter. The value of dongas as a sheltered habitat and forage reserve is eventually reduced, along with the ability of the landscape to offer any significant pastoral value during dry periods.

Traverse condition summary: (15 assessments)

Vegetation—good 27%, fair 40%, poor 20%, very poor 13%.

No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	13 (2006)	–
2.	Marginal slope to drainage floor	–	–
3.	Donga	2 (2006)	–
4.	Claypan	–	–
5.	Swamp	–	–
	Total	15 (2006) / 32 (1974)	3 (1974)



Bullseye land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	65%	**Stony limestone plains**—level plains with abundant mantle of Nullarbor Limestone fragments and outcrop.	Calcareous shallow loams (521).	Very scattered to scattered tussock grassland and bindii shrubland independently or co-dominated by *Sclerolaena* species (bindiis) and *Austrostipa scabra* (speargrass) (OBIG, SWOG), occasionally very scattered *Maireana sedifolia* (pearl bluebush) low shrubland (PBLS).
2.	25%	**Marginal slope to drainage floors**—very gently inclined slopes to level floors, 0.3 km wide, up to 3 km long, sparse stony mantle of limestone fragments, infrequent outcrop.	Calcareous loamy earths (542).	Scattered to dense grassland of *Austrodanthonia caespitosa* (wallaby grass) and *Austrostipa scabra* (SWOG) occasionally very scattered to moderately closed *Atriplex vesicaria* (bladder saltbush) low shrubland (BSSL).
3.	8%	**Dongas**—oval to circular, closed depressions, 1–3 m below the surrounding limestone plain, generally < 0.2 km in diameter, though can be up to 0.8 km; gilgai patches in donga floor have brought rounded Nullarbor Limestone boulders to the surface; marginal slope (annuli) around donga (< 0.2 km wide) sometimes present.	Red/brown non-cracking clays (622) interspersed with cracking gilgai clay soils (600).	Scattered to moderately closed *Grevillea nematophylla* groves (DGGR) or scattered *Acacia tetragonophylla* (curara) and *Pittosporum angustifolium* (native willow) (DCGR, DPGR) in the smaller dongas; with an understorey of *Chenopodium curvispicatum* surrounded by the tussock grasses. Gilgai patches dominated by perennial grasses; *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail). Marginal slopes around dongas support species of *Sclerolaena* (OBIG).
4.	1%	**Claypans**—irregular, smooth, level closed depressions, up to 0.4 km in extent.	Clay loam soils (542).	Unvegetated, occasionally as for unit 2.
5.	1%	**Swamps**—infrequent, level, circular depressions, up to 0.4 km in diameter occurring within unit 2.	Non-saline red-brown non-cracking clays (622).	Scattered *Muehlenbeckia florulenta* (lignum) low shrubland (LISW).

Bullseye land system: *Donga supporting grove of* Grevillea nematophylla *surrounded by perennial grasses.*

CAIGUNA LAND SYSTEM (7066 km², 6.0% of the survey area)

Gently undulating plains with residual calcareous low rises supporting low eucalypt woodland.

Land zone: Hampton Tableland and Mardabilla Plain.

Land type: 2

Geology: Quaternary residual and aeolian loam overlying Quaternary (Pleistocene) calcrete over Palaeogene and Neogene Limestone.

Geomorphology: Relict land surfaces, erosional at margins; level to gently undulating broad plains of residual and aeolian loam containing sheet and nodular calcrete, with occasional residual rises of calcrete or indurated Nullarbor Limestone; no organised drainage.

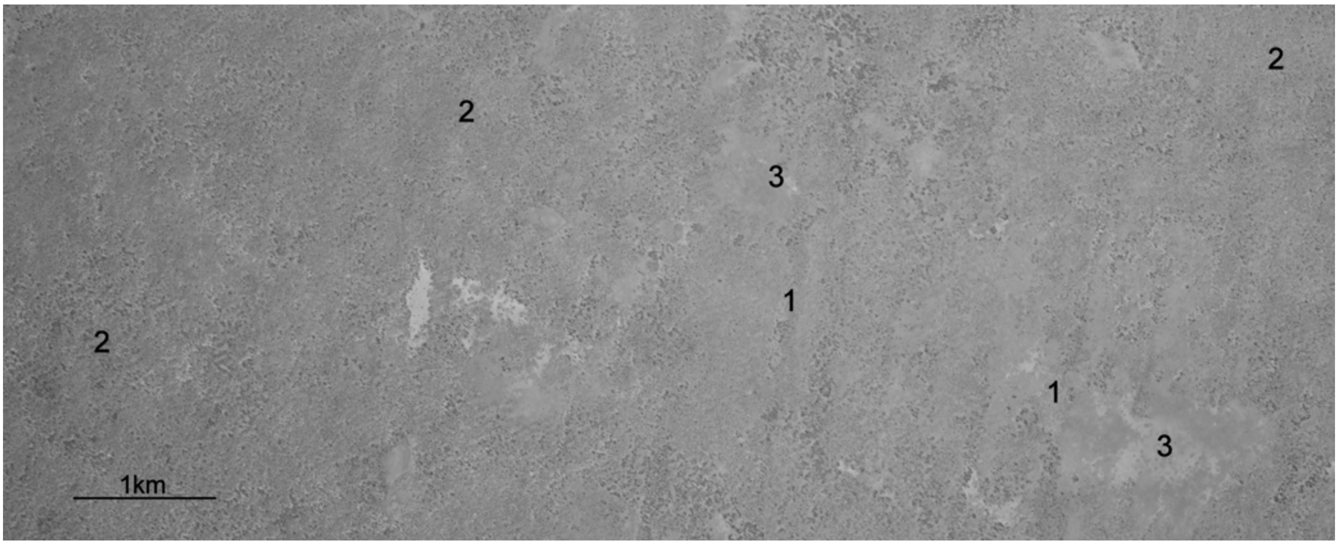
Land management: Some trees and shrubs, particularly at juvenile stage, are preferred by grazing animals and may be killed with heavy grazing pressure. Heavy grazing can be avoided by good land management, including control of total grazing pressure.

The south of the Caiguna land system is situated between other land systems that are susceptible to wildfires depending on seasonal conditions. The occurrence of Eucalypt speargrass open grasslands (ESOG) demonstrates the extensive ecological alteration caused by past fires. Strategic firebreaks may preserve intact vegetation communities and limit wildfire damage.

Traverse condition summary:
(201 assessments)

Vegetation—very good 41%, good 50%, fair 7%, poor 1%, very poor 1%.

No.	Landform	Traverse recordings	Inventory sites
1.	Residual calcrete rise	2	4
2.	Calcrete plain	188	9
3.	Drainage focus	11	3
	Total	201	16



Caiguna land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	5%	**Residual calcrete rises**—very gently inclined low rises of calcrete or indurated Nullarbor Limestone; variable mantle of calcareous fragments and outcrop.	Calcareous shallow loams (521).	Scattered low woodland of *Eucalyptus gracilis* (yorrell), *E. oleosa* subsp. *oleosa* (giant mallee) and/or *E. yalatensis* (yalata mallee) over mixed shrub species such as *Atriplex* (saltbushes), *Eremophila*, *Maireana* (bluebushes), *Melaleuca* and *Geijera linearifolia* (oil bush) (EXSW, EXCW) or as a dense grass understorey of *Austrostipa scabra* (speargrass) under very scattered mallee-form *Eucalyptus* species (ESOG).
2.	85%	**Calcrete plains**—level to very gently inclined plains with occasional mantle of calcrete nodules; plates of calcrete outcrop uncommon.	Calcareous loams of variable depth (521, 542).	Scattered to moderately closed low woodland of variable *Eucalyptus* species over a mixed shrub understorey of *Atriplex*, *Cratystylis conocephala* (false bluebush), *Eremophila*, *Geijera linearifolia, Maireana, Melaleuca* and *Westringia rigida* (EXSW, EXCW); occasionally with a very scattered tall shrub layer of *Myoporum platycarpum* (sugarwood) (ESCW) or dense stands of melaleuca (EMEW).
3.	10%	**Drainage foci**—level, irregularly shaped, closed depressions, up to 1.5 km in extent, receiving run-on from adjacent areas (units 1 and 2); surface mantle with occasional calcareous fragments.	Calcareous clay loam earths (542) or red/brown non-cracking clays (622).	Scattered mixed low shrubland either dominated by non-halophytic shrubs (PXLS) commonly featuring *Eremophila decipiens*, *E. deserti* and *Geijera linearifolia* or with a variable composition including halophytic shrubs (PXHS) such as *Lawrencia squamata*, *Lycium australe* (water bush), *Maireana sedifolia* (pearl bluebush), *Nitraria billardierei* (nitre bush) and *Tecticornia* spp. (samphires); occasionally *Eucalyptus gracilis* encroach down to depression margins (EXHS).

Caiguna land system: *Calcrete plain supporting eucalypt woodland over mixed shrubs.*

CARLISLE LAND SYSTEM (2066 km², 1.7% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Gently undulating stony calcrete plains supporting bindii grassland with sparse myall.

Land zone: Nyanga Plain.

Land type: 4

Geology: Partially deflated Quaternary (Pleistocene)—Neogene (Pliocene) calcrete and residual clay loam over Miocene Nullarbor Limestone.

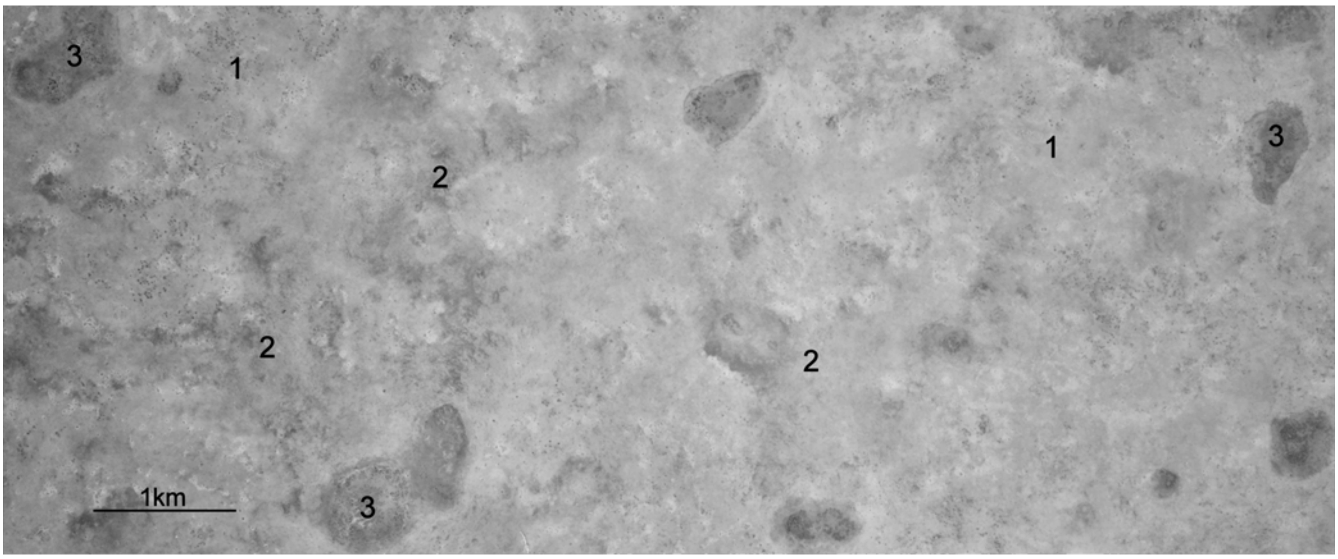
Geomorphology: Erosional surfaces; gently undulating plains of residual clay loam containing sheet and nodular calcrete dissected to expose Nullarbor Limestone, differential weathering of the surface has formed dongas of varying size and drainage floors in the south of the system, no organised drainage.

This system is intermediate in form between intact residual loamy calcrete plains of the Kyarra and Nyanga land systems and the deflated stony limestone plains of the Bullseye and Oasis land systems.

Land management: Donga vegetation communities are preferentially visited and browsed by introduced and native animals, and deteriorate with heavy grazing pressure. In this system camels are common and their browsing impact is becoming increasingly obvious in the opening up and deterioration of donga groves. Many donga tree species provide a valuable source of browse and are heavily utilised in dry periods. The condition of tree-based clumps in dongas provides an indication of range condition and the total grazing pressure of an area. The presence of juvenile plants and a dense understorey in a tree-based clump indicates improving range condition whilst heavy browse lines, broken limbs and an absence of young plants indicate deteriorating range condition and heavy grazing pressure. Overgrazing can be avoided by good land management, including control of total grazing pressure.

Traverse condition summary:
(106 assessments in 1974)

No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	–	–
2.	Drainage floor	–	–
3.	Donga	–	–
	Total	106/1974	10/1974



Carlisle land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	85%	**Stony limestone plains**—gently undulating plains, abundant stony mantle of calcareous fragments and Nullarbor Limestone outcrop.	Calcareous shallow loams (521).	Very scattered woodland to isolated individuals of *Acacia papyrocarpa* (myall) over a low shrub stratum commonly dominated by species of *Sclerolaena* (bindii) (MBIG, OBIG) or *Austrostipa scabra* (speargrass) and *Austrodanthonia caespitosa* (wallaby grass) grassland (SWOG).
2.	6%	**Drainage floors**—level to gently inclined open depressions within strongly dissected areas of stony plain and receiving run-on from unit 1.	Calcareous loams to various depths (521, 542).	Dense grassland dominated by *Austrostipa scabra* and *Austrodanthonia caespitosa* (SWOG).
3.	9%	**Dongas**—shallow closed depressions, generally 1.5–3 m below the surrounding calcrete plain (unit 1), up to 0.5 km in diameter, rounded limestone boulders occasionally present in areas of upheaval due to gilgai processes.	Deep clays (622) or gilgai clay soils (600).	Very scattered to moderately closed stands of *Grevillea nematophylla* and *Pittosporum angustifolium* (native willow) over an understorey of *Lycium australe* (water bush), *Atriplex cryptocarpa, Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush). *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) are common in gilgai areas. Very scattered *Acacia tetragonophylla* (curara) on the marginal slopes surrounding the dongas (DGGR, DPGR).

Carlisle land system: *Donga supporting* Grevillea nematophylla*, mulga and* Eragrostis *grasses; note boulders brought to surface by gilgai processes.*

CHOWILLA LAND SYSTEM (1532 km², 1.3% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Gently undulating stony limestone plains supporting scattered myall woodland and pearl bluebush shrubland on low ridges and a mosaic of grassland and halophytic shrubland in drainage floors along irregular joint patterns.

Land zone: Nullarbor Plain.

Land type: 10

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

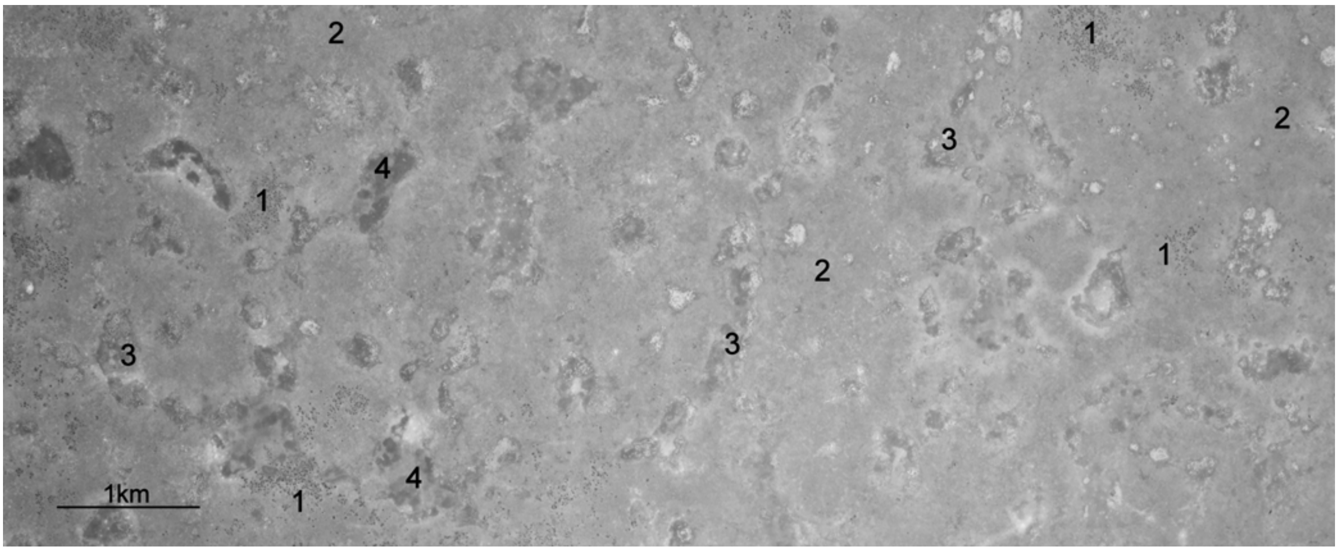
Geomorphology: Erosional surfaces; differential weathering of the deflated Nullarbor Limestone along irregular joint patterns has formed colluvial infilled drainage depressions separated by gently undulating low stony rises (irregular limestone hummocks) and ridges, relief seldom exceeds 5 m; drainage depressions occur as open depressions forming narrow drainage floors, up to 1.5 km long often terminating in oval claypans, up to 0.5 km in diameter, or as small closed drainage foci randomly distributed throughout the stony plains.

Land management: The majority of this system occurs outside pastoral leases and is dominated by chenopod vegetation. Rainfall and seasonal conditions determine species composition and abundance. The onset of dry seasonal conditions is best indicated by seasonally dependent subshrubs that begin to decline as dry conditions commence; perennial species such as *Atriplex vesicaria* lose their leaves in prolonged dry periods. Where grassland dominates the understorey then adjacent fire sensitive vegetation communities such as chenopod shrubland and myall woodland are at risk from fire. Where such areas are grazed and become burnt then total grazing pressure should be restricted from the burnt areas for a period set by seasonal conditions which will determine the effectiveness of recovery. Continuous grazing pressure can reduce such vegetation communities to seasonally dependent grassland, diminishing the landscape's ability to support herbivores during dry periods.

Traverse condition summary: (21 assessments)

Vegetation—very good 57%, good 38%, fair 5%.

No.	Landform	Traverse recordings	Inventory sites
1.	Limestone hummock (low rise)	–	–
2.	Stony limestone plain	13 (2006)	–
3.	Marginal slope to drainage floor	1 (2006)	–
4.	Claypan	7 (2006)	1 (2006)
	Total	21 (2006) / 50 (1974)	1 (2006) / 5 (1974)



Chowilla land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	5%	**Limestone hummocks (low rises)**—gently undulating low ridges and rises (up to 5 m relief); stony mantle of mixed-sized limestone fragments and outcrop common to abundant.	Skeletal calcareous shallow loams (521).	Very scattered to scattered *Acacia papyrocarpa* (myall) over an understorey dominated by either *Maireana sedifolia* (pearl bluebush) (MPBS), *Atriplex nummularia* (old man saltbush) and *A. vesicaria* (bladder saltbush) (MSAS) or *Austrostipa scabra* (speargrass) grassland (MSOG).
2.	55%	**Stony limestone plains**—gently undulating plains with common to abundant mantle of mixed-sized Nullarbor Limestone fragments and outcrop.	Calcareous shallow loams (521).	Very scattered to scattered *Maireana sedifolia* low shrubland (PBLS).
3.	25%	**Marginal slope to drainage floors**—gently inclined slopes, with a sparse mantle of mixed limestone fragments, drain into either open depressions forming narrow drainage floors, up to 1.5 km long or small closed randomly distributed drainage foci.	Saline calcareous loamy earths (542).	Slopes support scattered to moderately closed shrubland co-dominated by *Maireana sedifolia*, *Atriplex nummularia* and *A. vesicaria* (PXCS); drainage floors support a mosaic of moderately closed *Atriplex vesicaria* shrubland (BSSL), often co-dominant with *Tecticornia* spp. (samphires) (PXHS) or *Austrostipa scabra* (speargrass) and *Austrodanthonia caespitosa* (wallaby grass) grassland (SWOG).
4.	15%	**Claypans**—large oval, closed depressions, 0.5 km in diameter, smooth, level surface occurring as sumps within drainage floors (unit 2).	Red/brown non-cracking clays (622).	Very scattered to moderately closed *Atriplex vesicaria* low shrubland (BSSL) or *Austrostipa scabra* and *Austrodanthonia caespitosa* grassland (SWOG), occasionally unvegetated.

Chowilla land system: *Saline drainage floor supporting halophytic shrubland dominated by bladder saltbush and scattered samphire.*

COLVILLE LAND SYSTEM (421 km², 0.4% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Very gently undulating calcrete plains overlain by sandy loam supporting myall woodland over bindii grassland, enclosing sparse mulga in dongas and claypans.

Land zone: Carlisle Plain.

Land type: 3

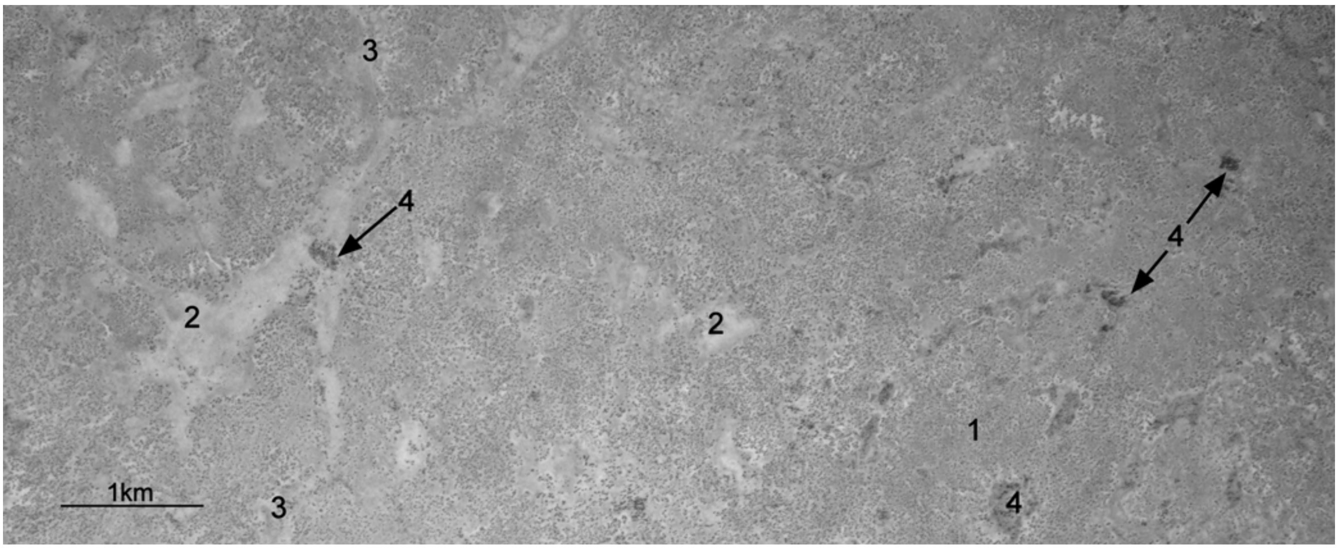
Geology: Quaternary residual sandy loam overlying Quaternary (Pleistocene) calcrete over Miocene Nullarbor Limestone.

Geomorphology: Relict land surfaces; very gently undulating plains of residual sandy loam containing sheet and nodular calcrete at or near the surface; drainage patterns restricted to relic river courses with infrequent depressions having gilgai micro-relief along their length; dongas and claypans exhibit centripetal drainage; ancient river courses and dongas are about 2 to 3 m below the calcrete plains surface.

Land management: This system occurs entirely on Unallocated Crown Land and is unmanaged. Feral camels and rabbits are common to the system and have a detrimental effect on the vegetation. The browsing impact of camels during dry periods can be significant to donga vegetation. The coalescence of piospheres around rabbit warrens leaves the understorey bare and exposed to wind erosion.

Traverse condition summary:
(3 assessments in 1974)

No.	Landform	Traverse recordings	Inventory sites
1.	Loamy plain overlain by aeolian sand	–	–
2.	Drainage focus	–	1 (1974)
3.	Drainage tract (ancient river course)	–	–
4.	Donga	–	–
	Total	3 (1974)	1 (1974)



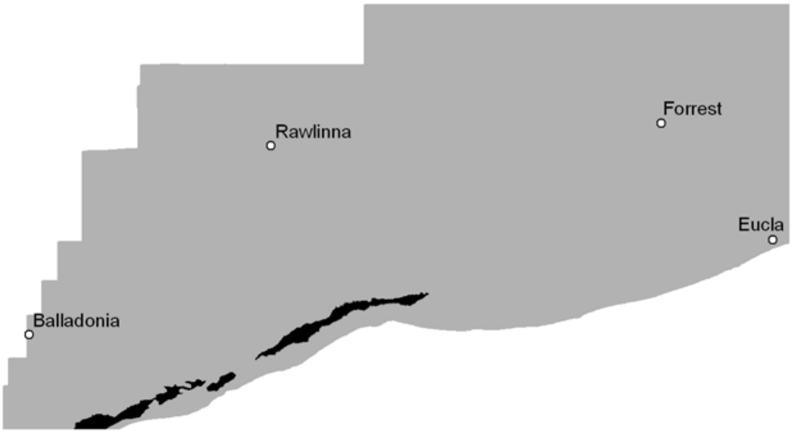
Colville land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	85%	**Loamy plains overlain by aeolian sand**—level to very gently inclined plains overlain by shallow sand sheets, stony mantle of calcrete nodules and fragments.	Red sandy earths or sandy loams over calcareous loams of variable depth (463).	Very scattered woodland of *Acacia papyrocarpa* (myall) over grassland dominated by species of *Sclerolaena* (bindii) (MBIG), or less frequently *Maireana sedifolia* (pearl bluebush) (MPBS).
2.	5%	**Drainage foci**—small circular, shallow claypans up to 0.3 km in diameter.	Deep clay loams (542).	Dense *Austrodanthonia caespitosa* (wallaby grass) and *Austrostipa scabra* (speargrass) grassland (SWOG), occasionally with sparse *Acacia aneura* (mulga) around the claypan margins.
3.	5%	**Drainage tracts (ancient river courses)**—level to gently inclined narrow drainage tracts (< 0.5 km wide) receiving run-on from unit 1, infrequent depressions, dongas (unit 4), with gilgai micro-relief occur along their length.	Deep clay loams (542).	Dense *Austrodanthonia caespitosa* and *Austrostipa scabra* grassland (SWOG), with very scattered *Acacia aneura*.
4.	5%	**Dongas**—closed oval depressions, up to 0.4 km in diameter, commonly with centripetal drainage patterns from flow received from the surrounding calcrete plain (unit 1).	Deep clays (622) or gilgai clay soils (600).	Very scattered to moderately closed stands of *Acacia aneura*, *Grevillea nematophylla* and *Pittosporum angustifolium* over an understorey of *Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush) (DGGR, DPGR).

Colville land system: *Myall woodland over pearl bluebush shrubland.*

CULVER LAND SYSTEM (1707 km^2, 1.4% of the survey area)

Gently undulating stony calcrete plains supporting low mallee woodland over sedges and hummock grasses.



Land zones: Mardabilla Plain and Hampton Tableland.

Land type: 8

Geology: Quaternary (Pleistocene) calcrete over Palaeogene and Neogene Limestone.

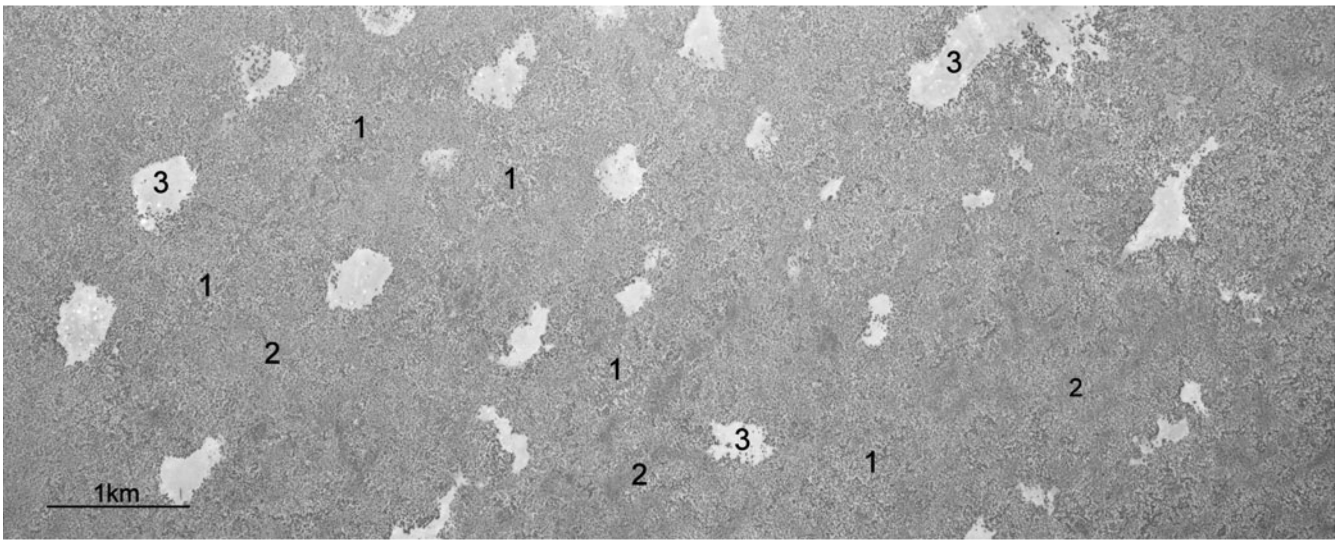
Geomorphology: Erosional surfaces; level to gently undulating stony plains of residual and aeolian loam containing sheet and nodular calcrete, irregularly dissected by differential weathering along joint patterns in underlying limestone, no organised drainage; broad calcrete plains interspersed with closed drainage foci, calcrete platforms and low rises.

Land management: Rugged and poorly accessible country. Vegetation is not preferred by livestock. The close association between grass-dominated drainage foci and the uniform nature of the mallee understorey composed of low scrub and sedges renders this land system susceptible to wildfires. Strategic firebreaks may limit the extent of damage caused by wildfires.

Traverse condition summary:
(48 assessments)

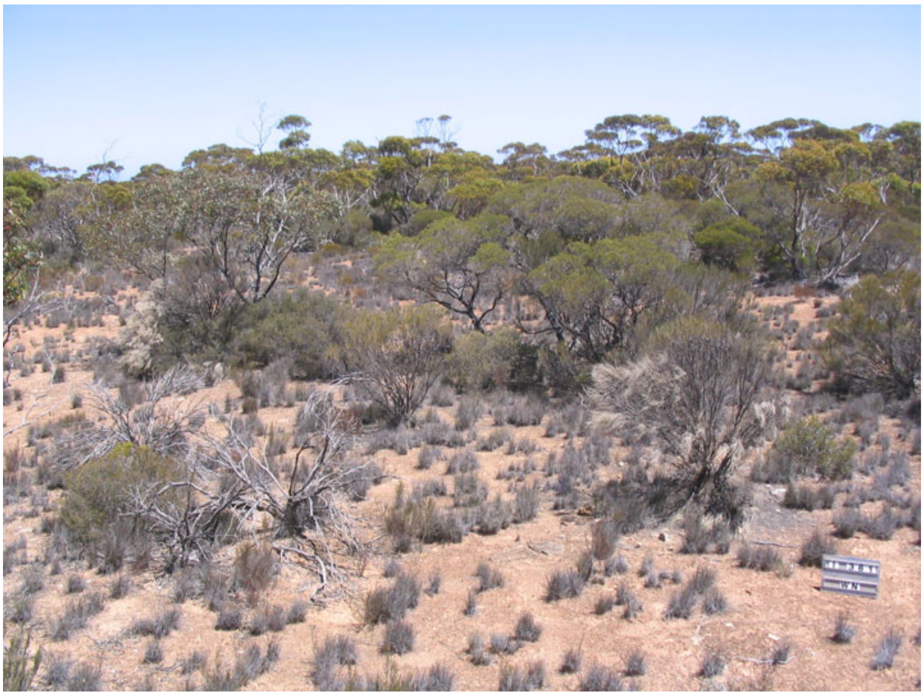
Vegetation—very good 48%, good 46%, fair 4%, poor 2%.

No.	Landform	Traverse recordings	Inventory sites
1.	Calcrete platform and low rise	–	1
2.	Calcrete plain	44	6
3.	Drainage focus	3	2
4.	Other	1	–
	Total	48	9



Culver land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	5%	**Calcrete platforms and low rises**—slightly raised platforms and low rises, sheets and plates of calcrete outcrop and a variable mantle of calcrete boulders and nodules common.	Calcareous shallow loams (521).	Scattered low mallee woodland of variable *Eucalyptus* species over scattered mixed scrub featuring *Allocasuarina helmsii*, *Melaleuca lanceolata*, *Dodonaea stenozyga*, *Acacia erinacea, Olearia calcarea*, *Pomaderris myrtilloides*, *Pultenaea elachista* and sedges *Gahnia lanigera* and *Tetraria capillaris* (LOMW).
2.	80%	**Calcrete plains**—level to very gently undulating plains, occasional mantle of calcrete nodules and laminae plates, outcrop uncommon.	Calcareous loams to variable depths (521, 542).	Scattered low mallee woodland of variable *Eucalyptus* species over scattered to moderately closed mixed scrub commonly featuring *Dodonaea stenozyga*, *Exocarpos aphyllus* (naked lady), *Geijera linearifolia* (oilbush), *Acacia erinacea, Olearia calcarea*, *Pomaderris myrtilloides*, *Westringia rigida* and sedges *Dianella revoluta*, *Gahnia lanigera* and *Tetraria capillaris* or hummock (spinifex) grass *Triodia scariosa* (LOMW). Occasional scattered to closed woodland dominated by *Melaleuca lanceolata* and *Eucalyptus oleosa* subsp. *oleosa* (giant mallee) with a variable understorey of shrubs and sedges (EMEW).
3.	15%	**Drainage foci**—level closed depressions defined by joint patterns, oval, commonly 0.4 km by 0.3 km in extent, receiving run-on from adjacent areas (units 1 and 2), surface mantle has occasional calcareous fragments.	Calcareous loamy earths (542) and red/brown non-cracking clays (622).	Scattered mixed shrubland dominated by *Eremophila decipiens* and *E. deserti* (PXLS), *Acacia cyclops* (coastal wattle), *Geijera linearifolia, Lawrencia squamata*, *Lycium australe* (water bush), *Maireana sedifolia* (pearl bluebush), *Nitraria billardierei* (nitre bush) and *Tecticornia* sp. (samphire) are common; or occasionally very scattered to scattered herbland of annual herbs and grasses (ANNH) or perennial grasses (SWOG).



Culver land system: *Calcrete plain supporting low mallee woodland over mixed shrubs and sedges.*

DAMPER LAND SYSTEM (390 km², 0.3% of the survey area)

Lagoonal saline clay flats supporting halophytic shrubland.

Land zone: Roe Plains.

Land type: 15

Geology: Quaternary (Pleistocene) lagoonal mud deposits, gypsiferous and calcareous clay; aeolian deposits; overlying Roe Calcarenite.

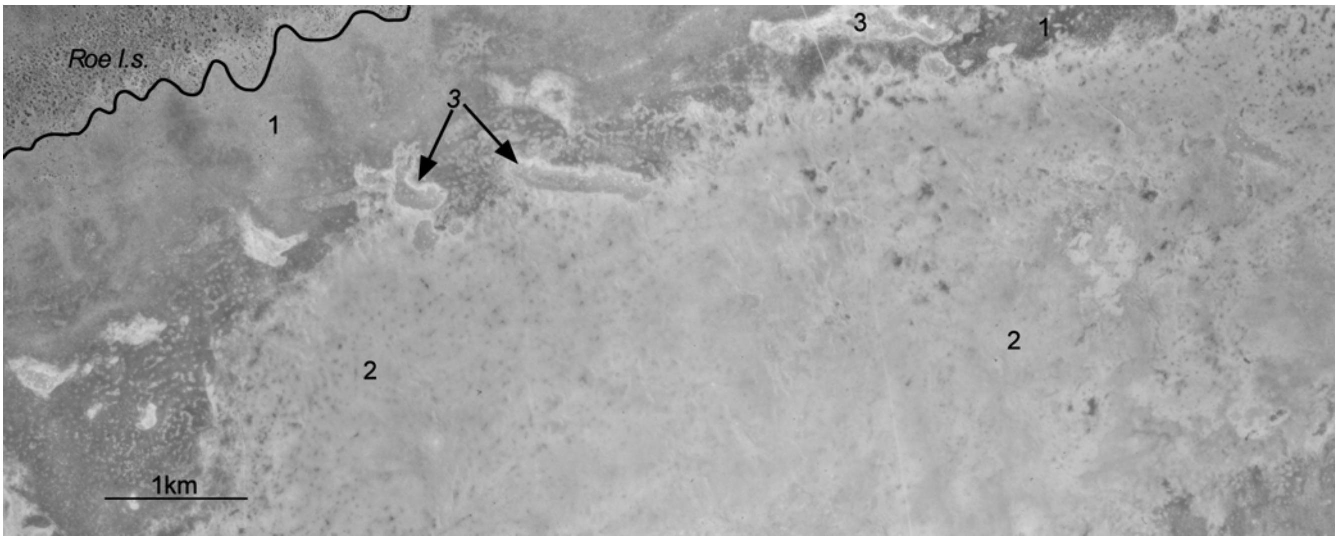
Geomorphology: Depositional surfaces; lagoonal surfaces of saline, gypsiferous calcareous clay; deflated aeolian deposits derived from lagoon surface forming minor low dunes. These landforms represent Pleistocene lagoons that became barred from the sea by advancing dunes.

Land management: This habitat is rarely impacted by grazing due to the high salt content of plants. Lack of slope renders most of this system generally not susceptible to water erosion. The system is subject to inundation; waterlogging for prolonged periods can adversely affect vegetation and prevent access. Wind erosion of the lagoon margins may be exacerbated by loss of stabilising perennial shrubs.

Traverse condition summary:
(35 assessments)

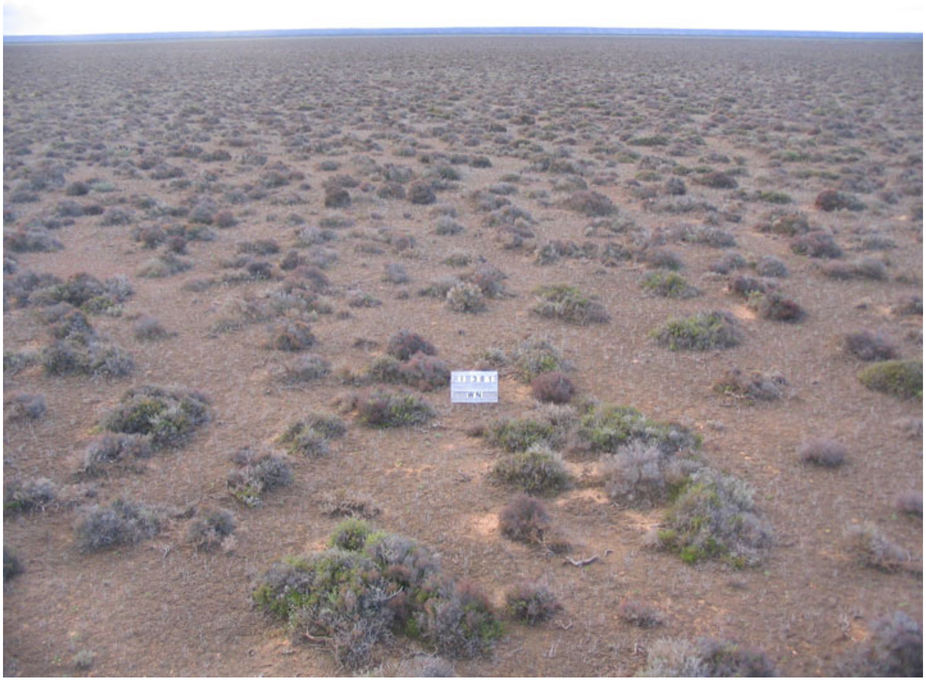
Vegetation—very good 26%, good 74%.

No.	Landform	Traverse recordings	Inventory sites
1.	Clay plain	32	2
2.	Gypsiferous plain	3	5
3.	Lagoonal low dune	–	–
	Total	35	7



Damper land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	60%	**Clay plains**—very gently sloping outer lagoon margin to samphire flats (Unit 2).	Shallow saline light clays (622).	Scattered to moderately closed mid to low shrubland of *Cratystylis conocephala* (false bluebush), *Nitraria billardierei* (nitre bush), *Atriplex vesicaria* (bladder saltbush), *Frankenia* sp. (frankenia), *Gunniopsis calcarea*, *Lycium australe* (water bush), *Maireana oppositifolia* and *Tecticornia* spp. (samphires) (PXHS).
2.	35%	**Gypsiferous plains**—level highly saline gypsiferous plains in lowest-lying areas surrounded by clay plains (Unit 1).	Variable depth saline gypsiferous clays (622), minor shallow calcareous loams (521).	Moderately closed low shrubland dominated by *Tecticornia* spp. (SAMP). *Maireana oppositifolia, Lawrencia squamata, Frankenia* spp., *Tecticornia disarticulata* and *Carpobrotus virescens* (coastal pigface) are common.
3.	5%	**Lagoonal low dunes**—low dunes composed of deflated lagoonal deposits with relief up to 2 m.	Gypsiferous and calcareous clays (622) and calcareous deep sands (442).	Variably vegetated depending on dune development. Commonly supports *Melaleuca quadrifaria*, *Nitraria billardierei*, *Cratystylis conocephala* and *Atriplex vesicaria.*

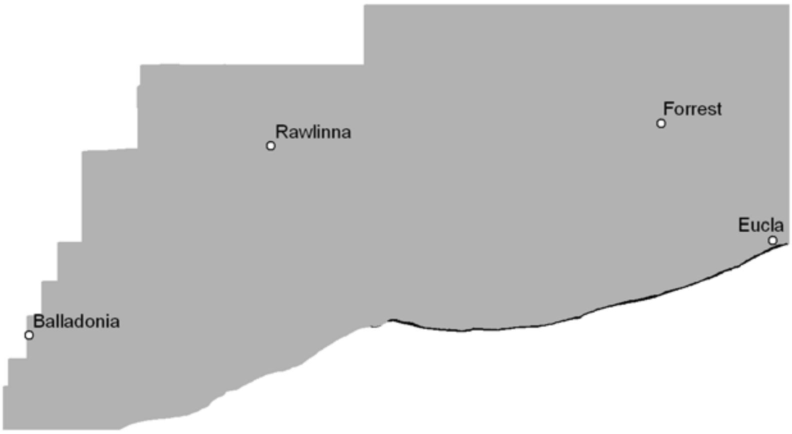


Damper land system:
Gypsiferous plain supporting samphire low shrubland.

DELISSER LAND SYSTEM (150 km², 0.1% of the survey area)

Seaward fringing edge of Roe Plains composed of beach, foredunes, swales and interdunal saline depressions supporting coastal shrubland.

Land zone: Roe Plains.



Land type: 14

Geology: Quaternary (Recent) aeolian calcareous and siliceous sand, gypsiferous mud deposits or calcarenite in interdunal depressions, overlying Roe Calcarenite.

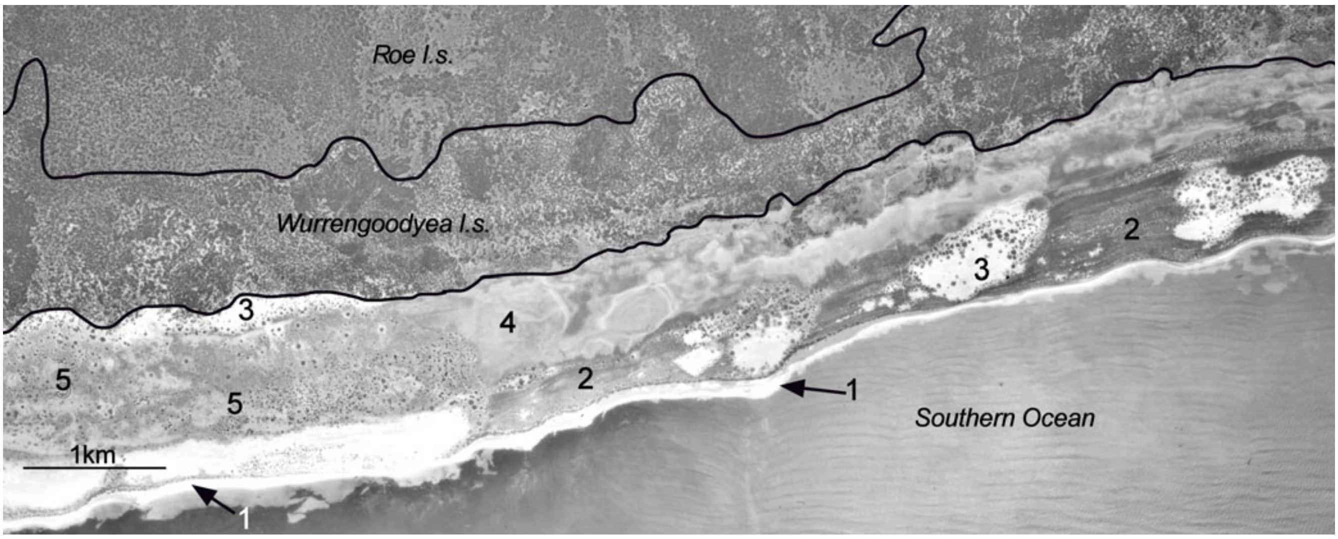
Geomorphology: Depositional surfaces; beaches, unconsolidated to partially consolidated foredunes susceptible to erosion through wave action, swales with depressions of calcareous silt, clay or lagoonal deposits; dunefields of unconsolidated parabolic dunes trending approximately north-south interspersed with mobile sand sheets becoming partially stabilised by vegetation adapted to sand inundation; exposed aeolian calcarenite in some areas.

Land management: Dunes are highly susceptible to wind erosion if vegetative cover is removed through fire or other disturbance resulting in sand drifts and large blow-outs.

Traverse condition summary:
(2 assessments)

Vegetation—good 100%.

No.	Landform	Traverse recordings	Inventory sites
1.	Beach	–	1
2.	Foredune	1	4
3.	Dunefield	1	1
4.	Lagoonal depression	–	–
5.	Interdunal calcarenite	–	–
6.	Sand (dune) ramp	–	–
	Total	2	6



Delisser land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	15%	**Beaches**—narrow beaches of calcareous sand on seaward side of foredunes.	Calcareous deep sands (442).	No vegetation. Commonly covered in dense mats of wave deposited dead seaweed.
2.	25%	**Foredunes**—unconsolidated to partially consolidated low dunes inland from beaches with gently inclined slopes and hummocky crests; relief up to 8 m.	Calcareous deep sands (442).	Coastal shrubland with moderately closed to closed thickets of *Acacia anceps* and *A. cyclops* (coastal wattle) with scattered shrubs of *Scaevola crassifolia* (thick-leaved fan-flower), *Threlkeldia diffusa, Leucophyta brownii, Euphorbia paralias, Olearia axillaris* (coastal daisybush) and sedges such as *Ficinia nodosa* (knotted club rush) (COAS).
3.	40%	**Dunefields**—unconsolidated mobile sand sheets and parabolic dunes with gentle to moderately inclined dune slopes, partial consolidation occurs as fringing vegetation and isolated clumps coalesce.	Calcareous deep aeolian sands (442).	Commonly lacking vegetation though coastal shrubland (COAS) species do occur in varying abundance. Vegetation adapted to sand inundation such as *Acacia anceps* and *A. cyclops* tend to occur as isolated clumps of tall to mid shrubs.
4.	10%	**Lagoonal depressions**—level narrow interdunal saline flats of variable length. Subject to occasional inundation.	Silty, saline clays and gypsiferous clays (622).	Bare or very scattered to moderately closed low shrubland of *Carpobrotus virescens* (coastal pigface) and *Tecticornia* spp. (samphires) (SAMP).
5.	10%	**Interdunal calcarenite**—narrow, level, stony interdunal exposure with moderate mantle of calcarenite fragments.	Skeletal calcareous aeolian sands (521).	Sparsely vegetated with isolated coastal species encroaching down from surrounding dunes. Shrubs commonly include *Acacia anceps* and *Scaevola crassifolia.*
6.	< 1%	**Sand (dune) ramps**—unconsolidated sand ramps against limestone cliff. Occur on the westernmost margin of the system.	Deep calcareous aeolian sands (442).	Bare or vegetated by isolated clumps of *Acacia anceps* and *A. cyclops.*

***Delisser land system:** Beach and eroded foredune colonised by coastal shrubland dominated by coastal wattle.*

GAFA LAND SYSTEM (8501 km², 7.2% of the survey area)

(modified and incorporating the land system formerly known as Loongana from Mitchell, McCarthy and Hacker 1979)

Very gently undulating stony limestone plains supporting pearl bluebush shrubland or bindii grassland with large claypans, infrequent dongas, lignum swamps and wide drainage floors supporting a mosaic of grassland and bladder saltbush shrubland.

Land zone: Nullarbor Plain.

Land type: 11

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

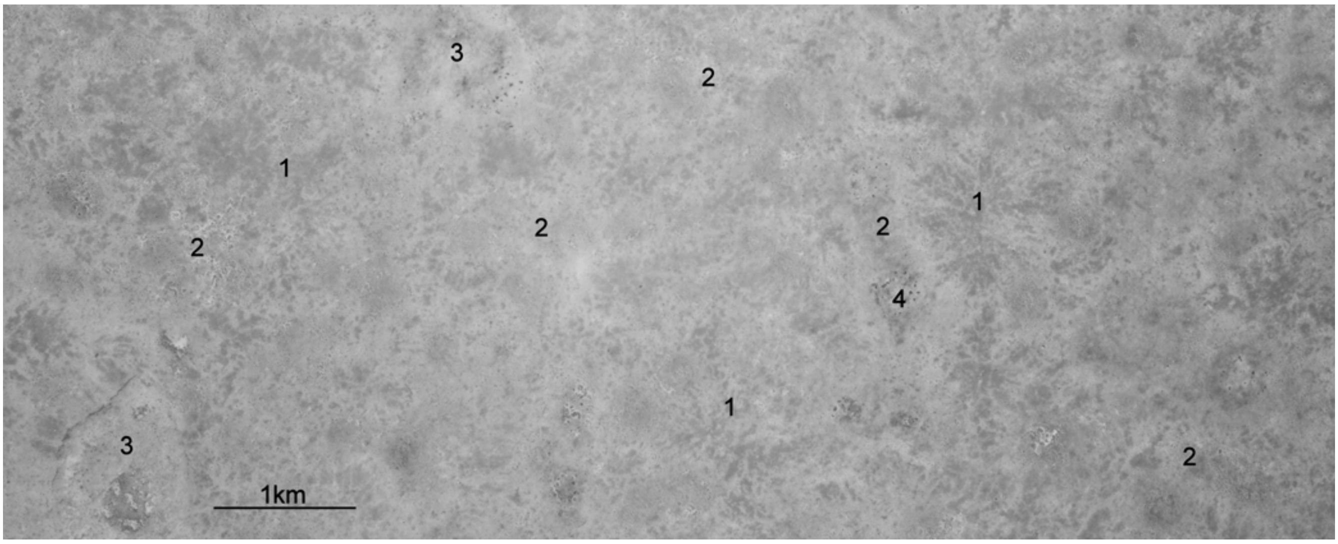
Geomorphology: Erosional surfaces; differential weathering of the deflated Nullarbor Limestone along joints has formed wide drainage floors separated by very gently undulating stony low rises and stony plains; open depressions with colluvial infill form drainage floors up to 3 km long; large irregularly shaped claypans and infrequent dongas; drainage patterns restricted to the ancient river tracts.

Land management: The chenopod vegetation of this system is susceptible to overgrazing. The management of chenopod shrubland should be based on the radial distribution of grazing around water points. As rainfall and season conditions determine species composition and abundance there are few management options for the herbage layer. The condition of seasonally dependent subshrubs should determine the timing of when to adjust stock numbers.

Traverse condition summary: (138 assessments)

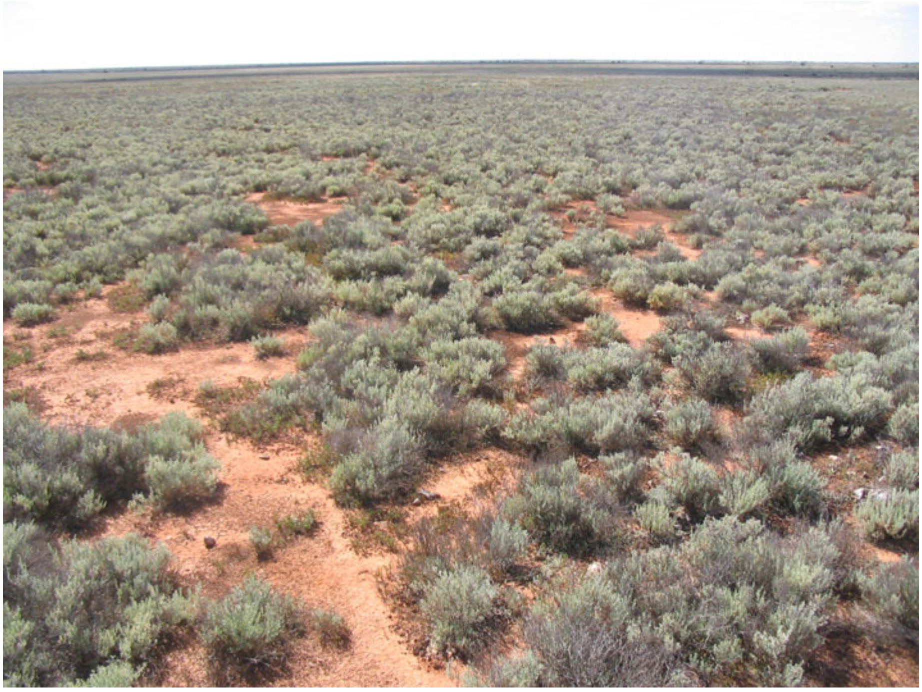
Vegetation—very good 2%, good 67%, fair 27%, poor 4%.

No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	90 (2006)	1 (2006)
2.	Marginal slope to drainage floor	33 (2006)	1 (2006)
3.	Claypan	13 (2006)	2 (2006)
4.	Swamp	–	–
5.	Donga	2 (2006)	1 (2006)
6.	Drainage tract (ancient river course)	–	–
	Total	138 (2006) / 47 (1974)	5 (2006) / 4 (1974)



Gafa land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	30%	**Stony limestone plains**—very gently undulating plains with moderate to abundant mantle of mixed-sized Nullarbor Limestone fragments and outcrop.	Calcareous shallow loams (521).	Open plains of *Sclerolaena* species (bindiis), *Austrostipa scabra* (speargrass) and *Austrodanthonia caespitosa* (wallaby grass) (OBIG) or very scattered *Maireana sedifolia* (pearl bluebush) low shrubland (PBLS).
2.	53%	**Marginal slope to drainage floors**—very gently inclined, broad stony slopes, with moderate to sparse mantle of mixed limestone fragments, draining to open depressions up to 3 km long, along irregular joint patterns.	Calcareous loamy earths (542).	Very scattered bindii grassland (OBIG) or *Maireana sedifolia* low shrubland (PBLS), grading downward into PXCS, until a moderately closed mosaic of *Atriplex vesicaria* (bladder saltbush) shrubland (BSSL) and/or grassland (SWOG) dominate the lower-lying areas.
3.	15%	**Claypans**—large oval, closed depressions, up to 1.3 km wide and 2.5 km long, smooth, level surface 1.5–3 m below surrounding stony plains (unit 1).	Red/brown non-cracking clays (622).	Very scattered to moderately closed grassland (SWOG) or *Atriplex vesicaria* shrubland (BSSL); occasionally unvegetated.
4.	1%	**Swamps**—level, circular depressions, up to 0.4 km in diameter occurring within unit 2.	Non-saline non-cracking clays (622).	Scattered *Muehlenbeckia florulenta* (lignum) low shrubland (LISW).
5.	1%	**Dongas**—circular, closed depressions, 1–3 m below the surrounding limestone plain, generally < 0.2 km in diameter; gilgai patches in donga floor have brought rounded Nullarbor Limestone boulders to the surface.	Red/brown non-cracking clays (622) interspersed with cracking gilgai clay soils (600).	Very scattered to scattered *Acacia tetragonophylla* (curara) and *Pittosporum angustifolium* (native willow) groves (DCGR, DPGR) with an understorey of *Chenopodium curvispicatum* surrounded by the tussock grasses *Austrostipa scabra* and *Austrodanthonia caespitosa*. Gilgai patches dominated by *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail).
6.	< 1%	**Drainage tracts (ancient river courses)**—level to gently inclined, sinuous, narrow (< 0.1 km wide), drainage tracts between stony plains (unit 1).	Red/brown non-cracking clays (622).	As for unit 3.



Gafa land system: *Extensive open drainage floor supporting bladder saltbush.*

GUMBELT LAND SYSTEM (5053 km^2, 4.3% of the survey area)

Sandy loam calcrete plains supporting eucalypt woodland with mixed scrub understorey.

Land zone: Nyanga Plain.

Land type: 2

Geology: Quaternary residual loam and aeolian sand overlying Quaternary (Pleistocene) and Neogene (Pliocene) calcrete.

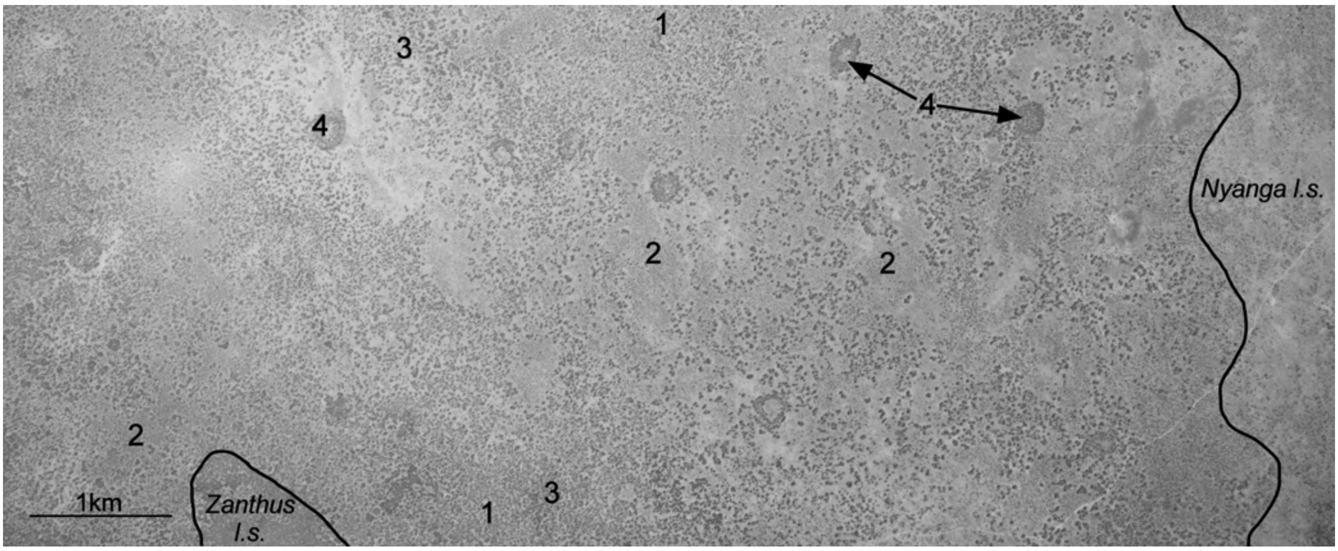
Geomorphology: Relict land surfaces; level to very gentle undulating plains of shallow aeolian sand over residual loam containing sheet and nodular calcrete; occasional isolated residual low calcrete rises; drainage foci within calcrete plain generally circular and 0.5 km in diameter, occasionally irregular and up to 1.5 km in extent; no organised drainage.

Land management: Some vegetation is grazed preferentially by herbivores and may decrease with heavy grazing pressure, particularly some chenopod species and trees at a juvenile stage. Over-grazing can be avoided by good land management, including control of total grazing pressure. Intense or frequent fires can influence the floristic composition of eucalypt woodland and in combination with grazing pressure can lead to the understorey becoming dominated by unpalatable species. Total grazing pressure should be restricted from burnt areas for a period set by seasonal conditions which will determine the effectiveness of recovery.

Traverse condition summary:
(381 assessments)

Vegetation—very good 22%, good 74%, fair 4%.

No.	Landform	Traverse recordings	Inventory sites
1.	Residual calcrete rise	5	–
2.	Loamy plain	300	5
3.	Loamy plain overlain by aeolian sand	71	7
4.	Drainage focus	5	–
	Total	381	12



Gumbelt land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	< 1%	**Residual calcrete rises**—gently inclined low rises of calcrete; variable mantle of calcrete nodules, fragments and outcrop.	Calcareous loamy earths of variable depth (521, 542).	Scattered eucalypt woodland, *Eucalyptus oleosa* subsp. *oleosa* (giant mallee) common with *Alectryon oleifolius* (mingah or bullock bush) over a chenopod understorey dominated *Atriplex nummularia* (old man saltbush) and *Maireana sedifolia* (pearl bluebush) (EXCW).
2.	75%	**Loamy plains**—level to very gently inclined plains sometimes with a sparse mantle of calcrete nodules.	Calcareous loamy earths of variable depth (521, 542).	Scattered woodland of variable *Eucalyptus* species, commonly dominated by *Eucalyptus gracilis* (yorrell) and *E. oleosa* subsp. *oleosa*, occasionally *E. salubris* (gimlet), often with *Myoporum platycarpum* (sugarwood) over a mixed shrub understorey, frequently dominated by chenopods (ESCW, EXCW, ESAW, EXSW, EXHS).
3.	20%	**Loamy plains overlain by aeolian sand**—level to very gently inclined plains.	Calcareous loamy earths of variable depth (521, 542).	Scattered *Acacia aneura* (mulga), *Casuarina pauper* (black oak) or eucalypt woodland, with a mixed shrub understorey (MUXW, CXCS, CXSS, EXCW, EXSW).
4.	5%	**Drainage foci**—closed drainage depressions within loamy calcrete plains (unit 2), generally circular, 0.5 km in diameter, occasionally irregular and up to 1.5 km in extent.	Calcareous loamy earths (542) with occasional clays (622).	Moderately closed to closed woodland of variable *Eucalyptus* species similar to unit 2.

***Gumbelt land system:** Loamy plains supporting eucalypt woodland over chenopod shrubland.*

HAIG LAND SYSTEM (552 km^2, 0.5% of the survey area)

Level loamy calcrete plains supporting chenopod shrubland or bindii grassland.

Land zone: Nyanga Plain.

Land type: 4

Geology: Quaternary residual clay loam overlying Quaternary (Pleistocene)—Neogene (Pliocene) calcrete over Miocene Nullarbor Limestone.

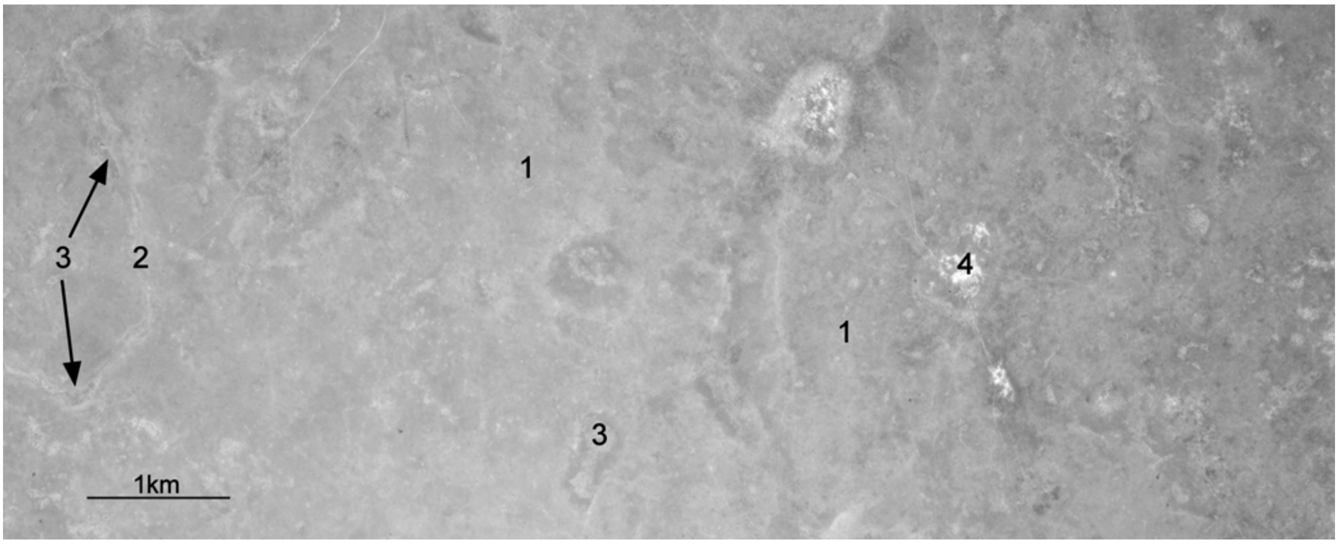
Geomorphology: Relict land surfaces; level to gently undulating open plains of residual clay loam containing sheet and nodular calcrete, dongas infrequent; drainage patterns restricted to the relics of ancient river courses with infrequent depressions having gilgai micro-relief or swamps along their length.

Land management: The majority of this system's chenopod species, particularly the low and subshrubs, are preferentially grazed by introduced and native animals. The chenopod plant community may become altered to bindii grassland with continuous, heavy grazing pressure. Overgrazing can be avoided by good land management, including control of total grazing pressure.

Traverse condition summary:
(115 assessments)

Vegetation—good 64%, fair 31%, poor 4%, very poor 1%.

No.	Landform	Traverse recordings	Inventory sites
1.	Loamy plain	112	5
2.	Drainage tract (ancient river course)	–	1
3.	Drainage focus (gilgai or swamp)	–	1
4.	Claypan	2	–
5.	Other	1	–
	Total	115	7



Haig land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	95%	**Loamy plains**—level to very gently undulating plains, generally a sparse mantle of calcrete nodules, though sometimes abundantly stony.	Calcareous loamy earths (542) of variable depth, some with saline subsoils.	Scattered to moderately closed *Atriplex vesicaria* (bladder saltbush) shrubland (BSSL) or bindii grassland (OBIG). Occasionally *Maireana sedifolia* (pearl bluebush) is co-dominant to dominant (PXCS, PBLS). Infrequent sparse stands of *Acacia papyrocarpa* (myall) where system transitions into Nyanga land system.
2.	1%	**Drainage tracts (ancient river courses)**—level to very gently inclined drainage tracts, often indistinct.	Saline calcareous clay loams (542), occasionally gypsiferous.	Scattered to moderately closed mid to low chenopod shrubland, commonly dominated by *Atriplex vesicaria* or co-dominated with *Maireana sedifolia* (BSSL, PXCS).
3.	3%	**Drainage foci**—irregularly shaped drainage sumps (gilgai or swamp) within indistinct drainage tracts (unit 2) or isolated within loamy plains (unit 1), irregular surfaces (< 0.1 km wide), occasional angular limestone fragments of variable size brought to the surface by shrink-swell clays.	Non-saline cracking clays (622) and gilgai clay soils (600).	Dense patches of perennial grasses; *Austrodanthonia caespitosa* (wallaby grass), *Austrostipa scabra* (speargrass), *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) with very scattered shrubs such as *Acacia oswaldii*, *A. tetragonophylla* (curara), *Chenopodium curvispicatum*, *Lycium australe* (water bush) and trees such as *Eremophila longifolia* (berrigan) and *Pittosporum angustifolium* (native willow) (GGSL); occasionally *Muehlenbeckia florulenta* (lignum) occurs as a closed community (LISW).
4.	1%	**Claypans**—closed depressions, up to 1 km in diameter, within units 1 and 2.	Deep clays (622).	Ranging from unvegetated to dense *Austrostipa scabra* and *Austrodanthonia caespitosa* grassland (SWOG).

***Haig land system:** Gilgai drainage focus supporting berrigan and native willow with an understorey of* Eragrostis *grasses. Note angular limestone boulders brought to surface by gilgai processes.*

JUBILEE LAND SYSTEM (934 km², 0.8% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Undulating and dissected calcrete plains supporting bindii grassland with very scattered myall and infrequent large dongas.

Land zone: Nyanga Plain.

Land type: 4

Geology: Dissected Quaternary residual clay loam overlying Quaternary (Pleistocene)—Neogene (Pliocene) calcrete over Miocene Nullarbor Limestone.

Geomorphology: Erosional surfaces; undulating plains of residual clay loam containing sheet and nodular calcrete, dissected by differential weathering along joints and relic ancient river courses to form long, narrow drainage floors with infrequent large dongas in the drainage foci, often with gilgai micro-relief; drainage patterns restricted to the ancient river courses.

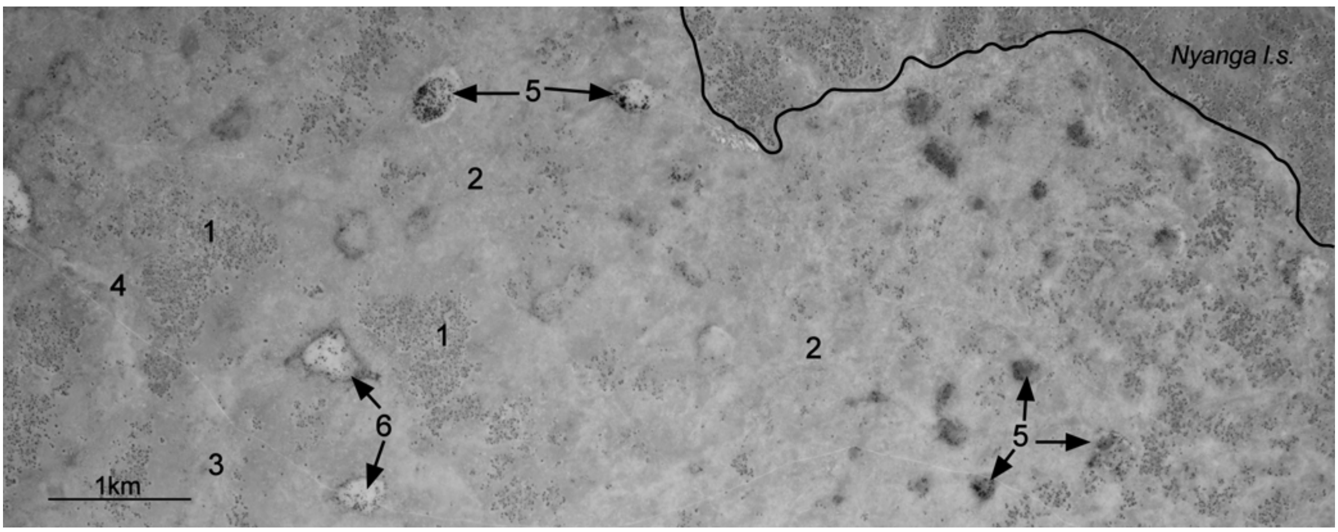
This system is intermediate in form between intact residual loamy calcrete plains of the Nyanga and Rabbit land systems and the deflated stony limestone plains of the Bullseye and Oasis land systems.

Land management: Donga vegetation communities are preferentially visited and browsed by herbivores, declining with heavy grazing pressure. Many of the tree species provide a valuable source of browse and are heavily utilised in dry periods. The condition of tree-based clumps in dongas provides an indication of range condition and the total grazing pressure of an area. The presence of juvenile plants and a dense understorey in a tree-based clump indicates good range condition whilst heavy browse lines, broken limbs and an absence of young plants indicates deteriorating range condition and heavy grazing pressure. Camels frequent this system and the impact of their browsing is opening up and deteriorating donga groves.

Traverse condition summary: (8 assessments)

Vegetation—fair 87%, poor 13%.

No.	Landform	Traverse recordings	Inventory sites
1.	Residual calcrete rise	–	–
2.	Loamy plain	7 (2006)	–
3.	Marginal slope	–	–
4.	Drainage tract (ancient river course)	–	–
5.	Donga	–	1
6.	Drainage focus (claypan or gilgai)	1 (2006)	–
	Total	8 (2006) / 78 (1974)	1 (2006) / 11 (1974)



Jubilee land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	10%	**Residual calcrete rises**—gently inclined low rises of calcrete, relief 4 m; stony mantle of calcrete fragments and outcrop.	Calcareous shallow loams (521).	Very scattered woodland to isolated individuals of *Acacia papyrocarpa* (myall) over *Sclerolaena* species (bindii) or less commonly very scattered *Maireana sedifolia* (pearl bluebush) (MBIG, MPBS).
2.	70%	**Loamy plains**—undulating to level open plains, with a stony mantle of calcareous fragments.	Calcareous loamy earths of variable depth (521, 542).	Very scattered *Sclerolaena* species or *Maireana sedifolia* low shrubland (OBIG, PBLS).
3.	10%	**Marginal slopes**—very gently inclined narrow tracts (< 500 m wide) receiving run-on from units 1 and 2, occasionally slightly stony.	Clay loams (542).	Dense *Austrostipa scabra* (speargrass) and *Austrodanthonia caespitosa* (wallaby grass) grassland (SWOG).
4.	5%	**Drainage tracts (ancient river courses)**—level to very gently inclined drainage tracts, mantle often stony with limestone outcrop common.	Saline calcareous clay loams, occasionally gypsiferous (542).	Scattered to moderately closed low chenopod shrubland, commonly dominated by *Atriplex vesicaria* (bladder saltbush) or *Austrostipa scabra* and *Austrodanthonia caespitosa* grassland (BSSL, SWOG).
5.	5%	**Dongas**—oval shallow, closed depressions, generally 2–5 m below the surrounding calcrete plain (unit 2), up to 1 km in diameter, rounded limestone boulders occasionally brought to the surface by gilgai mechanisms.	Red/brown non-cracking clays (622) or occasionally calcareous loamy earths (542) interspersed with cracking gilgai clays (600).	Very scattered to moderately closed stands of *Grevillea nematophylla* and *Pittosporum angustifolium* (native willow) over an understorey of *Lycium australe* (water bush), *Atriplex cryptocarpa, Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush), grasses *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) common in gilgai areas, very scattered *Acacia aneura* (mulga) or *A. tetragonophylla* (curara) on the donga margins (DGGR, DPGR).
6.	< 1%	**Drainage foci**—oval shaped drainage sumps (claypans and gilgai), commonly associated with unit 3. Occasional calcareous fragments of variable size brought to the surface by gilgai soil processes.	Deep clay loams (542) or gilgai clay soils (600).	Dense patches of perennial grasses; *Austrodanthonia caespitosa* and *Austrostipa scabra* (SWOG) or *Eragrostis* species with very scattered plants such as *Acacia tetragonophylla*, *Lycium australe* or *Pittosporum angustifolium* (GGSL).

***Jubilee land system:** Crests supporting sparse myall and lower slopes supporting bindii grassland above drainage focus.*

KANANDAH LAND SYSTEM (1641 km², 1.4% of the survey area)

Gently undulating weathered limestone plains supporting myall woodland over pearl bluebush shrubland or bindii grassland.

Land zone: Nyanga Plain.

Land type: 9

Geology: Quaternary (Pleistocene)—Neogene (Pliocene) Recrystallised (weathered) Limestone overlain by Quaternary residual loam.

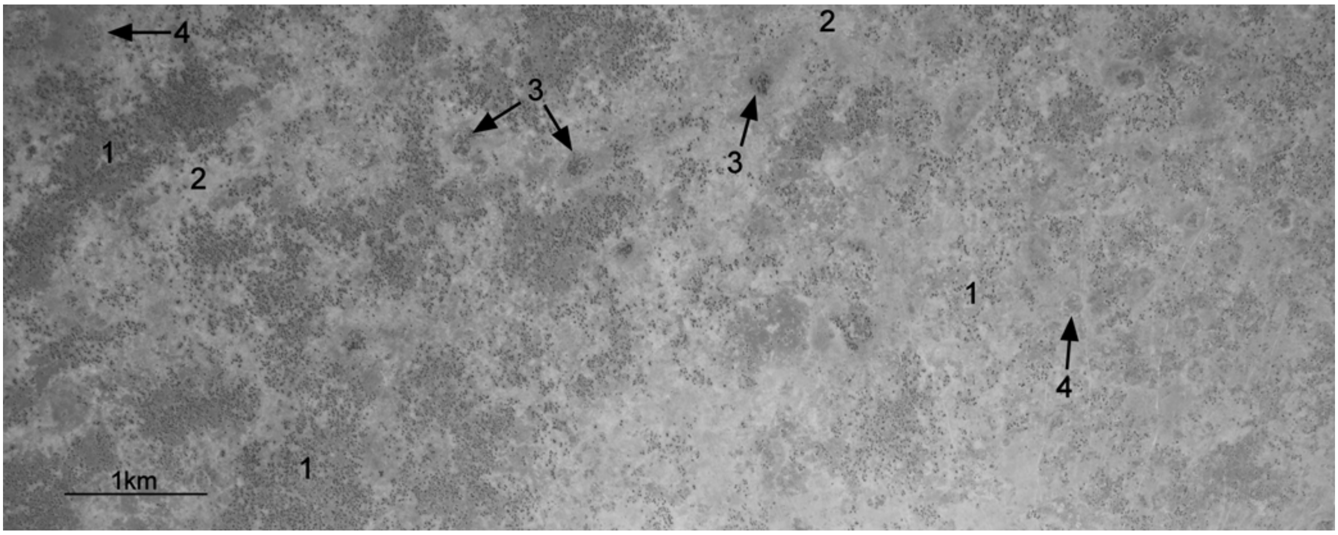
Geomorphology: Erosional surfaces; gently undulating plains of partially deflated residual loam over Recrystallised Nullarbor Limestone, differential weathering of the surface has formed small dongas and gilgai; no organised drainage.

Land management: The chenopod shrubland of this system is prone to preferential grazing by introduced and native animals. Where palatable perennial shrub cover is substantially depleted the vegetation is replaced by unpalatable stands of shrubs or reduced to seasonally dependent species, making these areas prone to wind erosion during dry periods. The condition of groves of *Alectryon oleifolius* (mingah or bullock bush) or *Eremophila longifolia* (berrigan) provides an indication of grazing pressure within an area. Heavy browse lines, broken limbs and overturned trees indicates excessive grazing pressure and deteriorating range condition. Overgrazing can be avoided by good management, including control of total grazing pressure.

Traverse condition summary:
(223 assessments)

Vegetation—very good 1%, good 27%, fair 58%, poor 14%.

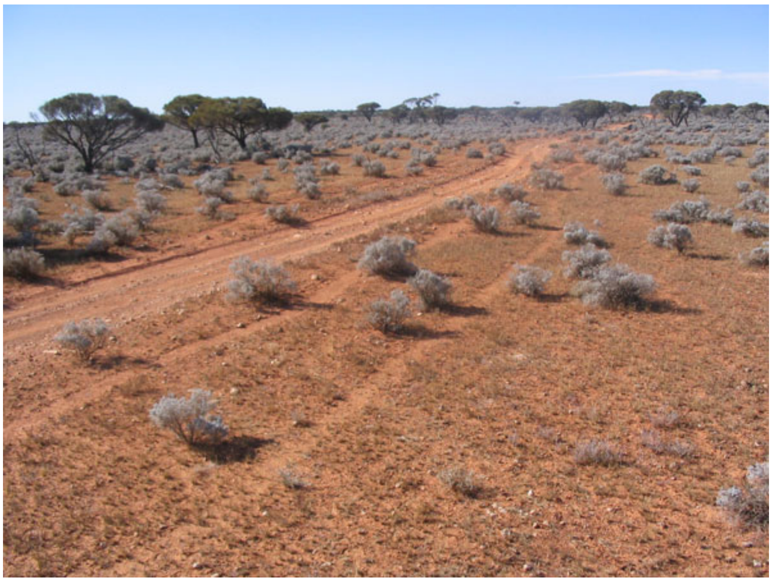
No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	176	6
2.	Drainage floor	40	1
3.	Donga	6	2
4.	Drainage focus (gilgai)	1	1
	Total	223	10



Kanandah land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	85%	**Stony limestone plains**—gently undulating plains, stony mantle of calcareous fragments of mixed size and Recrystallised Limestone outcrop.	Calcareous loamy earths (542) with calcareous shallow loams (521).	Scattered woodlands of *Acacia papyrocarpa* (myall) with either a scattered low shrub understorey dominated by *Maireana sedifolia* (pearl bluebush) (MPBS), mixed shrubs (MXSS), *Sclerolaena* species (bindii) (MBIG) or *Austrostipa scabra* (speargrass) grassland (MSOG). In the absence of myall, bindii grasslands are common with very scattered mixed shrubs of species of *Acacia* and *Senna* (XSBG). Occasional stands of very scattered *Casuarina pauper* (black oak) (CXCS).
2.	12%	**Drainage floors**—level to gently inclined, narrow (< 200 m wide), irregular, open depressions between gently undulating stony plains (unit 1), slightly stony mantle of calcareous fragments.	Calcareous clay loam to various depths (542), saline for deeper soils.	Scattered to moderately closed *Atriplex vesicaria* (bladder saltbush) shrubland (BSSL).
3.	2%	**Dongas**—shallow closed depressions, generally 2–4 m below the surrounding stony plain (unit 1), up to 0.3 km in diameter, irregular patches common due to gilgai processes containing occasional rounded limestone boulders.	Deep clays (622) or gilgai clays (600).	Grasses such as *Austrostipa platychaeta*, *Austrostipa scabra*, *Enneapogon caerulescens* (limestone grass), *E. cylindricus* (jointed nineawn), *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) are common to dongas with either very scattered to scattered stands of *Acacia tetragonophylla* (curara) around the donga margin (DCGR) or *Eremophila longifolia* (berrigan) in the centre (DBGR). *Pittosporum angustifolium* (native willow) and *Chenopodium curvispicatum* are regularly present.
4.	1%	**Drainage foci**—irregularly shaped drainage sumps (gilgai), (< 0.1 km wide), irregular surfaces.	Non-saline cracking clay gilgai soils (600).	Dense patches of perennial grasses; *Austrodanthonia caespitosa* (wallaby grass), *Austrostipa scabra*, *Eragrostis dielsii* and *E. setifolia* with very scattered *Pittosporum angustifolium*, *Acacia oswaldii*, *A. tetragonophylla* and stands of *Lycium australe* (water bush) (GGSL).

Kanandah land system: *Scattered myall woodland over pearl bluebush shrubland.*



KINCLAVEN LAND SYSTEM (4790 km², 4.0% of the survey area)

Level stony limestone plains supporting mixed shrubs and bindii grassland, with frequent dongas.

Land zone: Nullarbor Plain.

Land type: 12

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

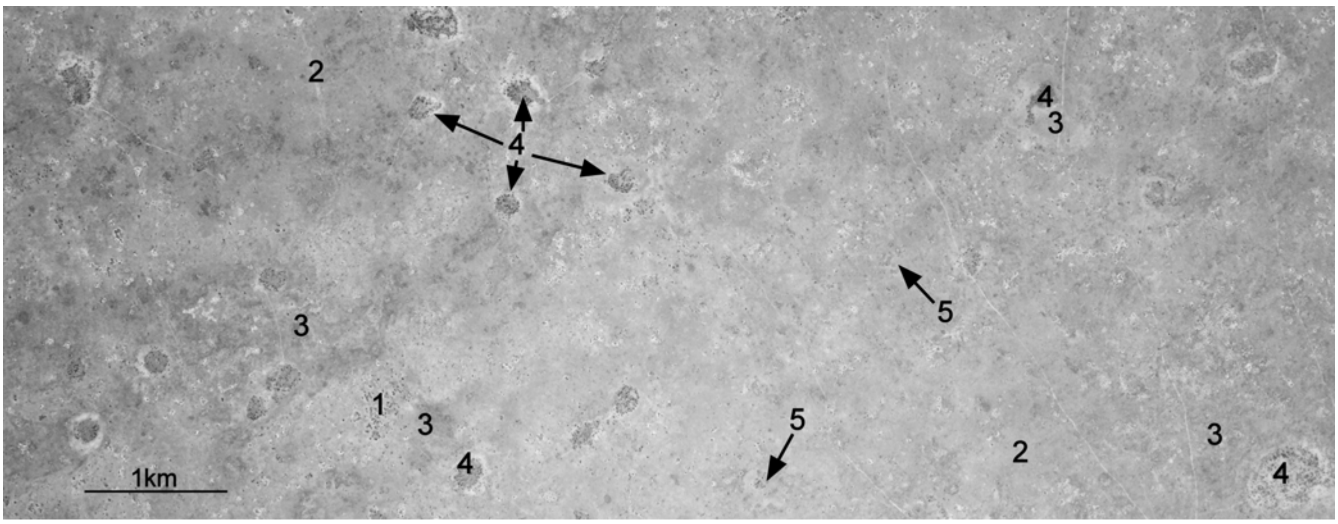
Geomorphology: Erosional surfaces; differential weathering of the deflated Nullarbor Limestone has formed large circular drainage foci: dongas with gilgai micro-relief and occasional swamps, and small irregular gilgai patches randomly distributed through stony plain; no organised drainage. Dongas are believed to have formed through water ponding in depressions in the limestone plain and solution further dissolving the limestone. Dongas are considered solution dolines rather than collapsed caves.

Land management: This system has been significantly affected by fire and rabbits. The stony plains support some areas of *Maireana sedifolia* (pearl bluebush) shrubland, though the majority of the plains are dominated by sparse, unpalatable perennial shrubs and seasonally dependent subshrubs and annuals. In comparison to the surrounding vast, open stony plains dongas are favoured habitats for many Nullarbor animals due to the benefits they offer, including a valuable source of browse during dry periods. Vegetation communities associated with dongas need to be preserved, primarily to ensure the heterogeneity of the northern Nullarbor Plain and to maintain sheltered habitats within the open plains but also for the production value dongas provide as an important source of browse during dry periods. Water points in dongas lead to animals camping within them, destroying the vegetation through over-grazing, opening up bush clumps and depleting the seed store as juvenile plants are continually eaten, eventually reducing the donga's value as a sheltered habitat and forage reserve. Loss of heterogeneity reduces the ability of the land-scape to offer any significant pastoral value during dry periods.

Traverse condition summary: (542 assessments)

Vegetation—good 24%, fair 58%, poor 17%, very poor 1%.

No.	Landform	Traverse recordings	Inventory sites
1.	Residual calcrete rise	–	–
2.	Stony limestone plain	460	8
3.	Marginal slope to donga	34	–
4.	Donga	32	3
5.	Gilgai	14	2
6.	Swamp	–	1
7.	Other	2	–
	Total	542	14



Kinclaven land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	< 1%	**Residual calcrete rises**—gently inclined low rises of calcrete or weathered limestone; mantle commonly composed of mixed-sized limestone fragments.	Calcareous shallow loams (521).	Scattered woodlands of *Acacia papyrocarpa* (myall) with either a scattered low shrub understorey of mixed shrubs (MXSS) or *Sclerolaena* species (bindii) (MBIG).
2.	70%	**Stony limestone plains**—level plains with extensive mantle of Nullarbor Limestone fragments and outcrop.	Calcareous shallow loams (521).	Very scattered to scattered open shrubland with species of *Acacia* and *Senna* over scattered low shrubs and bindii, tussock grassland dominated by species of *Sclerolaena* and *Austrostipa scabra* (speargrass) (XSBG). Where the shrub component is absent *Austrostipa scabra* and *Sclerolaena* species co-dominate (OBIG). In the west, adjacent to the weathered limestone plains of the Kanandah land system and in the south of the system, very scattered *Maireana sedifolia* (pearl bluebush) low shrubland (PBLS) is common.
3.	10%	**Marginal slope to dongas**—gently inclined stony slopes, with mantle of mixed limestone fragments, draining to dongas; absent on some dongas.	Calcareous loamy earths (542).	Very scattered to scattered low shrubland of *Sclerolaena* species (OBIG).
4.	15%	**Dongas**—oval to circular, closed depressions, generally 1–3 m below the surrounding limestone plain, up to 0.5 km in diameter; gilgai processes have brought rounded Nullarbor Limestone stones and boulders to the surface.	Deep clays (622) or gilgai clays (600).	Scattered to very scattered stands of *Acacia tetragonophylla* (curara) (DCGR) or *Grevillea nematophylla* (DGGR) with an understorey of tussock grasses; *Austrostipa scabra*, *Enneapogon* and *Eragrostis* species, and very scattered *Pittosporum angustifolium* (native willow), *Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush).
5.	5%	**Gilgai**—irregularly shaped gilgai patches within units 2 and 4, irregular surfaces (< 0.1 km in extent), Nullarbor Limestone fragments of mixed size brought to the surface by shrink-swell clays.	Non-saline cracking clay gilgai soils (600).	Dense patches of perennial grasses; *Austrodanthonia caespitosa*, *Austrostipa scabra*, *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) with individual *Eremophila longifolia* and *Pittosporum angustifolium* trees among very scattered shrubs of *Acacia oswaldii*, *A. tetragonophylla*, *Chenopodium curvispicatum*, *Lawrencia squamata* (grey fan leaf) and *Lycium australe* (water bush) (GGSL).
6.	< 1%	**Swamps**—uncommon, level, circular depressions, to 0.3 km in extent, occurs within stony limestone plains (unit 2).	Non-saline non-cracking clays (622).	Scattered *Muehlenbeckia florulenta* (lignum) with *Eragrostis dielsii* (LISW); *Acacia aneura* (mulga), *A. tetragonophylla* and *Pittosporum angustifolium* occur on swamp margins.

***Kinclaven land system:** Open stony limestone plain supporting very scattered mixed shrubs over bindii grassland.*

KITCHENER LAND SYSTEM (405 km^2, 0.3% of the survey area)

Gently undulating stony plains supporting mixed acacia shrubs and bindii grassland with sparse black oak.

Land zone: Nullarbor and Nyanga Plains.

Land type: 11

Geology: Predominantly Miocene Nullarbor Limestone, partially overlain by deflated Quaternary (Pleistocene)—Neogene (Pliocene) calcrete and residual calcareous loam.

Geomorphology: Erosional surfaces; gently undulating plains of residual calcareous loam and sheet calcrete dissected to expose Nullarbor Limestone, differential weathering of the surface has formed infrequent dongas; no organised drainage.

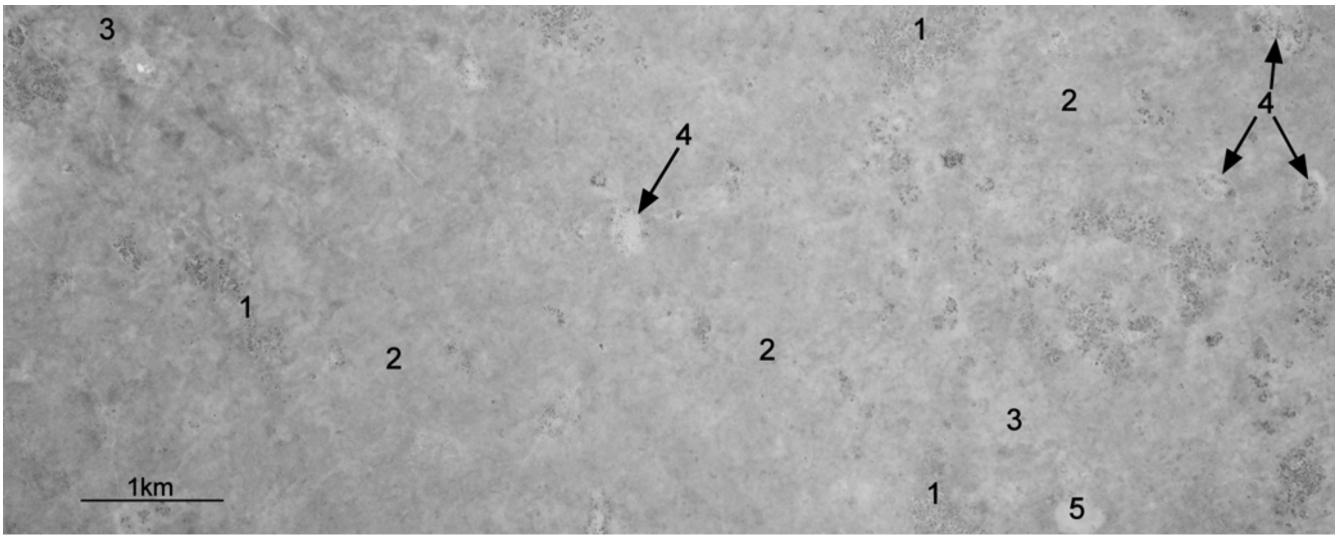
This system is intermediate in form between the intact residual loamy calcrete plains of the Nyanga land system, the recrystallised limestone plains of the Kanandah land system and the deflated stony limestone plains of the Naretha land system.

Land management: This system has been considerably affected by rabbits and severe wildfires. Much of the vegetation has been irreversibly altered to seasonally dependent bindii grassland. The majority of perennial shrubs present are largely unpalatable. Bindii grassland provides an abundant food source during favourable seasonal conditions, but quickly becomes inadequate when dry conditions prevail. The limited abundance of palatable perennials makes this system prone to degradation if stock numbers are not reduced during dry periods. *Alectryon oleifolius* (mingah or bullock bush) is a valuable mineral source and is preferentially browsed during dry periods. The condition of *Alectryon oleifolius* groves provides an indication of range condition and the total grazing pressure of an area. The presence of juvenile plants indicates improving range condition whilst heavy browse lines, broken limbs and overturned trees indicate deteriorating range condition and excessive grazing pressure. Overgrazing can be avoided by good management, including control of total grazing pressure.

Traverse condition summary: (56 assessments)

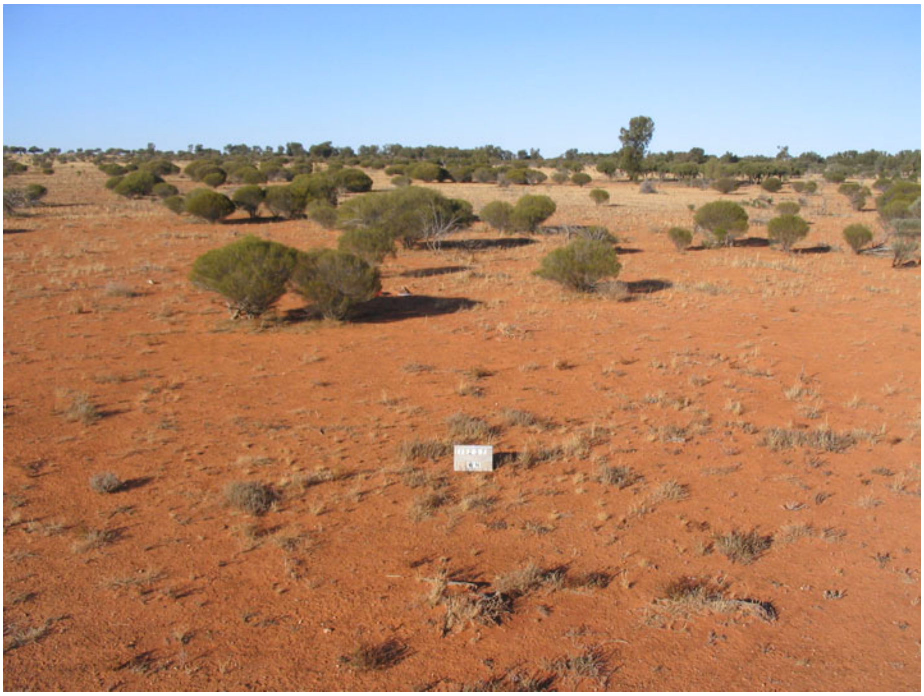
Vegetation—good 7%, fair 73%, poor 20%.

No.	Landform	Traverse recordings	Inventory sites
1.	Residual calcrete rise	–	1
2.	Stony limestone plain	15	2
3.	Drainage floor	39	2
4.	Donga	2	2
5.	Clay plain	–	1
	Total	56	8



Kitchener land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	5%	**Residual calcrete rises**—gently inclined low rises of calcrete; abundant mantle of calcrete fragments with occasional outcrop.	Calcareous shallow loams (521).	Very scattered *Casuarina pauper* (black oak) over a tall shrubland of *Acacia burkittii* (jam) and *Alectryon oleifolius* (mingah) (CAOS).
2.	85%	**Stony limestone plains**—gently undulating plains, common stony mantle of mixed-sized calcareous fragments with Nullarbor Limestone outcrop common.	Calcareous shallow loams (521).	Very scattered tall shrubland of *Acacia burkittii* and *Eremophila longifolia* (berrigan) over a low shrub stratum dominated by species of *Sclerolaena* (bindii) (XSBG, OBIG) or *Austrostipa scabra* (speargrass) and *Austrodanthonia caespitosa* (wallaby grass) grassland (SWOG). Sparse *Acacia papyrocarpa* (myall) (MSOG), *Casuarina pauper* and groves *Alectryon oleifolius* occur infrequently.
3.	5%	**Drainage floors**—level to gently inclined, irregular, open depressions between dissected stony plains (units 1 and 2).	Calcareous loams to various depths (521, 542).	Very scattered to scattered tall shrubland of *Acacia burkittii*, *A. aneura* (mulga), *Eremophila longifolia* and *Pittosporum angustifolium* (native willow) over a low shrub stratum dominated by species of *Sclerolaena* (XAOS, XSBG, OBIG).
4.	3%	**Dongas**—shallow closed depressions, generally 1–3 m below the surrounding plains (unit 2 and 3), < 0.5 km in diameter, limestone boulders present in areas where gilgai processes have caused upheaval.	Deep clays (622) or gilgai clay soils (600).	Scattered to very scattered stands of *Acacia tetragonophylla* (curara) and *Eremophila longifolia* in varying abundance (DCGR, DBGR). *Acacia burkittii*, *Pittosporum angustifolium*, *Enchylaena tomentosa,* (ruby saltbush), *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) common.
5.	2%	**Clay plains**—level to gently inclined open depressions within dissected areas of stony plains, receiving run-on from units 1 or 2.	Deep, non-saline non-cracking clays (622).	Scattered to moderately closed bindii grassland commonly supporting *Austrodanthonia caespitosa, Austrostipa scabra, Sclerolaena patenticuspis*, *S. obliquicuspis* and *Sida spodochroma* (OBIG).



***Kitchener land system:** Gently undulating plain supporting a very scattered tall shrubland of jam over bindii grassland.*

KOONJARRA LAND SYSTEM (1067 km², 0.9% of the survey area)

Low calcrete breakaways enclosing large stony-floored depressions supporting chenopod shrubland or grassland around drainage foci with gilgai micro-relief.

Land zone: Nyanga Plain.

Land type: 5

Geology: Miocene Nullarbor Limestone and Quaternary (Pleistocene)—Neogene (Pliocene) calcrete.

Geomorphology: Erosional surfaces; low breakaways form plateau edges to calcrete plain, moderately inclined saline slopes; large, closed depressions gently inclined to level limestone floors, centripetal drainage patterns to drainage foci with gilgai micro-relief. Solution of limestone and deflation of clay are believed to be responsible for depression formation.

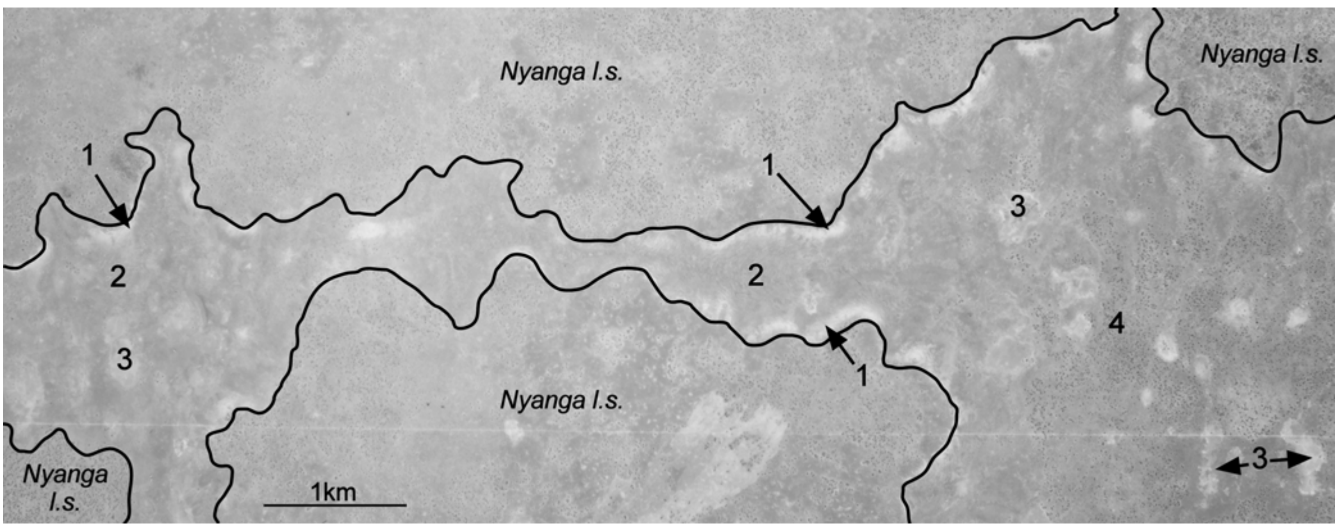
Land management: Breakaways (unit 1) have fragile slopes which are highly susceptible to water erosion, particularly if perennial shrub cover is reduced or the soil surface is disturbed. To maintain tracks that occur on breakaway slopes and to protect fragile vegetation communities associated with the slopes bunds should be constructed to control the volume and erosive potential of water flow channelled by the tracks.

The chenopod vegetation is highly preferred by introduced and native animals due to its low-lying position in the landscape in association with drainage foci with gilgai micro-relief. Continuous heavy grazing can reduce productive vegetation communities to unpalatable and seasonally dependent subshrubs and annuals. Heavy grazing can be avoided by good land management, including control of total grazing pressure.

Traverse condition summary:
(186 assessments)

Vegetation—very good 3%, good 75%, fair 18%, poor 4%.

No.	Landform	Traverse recordings	Inventory sites
1.	Breakaway	7	2
2.	Marginal slope to depression floor	145	3
3.	Drainage focus (gilgai or swamp)	5	7
4.	Residual calcrete rise	29	2
	Total	186	14



Koonjarra land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Breakaways**—low breakaways form plateau edges of calcrete plain, moderately inclined slopes; variably stripped with calcrete outcrop common with an abundant mantle of calcrete boulders and pebbles.	Calcrete over heavy clay.	Very scattered *Acacia papyrocarpa* (myall) and mixed chenopod shrubland (MXCS) commonly occur on upper slope grading down into scattered *Lawrencia squamata* (grey fan leaf) low shrubland (LAWS).
2.	85%	**Marginal slopes to depression floors**—gently inclined slopes grading to level drainage floors, mantle variable from stony to sparse dependent on proximity to breakaways (unit 1), Nullarbor Limestone outcrop infrequent.	Calcareous loamy earths (542) or red deep sandy duplexes (405).	Scattered low shrubland dominated by *Maireana sedifolia* (pearl bluebush) (PBLS) or co-dominated with *Atriplex nummularia* (old man saltbush) and *A. vesicaria* (bladder saltbush) (PXCS).
3.	5%	**Drainage foci**— (i) gilgaied depressions (commonly < 50 m, seldom > 200 m in diameter) within unit 2, irregular surfaces due to gilgai micro-relief and minor crabholes, occasional sub-rounded limestone fragments of variable size brought to the surface by shrink-swell clays.	Cracking clay gilgai soils (600), occasionally saline.	Dense patches of perennial grasses; *Austrodanthonia caespitosa* (wallaby grass), *Austrostipa scabra* (speargrass), *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) with shrubs at variable densities such as *Atriplex nummularia*, *Nitraria billardierei* (nitre bush), *Eremophila maculata, Lawrencia squamata* (GGSL).
		ii) swamps and foci up to 150 m in extent occurring within unit 2, sometimes with gilgai micro-relief.	Non-saline cracking clays, gilgai clay soils (600).	Scattered *Muehlenbeckia florulenta* (lignum) low shrubland with *Eragrostis dielsii* and *E. setifolia* grasses (LISW).
4.	9%	**Residual calcrete rises**—very gently inclined low rises of calcrete; variable mantle of calcrete fragments with occasional Nullarbor Limestone outcrop.	Calcareous shallow loams (521).	Scattered *Atriplex nummularia*, *A. vesicaria* and *Maireana sedifolia* with a very scattered to scattered overstorey of *Acacia papyrocarpa* (MXCS).

Koonjarra land system: *Drainage focus with gilgai micro-relief supporting lignum swamp. Behind to the left scattered myall over chenopod shrubland on a low calcrete rise grades into a marginal slope on the right.*

KYARRA LAND SYSTEM (2099 km^2, 1.8% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Level loamy calcrete plains supporting bindii grassland with sparse myall.

Land zone: Nyanga Plain.

Land type: 4

Geology: Quaternary residual clay loam overlying Quaternary (Pleistocene)—Neogene (Pliocene) calcrete over Miocene Nullarbor Limestone.

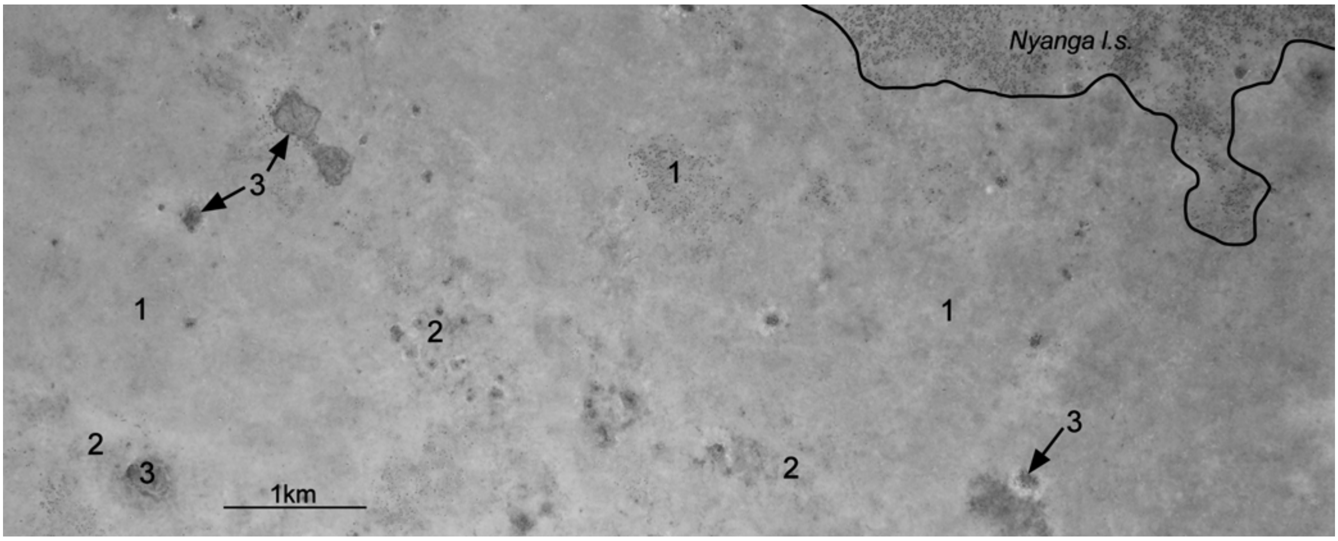
Geomorphology: Erosional surfaces; level plains of partially dissected residual clay loam containing sheet and nodular calcrete, differential weathering has exposed Nullarbor Limestone on the marginal slopes of infrequent dongas and at the edges of the calcrete plateau as the system transitions into the Bullseye or Carlisle land systems; no organised drainage.

Land management: Donga vegetation communities are preferentially visited and browsed by herbivores and deteriorate with heavy grazing pressure, particularly during dry periods. The condition of tree-based clumps in dongas provides an indication of range condition and the total grazing pressure of an area. The presence of juvenile plants and a dense understorey in a tree-based clump indicates improving range condition whilst heavy browse lines, broken limbs and an absence of young plants indicates deteriorating condition and heavy grazing pressure. The common presence of camels is increasingly impacting upon tree-based clumps and the donga vegetation. Overgrazing can be avoided by good land management, including control of total grazing pressure.

Traverse condition summary: (62 assessments)

Vegetation—good 69%, fair 18%, poor 11%, very poor 2%.

No.	Landform	Traverse recordings	Inventory sites
1.	Loamy plain	59	3 (2006)
2.	Drainage floor	–	–
3.	Donga	3	1 (2006)
	Total	62 (2006) / 10 (1974)	4 (2006) / 3 (1974)



Kyarra land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	60%	**Loamy plains**—level to very gently inclined plains, with slightly stony mantle of calcareous fragments.	Calcareous loamy earths of variable depth (521, 542).	Very scattered woodland to isolated individuals of *Acacia papyrocarpa* (myall) over open plains dominated by species of *Sclerolaena* (bindii) or *Austrostipa scabra* (speargrass) grassland (MBIG, MSOG, OBIG, SWOG).
2.	30%	**Drainage floors**—level, lower slopes of unit 1, with a stony mantle of calcareous fragments and occasional Nullarbor Limestone outcrop; gilgai micro-relief uncommon.	Calcareous loamy earths of variable depth (521, 542).	Dense *Austrostipa scabra* grassland (SWOG), occasional *Acacia oswaldii* or *A. tetragonophylla* (curara) in gilgai patches dominated by the grasses *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) (GGSL).
3.	10%	**Dongas**—shallow closed depressions, generally 1.5–3 m below the surrounding calcrete plain (unit 1 or 2), up to 0.5 km in diameter, rounded limestone boulders occasionally present in areas of upheaval due to gilgai processes.	Deep clays (622) or gilgai clay soils (600).	Very scattered to scattered stands of *Pittosporum angustifolium* (native willow) over an understorey of *Chenopodium curvispicatum*, *Eragrostis dielsii* and *E. setifolia* (DPGR). Very scattered *Acacia tetragonophylla* around the donga margins.

***Kyarra land system.** Open bindii grassland with sparse myall on loamy calcrete plain.*

KYBO LAND SYSTEM (1289 km^2, 1.1% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Undulating stony limestone plains supporting pearl bluebush shrubland along a deflated fault scarp and on low ridges, dissected by wide drainage floors and clay plains supporting grassland and herbland.

Land zone: Nullarbor Plain.

Land type: 11

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

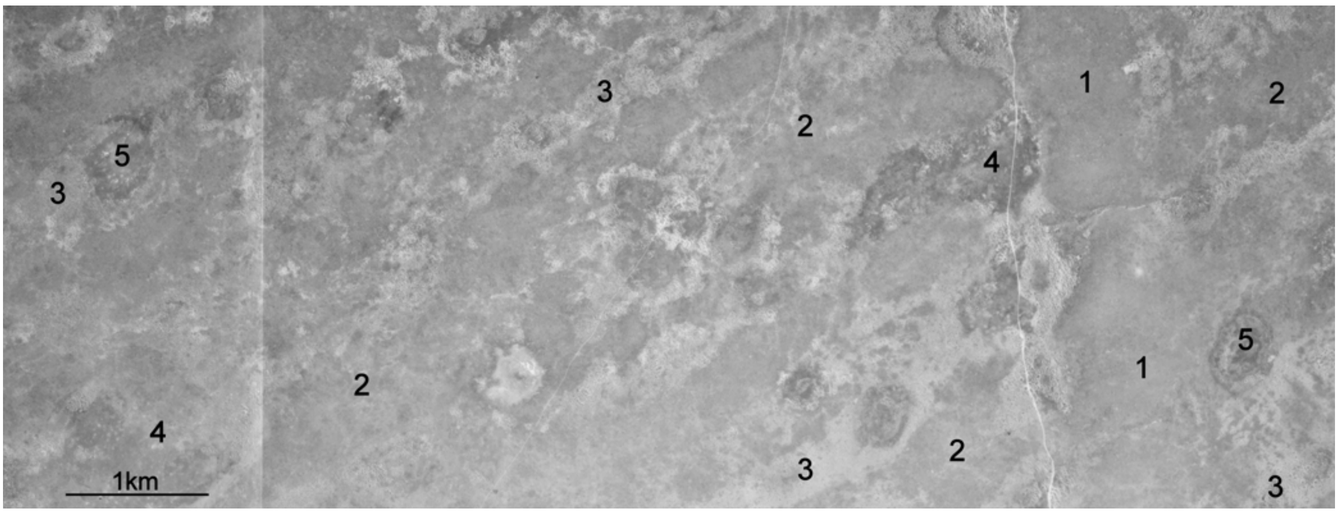
Geomorphology: Erosional surfaces; a deflated fault scarp trending north-south for nearly 40 km characterises this system, elongated colluvial infilled clay drainage floors lie to the west of the low scarp; elsewhere superficial weathering of the limestone plain along north-east to south-west trending joint patterns has formed undulating stony ridges separated by broad, level drainage floors, up to 8 km long and < 1 km wide, with infrequent claypans and dongas forming large drainage foci in the lower-lying areas.

Land management: The system is dominated by *Maireana sedifolia* (pearl bluebush) on the stony plains and seasonally dependent subshrubs, grasses and herbage on the drainage floors. In dry seasons drainage floors offer very little pastoral value, despite their importance during favourable seasons. This leads to increased grazing pressure of perennial chenopod species as soon as seasonally dependent subshrubs begin to decline with the onset of dry conditions. Chenopod shrubland requires careful management as it provides the maintenance diet to support herbivores during dry periods when ephemeral foliage is low or absent, as well as their crucial role in protecting the soil surface, thereby providing landscape stability. There are few management options for the ephemeral foliage along the drainage floors as rainfall and season conditions determine species composition and abundance. These areas should be carefully monitored to ensure that they are not reduced to less palatable plants such as *Rhodanthe floribunda* and *Zygophyllum iodocarpum*.

Traverse condition summary: (174 assessments)

Vegetation—good 59%, fair 28%, poor 13%.

No.	Landform	Traverse recordings	Inventory sites
1.	Deflated fault scarp	–	–
2.	Stony limestone plain	62	3
3.	Marginal slope to drainage floor	57	–
4.	Clay plain	53	4
5.	Claypan	–	2
6.	Donga	2	3
7.	Drainage tract (ancient river course)	–	–
	Total	174	12



Kybo land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	3%	**Deflated fault scarp**—low scarp with moderately inclined slope, abundant stony mantle with regular Nullarbor Limestone outcrop.	Skeletal calcareous shallow loams (521).	Very scattered to scattered *Maireana sedifolia* (pearl bluebush) low shrubland (PBLS), occasionally with very scattered *Acacia papyrocarpa* (myall) with infrequent *Casuarina pauper* (black oak), *Myoporum platycarpum* (sugarwood) and *Pittosporum angustifolium* (native willow) (MPBS).
2.	45%	**Stony limestone plains**—undulating stony plains and ridges with an abundant mantle of mixed-sized Nullarbor Limestone fragments, with regular outcrop.	Calcareous shallow loams (521).	Very scattered to scattered low shrubland of *Maireana sedifolia* (PBLS), occasionally with very scattered *Senna artemisioides* on crests of ridges, or very scattered to moderately closed bindii grassland varying in composition with *Sclerolaena* species (bindiis) and *Austrostipa scabra* (speargrass) (OBIG).
3.	30%	**Marginal slope to drainage floors**—gently inclined stony slope, with a mantle of mixed limestone fragments, draining to wide, closed depressions defined by north-east to south-west trending joint patterns.	Calcareous loamy earths (542).	Scattered low shrubland of *Maireana sedifolia* (PBLS), grading into moderately closed *Atriplex vesicaria* (bladder saltbush) shrubland (BSSL), *Sclerolaena* species (OBIG) or *Austrodanthonia caespitosa* (wallaby grass) and *Austrostipa scabra* grassland (SWOG).
4.	16%	**Clay plains**—extensive, level, smooth, open plains along north-east to south-west trending joint patterns and along base of low fault scarp (unit 1).	Deep red/brown non-cracking clays (622).	Open grassland dominated by *Austrodanthonia caespitosa* and *Austrostipa scabra* (SWOG), *Sclerolaena* species (OBIG) or scattered annual herbland with a variety of annual herbaceous species such as *Carrichtera annua* (Ward's weed), *Rhodanthe floribunda* and *Zygophyllum iodocarpum* (ANNH).
5.	5%	**Claypans**—large oval, closed depressions, up to 1 km in extent, smooth, level surface 1–3 m below surrounding stony plains (unit 2).	Deep red/brown non-cracking clay (622).	As for unit 4 or very scattered to moderately closed low shrubland dominated by *Atriplex vesicaria* (BSSL), occasionally unvegetated.
6.	1%	**Dongas**—circular, closed depressions, within drainage floors (unit 3) or clay plains (unit 4) as drainage sumps, up to 1 km in diameter.	Deep clay (622), occasional gilgai clay soils (600).	Very scattered stands of *Eremophila longifolia* (berrigan) or *Acacia tetragonophylla* (curara) and *Pittosporum angustifolium* with a very scattered, moderately closed understorey of *Atriplex cryptocarpa*, *Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush) (DBGR, DCGR).
7.	< 1%	**Drainage tracts (ancient river courses)**—level to gently inclined, long, narrow (< 0.1 km wide), drainage tracts between stony plains (unit 2).	Red/brown non-cracking clays (622).	As for unit 3.

Kybo land system: *Clay plain supporting annual herbland dominated by* Rhodanthe floribunda *at the foot of the deflated fault scarp. Myall woodland is concentrated around a drainage line cutting down the scarp.*

LEFROY LAND SYSTEM (9 km^2, < 0.1% of the survey area)

(modified from Payne, Mitchell and Hennig 1998)

Salt lakes and fringing saline plains, sandy plains and dunes with halophytic shrubland.

Land zone: Coonana–Ragged Plateau of the Yilgarn Plateau Province.

Land type: 15

Geology: Quaternary lacustrine saline clay and sand, saline alluvium and aeolian sand, and gypsum.

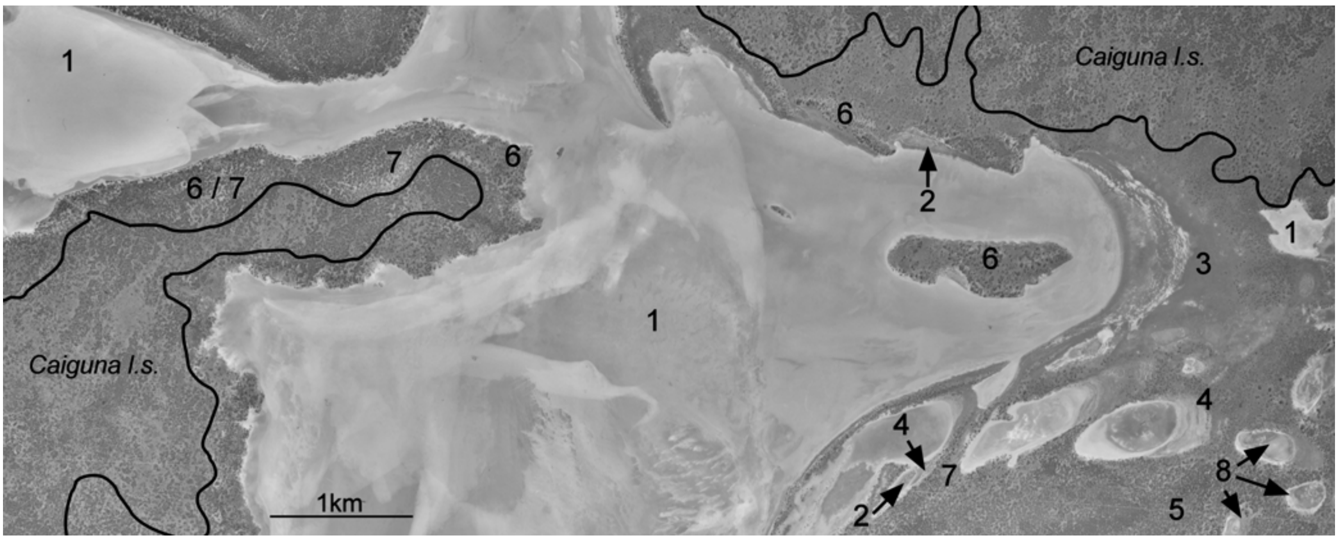
Geomorphology: Depositional surfaces; lake beds, drainage foci, claypans and fringing level to very gently inclined plains of saline alluvium; sandy banks, low sand dunes and undulating kopi dunes above and surrounding saline plains; alluvial plains on margin of system subject to sheet flow.

Land management: Lack of slope renders most of this system generally resistant to soil erosion. Wind erosion at lake margins may be exacerbated by loss of stabilising perennial shrubs. The vegetation of this system is highly preferred for grazing by herbivores rendering it susceptible to overgrazing and consequent degradation. Overgrazing can be avoided by good land management, including control of total grazing pressure.

Traverse condition summary: (3 assessments)

Vegetation—very good 33%, good 67%.

No.	Landform	Traverse recordings	Inventory sites
1.	Lake bed	1	–
2.	Saline plain	–	1
3.	Alluvial plain	–	1
4.	Sandy bank	–	–
5.	Loamy plain	2	–
6.	Kopi dune	–	1
7.	Dune	–	–
8.	Drainage zone	–	–
	Total	3	3



Lefroy land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	70%	**Lake bed**—lake floors.	Highly saline and/or gypsiferous sediments (102).	Unvegetated.
2.	5%	**Saline plains**—level, highly saline lower plains often adjacent to unit 1.	Red/brown non-cracking clays (622).	Very scattered to scattered *Tecticornia* spp. (samphires) dominated low shrubland; *Frankenia* sp. (frankenia) common (SAMP).
3.	20%	**Alluvial plains**—level saline alluvial plains, marginally higher than unit 2.	Red deep duplex soils (405).	Scattered to moderately closed halophytic low shrubland with *Atriplex vesicaria* (bladder saltbush), *Cratystylis subspinescens* (sage), *Frankenia* sp., *Maireana* spp. (bluebushes) and *Tecticornia* spp. (PXHS).
4.	1%	**Sandy banks**—banks and low rises with uneven surfaces, up to 2 m above surrounding plains (units 2 and 3).	Red deep sands (445).	Scattered shrubland with very variable mixtures of halophytic and non-halophytic shrubs (PXLS).
5.	1%	**Loamy plains**—level plains on the landward margins of the system.	Red deep sandy duplex (405) or red sandy earths (463).	Very scattered to scattered *Eucalyptus* species woodland with a variable scrub layer commonly dominated by *Eremophila* species (EXSW).
6.	1%	**Kopi dunes**—low dunes with gently undulating crests and uneven surfaces, gentle side slopes and up to 8 m above lake beds (unit 1) and saline plains (unit 3).	Encrusted gypsiferous sediments with shallow red sand in pockets (703).	Scattered woodland or tall shrubland with *Eucalyptus*, *Casuarina* and *Callitris* species over scattered low halophytic shrubs belonging to the genera *Atriplex*, *Cratystylis, Frankenia*, *Maireana*, *Rhagodia* and *Tecticornia* (KOPI).
7.	1%	**Dunes**—aeolian deposits up to 10 m high fringing lake beds (unit 1).	Red deep sands (445).	Scattered woodland of *Eucalyptus* and *Callitris* species or tall scrub dominated by *Acacia ligulata* (umbrella wattle), *Dodonaea viscosa* (sticky hopbush), *Grevillea* sp. over mixed low shrubs (EXSW), occasionally with hummock (spinifex) grass *Triodia scariosa*.
8.	1%	**Drainage zones**—drainage lines, drainage foci and claypans.	Red/brown non-cracking clays (622).	Halophytic low shrubland in drainage lines (SAMP). Drainage foci with variable halophytic and non-halophytic communities, commonly *Muehlenbeckia florulenta* (lignum) (LISW). Claypans are unvegetated.

Lefroy land system: *Saline plains supporting halophytic low shrubland bordered by kopi dunes supporting scattered woodland.*

LOWRY LAND SYSTEM (65 km², 0.1% of the survey area)

Undulating weathered limestone low rise overlain by shallow residual sand and calcrete supporting pearl bluebush shrubland.

Land zone: Nullarbor Plain.

Land type: 9

Geology: Quaternary (Pleistocene)—Neogene (Pliocene) Recrystallised (weathered) Limestone overlain by Quaternary residual sandy loam.

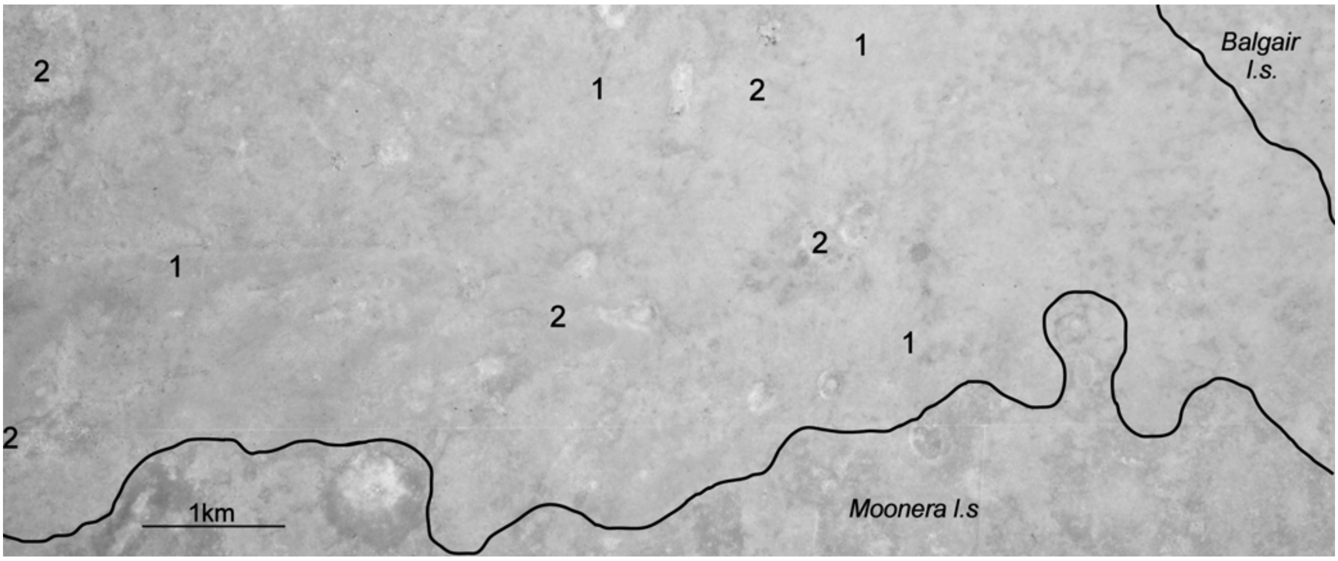
Geomorphology: Erosional surfaces; undulating low rise composed of Recrystallised Nullarbor Limestone and calcrete standing above surrounding plain of deflated Nullarbor Limestone. Residual sandy loam varies with depth from shallow over crests to deep in depressions and rises' edges, donga-like depressions at base and edges of rise.

Land management: Vegetation associated with the drainage foci is prone to preferential grazing. Foci support tree-based bush clumps commonly around grevillea, mulga, curara and native willow. These areas are frequented by native, domestic and feral animals due to the shelter and browse they offer compared to the surrounding open plain. Overgrazing can be avoided by good land management, including control of total grazing pressure.

Traverse condition summary:
(16 assessments)

Vegetation—very good 6%, good 63%, fair 25%, poor 6%.

No.	Landform	Traverse recordings	Inventory sites
1.	Residual calcrete rise	13	1
2.	Drainage focus	3	–
	Total	16	1



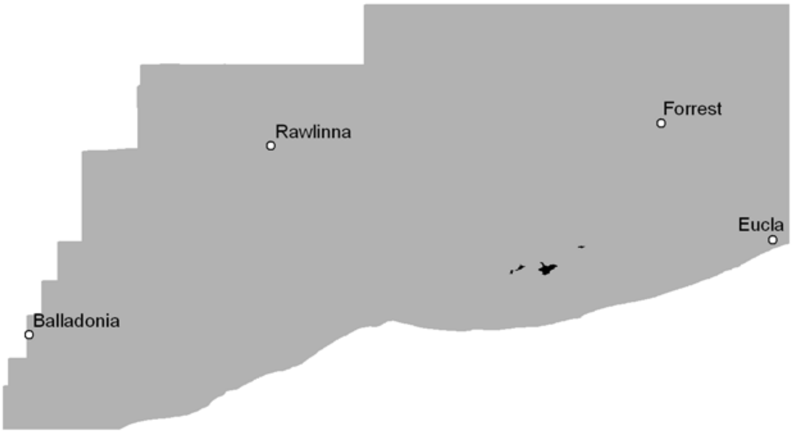
Lowry land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	95%	**Residual calcrete rise**—undulating low rises, very stony mantle of fine to medium-sized Recrystallised Limestone and calcrete fragments.	Calcareous shallow sandy loam (521).	Moderately closed *Maireana sedifolia* (pearl bluebush) shrubland (PBLS), occasional isolated trees of *Myoporum platycarpum* (sugarwood).
2.	5%	**Drainage foci**—stony, level to gently inclined, closed depressions (< 0.3 km in diameter) between undulating low rises (unit 1).	Calcareous sandy loam to various depths (542).	Very scattered to scattered trees and tall shrubs (DCGR). Tree species commonly present include *Grevillea nematophylla*, *Pittosporum angustifolium* (native willow), *Acacia aneura* (mulga) and *A. tetragonophylla* (curara) over *Chenopodium curvispicatum*, *Enchylaena tomentosa* (ruby saltbush), *Ptilotus obovatus* (cotton bush) and the grass *Enneapogon cylindricus* (jointed nineawn).

***Lowry land system:** Pearl bluebush shrubland from crest of low rise looking down towards drainage depressions supporting mixed shrubs.*

MOODINI LAND SYSTEM (123 km², 0.1% of the survey area)

Level to gently undulating plains of residual sand and calcrete near the edge of the Bunda Plateau supporting eucalypt or myall woodland.



Land zone: Hampton Tableland.

Land type: 7

Geology: Quaternary (Pleistocene) residual calcareous sand containing sheet and nodular calcrete near the surface, over Miocene Mullamullang Limestone.

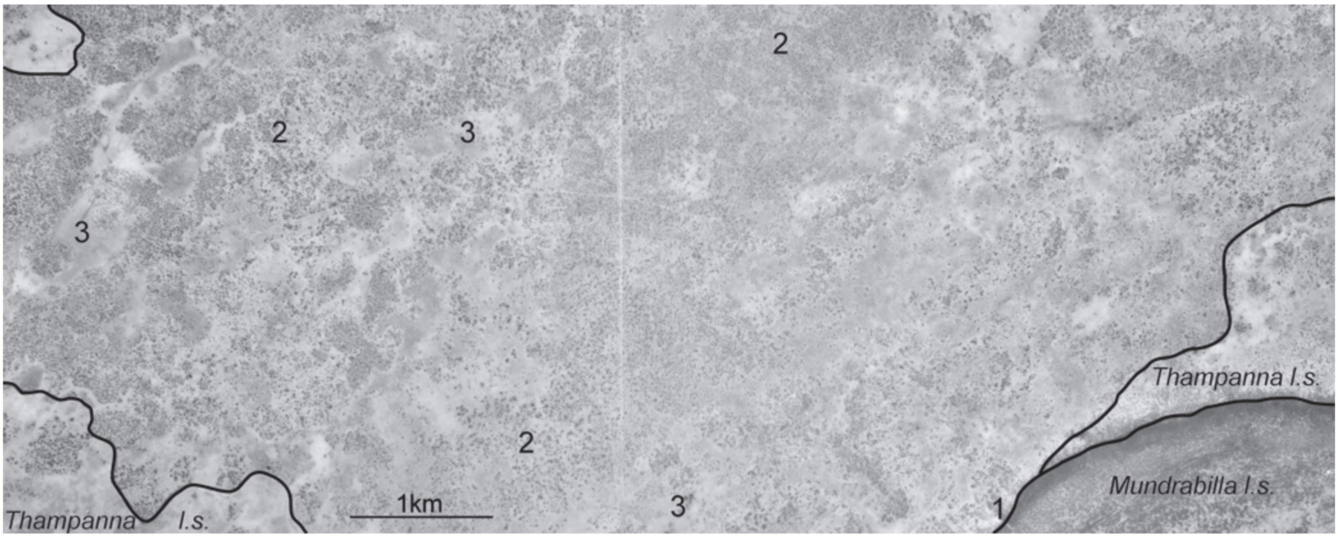
Geomorphology: Relict land surfaces; level to gently inclined rises of undissected residual sandy loam and calcrete, derived from weathered residual aeolian deposits, formerly aeolian calcarenite; small, narrow drainage foci; marine-eroded scarp forms southern edge of Bunda Plateau.

Land management: The mid to low shrub stratum is prone to preferential grazing by introduced and native animals rendering the system susceptible to overgrazing and altering the floristic diversity. Fire is a major threat to the integrity of the vegetation, particularly as grasses encroach inwards at the system margins increasing fire susceptibility.

Traverse condition summary:
(51 assessments)

Vegetation—very good 14%, good 49%, fair 31%, poor 4%, very poor 2%.

No.	Landform	Traverse recordings	Inventory sites
1.	Scarp	1	–
2.	Plain of residual sand and calcrete	50	6
3.	Drainage focus	–	1
	Total	51	7



Moodini land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Scarp**—marine-eroded scarp or cliff. Vertical to steep slopes with abundant stony fragments and outcrop of Mullamullang or, less commonly, Nullarbor Limestone.	Shallow calcareous aeolian sands (421).	Moderately closed patches of woodland of *Eucalyptus gracilis* (yorrell), *E. yalatensis* (yalata mallee) and *Melaleuca lanceolata* with variable mid to low shrubland of *Atriplex nummularia* (old man saltbush) and *Westringia rigida* (ESAW, EXSW) amidst stony outcrop.
2.	70%	**Plains of residual sand and calcrete**—level to gently inclined plains with a calcrete horizon close to the surface, with a sparse to well developed mantle of calcrete nodules and fragments.	Calcareous loamy earths (542) to variable depths.	Scattered to moderately closed *Eucalyptus gracilis* and *E. yalatensis* woodland with a variable scrub understorey of *Atriplex nummularia*, *Exocarpos aphyllus*, *Eremophila weldii*, *Geijera linearifolia*, *Maireana erioclada, M. sedifolia, Melaleuca lanceolata, Olearia calcarea*, *Rhagodia crassifolia, Westringia rigida* and *Austrostipa scabra* (speargrass) (EXSW) or scattered *Acacia papyrocarpa* (myall) woodland when eucalypts are sparse or absent over shrubland dominated by *Cratystylis conocephala* (false bluebush) (MFBW).
3.	29%	**Drainage foci**—narrow depositional areas receiving run-on.	Calcareous loamy earths (542) almost grading to clay.	Sparse *Eucalyptus gracilis* and *Melaleuca lanceolata* with a scattered to moderately closed understorey of *Cratystylis conocephala* and *Eremophila weldii* (EMEW) or moderately closed *Atriplex vesicaria* (bladder saltbush) low shrubland (BSSL).

***Moodini land system:** Level plain of sandy loam over calcrete supporting myall woodland and false bluebush shrubland.*

MOONERA LAND SYSTEM (4234 km^2, 3.6% of the survey area)

Very gently undulating stony limestone plains defined by north-east to south-west trending joint patterns supporting pearl bluebush shrubland on low ridges and bladder saltbush shrubland on drainage floors.

Land zone: Nullarbor Plain.

Land type: 11

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

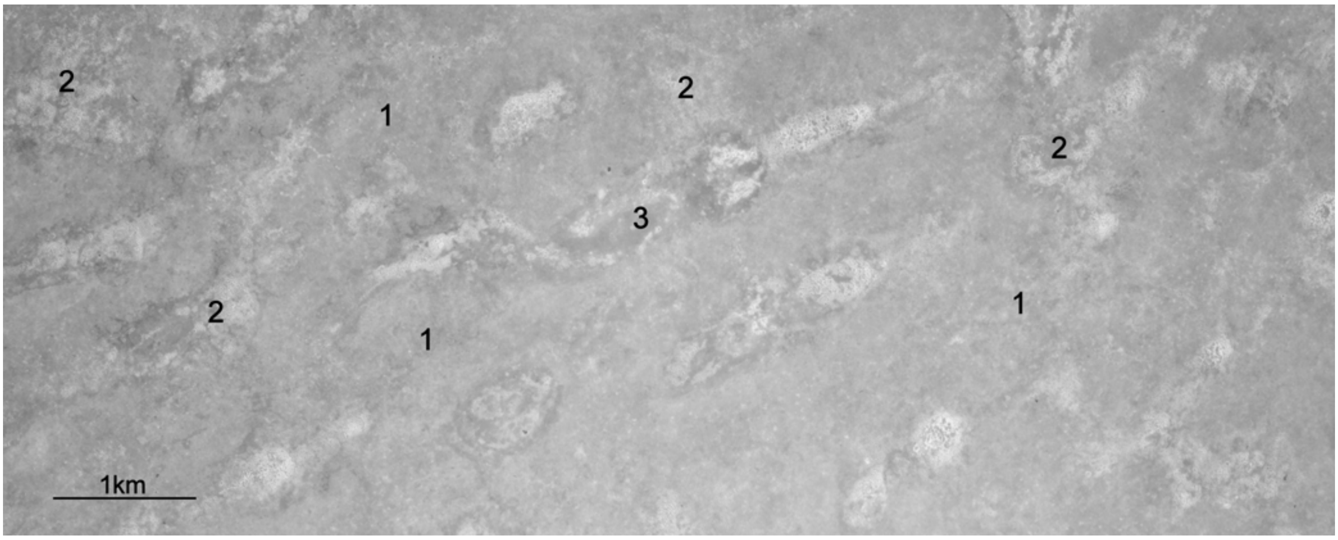
Geomorphology: Erosional surfaces; differential weathering of the deflated Nullarbor Limestone along north-east to south-west trending joint patterns has formed wide drainage floors separated by very gently undulating broad, stony low rises and ridges; drainage floors with colluvial infill, generally closed depressions though sometimes open through linked marginal slopes between stony plains, rarely longer than 3 km; large infrequent irregular claypans, < 1 km in extent.

Land management: The system is dominated by chenopod vegetation. As long lived plants well adapted to arid environments they have a crucial role in landscape stability providing a protective cover for the soil surface. Managing stock numbers so that chenopod shrubs are not heavily overgrazed will maintain the long-term viability of the chenopod communities, leading to protection of the soil surface. As rainfall and season conditions determine species composition and abundance there are few management options for the herbage layer. Vegetation condition should determine when to adjust stock numbers.

Traverse condition summary:
(319 assessments)

Vegetation—good 73%, fair 22%, poor 4%, very poor 1%.

No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	226	5
2.	Marginal slope to drainage floor	91	4
3.	Claypan	2	1
	Total	319	10



Moonera land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	60%	**Stony limestone plains**—very gently undulating plains with abundant mantle of mixed-sized Nullarbor Limestone fragments and outcrop.	Calcareous shallow loams (521).	Very scattered to scattered low shrubland of *Maireana sedifolia* (pearl bluebush) (PBLS), occasionally co-dominate with populations of *Acacia burkittii* (jam) or *Senna artemisioides* on crests of ridges (PBAC).
2.	30%	**Marginal slope to drainage floors**—very gently inclined stony slopes, with mantle of mixed limestone fragments, draining to wide, closed (occasionally open) depressions, < 3 km defined by north-east to south-west trending joint patterns.	Calcareous loamy earths (542).	Scattered mixed chenopod low shrubland (PXCS), grading downwards into moderately closed *Atriplex vesicaria* (bladder saltbush) shrubland (BSSL), or occasionally *Austrostipa scabra* (speargrass) (SWOG).
3.	10%	**Claypans**—large oval, closed depressions, up to 0.9 km in diameter, smooth, level surface 2–5 m below surrounding stony plains (unit 1).	Red/brown non-cracking clay (622).	Very scattered to moderately closed low shrubland dominated by *Atriplex vesicaria* (BSSL) or by *Sclerolaena* species (bindiis) (OBIG); occasionally unvegetated.

Moonera land system: *Drainage floor supporting bladder saltbush surrounded by stony limestone plain supporting pearl bluebush.*

MOOPINA LAND SYSTEM (107 km^2, 0.1% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Level plains of residual sandy clay and calcrete near the edge of the Bunda Plateau supporting dense eucalypt and melaleuca woodland with false bluebush-dominated shrubland in narrow drainage foci.

Land zone: Hampton Tableland.

Land type: 7

Geology: Quaternary (Pleistocene) residual sandy clay containing sheet and nodular calcrete near the surface, over Miocene Nullarbor Limestone.

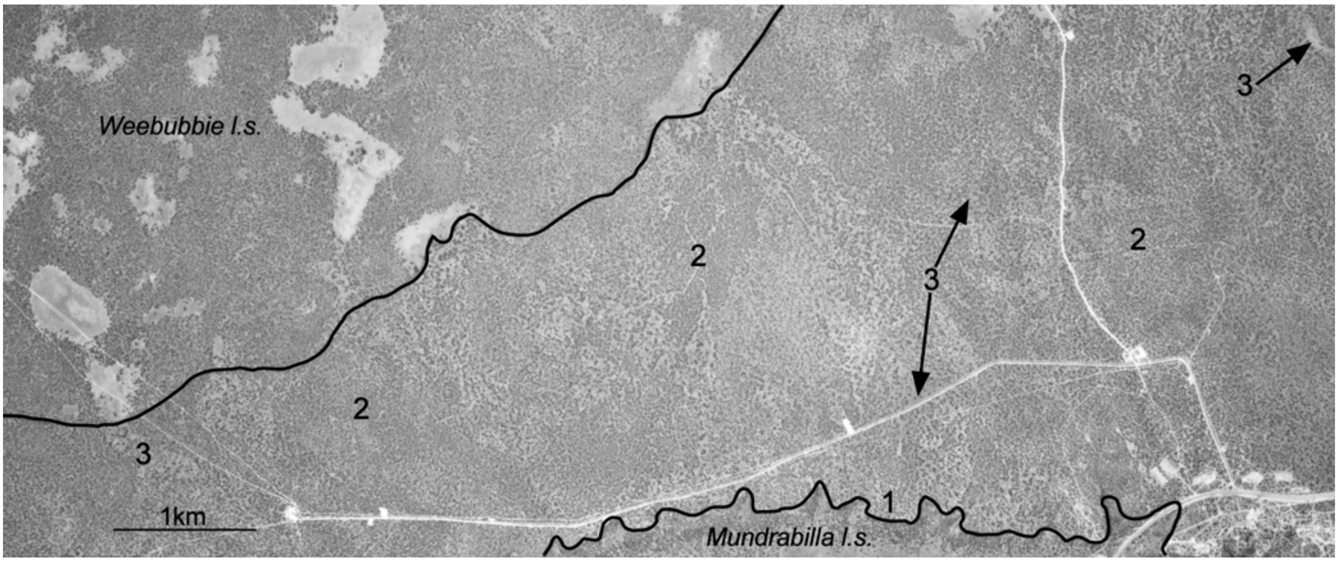
Geomorphology: Relict land surfaces; level to gently inclined rises of undissected residual sandy clay and calcrete, derived from weathered residual aeolian deposits, relief seldom exceeds 1 m; small, narrow drainage foci; marine-eroded scarp forms southern edge of Bunda Plateau.

Land management: Due to the coarse surface texture of the major unit (unit 2) and the stability provided by the closed woodland this system has low susceptibility to erosion. The increase in fire susceptibility as grasses encroach inwards from the system's margins through disturbance mechanisms is a major threat to vegetation integrity.

Traverse condition summary:
(7 assessments)

Vegetation—good 86%, fair 14%.

No.	Landform	Traverse recordings	Inventory sites
1.	Scarp	–	–
2.	Plains of residual clay and calcrete	7 (2006)	1 (2006)
3.	Drainage focus	–	1 (2006)
	Total	7 (2006) / 9 (1974)	2 (2006) / 1 (1974)



Moopina land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Scarp**—marine-eroded scarp or cliff. Steep slopes or vertical faces with abundant stony fragments and outcrop of Nullarbor Limestone.	Shallow calcareous aeolian sands (421).	Moderately closed patches of woodland of *Eucalyptus gracilis* (yorrell), *E. yalatensis* (yalata mallee) and *Melaleuca lanceolata* with variable mid to low shrubland of *Atriplex nummularia* (old man saltbush) and *Westringia rigida* (EXSW) amidst stony outcrop.
2.	75%	**Plains of residual clay and calcrete**—level to gently undulating plains with occasional low rises, a calcrete horizon exists close to the surface.	Calcareous shallow loams (521), with some calcareous loamy earths (542).	Moderately closed *Eucalyptus gracilis*, *Melaleuca lanceolata* and *M. quadrifaria* woodland with a variable scrub understorey of *Atriplex nummularia*, *Eremophila weldii*, *Exocarpos aphyllus*, *Geijera linearifolia*, *Maireana erioclada, Olearia calcarea*, *Rhagodia crassifolia, Westringia rigida* and *Zygophyllum aurantiacum* (EMEW) or scattered eucalypt woodland as the melaleuca component decreases (EXSW).
3.	24%	**Drainage foci**—narrow depositional areas receiving run-on.	Deep loams grading to light clays (542) or red/brown non-cracking clays (622).	Sparse *Eucalyptus gracilis* and *Melaleuca lanceolata* with a scattered to moderately closed understorey of *Cratystylis conocephala* (false bluebush) and *Eremophila weldii* (EMEW).

Moopina land system:
Drainage focus supporting eucalypt and melaleuca woodland over false bluebush shrubland.

MORRIS LAND SYSTEM (3323 km², 2.8% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Level to very gently undulating stony limestone plains supporting pearl bluebush shrubland separated by drainage floors and claypans along irregular joint patterns supporting bladder saltbush shrubland and grassland.

Land zone: Nullarbor Plain.

Land type: 11

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

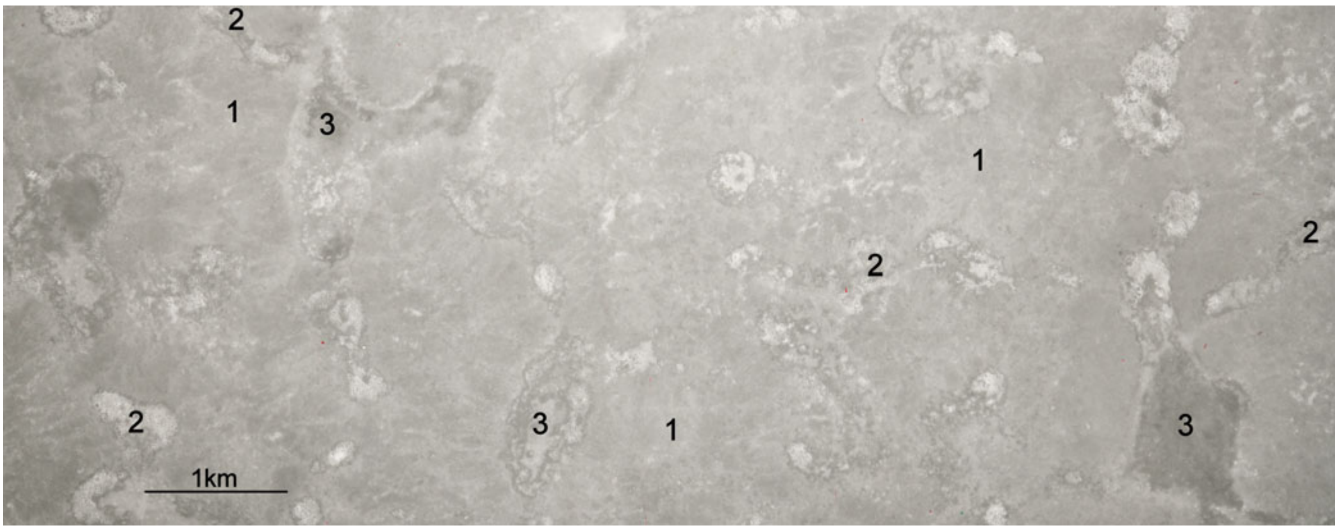
Geomorphology: Erosional surfaces; differential weathering of the deflated Nullarbor Limestone along irregular joint patterns has formed sinuous drainage floors, up to 3 km long, separated by very gently undulating low stony plains, with less than 2 m relief; drainage floors form closed depressions with colluvial infill; large, irregular claypans in drainage foci, up to 1.5 km in extent.

Land management: The majority of this system occurs outside pastoral leases and is dominated by chenopod vegetation. Rainfall and seasonal conditions determine species composition and abundance. The onset of dry seasonal conditions is best indicated by seasonally dependent subshrubs that begin to decline as dry conditions commence. Perennial species such as *Atriplex vesicaria* (bladder saltbush) lose their leaves in prolonged dry periods.

Traverse condition summary: (49 assessments)

Vegetation—very good 14%, good 74%, fair 12%.

No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	43 (2006)	–
2.	Marginal slope to drainage floor	3 (2006)	–
3.	Claypan	3 (2006)	–
	Total	49 (2006) / 26 (1974)	3 (1974)



Morris land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	66%	**Stony limestone plains**—very gently undulating plains with abundant mantle of mixed-sized Nullarbor Limestone fragments and outcrop.	Calcareous shallow loams (521).	Very scattered to scattered low shrubland of *Maireana sedifolia* (pearl bluebush) (PBLS).
2.	20%	**Marginal slope to drainage floors**—level to very gently inclined slopes, with a sparse mantle of mixed limestone fragments, draining to sinuous, narrow, closed depressions along irregular joint patterns, up to 3 km long and 0.4 km wide.	Calcareous loamy earths (542).	Scattered low shrubland of *Maireana sedifolia* (PBLS), grading into mixed chenopod shrubland (PXCS) before becoming dominated by moderately closed *Atriplex vesicaria* (bladder saltbush) shrubland (BSSL).
3.	14%	**Claypans**—large irregular, closed depressions, up to 2 km in extent, smooth, level surface occurring within drainage floors (unit 2).	Red/brown non-cracking clays (622).	Very scattered to moderately closed low shrubland dominated by *Atriplex vesicaria* (BSSL), occasionally *Austrostipa scabra* (speargrass) and *Austrodanthonia caespitosa* (wallaby grass) grassland (SWOG) or unvegetated.

Morris land system: *Marginal slope supporting mixed chenopod shrubland co-dominated by pearl bluebush and bladder saltbush.*

MUNDRABILLA LAND SYSTEM (1688 km², 1.4% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Landward section of calcarenite coastal plain supporting myall woodland over false bluebush and open shrubland dominated by chenopods and nitre bush.

Land zone: Roe Plains.

Land type: 13

Geology: Quaternary colluvium, clay loam containing sheet or nodular calcrete over Neogene (Late Pliocene) Roe Calcarenite. Roe Calcarenite overlies Cainozoic (Late Oligocene—Early Miocene) Abrakurrie Limestone in the western and central parts and (Eocene) Wilson Bluff Limestone in the eastern part of the Roe Plains.

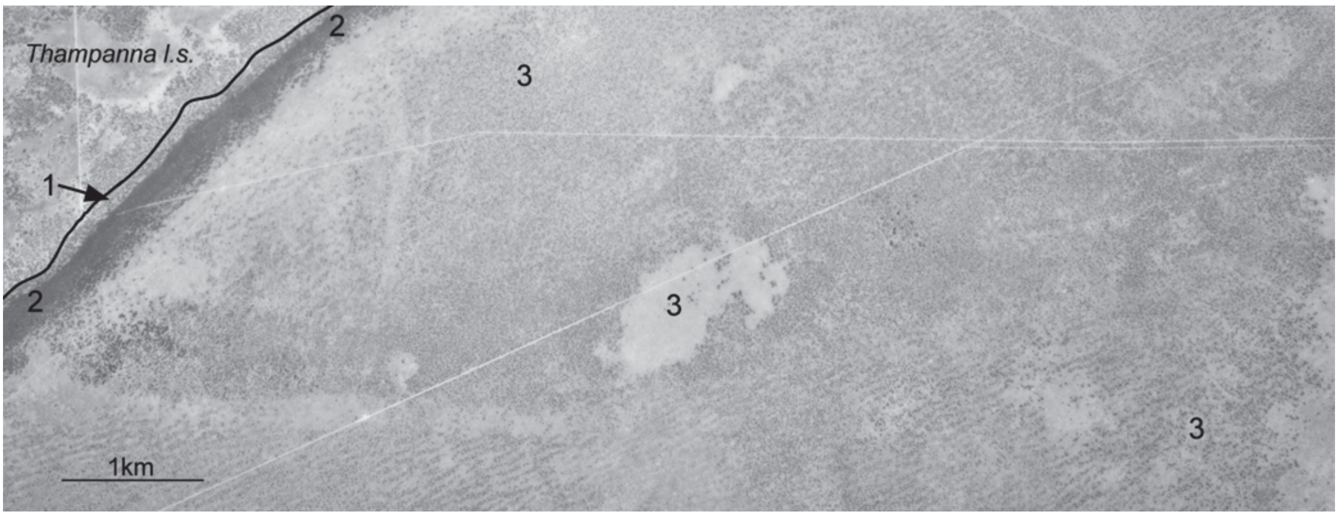
Geomorphology: Depositional land surfaces; coastal plain with landward margin backed by marine-eroded scarp with colluvium forming footslope at base; level calcarenite plain covered by shallow in situ clay loam containing sheet and nodular calcrete.

Land management: The steep slope of the Hampton Scarp makes these areas highly susceptible to erosion. Bunds and water-lets should be constructed on scarp tracks to reduce the volume and erosive potential of water flow channelled by tracks. Palatable flora can be eliminated under continuous heavy grazing, particularly following a fire. Overgrazing can be avoided by appropriate land management.

Traverse condition summary:
(127 assessments)

Vegetation—very good 26%, good 64%, fair 9%, poor 1%.

No.	Landform	Traverse recordings	Inventory sites
1.	Scarp	–	2
2.	Footslope	2	2
3.	Calcarenite loamy plain	125	15
	Total	127	19



Mundrabilla land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Scarp**—marine-eroded scarp to 90 m. Steep slopes with abundant Abrakurrie, Mullamullang and Nullarbor Limestone outcrop and scree.	Shallow calcareous loams (521).	Scattered to moderately closed woodland of *Eucalyptus diversifolia* (soap mallee), *E. gracilis* (yorrell) and *Melaleuca lanceolata* with variable mid to low shrubland of *Atriplex nummularia* (old man saltbush), *A. vesicaria* (bladder saltbush), *Olearia calcarea* and *Maireana* species (bluebushes) (EXSW) amidst stony outcrop.
2.	4%	**Footslopes**—moderately inclined slopes formed by colluvium (< 1 km wide) below scarp face (unit 1), merging into level plain (unit 3 or Roe land system).	Calcareous loamy earths (542).	Scattered to moderately closed shrubland of *Atriplex vesicaria* (BSSL) or mixed chenopod shrubland where *Atriplex nummularia* and *Maireana* species become more common (PXCS). Occasional shrubs common to EXSW become more frequent closer to scarp outcrop.
3.	95%	**Calcarenite loamy plains**—level plains with sheet and nodular calcrete at shallow depth.	Deep calcareous loamy earths (542), occasionally shallow loams (521).	Scattered to moderately closed *Acacia papyrocarpa* (myall) woodland over *Cratystylis conocephala* (false bluebush) and *Geijera linearifolia* (oilbush) (MFBW). Where the tree stratum lessens or disappears very scattered to moderately closed mixed chenopod shrubland occurs, often dominated by *Nitraria billardierei* (nitre bush) (MXCS, PXCS or NXCS).

Mundrabilla land system: *Loamy plain supporting mixed chenopod shrubland, Hampton Range with eucalypt woodland in the background.*

NANAMBINIA LAND SYSTEM (570 km², 0.5% of the survey area)

Level to gently undulating stony limestone plains supporting scattered sugarwood over chenopod shrubland or grassland.

Land zone: Mardabilla Plain.

Land type: 11

Geology: Pleistocene calcrete or Miocene Nullarbor Limestone.

Geomorphology: Erosional surfaces; level to gently inclined depressions and gently undulating plains subject to very diffuse sheet flow; relics of ancient river courses with infrequent drainage foci having gilgai micro-relief along the base of some narrow depressions.

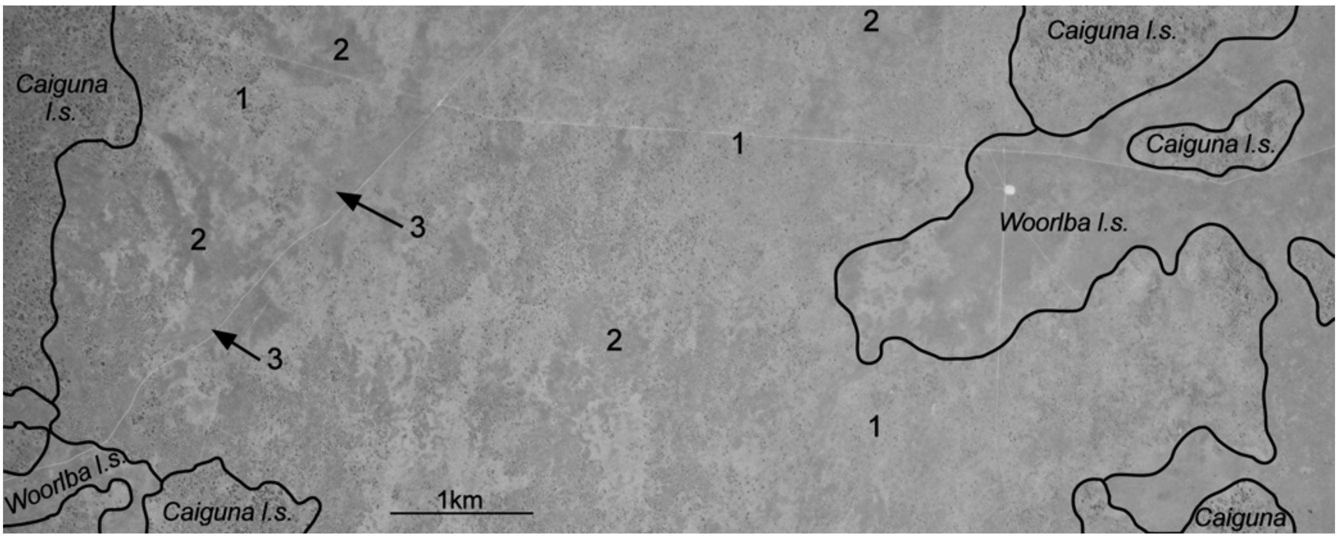
Land management: Chenopod vegetation communities are preferentially grazed. This system receives diffuse drainage from neighbouring systems providing favourable growing conditions for plants. Under continuous grazing unpalatable and seasonally dependent shrubs and annuals may replace palatable perennial species. Heavy grazing can be avoided by good management, including control of total grazing pressure.

Grassland dominates some areas and due to a high fuel load following favourable seasons these areas are susceptible to fire. Adjacent vegetation communities are at risk of being burnt and invaded by grasses. Strategic firebreaks may prevent fragmentation and preserve intact vegetation communities.

Traverse condition summary:
(114 assessments)

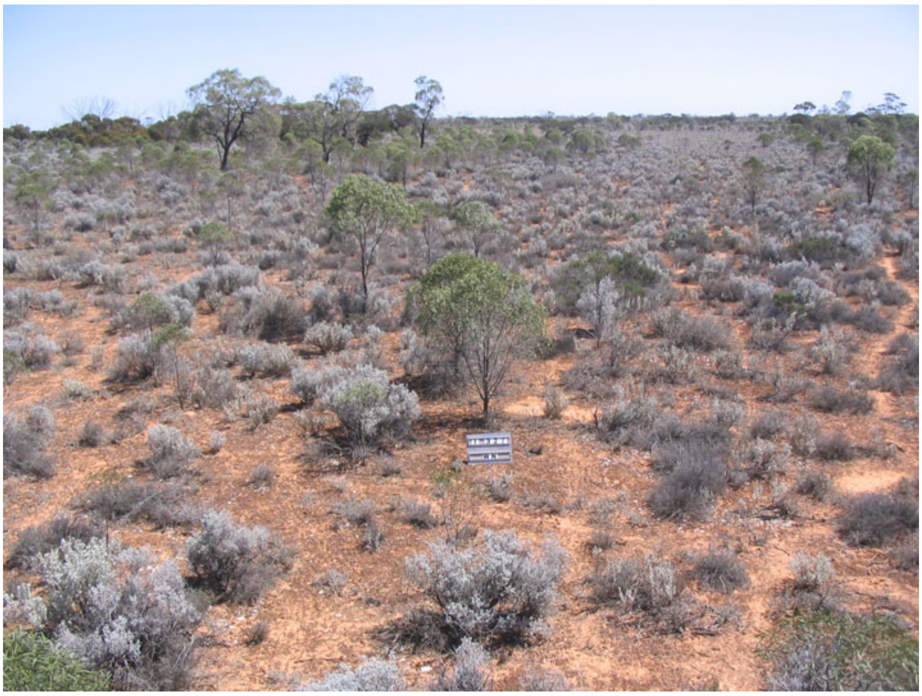
Vegetation—very good 5%, good 59%, fair 28%, poor 7%, very poor 1%.

No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	44	2
2.	Loam plain	60	2
3.	Saline drainage focus	3	1
4.	Clay floored depression	5	–
5.	Low granite rise	2	–
6.	Drainage tract (ancient river course)	–	–
	Total	114	5



Nanambinia land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	50%	**Stony limestone plains**—level to gently inclined plains with a stony mantle of mixed-sized calcareous fragments, calcrete or Nullarbor Limestone outcrop common.	Calcareous shallow loams (521).	Scattered tall shrubland dominated by *Myoporum platycarpum* (sugarwood) over *Maireana sedifolia* (pearl bluebush) and *Atriplex vesicaria* (bladder saltbush) (SWCS).
2.	45%	**Loam plains**—level to gently inclined plains with a sparse stony mantle, with occasional Nullarbor Limestone outcrop.	Mostly calcareous loamy earths (542), with some calcareous shallow loams (521).	Scattered mid to low shrubland co-dominated by *Atriplex nummularia* (old man saltbush), *A. vesicaria* and *Maireana sedifolia* (PXCS) or *Austrodanthonia caespitosa* (wallaby grass) and *Austrostipa scabra* (speargrass) open grassland (SWOG). Occasionally very scattered *Myoporum platycarpum* (sugarwood) is present (SWCS).
3.	4%	**Saline drainage foci**—drainage sumps within units 1 and 2.	Clay loam grading to saline clay subsoils (542, 622).	Scattered to moderately closed low halophytic shrubland of *Atriplex vesicaria* and *Tecticornia* spp. (samphires) (PXHS).
4.	1%	**Clay floored depressions**—smooth, level, closed drainage depressions, variable in size and shape, receiving drainage from units 1 or 2.	Deep, often saline, calcareous clay loams (542) or light clays (622).	Scattered to moderately closed low shrubland dominated by *Atriplex vesicaria* (BSSL) or as for unit 2.
5.	< 1%	**Low granite rises**—Granite outcrop occurring as low rises, generally less than 5 m relief, with gritty-sandy margin.	Very shallow red sands (423) or loams (522) on granite.	Unvegetated to very scattered tall to mid shrubland of mixed shrubs including *Acacia ligulata* and *Dodonaea lobulata* with *Ptilotus obovatus* (cotton bush) understorey (GROS).
6.	< 1%	**Drainage tracts (ancient river courses)**—level to very gently inclined drainage tracts.	Saline calcareous clay loams (542), occasionally gypsiferous.	Scattered to moderately closed mid to low chenopod shrubland, commonly dominated by *Atriplex vesicaria* or co-dominated with *Maireana sedifolia* (BSSL, PXCS).



Nanambinia land system: *Loamy plain supporting sugarwood chenopod shrubland in good condition.*

NARETHA LAND SYSTEM (1547 km^2, 1.3% of the survey area)

Gently undulating stony limestone plains with sandy loam supporting mixed acacia and pearl bluebush shrubland over bindii grassland.

Land zone: Nullarbor Plain.

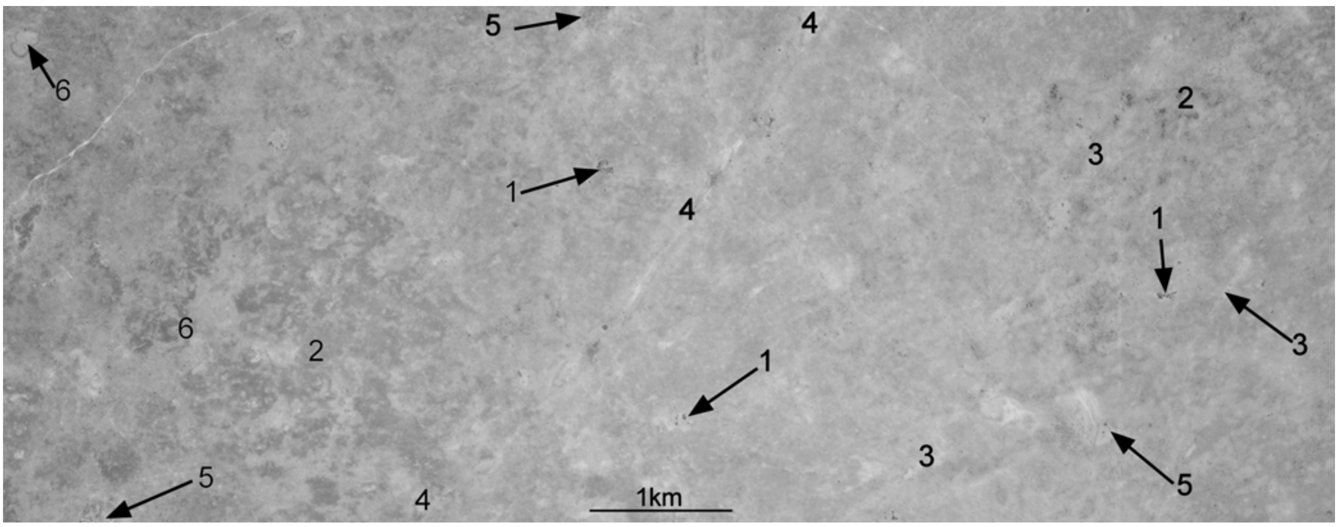
Land type: 11

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

Geomorphology: Erosional surfaces; gently undulating plains of Nullarbor Limestone partially overlain by shallow sandy loams; differential weathering of the surface has formed long, narrow drainage tracts, occasional dongas with gilgai micro-relief and very shallow clay depressions; infrequent relic ancient river courses form sinuous, narrow drainage tracts that terminate indistinctly into the surrounding plains.

The occurrence of the red shallow sandy loam may be the salient feature influencing the vegetation communities within this system. The physical geography, in the form of the nearby residual calcrete plains, and the depositional processes associated with a strong wind regime and ancient water courses have possibly influenced soil properties. Alternatively, the soil surface may reflect sand mobility caused through past or present disturbance events. These factors in combination or individually have influenced soil properties developing a floristic ecotone of mixed species composition between the calcrete plain of the Nyanga land zone and the Nullarbor Plain of the Nullarbor land zone.

Land management: The intermixed populations of flora make monitoring rangeland condition difficult. This system has been significantly influenced by wildfires, rabbits and stock. The combination of fire and herbivore grazing has reduced the diversity of palatable perennial species leading to the abundance of unpalatable acacias. Many of the acacia species that dominate the open plains occur as similarly aged stands, having responded favourably to post-fire conditions and the reduced competition from palatable species suppressed by grazing. Careful management is required to maintain the chenopod component of vegetation communities whilst under continuous grazing, to avoid the system becoming completely dominated by unpalatable perennial species such as *Acacia burkittii* (jam). The gradual reduction in chenopod diversity may not immediately affect production systems but it does expose the landscape to further invasion by less palatable and shorter-lived species. Post-fire grazing pressure should be restricted from burnt areas for a period set by seasonal conditions which will determine the effectiveness of recovery by the less fire-tolerant flora.



Traverse condition summary:
(139 assessments)

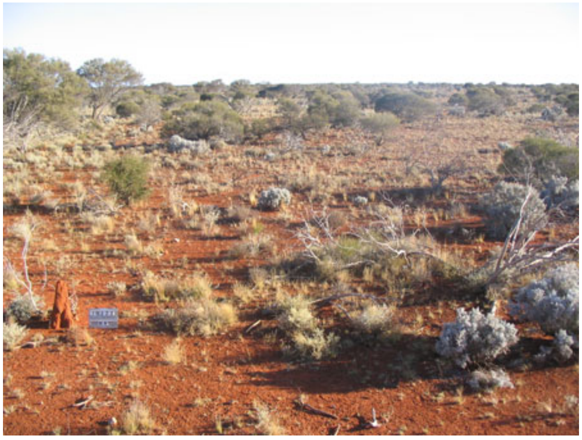
Vegetation—good 30%, fair 58%, poor 12%.

Naretha land system

No.	Landform	Traverse recordings	Inventory sites
1.	Residual calcrete rise	–	–
2.	Stony limestone plain	110	3
3.	Drainage tract	26	2
4.	Ancient river course drainage tract	–	–
5.	Donga	2	1
6.	Clay depression	1	1
	Total	139	7

Unit	Area (%)	Landform	Soil	Vegetation
1.	< 1%	**Residual calcrete rises**—gently inclined low rises of calcrete; mantle commonly composed of mixed-sized calcrete fragments.	Calcareous shallow loams (521).	Very scattered *Casuarina pauper* (black oak) over *Maireana sedifolia* (pearl bluebush) low shrubland (CXCS).
2.	90%	**Stony limestone plains**—gently undulating plains, abundant to common stony mantle of mixed-sized, angular to sub-angular calcareous fragments with Nullarbor Limestone outcrop common.	Calcareous shallow loams (521) or red shallow loam (522).	Scattered tall shrubland of *Acacia burkittii* (jam) (XAOS), sometimes over a low shrub stratum dominated by species of *Sclerolaena* (bindii) (XSBG), or co-dominated with *Maireana sedifolia* (PBAC). *Ptilotus obovatus* (cotton bush) is common.
3.	5%	**Drainage tracts**—gently inclined, long (up to 1.5 km in extent), narrow (< 70 m wide), open depressions between stony plains (unit 2), gilgaied depressions occasionally present.	Sandy loam or clay loam to light clay (542), over fine quartz and calcrete gravels at depth.	Very scattered acacia shrubland commonly featuring *Acacia aneura* (mulga) *A. burkittii* and *A. tetragonophylla* (curara) with *Ptilotus obovatus* and *Salsola kali* (roly poly) common through the tract's centre (DRAS).
4.	< 1%	**Ancient river course drainage tracts**—level to gently inclined, long and sinuous, narrow (< 0.1 km wide), drainage tracts between stony plains (unit 2).	Red/brown non-cracking clays (622).	As for unit 3 (DRAS) or as scattered low shrubland of *Atriplex cryptocarpa* with sparse *Acacia burkittii* and *Eremophila longifolia* (berrigan) (DDSS).
5.	2%	**Dongas**—shallow closed depressions, generally 1.5–3 m below the surrounding plains (unit 2), < 0.25 km in diameter, rounded limestone boulders present in areas where gilgai mechanisms have caused upheaval.	Deep clay (622) or gilgai clay soils (600).	Scattered to very scattered stands of *Acacia burkittii* and *A. tetragonophylla*, *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) dominant in the gilgai areas (DCGR).
6.	3%	**Clay depressions**—level to very gently inclined, shallow closed depressions (< 0.1 km in diameter), receiving run-on from surrounding stony plains (unit 2) and drainage tracts (unit 3).	Deep, red loamy earths (544) or non-cracking clays (622).	Scattered low shrubland of *Acacia tetragonophylla*, *Maireana sedifolia* and *Ptilotus obovatus* among moderately closed grassland commonly supporting *Austrodanthonia caespitosa* (wallaby grass), *Austrostipa scabra* (speargrass), *Enneapogon caerulescens* (limestone grass) and *E. cylindricus* (jointed nineawn) (PBAC).

***Naretha land system:** Drainage tract with sandy loam supporting acacia shrubland. Termite mounds are not uncommon in the drainage tracts of this land system.*



NIGHTSHADE LAND SYSTEM (3373 km², 2.8% of the survey area)

Gently undulating stony limestone plains dominated by tussock grassland with occasional saline drainage foci supporting halophytic shrubs.

Land zone: Nullarbor Plain.

Land type: 11

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

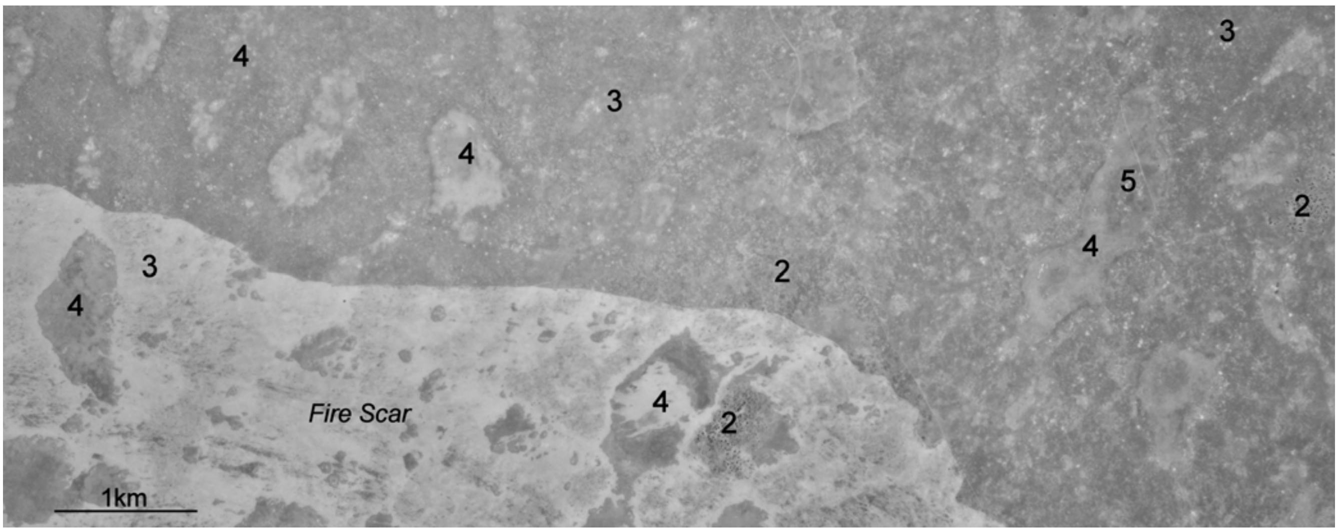
Geomorphology: Erosional surfaces; differential weathering along irregular joint patterns through the deflated Nullarbor Limestone has formed gently undulating stony plains with occasional low rises of up to 5 m relief, surrounding closed drainage depressions or separated by open drainage floors; saline drainage foci occur irregularly.

Land management: This system has been extensively and repeatedly burnt. The landscape has been irreversibly altered to seasonally dependent grassland. Following favourable seasons these tussock grasslands are highly flammable. Wildfires in hot months with strong winds can cause considerable damage to adjacent vegetation communities that are less fire adapted, as well as station infrastructure. After fire, wind erosion may occur. Strategic firebreaks may preserve adjacent vegetation communities.

Traverse condition summary: (286 assessments)

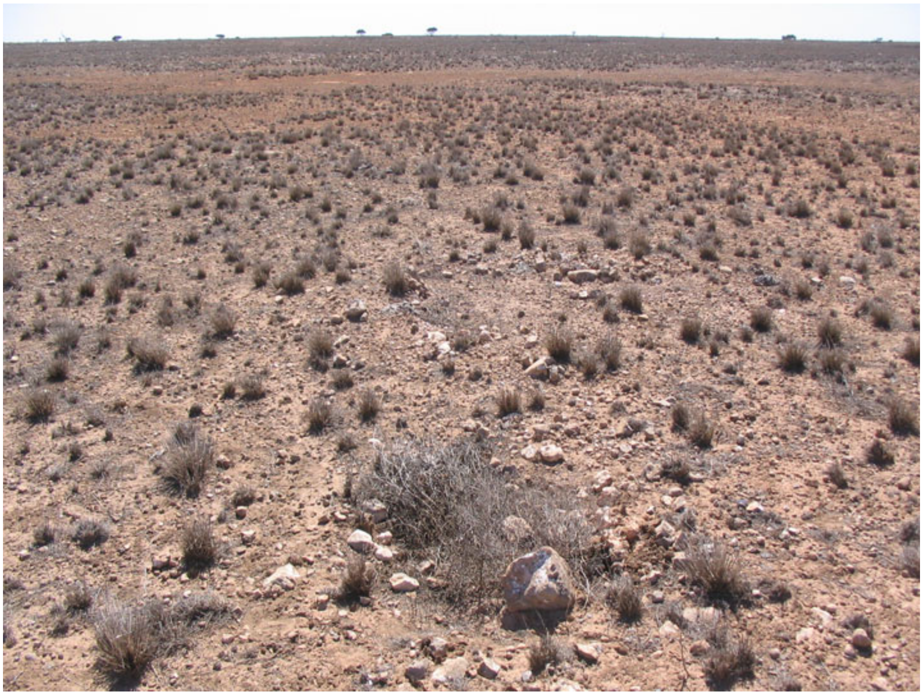
Vegetation—good 77%, fair 19%, poor 4%.

No.	Landform	Traverse recordings	Inventory sites
1.	Residual calcrete rise	–	1
2.	Limestone hummock (low rise)	–	1
3.	Stony limestone plain	124	–
4.	Marginal slope to drainage floor	111	3
5.	Saline drainage focus	51	2
	Total	286	7



Nightshade land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	< 1%	**Residual calcrete rises**—gently inclined low rises of calcrete; variable mantle of calcrete fragments with occasional outcrop.	Calcareous shallow loams (521).	Very scattered *Casuarina pauper* (black oak) woodland over an understorey of mixed shrubs or dominated by chenopods (CXCS).
2.	3%	**Limestone hummocks (low rises)**—gently undulating low rises of Nullarbor Limestone; stony mantle of calcareous fragments and outcrop common to abundant.	Skeletal calcareous shallow loams (521).	Dense grassland of *Austrodanthonia caespitosa* (wallaby grass) and *Austrostipa scabra* (speargrass) (SWOG), occasionally under very scattered stands of *Eucalyptus gracilis* (yorrell) and *E. yalatensis* (yalata mallee) (ESOG).
3.	50%	**Stony limestone plains**—level to gently inclined plains with a stony mantle of mixed-sized calcareous fragments, outcrop common.	Calcareous shallow loams (521).	Dense grassland of *Austrodanthonia caespitosa* and *Austrostipa scabra* (SWOG).
4.	45%	**Marginal slope to drainage floors**—level to gently inclined, open or closed depressions, with a sparse stony mantle.	Mostly deep calcareous loamy earths (542), occasionally light clay (622).	As for unit 3.
5.	2%	**Saline drainage foci**—closed drainage sumps (10–100 m wide) within units 3 and 4.	Saline clay loam (542).	Scattered to moderately closed low halophytic shrubland dominated by *Atriplex vesicaria* and *Tecticornia* spp. (samphires) (PXHS).



Nightshade land system: *Stony limestone plains dissected by narrow drainage floor, both units support grassland.*

NURINA LAND SYSTEM (2,247 km², 1.9% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Stony limestone plains dissected by broad drainage floors supporting grassland or bladder saltbush shrubland, gilgai patches common.

Land zone: Nullarbor Plain.

Land type: 12

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

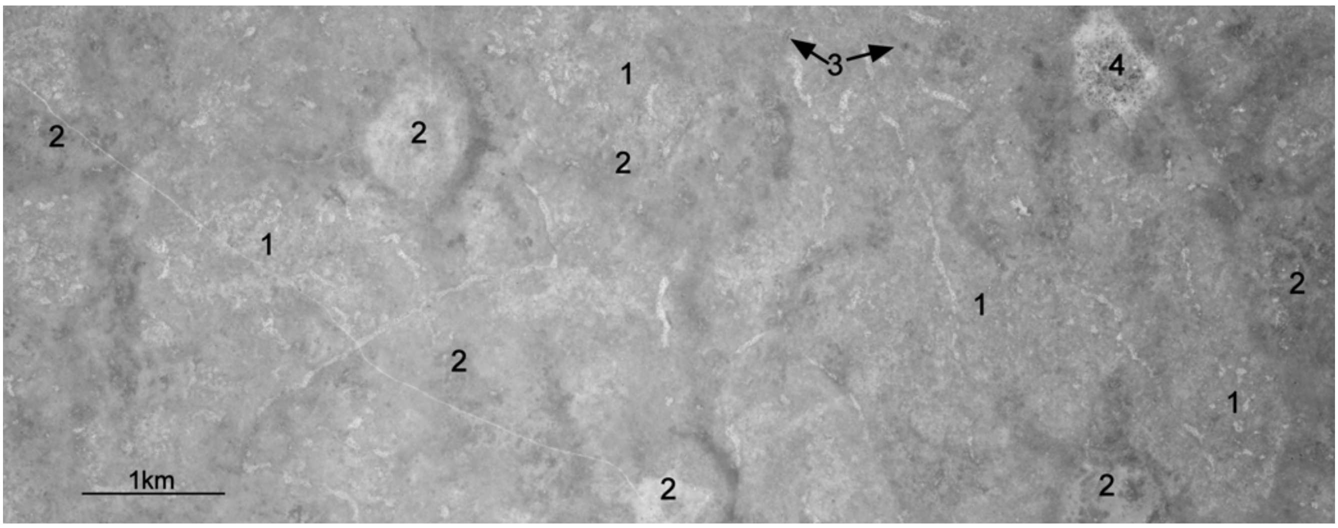
Geomorphology: Erosional surfaces; differential weathering of the level to very gently undulating, stony plains of Nullarbor Limestone have formed broad, open, shallow depressions infilled by colluvium; gilgai patches characterise this system; infrequent large dongas with gilgai micro-relief; drainage patterns restricted to relic ancient river courses with gilgai micro-relief along their length.

Land management: This system has been considerably affected by fire and grassland dominates much of it. Perennial shrubs are particularly at risk because of their scarcity due to previous fires, the susceptibility of the present landscape to fire and impact of continuous grazing. With much of the system consisting of seasonally dependent subshrubs and grassland, grazing by herbivores during dry periods can significantly impact upon the species composition of perennial plants by exhausting the seed bank through killing off juveniles. Due to the scarcity of perennial foliage vegetation that offers a valuable mineral source, particularly during dry periods, is preferentially browsed. *Alectryon oleifolius* (mingah or bullock bush) groves and trees that occur near gilgai patches such as *Eremophila longifolia* (berrigan) and *Pittosporum angustifolium* (native willow) provide an indication of range condition and the total grazing pressure. The presence of juvenile plants indicates improving range condition whilst heavy browse lines, broken limbs and overturned trees indicate deteriorating range condition and excessive grazing pressure. Overgrazing can be avoided by good land management, including control of total grazing pressure.

Traverse condition summary:
(204 assessments)

Vegetation—good 52%, fair 42%, poor 5%, very poor 1%.

No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	154	3
2.	Marginal slope to drainage floor	43	1
3.	Drainage focus (gilgai)	3	3
4.	Donga	4	2
5.	Drainage tract (ancient river course)	–	–
	Total	204	9



Nurina land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	55%	**Stony limestone plains**—level to very gently undulating stony plains, abundant mantle of angular mixed-sized Nullarbor Limestone fragments, outcrop common.	Calcareous shallow loams (521).	Very scattered to moderately closed grassland dominated by *Austrostipa scabra* (speargrass) (SWOG) or co-dominated with *Sclerolaena* species (OBIG). Very scattered *Maireana sedifolia* (pearl bluebush) low shrubland (PBLS) is common in the south. Infrequent groves of *Alectryon oleifolius* (mingah).
2.	40%	**Marginal slope to drainage floors**—very gently inclined slopes draining along broad, open, shallow depressions into level, circular drainage floors; sparse stones on level surface.	Calcareous loamy earths (542) of variable depth, deeper saline subsoils.	Scattered to moderately closed *Atriplex vesicaria* (bladder saltbush) shrubland (BSSL) or *Sclerolaena* species and/or *Austrodanthonia caespitosa* (wallaby grass) and *Austrostipa scabra* grassland (OBIG, SWOG).
3.	2%	**Drainage foci (gilgai)**—irregularly shaped gilgai patches within units 1, 2 and 5, irregular surfaces (< 1 km wide), Nullarbor Limestone rocks of variable size brought to the surface by shrink-swell clays.	Non-saline cracking clays (622) or gilgai clay soils (600).	Dense patches of perennial grasses; *Austrodanthonia caespitosa*, *Austrostipa scabra*, *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) with very scattered shrubs such as *Acacia oswaldii*, *A. tetragonophylla* (curara), *Chenopodium curvispicatum*, *Lycium australe* (water bush) and trees such as *Eremophila longifolia* (berrigan) and *Pittosporum angustifolium* (native willow) (GGSL).
4.	2%	**Dongas**—closed depressions, generally 1.5–3 m below the surrounding stony plains (unit 1), up to 0.4 km in diameter, gilgai micro-relief common with rounded limestone boulders regularly brought to the surface through gilgai mechanisms.	Deep clays (622) or gilgai clay soils (600).	Very scattered to moderately closed stands of *Eremophila longifolia* with scattered *Acacia tetragonophylla* and *Pittosporum angustifolium* surrounded by an understorey of very scattered to moderately closed understorey of *Atriplex cryptocarpa, Chenopodium curvispicatum, Enchylaena tomentosa* (ruby saltbush) and *Lycium australe*; *Eragrostis* grasses common in gilgai areas (DBGR).
5.	1%	**Drainage tracts (ancient river courses)**—level to gently inclined, sinuous, narrow (< 0.1 km wide), drainage tracts between stony plains (unit 1).	Saline calcareous clay loams (542), occasionally gypsiferous.	Scattered to moderately closed mid to low chenopod shrubland, commonly dominated by *Atriplex vesicaria* (BSSL) or *Sclerolaena* species (OBIG).

***Nurina land system:** Gilgai patch supporting water bush and* Eragrostis *grasses amongst stony grassland plain.*

NYANGA LAND SYSTEM (12 990 km^2, 11.0% of the survey area)

(formerly Gunnadorah land system modified from Mitchell, McCarthy and Hacker 1979)

Level loamy calcrete plains supporting myall or casuarina woodland over chenopod understorey.

Land zone: Nyanga Plain.

Land type: 3

Geology: Quaternary residual clay loam overlying Quaternary (Pleistocene)—Neogene (Pliocene) calcrete over Miocene Nullarbor Limestone.

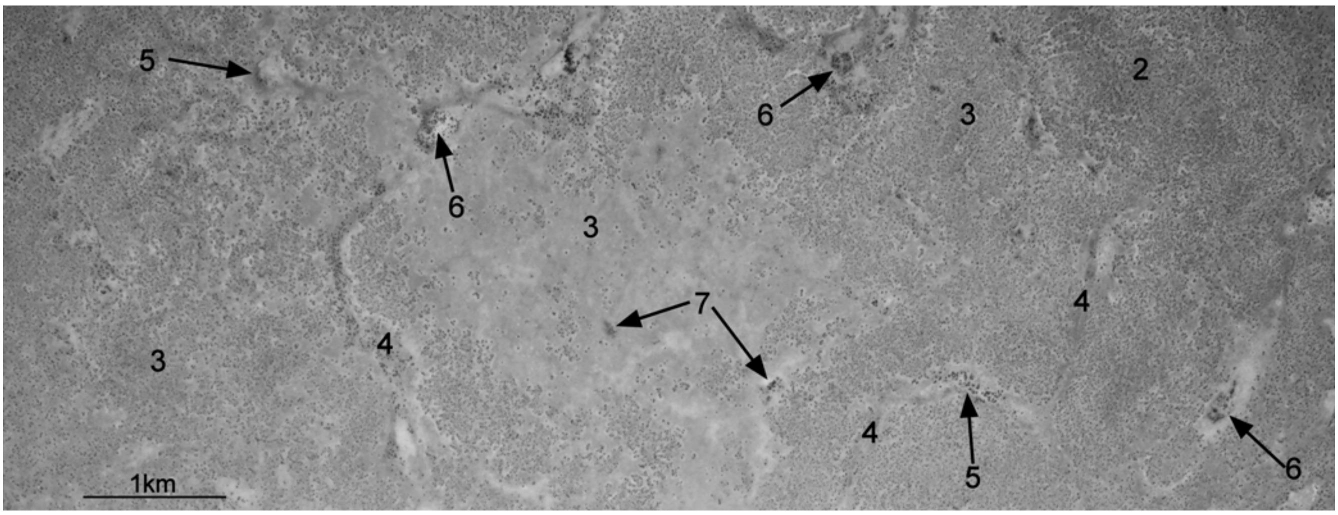
Geomorphology: Relict land surfaces; level plains of undissected residual clay loam containing sheet and nodular calcrete; infrequent dongas; isolated residual low calcrete rises; drainage patterns restricted to the relics of ancient river courses with infrequent drainage foci (gilgai or swamps) along their length.

Land management: Certain vegetation is preferentially grazed by herbivores and may decrease with heavy grazing pressure, particularly some species of trees and chenopods. *Alectryon oleifolius* (mingah or bullock bush), *Santalum acuminatum* (quandong) and *S. spicatum* (sandalwood) provide a valuable mineral source and are preferentially browsed during dry periods. The condition of *A. oleifolius, S. acuminatum* and *S. spicatum* groves can provide an indication of range condition and the total grazing pressure in an area. The presence of *Santalum* seedlings and unbrowsed suckers of *A. oleifolius* indicate improving range condition whilst heavy browse lines, broken limbs and uprooted trees indicate deteriorating range condition and excessive grazing pressure. Bush clumps consisting primarily of berry dispersed plants under trees and tall shrubs are a common feature in healthy myall woodlands. Deteriorating bush clumps at the base of *Acacia papyrocarpa* (myall) and other trees also indicate declining range condition. Overgrazing can be avoided by good management, including control of total grazing pressure. Intense or frequent fires can influence the floristic composition of myall woodland and in combination with grazing pressure can lead to the understorey becoming dominated by unpalatable species or altered to grassland. Total grazing pressure should be restricted from burnt areas for a period set by seasonal conditions which will determine the effectiveness of recovery.

No.	Landform	Traverse recordings	Inventory sites
1.	Residual calcrete rise	14	4
2.	Loamy plain overlain by aeolian sand	5	5
3.	Loamy plain	1008	28
4.	Drainage tract (ancient river course)	11	–
5.	Drainage focus	6	–
6.	Donga	–	–
7.	Gilgai	–	1
8.	Other	1	–
	Total	1045	38

Traverse condition summary:
(1045 assessments)

Vegetation—very good 7%, good 75%, fair 15%, poor 3%.



Nyanga land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Residual calcrete rises**—gently inclined low rises of calcrete; variable mantle of calcrete nodules, fragments and outcrop.	Calcareous shallow loams (521).	Very scattered *Casuarina pauper* (black oak) woodland over an understorey of mixed shrubs or dominated by chenopods (CXSS, CXCS). Occasionally *Acacia papyrocarpa* (myall) or *A. burkittii* (jam) are dominant (MXCW, CAOS, XAOS).
2.	5%	**Loamy plains overlain by aeolian sand**—level to very gently inclined plains variably overlain by shallow sand sheets.	Red sandy earths (463) or sandy loams (521) over calcareous loams of variable depth.	Mixed shrubland, commonly dominated by species of *Acacia*, *Dodonaea* and *Eremophila* with or without scattered *Casuarina pauper* (DEXS, ACMS, CXSS).
3.	90%	**Loamy plains**—level to very gently inclined plains, sometimes with a sparse mantle of calcrete nodules.	Mostly calcareous loamy earths (542) and minor clays (622). Deep profiles with saline subsoils.	Scattered to moderately closed *Acacia papyrocarpa* woodland over a chenopod understorey (MXCS, MPBS, MSAS, MHXS). Myall woodland may also be co-dominated with *Myoporum platycarpum* (sugarwood) (MSCW) or have a mixed shrub understorey (MXSS, MFBW). Less common is scattered *Casuarina pauper* woodland with a chenopod understorey (CXCS) or *Acacia aneura* (mulga) woodland (MUXW). Among the extensive tracts of woodland are open plains of scattered chenopod shrubland or grassland (PXCS, SWOG).
4.	1%	**Drainage tracts (ancient river courses)**—level to very gently inclined drainage tracts.	Saline calcareous clay loams (542), occasionally gypsiferous.	Scattered to moderately closed mid to low chenopod shrubland, commonly dominated by *Atriplex vesicaria* (bladder saltbush) or co-dominated with *Maireana sedifolia* (pearl bluebush) (BSSL, PXCS).
5.	1%	**Drainage foci**—irregularly shaped drainage sumps (swamps or gilgai) within flow zones (unit 4).	Deep non-saline clay loams (542).	Scattered low shrubland dominated by *Muehlenbeckia florulenta* (lignum) and grasses such as *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) (LISW, GGSL).
6.	2%	**Dongas**—rounded shallow, closed depressions, generally 2–5 m below the surrounding calcrete plain (unit 3), or within drainage tracts (unit 4), up to 0.3 km in diameter, rounded limestone boulders occasionally present in areas of upheaval due to gilgai processes.	Red/brown non-cracking clays (622) interspersed with cracking clays (600).	Very scattered to moderately closed stands of *Acacia tetragonophylla* (curara), *Eremophila longifolia* (berrigan) or *Grevillea nematophylla* with scattered *Pittosporum angustifolium* (native willow) over a moderately closed understorey of *Atriplex cryptocarpa, Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush), surrounded by very scattered *Lycium australe* (water bush). *Eragrostis* grasses are common to gilgai areas (DCGR, DBGR, DGGR).
7.	< 1%	**Gilgai**—patches (< 0.1 km wide) with irregularly distributed mounds and depressions within loamy plains (unit 3), occasional calcareous fragments of variable size brought to the surface by gilgai soil processes.	Cracking gilgai clay soils (600).	Dense patches of perennial grasses; *Austrodanthonia caespitosa* (wallaby grass), *Austrostipa scabra* (speargrass) and *Eragrostis* species surround very scattered plants such as *Lycium australe* (water bush), *Nitraria billardierei* (nitre bush) or *Pittosporum angustifolium* (GGSL).

Nyanga land system: *Loamy plain supporting myall woodland and chenopod shrubland.*

OASIS LAND SYSTEM (4180 km², 3.5% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Level stony limestone plains supporting bindii grassland with numerous small dongas.

Land zone: Nullarbor Plain.

Land type: 12

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

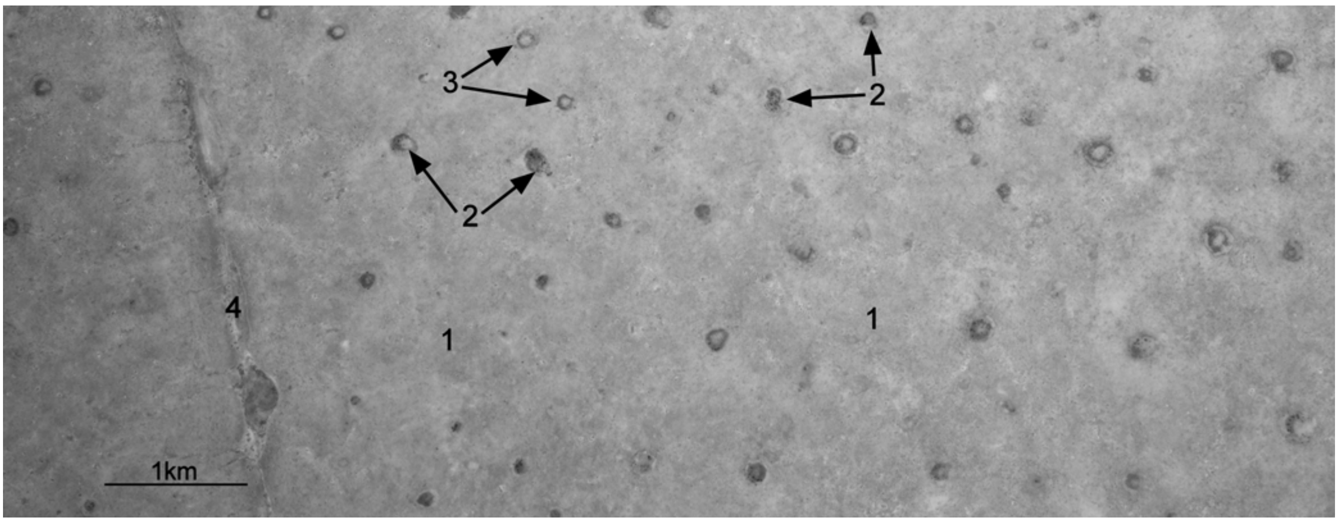
Geomorphology: Erosional surfaces; differential weathering of the deflated Nullarbor Limestone has formed numerous small, shallow circular drainage foci (dongas) along irregular north-west to south-east trending rectilinear joint patterns, gilgai micro-relief common in dongas; drainage restricted to relic ancient river courses. Dongas are believed to have formed through water ponding in depressions in the limestone plain and solution further dissolving the limestone. Dongas are considered solution dolines rather than collapsed caves.

Land management: The system occurs entirely on Unallocated Crown Land and is unmanaged. Donga habitats provide shelter to animals and plants, particularly when compared to the surrounding extensive, open stony plains. Donga vegetation communities are important to the heterogeneity of the ecosystems of the northern Nullarbor Plain. Loss of floristic diversity reduces the ability of the landscape to support associated biological communities, especially during dry periods. Fire and uncontrolled grazing by camels and rabbits are the greatest threat to this system.

Traverse condition summary: (112 assessments in 1974)

1974 vegetation ratings—very good 22%, fair 7%, poor 71%.

No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	–	–
2.	Donga	–	1 (2006)
3.	Claypan	–	–
4.	Drainage tract (ancient river course)	–	–
	Total	112 (1974)	1 (2006) / 10 (1974)



Oasis land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	90%	**Stony limestone plains**—level plains with abundant mantle of Nullarbor Limestone fragments and outcrop.	Calcareous shallow loams (521).	Open plains dominated by *Sclerolaena* species (bindiis) or *Austrostipa scabra* (speargrass) (OBIG, SWOG), occasional sparse *Maireana sedifolia* (pearl bluebush) low shrubland (PBLS).
2.	8%	**Dongas**—small circular, closed depressions, 1–2 m below the surrounding limestone plain, generally < 0.2 km in diameter; rounded Nullarbor Limestone boulders in gilgai patches in donga floor.	Red/brown non-cracking clays (622) interspersed with cracking clays (600).	Larger dongas support scattered to moderately closed *Grevillea nematophylla* groves (DGGR), smaller dongas support scattered *Acacia tetragonophylla* (curara) and *Pittosporum angustifolium* (native willow) (DCGR, DPGR); with an understorey of *Chenopodium curvispicatum* surrounded by annual herbs and grasses (ANNH). Gilgai patches dominated by *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail).
3.	2%	**Claypans**—small, circular, smooth, closed depressions, 0.15 km in diameter.	Deep clay loam soils (542).	Scattered to moderately closed grassland of *Austrodanthonia caespitosa* (wallaby grass) and *Austrostipa scabra* (SWOG) or *Atriplex vesicaria* (BSSL) shrubland.
4.	< 1%	**Drainage tracts (ancient river courses)**—level to gently inclined, sinuous, narrow (up to 0.3 km wide), drainage tracts between stony plains (unit 1), infrequent irregular large depressions up to 1 km wide and 7 km long.	Red/brown non-cracking clays (622), some deep clay loams (542).	As for unit 3 in drainage tracts. Moderately closed *Grevillea nematophylla* groves with *Pittosporum angustifolium* and *Chenopodium curvispicatum* in large depressions (DGGR).

Oasis land system: *Level stony plains of bindii grassland and small dongas supporting groves of* Grevillea nematophylla *and* Pittosporum angustifolium.

PONDANA LAND SYSTEM (1649 km², 1.4% of the survey area)

Gently undulating stony limestone plains supporting pearl bluebush shrubland with large rounded claypan depressions supporting bladder saltbush shrubland or annual herbland.

Land zone: Nullarbor Plain.

Land type: 11

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

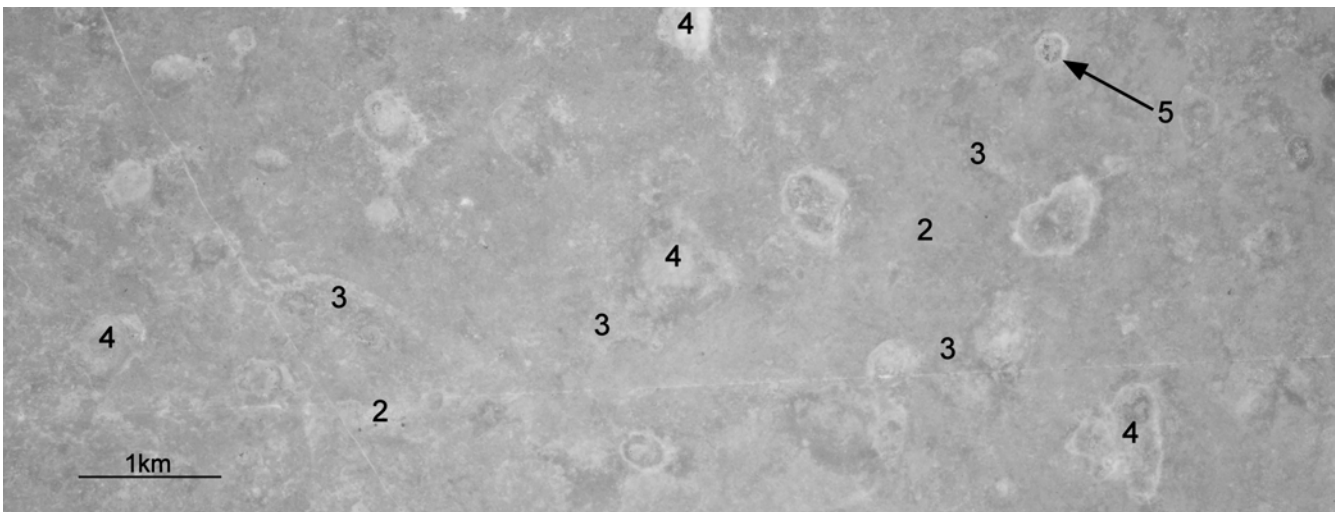
Geomorphology: Erosional surfaces; differential weathering of the deflated Nullarbor Limestone has formed large, closed depressions with level claypan floors. These units characterise this system, elsewhere the extensive limestone plain has superficially weathered to form dongas with gilgai micro-relief or drainage floors along north-south trending joint patterns; drainage restricted to relic ancient river courses.

Land management: The herbaceous species, grasses and subshrubs that occur in the claypans and drainage floors are preferentially grazed by herbivores. Such plants, particularly the subshrubs, are important sources of protein for Nullarbor production systems. Grazing of preferentially favoured areas such as claypans and dongas needs to be monitored to avoid loss of palatable species, leading to replacement by unpalatable species, or becoming susceptible to wind erosion further reducing the ability of the landscape to adequately support perennial plants species.

Traverse condition summary: (188 assessments)

Vegetation—good 47%, fair 36%, poor 16%, very poor 1%.

No.	Landform	Traverse recordings	Inventory sites
1.	Residual calcrete rise	–	–
2.	Stony limestone plain	130	–
3.	Marginal slope to drainage floor	40	1
4.	Claypan	15	4
5.	Donga	2	–
6.	Drainage tract (ancient river course)	–	1
7.	Other	1	–
	Total	188	6



Pondana land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	< 1%	**Residual calcrete rises**—gently inclined low rises of calcrete; mantle commonly composed of mixed-sized calcrete fragments.	Calcareous shallow loams (521).	Very scattered *Acacia papyrocarpa* (myall) or *Casuarina pauper* (black oak) over mixed chenopod shrubland (MXCS, CXCS).
2.	75%	**Stony limestone plains**—very gently undulating plains with extensive mantle of mixed-sized Nullarbor Limestone fragments and outcrop.	Calcareous shallow loams (521).	Very scattered to scattered low shrubland of *Maireana sedifolia* (pearl bluebush) (PBLS) or *Sclerolaena* species (bindiis) (OBIG).
3.	8%	**Marginal slope to drainage floors**—very gently inclined stony slope, with mantle of mixed limestone fragments, draining into claypans (unit 4) or, in the west of the system, into elongate depressions defined by north-south joint patterns.	Calcareous loamy earths (542).	Scattered low shrubland of *Maireana sedifolia* (PBLS), grading downwards into moderately closed *Atriplex vesicaria* (bladder saltbush) shrubland (BSSL).
4.	15%	**Claypans**—large oval, closed depressions, generally 0.5 km in diameter (occasionally up to 1 km in diameter), smooth, level surface 2–5 m below surrounding stony plains (unit 2) or at lowest position in drainage floors (unit 3).	Deep non-saline red/brown non-cracking clays (622).	Moderately closed *Atriplex vesicaria* low shrubland (BSSL) or dominated by *Sclerolaena* species (OBIG) or scattered annual herbland (ANNH) varying in composition with *Atriplex cryptocarpa*, *Austrostipa scabra* (speargrass) and *Sida spodochroma,* among a variety of annual herbaceous species, occasional isolated stands or individuals of *Eremophila longifolia* (berrigan) or *Pittosporum angustifolium* (native willow).
5.	1%	**Dongas**—circular, closed depressions, 1.5–3 m below the surrounding limestone plain, up to 0.5 km in diameter, gilgai patches common.	Deep clays (622) or gilgai cracking clay soils (600).	Very scattered stands of *Eremophila longifolia* and *Pittosporum angustifolium* with dense patches of perennial grasses; *Austrodanthonia caespitosa* (wallaby grass), *Austrostipa scabra*, *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) (DBGR).
6.	1%	**Drainage tracts (ancient river courses)**—level to gently inclined, long, narrow (< 0.1 km wide), drainage tracts between stony plains (unit 2), infrequent irregular claypans up to 1 km long in extent.	Red/brown non-cracking clays (622).	Moderately closed low shrubland of *Atriplex cryptocarpa* and *A. acutibractea* (toothed saltbush), occasional closed stands of *Eremophila longifolia* and *Acacia burkittii* (jam) (DDSS).

Pondana land system: *Claypan depression supporting annual herbland surrounded by stony limestone plain supporting bindii grassland.*

PONTON LAND SYSTEM (23 km^2, < 0.1% of the survey area)

Channels with narrow flanking alluvial plains.

Land zone: Nyanga Plain.

Land type: 15

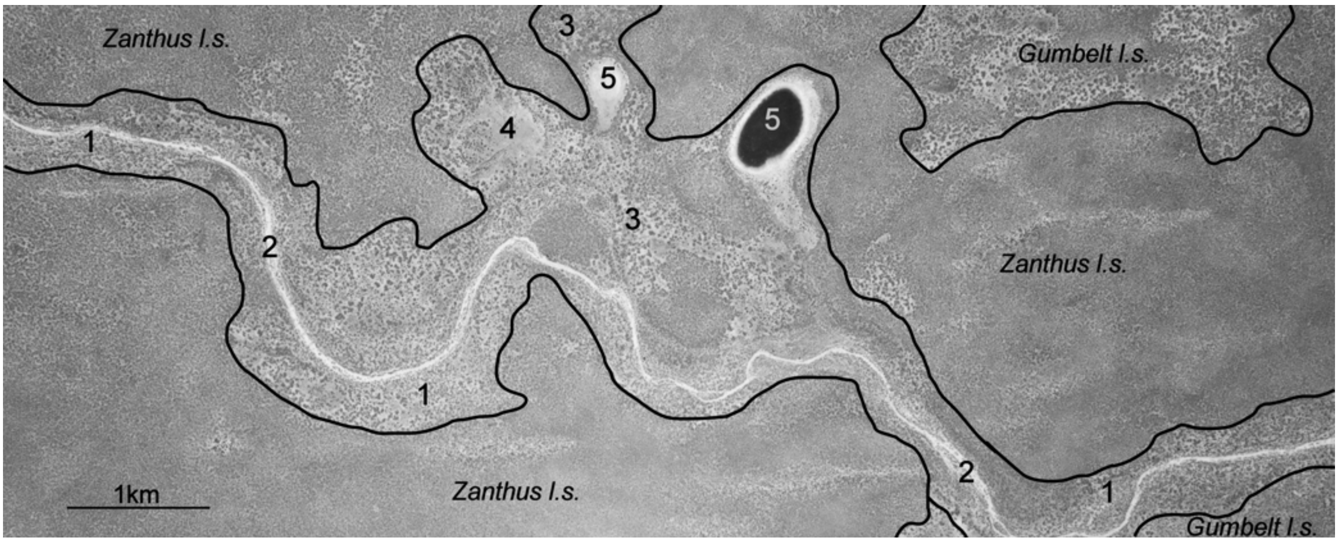
Geology: Quaternary (Pleistocene)—Recent alluvial deposits consisting of clay, silt, quartz sand, and gravel deposits.

Geomorphology: Depositional surfaces; main channel flanked by alluvial plains and sandy banks; creek bed contains sand and gravel; saline alluvial deposits at channel outlet; meandering channel, relief less than 5 m, intermittently flooded by intense rainfall events associated with infrequent cyclonic low pressure systems.

Land management: The vegetation of the system is not preferred by livestock and is generally not prone to degradation. To the west beyond the boundary of this survey the vegetation becomes more palatable with proximity to the lake systems that form the headwaters for Ponton Creek.

Traverse condition summary:
(not traversed)

No.	Landform	Traverse recordings	Inventory sites
1.	Sandy bank	–	–
2.	Creek bed	–	–
3.	Saline plain	–	–
4.	Drainage focus	–	–
5.	Saline claypan	–	–
	Total	–	–



Ponton land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	80%	**Sandy banks**—gently to moderately inclined slopes bordering creek bed (unit 2).	Sandy loams (521), red deep sands (445) or red sandy earths (463).	Fringing vegetation communities of scattered to closed woodland consisting of *Eucalyptus concinna* (Victoria desert mallee), *E. gracilis* (yorrell), *E. oleosa* subsp. *oleosa* (giant mallee) and *Casuarina pauper* (black oak) over mixed scrub (EXSW) or tall shrubland with a variable composition of halophytic and non-halophytic shrubs (SBLS).
2.	15%	**Creek bed**—main channel up to 60 m wide, incised to up to 5 m below unit 1.	River beds of sands, gravels and bedloads of cobbles (703).	Unvegetated to sparsely vegetated with variable shrubs, rushes and grasses.
3.	4%	**Saline plains**—level, highly saline lower plains often adjacent to lake bed.	Red/brown non-calcareous clays with calcareous gravels or gypsum-saline clays (622).	Scattered to moderately closed low halophytic shrubland dominated by *Tecticornia* spp. (samphires) (SAMP) or co-dominated with *Atriplex* species (saltbushes) and *Maireana* species (bluebushes) (PXHS), very scattered *Casuarina pauper*.
4.	1%	**Drainage foci**—claypans and drainage foci.	Shallow clay (622) or shallow red sand and gypsiferous deposits (102) in pockets.	Halophytic low shrubland in drainage lines (PXHS, SAMP). Drainage foci with variable halophytic and non-halophytic communities.
5.	< 1%	**Saline claypans**—bare circular depressions.	Highly saline gypsiferous sediments (102).	Unvegetated.

Ponton land system: *Ponton Creek main channel.*

RABBIT LAND SYSTEM (350 km², 0.3% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Level loamy calcrete plains dominated by bindii grassland.

Land zone: Nyanga Plain.

Land type: 4

Geology: Quaternary residual clay loam overlying Quaternary (Pleistocene)—Neogene (Pliocene) calcrete over Miocene Nullarbor Limestone.

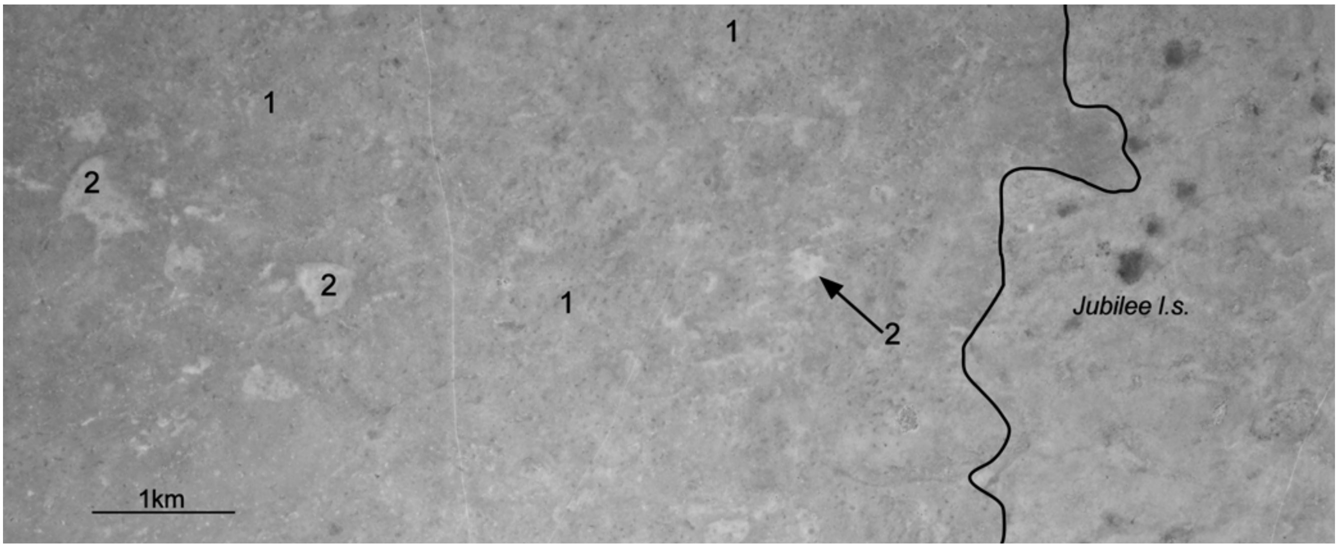
Geomorphology: Relict land surfaces; level plains of residual clay loam containing sheet and nodular calcrete; infrequent small, shallow claypans; no organised drainage pattern.

Land management: Loamy plains (unit 1) occupy 95% of the system. Evidence of shrub stumps and roots in remnant shrub mounds suggests that the plains once supported chenopod shrubland but is now irreversibly altered to seasonally dependent bindii grassland. Rabbit warrens are common and the system is highly susceptible to fire. The system occurs entirely on Unallocated Crown Land and is unmanaged. If the system were to be managed to limit the extent of fire and protect the remaining isolated perennial shrubs and adjacent systems' woodland then fire breaks and tracks would prove worthwhile.

Traverse condition summary:
(19 assessments in 1974)

1974 Vegetation—poor 100%.

No.	Landform	Traverse recordings	Inventory sites
1.	Loamy plain	–	–
2.	Drainage focus	–	–
	Total	19 (1974)	3 (1974)



Rabbit land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	95%	**Loamy plains**—level to very gently undulating plains; generally a sparse mantle of calcrete nodules, though sometimes abundant.	Calcareous loamy earths of variable depth (521, 542). Non-saline at surface but saline at depth.	Scattered to moderately closed bindii grassland commonly supporting *Sclerolaena patenticuspis*, *S. obliquicuspis, Sida spodochroma, Austrodanthonia caespitosa* (wallaby grass) and *Austrostipa scabra* (speargrass) (OBIG). Perennial shrubs such as *Maireana sedifolia* (pearl bluebush) exist as isolated individuals or small clumps.
2.	5%	**Drainage foci**—small, shallow claypans up to 0.5 km in extent.	Deep clay loams (542).	Scattered to moderately closed *Austrostipa scabra* and *Austrodanthonia caespitosa* grassland (SWOG).

Rabbit land system: *Clay loam and calcrete plain supporting bindii grassland.*

REID LAND SYSTEM (3998 km², 3.4% of the survey area)

(modified and incorporating the land system formerly known as Deakin from Mitchell, McCarthy and Hacker 1979)

Level to very gently undulating stony limestone plains supporting pearl bluebush shrubland along low ridges and bladder saltbush shrubland in narrow, parallel drainage floors defined by north-west to south-east trending joint patterns.

Land zone: Nullarbor Plain.

Land type: 11

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

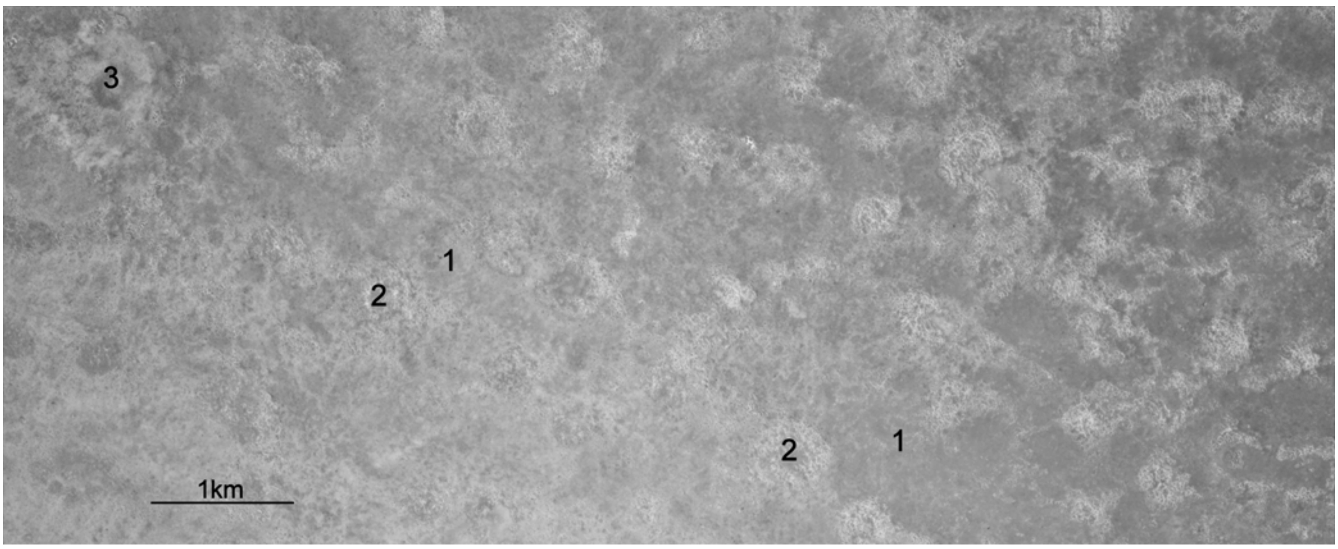
Geomorphology: Erosional surfaces; differential weathering of the deflated Nullarbor Limestone along predominantly north-west to south-east trending joint patterns has formed linked, circular drainage foci along narrow drainage floors extending for up to 5 km, separated by very gently undulating, low stony ridges; drainage floors form open depressions with colluvial infill; infrequent, large (up to 1 km in extent), irregular shaped claypans in drainage foci; dongas occasionally present in the northern areas as the land system transitions into the Oasis land system.

Land management: Most of this system occurs outside pastoral leases and is dominated by chenopod vegetation. Rainfall and seasonal conditions determine species composition and abundance. The best indication of drying conditions is provided by seasonally dependent subshrubs that begin to decline with dry seasonal conditions.

Traverse condition summary: (38 assessments)

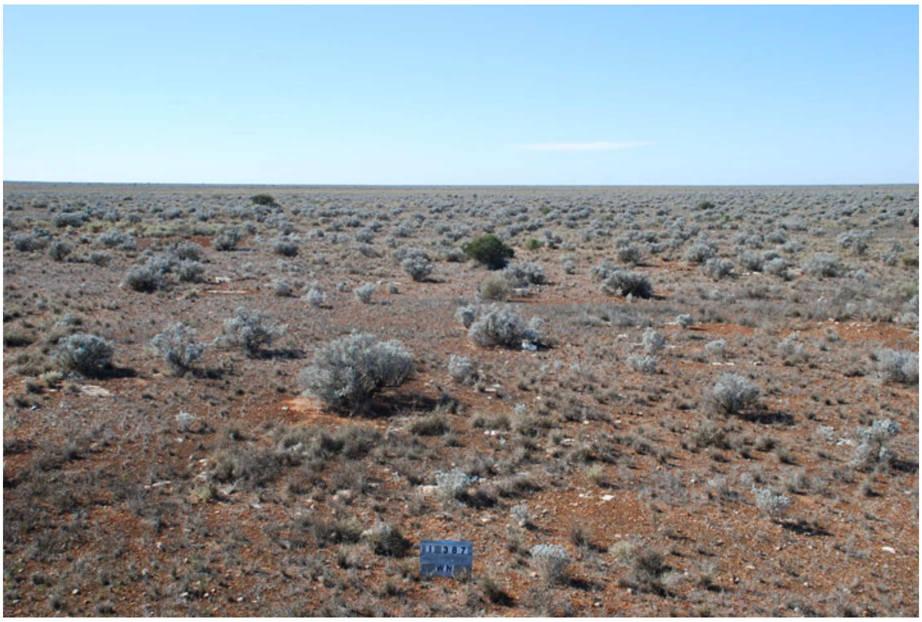
Vegetation—very good 37%, good 47%, fair 8%, poor 8%.

No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	19	1
2.	Marginal slope to drainage floor	1	–
3.	Claypan	18	–
4.	Donga	–	–
	Total	38 (2006) / 80 (1974)	1 (2006) / 10 (1974)



Reid land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	40%	**Stony limestone plains**—very gently undulating plains with abundant mantle of mixed-sized Nullarbor Limestone fragments and outcrop.	Calcareous shallow loams (521).	Very scattered to scattered low shrubland of *Maireana sedifolia* (pearl bluebush) (PBLS), less commonly *Austrostipa scabra* (speargrass) and *Austrodanthonia caespitosa* (wallaby grass) grassland (SWOG) or co-dominated with *Sclerolaena* species (OBIG).
2.	50%	**Marginal slope to drainage floors**—level to very gently inclined slopes, with a sparse mantle of mixed limestone fragments, draining to circular drainage foci, linked along narrow (< 0.5 km wide), open depressions (< 5 km long) defined by north-west to south-east trending joint patterns.	Calcareous loamy earths (542).	Scattered to moderately closed mixed chenopod low shrubland (PXCS) becoming dominated by *Atriplex vesicaria* (bladder saltbush) (BSSL), occasionally co-dominant with *Tecticornia* spp. (samphires) (PXHS) or *Austrostipa scabra* and *Austrodanthonia caespitosa* grassland (SWOG).
3.	10%	**Claypans**—large irregular, closed depressions, up to 1 km in diameter, smooth, level surface occurring within drainage floors (unit 2).	Red/brown non-cracking clays (622).	Very scattered to moderately closed *Atriplex vesicaria* low shrubland (BSSL) or annual herbland (ANNH), occasionally unvegetated.
4.	< 1%	**Dongas**—small circular, closed depressions, 1–2 m below the surrounding limestone plain, generally < 0.2 km in diameter; rounded Nullarbor Limestone boulders in gilgai patches in donga floor.	Red/brown non-cracking clays (622) interspersed with cracking clays (600).	Scattered groves of *Grevillea nematophylla* and *Pittosporum angustifolium* (native willow) (DGGR, DPGR); with *Acacia tetragonophylla* (curara) and an understorey of *Chenopodium curvispicatum* surrounded by annual herbs and grasses (ANNH). Gilgai patches dominated by *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail).



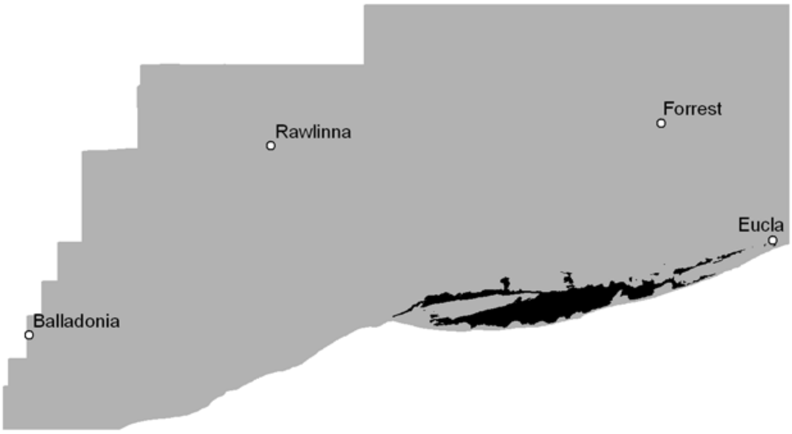
Reid land system: *Stony limestone plain supporting very scattered pearl bluebush low shrubland.*

ROE LAND SYSTEM (2853 km², 2.4% of the survey area)

Calcarenite coastal plain supporting eucalyptus and melaleuca woodland.

Land zone: Roe Plains.

Land type: 13



Geology: Quaternary colluvium, residual sandy clay loam or clay loam containing sheet or nodular calcrete over Neogene (Late Pliocene) Roe Calcarenite. Roe Calcarenite overlies Cainozoic (Late Oligocene—Early Miocene) Abrakurrie Limestone in the western and central parts and (Eocene) Wilson Bluff Limestone in the eastern part of the Roe Plains.

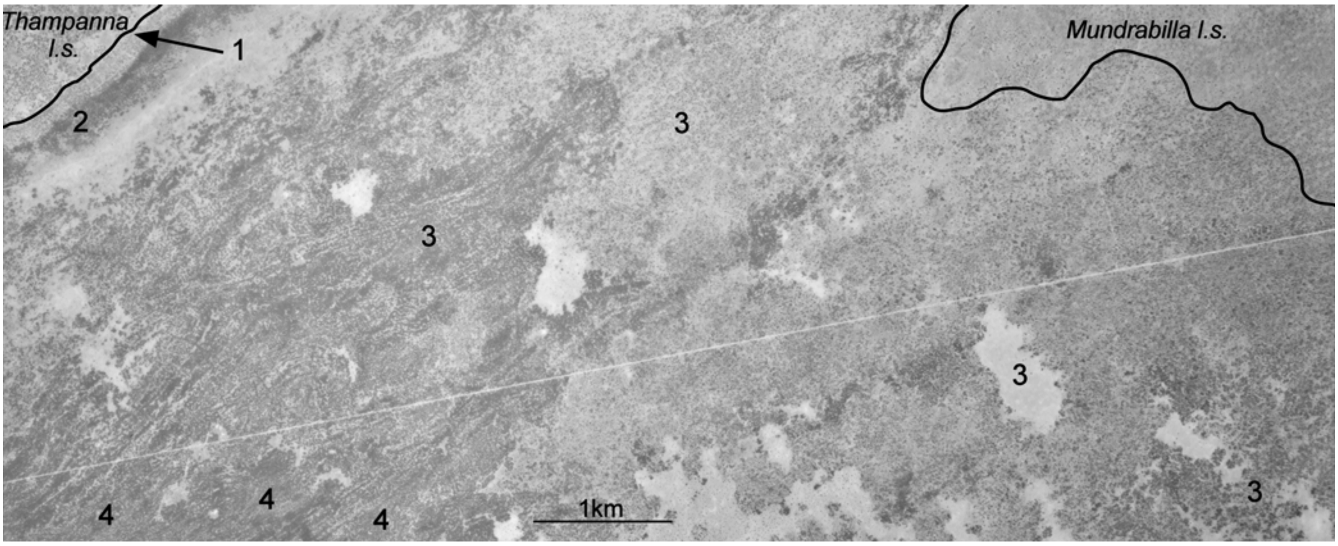
Geomorphology: Depositional land surfaces; coastal plain with some sections of landward margin backed by marine-eroded scarp with colluvium forming footslope at base; level calcarenite plain covered by shallow in situ clay loam, with superficial sands, containing calcrete nodules, low rises parallel with the scarp composed of residual sandy clay and calcrete altered from aeolian limestone.

Land management: The steep slope of the Hampton Scarp makes these areas highly susceptible to erosion. Bunds and water-lets should be constructed on scarp tracks to reduce the volume and erosive potential of water flow. Heavy grazing can cause a reduction in palatable flora, particularly following a fire. Overgrazing can be avoided by appropriate land management.

Traverse condition summary:
(64 assessments)

Vegetation—very good 48%, good 47%, fair 3%, poor 2%.

No.	Landform	Traverse recordings	Inventory sites
1.	Scarp	–	–
2.	Footslope	–	1
3.	Calcarenite loamy plain	64	18
4.	Low rise	–	1
	Total	64	20



Roe land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Scarp**—marine-eroded scarp to 90 m. Steep slopes with abundant Abrakurrie, Mullamullang and Nullarbor Limestone outcrop and scree.	Shallow calcareous shallow loams (521).	Scattered to moderately closed woodland of variable *Eucalyptus* species including: *E. diversifolia* (soap mallee), *E. gracilis* (yorrell), *E. oleosa* subsp. *oleosa* (giant mallee) and *Melaleuca lanceolata* with mid to low shrubland of *Atriplex* species (saltbushes), *Maireana* species (bluebushes) and *Olearia calcarea* (EXSW or EMCW) amidst stony outcrop.
2.	4%	**Footslopes**—moderately inclined slopes formed by colluvium (< 1 km wide) below scarp face (unit 1), merging into level plain (unit 3 or Mundrabilla land system). Limestone fragments can cover much of the surface and outcrop is common.	Calcareous shallow loams (521) grading to deep calcareous loamy earths (542) toward unit 3.	Moderately closed woodland of *Eucalyptus brachycalyx*, *Melaleuca lanceolata, M. quadrifaria* and *Myoporum platycarpum* (sugarwood) over mixed shrubland dominated by *Cratystylis conocephala* (false bluebush), *Nitraria billardierei* (nitre bush), *Atriplex vesicaria* (bladder saltbush) and *Zygophyllum* sp. (EMEW or EMCW).
3.	90%	**Calcarenite loamy plains**—level plains with sheet and nodular calcrete at variable depth.	Calcareous shallow loams (521) or brownish calcareous loamy earths (542) commonly overlain by organic matter and leaf litter.	Scattered to moderately closed woodland of *Eucalyptus brachycalyx*, *E. gracilis*, *E. oleosa* subsp. *oleosa*, *Melaleuca lanceolata* and *M. quadrifaria* over mixed shrubland featuring *Geijera linearifolia* (oilbush), *Cratystylis conocephala*, *Eremophila decipiens, E. deserti*, *Atriplex vesicaria* and *Olearia calcarea* (EMEW or EMCW). *Acacia papyrocarpa* (myall) may feature commonly at the system's landward margins (MFBW).
4.	5%	**Low rises**—gently inclined slopes of residual sandy clay with a shallow horizon of sheet and nodular calcrete.	Calcareous loamy earths (542).	Scattered to moderately closed woodland or tall scrubland dominated by various mallee-form *Eucalyptus* and *Melaleuca* species with a variable shrub understorey (EMEW, EMCW or EXSW).

***Roe land system**: Loamy plains below Hampton range supporting eucalypt and melaleuca woodland over bladder saltbush and false bluebush.*

SEEMORE LAND SYSTEM (415 km^2, 0.4% of the survey area)

Level stony plains supporting pearl bluebush shrubland with sparse myall and black oak.

Land zone: Nullarbor Plain.

Land type: 10

Geology: Miocene Nullarbor Limestone partially overlain by deflated Quaternary residual loam and occasional Quaternary (Pleistocene)—Neogene (Pliocene) calcrete.

Geomorphology: Erosional surfaces; level plains of partially deflated residual loam exposing Nullarbor Limestone, differential weathering of the surface has formed small dongas and gilgai; no organised drainage.

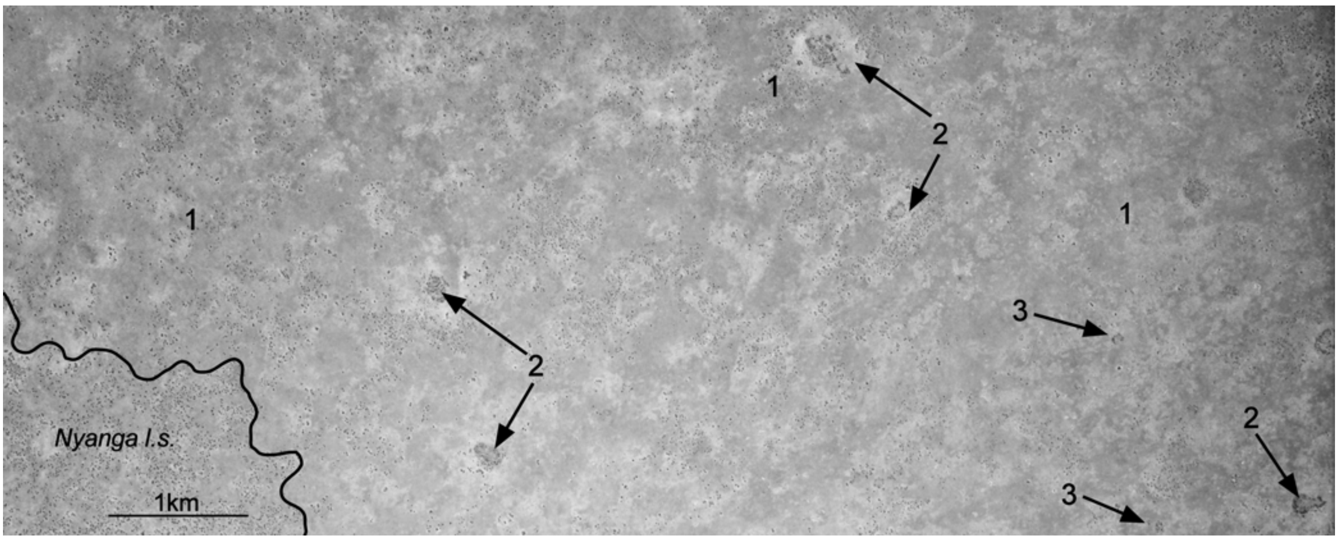
This system is intermediate in form between the intact residual loamy calcrete plains of the Nyanga land system, the recrystallised limestone plains of the Kanandah land system and the deflated stony limestone plains of the Kinclaven land system.

Land management: The vegetation contains intact chenopod shrubland that is prone to preferential grazing by introduced and native animals. Rabbits are common and the piosphere effect around warrens is a regular feature. Camels also frequent this system and their browsing impact is recognisable by browse lines in the tree species. Control of total grazing pressure will assist in preserving the vegetation that forms a transitional zone between different forms of calcareous geology.

Traverse condition summary:
(15 assessments)

Vegetation—good 60%, fair 40%.

No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	13	2
2.	Donga	2	–
3.	Drainage focus	–	–
	Total	15	2



Seemore land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	90%	**Stony limestone plains**—level plains, variable stony mantle of calcareous fragments and Nullarbor Limestone outcrop.	Calcareous loams to various depths (542, 521).	Scattered *Acacia papyrocarpa* (myall) woodland with stands of *Casuarina pauper* (black oak) amongst very scattered to scattered low shrubland dominated by *Maireana sedifolia* (pearl bluebush) (MPBS, PBLS).
2.	5%	**Dongas**—shallow closed depressions, generally 1.5–3 m below the surrounding stony plain (unit 1), up to 0.2 km in diameter.	Deep clays (622) or gilgai clay soils (600).	Very scattered to moderately closed stands of *Grevillea nematophylla* with *Pittosporum angustifolium* (native willow) and *Acacia tetragonophylla* (curara) over *Chenopodium curvispicatum* and *Enchylaena tomentosa* (ruby saltbush); grasses *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) common in gilgai areas (DGGR).
3.	5%	**Drainage foci**—irregularly shaped drainage sumps (gilgai), (< 50 m wide), irregular surfaces.	Non-saline cracking gilgai clay soils (600).	Dense patches of perennial grasses: *Austrodanthonia caespitosa* (wallaby grass), *Austrostipa scabra* (speargrass), *Eragrostis dielsii* and *E. setifolia* with very scattered *Pittosporum angustifolium*, *Acacia oswaldii*, *A. tetragonophylla, Chenopodium curvispicatum* and *Lycium australe* (water bush) (GGSL).

Seemore land system:
Piosphere effect around a rabbit warren in pearl bluebush shrubland.

SHAKEHOLE LAND SYSTEM (4045 km², 3.4% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Gently undulating stony limestone plains supporting pearl bluebush shrubland with sparse myall on rises and a mosaic of grassland and bladder saltbush shrubland in drainage floors along regular joint patterns trending north-east to south-west.

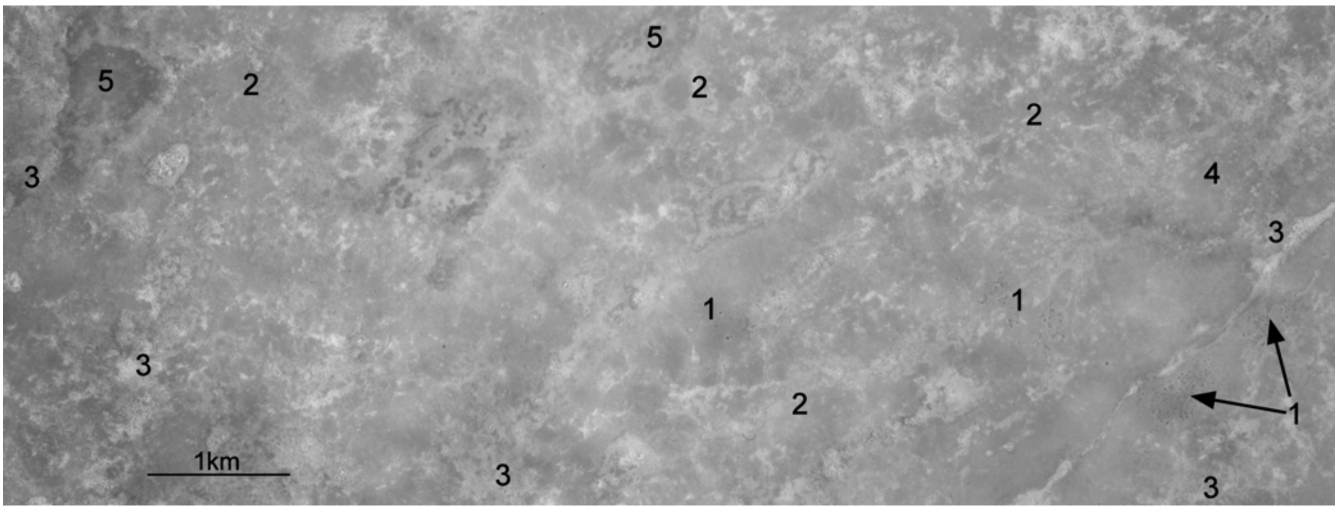
Land zone: Nullarbor Plain.

Land type: 10

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

Geomorphology: Erosional surfaces; differential weathering of the deflated Nullarbor Limestone along north-east to south-west trending joint patterns has formed long, open depressions separated by gently undulating low stony rises (irregular limestone hummocks) and ridges; colluvial infilling of these joint controlled depressions has formed a series of narrow drainage floors, up to 10 km long; large drainage foci within drainage floors consist of closed, round claypans < 1 km in diameter or open, irregular clay plains up to 3 km in extent.

Land management: The long open depressions forming the drainage floors make this system particularly susceptible to fire, particularly where the mosaic of chenopod shrubland and grassland has become dominated by grassland. With suitable winds fire can run the entire length of drainage floors, in places burning up and over through the scattered myall woodlands on the rises adjacent to the drainage floors. In such instances fire sensitive flora such as *Atriplex vesicaria* (bladder saltbush) and *Acacia papyrocarpa* (myall) can be eliminated. With continuous grazing pressure the vegetation can become reduced to seasonally dependent grassland, losing its ability to support herbivores during dry periods. Overgrazing can be avoided by good land management. Total grazing pressure should be restricted from burnt areas for a period set by seasonal conditions which will determine the effectiveness of recovery. The chenopod vegetation that dominates this system is important to sustaining herbivores through dry periods. Vegetation condition should determine stocking rates, with the decline of seasonally dependent subshrubs indicating the onset of dry conditions.



Traverse condition summary:
(355 assessments)

Vegetation—very good 5%, good 55%, fair 26%, poor 11%, very poor 3%.

No.	Landform	Traverse recordings	Inventory sites
1.	Limestone hummock (low rise)	2	2
2.	Stony limestone plain	187	2
3.	Marginal slope to drainage floor	152	5
4.	Clay plain	13	1
5.	Claypan	1	1
	Total	355 (2006) / 50 (1974)	11 (2006) / 3 (1974)

Shakehole land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	5%	**Limestone hummocks (low rises)**—gently undulating low ridges and rises (up to 3 m relief); stony mantle of mixed-sized limestone fragments and outcrop common to abundant.	Skeletal calcareous shallow loamy earths (521).	Very scattered *Acacia papyrocarpa* (myall) over an understorey dominated by *Maireana sedifolia* (pearl bluebush) (MPBS) or *Austrostipa scabra* (speargrass) grassland (MSOG).
2.	50%	**Stony limestone plains**—gently undulating plains with common to abundant mantle of mixed-sized Nullarbor Limestone fragments and outcrop.	Calcareous shallow loams (521).	Very scattered to scattered low shrubland of *Maireana sedifolia* (PBLS) or *Sclerolaena* species (bindiis) (OBIG). Very infrequently isolated groves of *Eucalyptus yalatensis* (yalata mallee) occur over mixed low chenopod shrubland.
3.	35%	**Marginal slope to drainage floors**—gently inclined slopes, with a sparse mantle of mixed limestone fragments, bordering < 10 km long, narrow (0.2 km wide), level, open depressions defined by joint patterns trending north-east to south-west.	Calcareous loamy earths (542), occasionally saline.	Slopes support scattered to moderately closed shrubland co-dominated by *Maireana sedifolia*, *Atriplex nummularia* (old man saltbush) and *A. vesicaria* (bladder saltbush) (PXCS), or bindii grassland co-dominated by *Austrostipa scabra*, *Austrodanthonia caespitosa* (wallaby grass) and *Sclerolaena* species (OBIG). Level drainage floors support a mosaic of moderately closed *Atriplex vesicaria* shrubland (BSSL), *Tecticornia* spp. (samphires) (PXHS) and/or grassland (SWOG).
4.	5%	**Clay plains**—large, irregular, open depressions, up to 3 km in extent, level surface occurring within lowest-lying areas of drainage floors (unit 3).	Red/brown non-cracking clays (622).	Very scattered to moderately closed *Atriplex vesicaria* low shrubland (BSSL) or *Austrostipa scabra* and *Austrodanthonia caespitosa* grassland (SWOG), occasionally unvegetated.
5.	5%	**Claypans**—large round, closed depressions, < 1 km in diameter, smooth, level surface occurring within drainage floors (unit 3).	Red/brown non-cracking clays (622).	As for unit 4.

***Shakehole land system:** Limestone hummock supporting very scattered myall woodland over pearl bluebush low shrubland. Low-lying area in background shows a drainage floor supporting bladder saltbush.*

SKINK LAND SYSTEM (4000 km², 3.4% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Level to very gently undulating stony limestone plains supporting pearl bluebush shrubland on broad low ridges and bladder saltbush shrubland in narrow drainage floors defined by north-east to south-west trending joint patterns.

Land zone: Nullarbor Plain.

Land type: 11

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

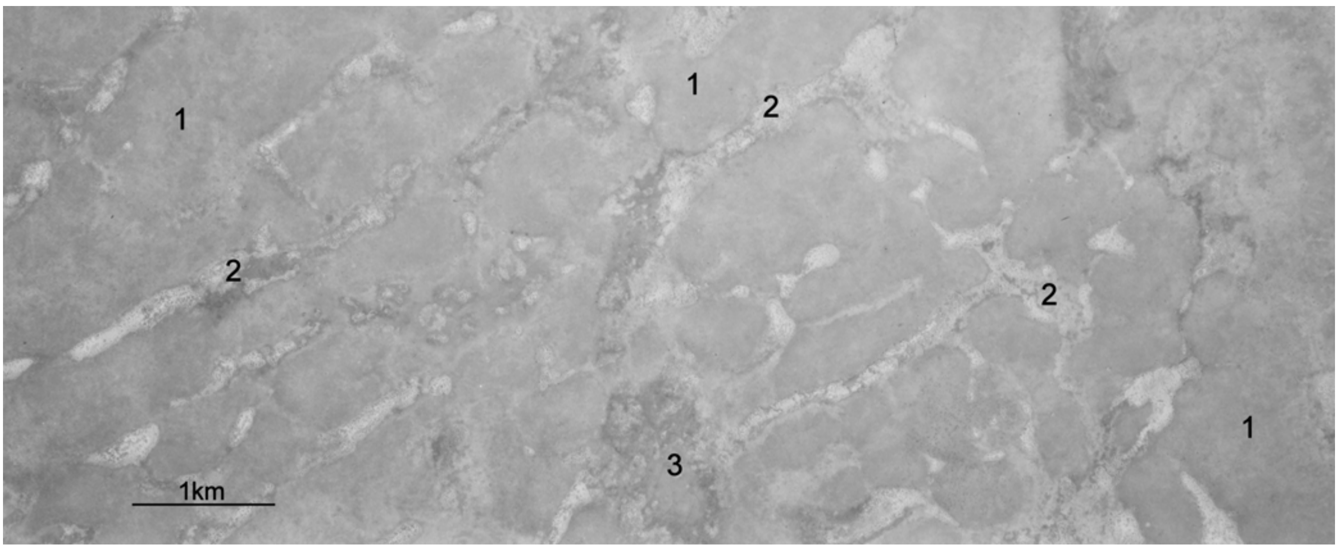
Geomorphology: Erosional surfaces; differential weathering of the deflated Nullarbor Limestone along predominantly north-east to south-west trending joint patterns has formed long, narrow drainage floors, generally up to 10 km long occasionally longer, separated by very gently undulating broad, stony low rises and ridges; drainage floors form open depressions with colluvial infill; large oval claypans in drainage foci, < 1 km in extent; dongas are occasionally found in the northern areas.

Land management: The majority of this system occurs outside pastoral leases and is dominated by chenopod vegetation. This is susceptible to overgrazing, particularly during dry periods. Rainfall and season conditions influence species composition and abundance. Vegetation condition should determine stocking rates.

Traverse condition summary: (85 assessments)

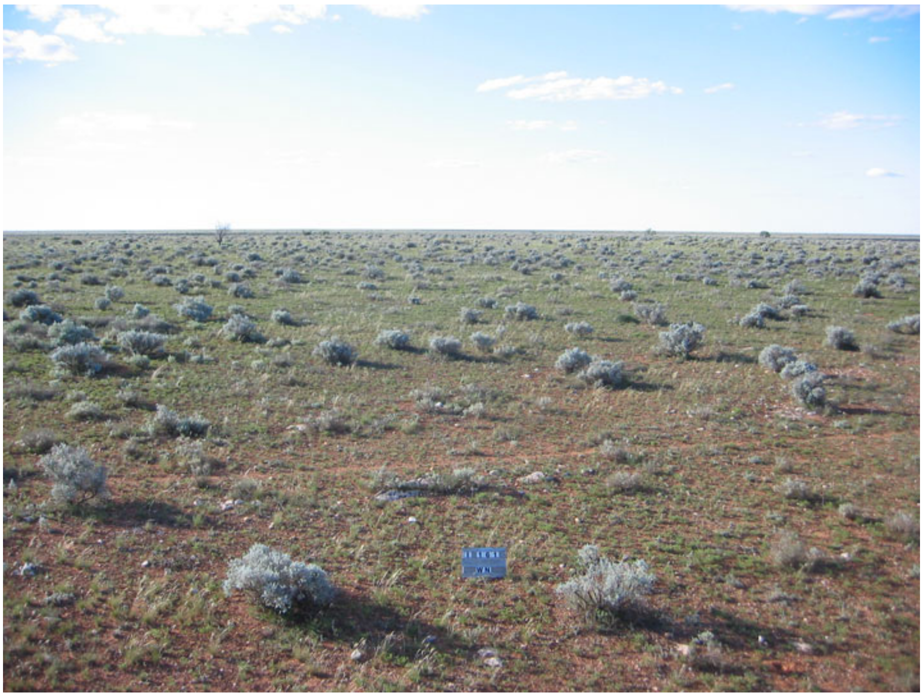
Vegetation—very good 19%, good 60%, fair 19%, poor 2%.

No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	56	1 (2006)
2.	Marginal slope to drainage floor	15	–
3.	Claypan	14	1 (2006)
4.	Donga	–	–
	Total	85 (2006) / 147 (1974)	2 (2006) / 9 (1974)



Skink land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	60%	**Stony limestone plains**—very gently undulating plains with abundant mantle of mixed-sized Nullarbor Limestone fragments and outcrop.	Calcareous shallow loams (521).	Very scattered to scattered low shrubland of *Maireana sedifolia* (pearl bluebush) (PBLS) or *Sclerolaena* species (bindiis) (OBIG).
2.	30%	**Marginal slope to drainage floors**—level to very gently inclined slopes, with a sparse mantle of mixed limestone fragments, draining to long, narrow, open depressions defined by north-east to south-west trending joint patterns, generally < 10 km long but occasionally longer.	Calcareous loamy earths (542).	Scattered low shrubland of *Maireana sedifolia* (PBLS), grading downwards into moderately closed *Atriplex vesicaria* (bladder saltbush) shrubland (BSSL), or occasionally *Austrostipa scabra* (speargrass) (SWOG).
3.	10%	**Claypans**—large round to oval, closed depressions, up to 0.9 km in diameter, smooth, level surface occurring within drainage floors (unit 2).	Red/brown non-cracking clays (622).	Very scattered to moderately closed low shrubland dominated by *Atriplex vesicaria* (BSSL) or *Austrostipa scabra* and *Austrodanthonia caespitosa* (wallaby grass) grassland (SWOG), occasionally unvegetated.
4.	< 1%	**Dongas**—circular, closed depressions, 1–3 m below the surrounding limestone plain, generally < 1 km in extent; infrequent rounded Nullarbor Limestone fragments occur at surface in gilgai patches.	Red/brown non-cracking clays (622) interspersed with cracking gilgai clays (600).	Very scattered to scattered *Pittosporum angustifolium* (native willow) groves with *Acacia tetragonophylla* (curara) and *Chenopodium curvispicatum*. Gilgai patches dominated by *Eragrostis dielsii* (red grass) and *E. setifolia* (neverfail) (DPGR).



Skink land system: *Stony limestone plain supporting very scattered pearl bluebush low shrubland.*

THAMPANNA LAND SYSTEM (5284 km², 4.5% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Undulating ridges supporting eucalypt and myall low open woodland separated by joint controlled drainage floors supporting a mosaic of chenopod shrubland and grassland.

Land zone: Hampton Tableland.

Land type: 7

Geology: Miocene Abrakurrie, Mullamullang Member and Nullarbor Limestone and Quaternary colluvium.

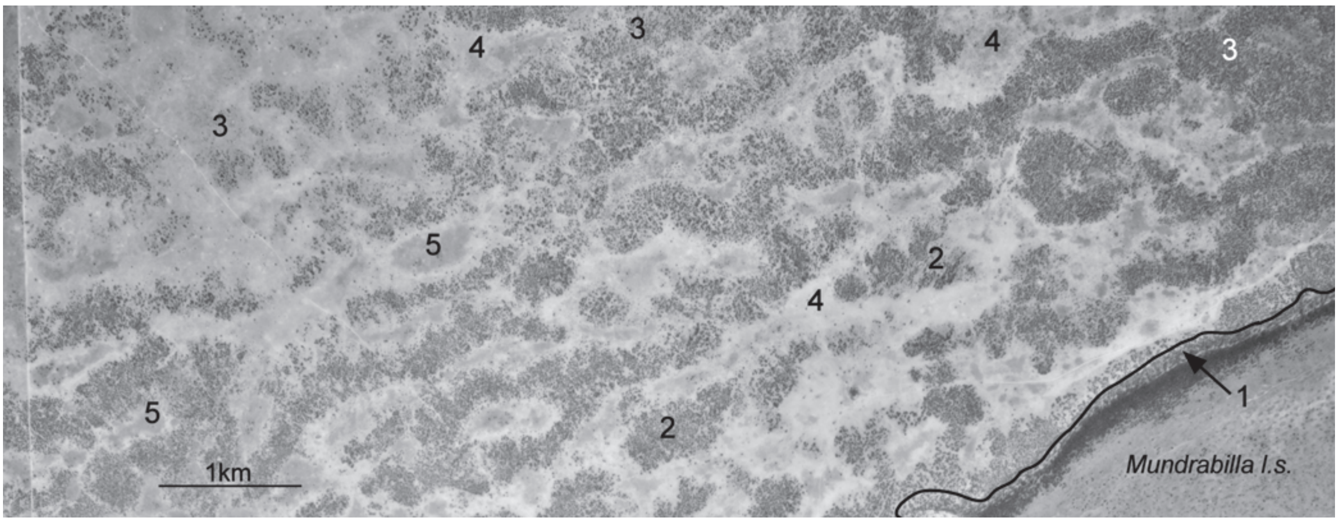
Geomorphology: Erosional surfaces; undulating low stony rises (irregular limestone hummocks) and ridges separated by irregularly shaped open depressions formed through differential weathering of limestones along predominantly north-east to south-west trending joint patterns, ridges show more relief in the south (7 m) than in the north (3 m); colluvial infilling along joints has formed drainage floors along depressions, up to 4 km long and 0.5 km wide; marine-eroded scarp forms southern edge of Bunda Plateau.

Land management: Drainage floors once supported a mosaic of grassland and shrubland but many are now significantly fragmented and altered to predominantly grassland through the combined effects of rabbits, stock and fire. This has increased the fire susceptibility of these areas. Though the adjacent woodland does not support an abundance of grasses, the marginal slopes to drainage floors and the system's northern margin are vulnerable to fire as grasses encroach into the system threatening the integrity of the woodland leading to further fragmentation. In areas affected by fire total grazing pressure should be restricted for a period set by seasonal conditions which will determine the effectiveness of recovery. Continuous grazing pressure immediately after fire and/or through extended dry periods can reduce the vegetation communities of this system to seasonally dependent grassland among unpalatable shrubs and trees, diminishing the landscape's ability to support herbivores during dry periods.

Traverse condition summary: (723 assessments)

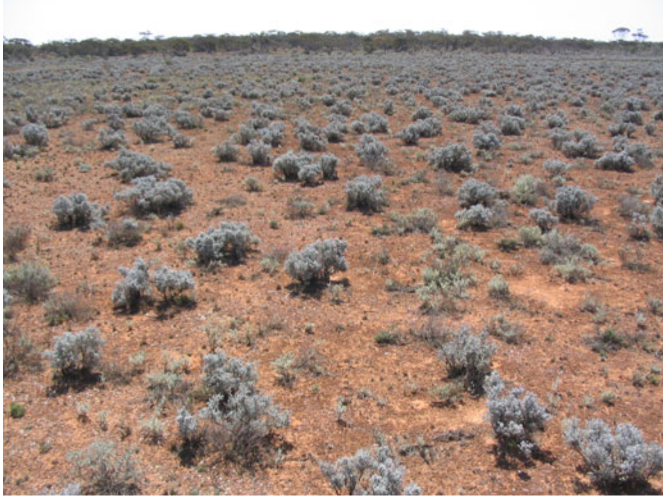
Vegetation—very good 3%, good 46%, fair 31%, poor 17%, very poor 3%.

No.	Landform	Traverse recordings	Inventory sites
1.	Scarp	2	2
2.	Limestone hummock (low rise)	105	10
3.	Stony limestone plain	204	2
4.	Marginal slope to drainage floor	410	18
5.	Claypan	2	4
	Total	723 (2006) / 99 (1974)	36 (2006) / 12 (1974)



Thampanna land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Scarp**—marine-eroded scarp. Steep slopes or vertical faces with abundant stony fragments and outcrop of Abrakurrie and Mullamullang or, less commonly, Nullarbor Limestone.	Shallow calcareous aeolian sands (421) and some calcareous shallow loams (521).	Moderately closed patches of woodland of *Eucalyptus gracilis* (yorrell), *E. yalatensis* (yalata mallee) and *Melaleuca lanceolata* with variable mid to low shrubland of *Atriplex nummularia* (old man saltbush) and *Westringia rigida* (EXSW) amidst stony outcrop.
2.	20%	**Limestone hummocks (low rises)**—undulating ridges and rises (up to 7 m relief); stony mantle of mixed-sized limestone fragments and outcrop common to abundant.	Skeletal calcareous shallow loams (521).	Scattered to moderately closed woodland of *Eucalyptus gracilis* and *E. yalatensis* with a variable mid to low shrub understorey (ESAW, EXSW), *Melaleuca lanceolata* is common in the tall shrub stratum in the south of the system, near the scarp (EMCW). In the north *Acacia papyrocarpa* (myall) replaces the eucalypts as the dominant tree over an understorey of *Atriplex nummularia* and *A. vesicaria* (bladder saltbush) (MSAS) or *Austrostipa scabra* (speargrass) (MSOG).
3.	29%	**Stony limestone plains**—gently undulating plains commonly with a mantle of mixed-sized limestone fragments and outcrop.	Calcareous shallow loams (521).	Very scattered to scattered low shrubland of *Maireana sedifolia* (pearl bluebush) (PBLS), occasionally with *Acacia papyrocarpa* and *Atriplex nummularia* and *A. vesicaria* (MXCS).
4.	45%	**Marginal slope to drainage floors**—level to gently inclined slopes, with a sparse mantle of mixed limestone fragments, draining to open irregular depressions, up to 4 km long and 0.5 km wide, defined by joint patterns trending predominantly north-east to south-west.	Saline calcareous loamy earths (542).	Scattered mixed chenopod shrubland of *Maireana sedifolia, Atriplex nummularia* and *A. vesicaria* (PXCS), occasionally with dense stands of *Myoporum platycarpum* (sugarwood) (SWCS), grading downwards into moderately closed *Atriplex vesicaria* shrubland (BSSL) or *Austrostipa scabra* and *Austrodanthonia caespitosa* (wallaby grass) grassland (SWOG); saline patches support *Tecticornia* spp. (samphires) amongst chenopods (PXHS).
5.	5%	**Claypans**—oval to irregular closed depressions, 0.5 km in extent, smooth surface occurring as level sumps between units 2 and 3.	Red/brown non-cracking clays (622).	Very scattered to moderately closed *Atriplex vesicaria* low shrubland (BSSL) or *Austrostipa scabra* and *Austrodanthonia caespitosa* grassland (SWOG) or unvegetated.



Thampanna land system: *Drainage floor supporting pearl bluebush and bladder saltbush low shrubland. In the background a low limestone hummock supports eucalypt woodland.*

TOOLINNA LAND SYSTEM (1879 km^2, 1.6% of the survey area)

Undulating stony limestone plain supporting low mallee woodland grading seaward into coastal heath and scrub along clifftops.

Land zone: Hampton Tableland.

Land type: 8

Geology: Upper Eocene Toolinna Limestone in the west and Miocene Abrakurrie Limestone in the east.

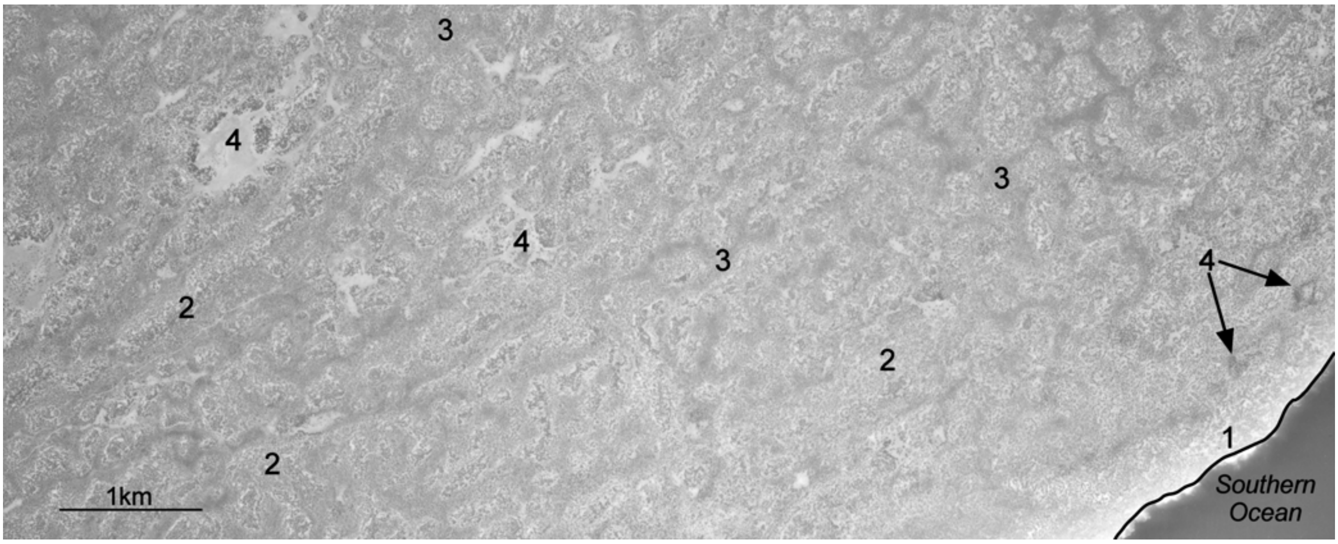
Geomorphology: Erosional surfaces; differential weathering along joint patterns has dissected indurated Toolinna and Abrakurrie Limestone leaving low stony rises (irregular limestone hummocks) separated by stony marginal slopes and irregular drainage foci in-filled with colluvium. Drainage foci subject to periods of temporary inundation; marine-eroded cliffs form southern edge of Bunda Plateau.

Land management: Rugged and poorly accessible country. Vegetation is not preferred by livestock. The predominance and uniform nature of the mallee understorey of low scrub and sedges, particularly in dry periods, renders this land system susceptible to extensive wildfires. Strategic firebreaks may limit the extent of wildfire damage.

Traverse condition summary:
(55 assessments)

Vegetation—very good 98%, fair 2%.

No.	Landform	Traverse recordings	Inventory sites
1.	Cliff	–	–
2.	Limestone hummock (low rise)	4	7
3.	Marginal slope to drainage focus	48	–
4.	Drainage focus	3	2
	Total	55	9



Toolinna land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Cliff**—marine-eroded cliff face, abundant angular stony mantle or sparse patches of shallow aeolian sand deposits.	Shallow aeolian siliceous sands (421), weakly bioclastic.	Heathland and dwarfed closed low thickets of *Adenanthos forrestii, Banksia media*, *Beaufortia micrantha, Boronia crassifolia, Conostephium drummondii, Eucalyptus incrassata*, *Melaleuca quadrifaria* and *Pultenaea heterochila* (BCHS). Banksia component disappears east of Toolinna Cove and vegetation grades into moderately closed dwarfed woodland of *Eucalyptus discreta* and *E. incrassata* with a scattered scrub understorey of *Beaufortia empetrifolia, Hakea nitida and Melaleuca lanceolata* (ECHW), coincides with sand deposits.
2.	44%	**Limestone hummocks (low rises)**—weathered outcrop of indurated Toolinna or Abrakurrie Limestone, with an abundant mantle of angular limestone fragments.	Skeletal calcareous shallow loams (521).	Scattered low mallee woodland of variable *Eucalyptus* species over scattered mixed scrub and sedges (LOMW).
3.	50%	**Marginal slope to drainage foci**—gently inclined stony surfaces with extensive mantle of angular limestone fragments and exposed calcrete sheets or weathered outcrop; between unit 2 and draining to depressions (unit 4).	Calcareous shallow loams (521).	Scattered low mallee woodland of variable *Eucalyptus* species over scattered to moderately closed mixed scrub featuring *Allocasuarina helmsii, Dodonaea stenozyga, Halgania andromedifolia, Melaleuca lanceolata, Olearia* spp., *Pomaderris myrtilloides, Spyridium tricolor, Templetonia retusa;* hummock (spinifex) grass *Triodia scariosa* and sedges such as *Gahnia lanigera*, *Dianella revoluta* and *Tetraria capillaris* (LOMW). On landward margins of the system patches exist of moderately closed woodland or tall scrubland dominated by *Eucalyptus diversifolia* (soap mallee), *E. yalatensis*, *Melaleuca lanceolata* and *Allocasuarina helmsii* with a variable shrub understorey (EMEW).
4.	5%	**Drainage foci**—level, irregular, closed depressions defined by joint patterns, commonly narrow up to 0.5 km in extent, receiving run-on from adjacent areas (units 2 and 3), surface mantle of sparse large limestone fragments.	Dark brown, deep calcareous loams over lighter clay loams (542) or deep non-saline clays (622).	Scattered tall shrubland of *Acacia cyclops* (coastal wattle) with very scattered *Eucalyptus yalatensis* (yalata mallee). Both species form bush clumps that provide shelter for a variety of other shrubs. Sedges also occur densely around the edges of the depression indicating inundation levels (DDXS).

***Toolinna land system:** Drainage focus supporting scattered coastal wattle; limestone hummocks supporting eucalyptus mallee woodland surround the depression.*

VANESK LAND SYSTEM (1107 km², 0.9% of the survey area)

Gently undulating stony limestone plains defined by north-south trending joint patterns supporting pearl bluebush shrubland and scattered myall woodland on low ridges and halophytic shrubland on saline drainage floors.

Land zone: Nullarbor Plain.

Land type: 10

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

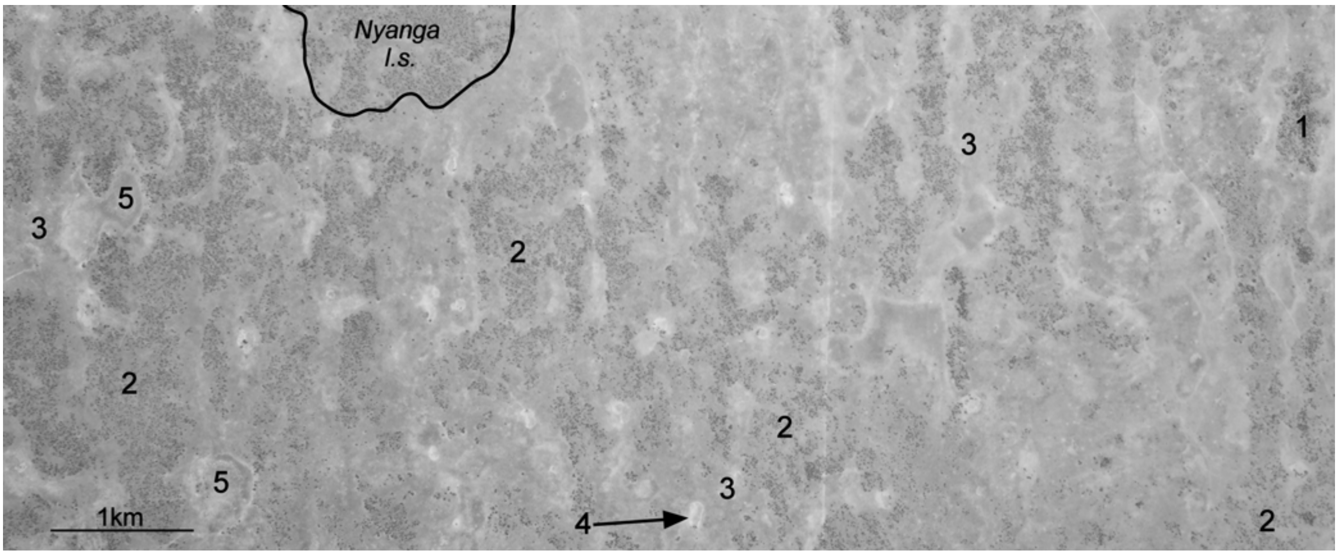
Geomorphology: Erosional surfaces; differential weathering along joint-controlled patterns trending north-south through the Nullarbor Limestone has formed marginal slopes to drainage floors, with saline drainage foci, separated by partially deflated, parallel, elongated low ridges. Infrequent residual calcrete rises through the system are associated with the adjacent calcrete plain of the Nyanga land zone.

Land management: The high salt content of the halophytic vegetation associated with the saline drainage floors can affect the grazing range of domestic stock during dry periods, leading to over-grazing of areas within the grazing radius of water points. Where palatable perennial shrub cover is reduced the vegetation is replaced by seasonally dependent annual species. Such areas are prone to wind erosion during dry periods. Overgrazing can be avoided by good land management, including control of total grazing pressure.

Traverse condition summary:
(64 assessments)

Vegetation—very good 2%, good 73%, fair 20%, poor 5%.

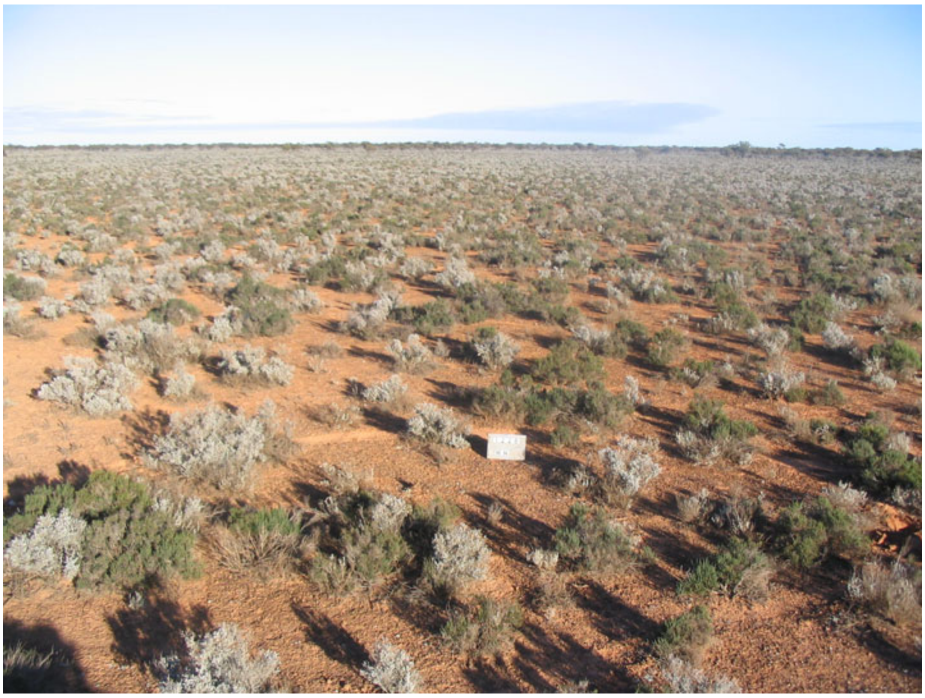
No.	Landform	Traverse recordings	Inventory sites
1.	Residual calcrete rise	–	1
2.	Stony limestone plain	36	–
3.	Marginal slope to drainage floor	20	2
4.	Saline drainage focus	–	1
5.	Claypan	8	2
	Total	64	6



Vanesk land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	< 1%	**Residual calcrete rises**—gently inclined low rises of calcrete; variable mantle of calcrete fragments with occasional outcrop.	Calcareous shallow loam (521).	Very scattered *Casuarina pauper* (black oak) and *Alectryon oleifolius* (mingah) amongst an understorey of mixed shrubs or dominated by chenopods (CXCS).
2.	50%	**Stony limestone plains**—gently inclined elongated, low ridges, forming undulating plains, stony mantle of mixed-sized calcareous fragments, Nullarbor Limestone outcrop common.	Calcareous shallow loam (521).	Scattered to moderately closed *Maireana sedifolia* (pearl bluebush) shrubland (PBLS) without or with scattered *Acacia papyrocarpa* (myall) woodland (MPBS).
3.	45%	**Marginal slopes to drainage floors**—gently inclined to level, smooth, narrow (< 0.5 km wide) open depressions (up to 5 km long) between gently undulating stony ridges (unit 1).	Calcareous heavy loams to light clay loams of variable depth (521, 542).	Scattered to moderately closed *Maireana sedifolia* shrubland (PBLS) on upper section of slopes becoming co-dominant with and then replaced by *Atriplex vesicaria* (bladder saltbush) towards the drainage floor (PXCS, BSSL).
4.	2%	**Saline drainage foci**—smooth, level, closed depressions (< 0.3 km diameter) within marginal slopes to drainage floors (unit 3).	Deep saline clay loams (542).	Scattered to moderately closed low shrubland co-dominated by *Atriplex vesicaria*, *Maireana sedifolia* and *Tecticornia* spp. (samphires) (PXHS); occasionally *Acacia papyrocarpa* is present (MHXS).
5.	3%	**Claypans**—smooth, level, closed, oval depressions (< 0.8 km diameter).	Red/brown non-cracking clays (622).	Scattered to moderately closed *Atriplex vesicaria* low shrubland (BSSL) or very scattered to scattered annual herbland (ANNH).

Vanesk land system: *Saline drainage focus supporting halophytic shrubland. In the background is an elongated, low ridge supporting myall woodland.*



VIRGINIA LAND SYSTEM (1689 km^2, 1.4% of the survey area)

Gently undulating weathered limestone plains defined by north-south trending joint patterns supporting myall woodland on low ridges and halophytic shrubland on saline drainage floors.

Land zone: Nyanga Plain.

Land type: 9

Geology: Quaternary (Pleistocene)—Neogene (Pliocene) Recrystallised (weathered) Limestone overlain by Quaternary residual loam.

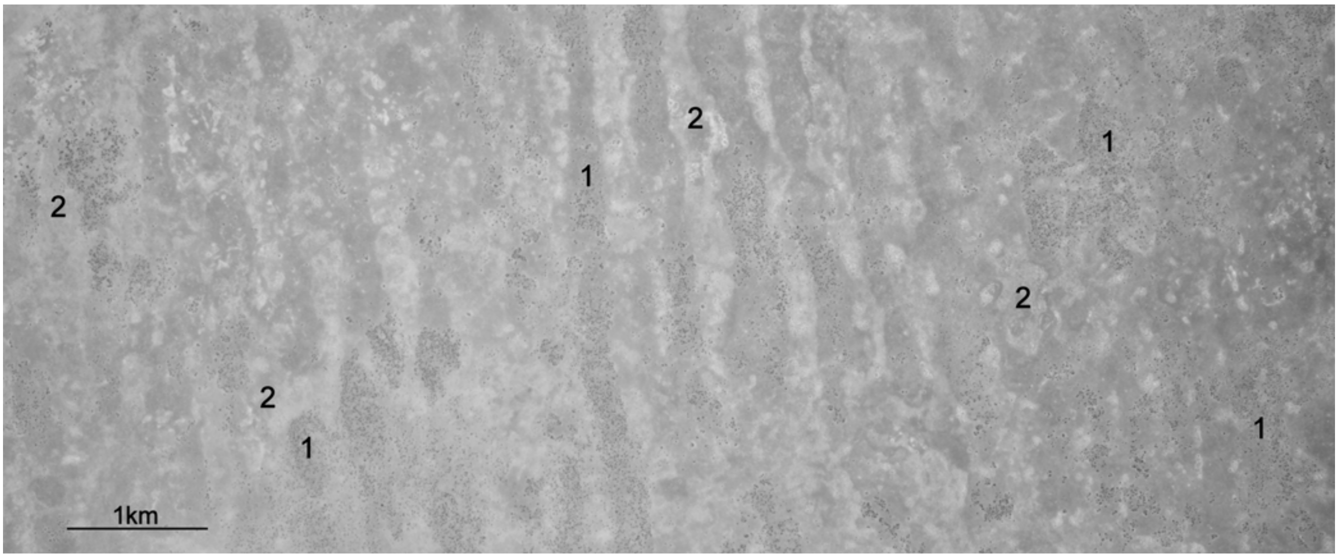
Geomorphology: Erosional surfaces; differential weathering of Recrystallised Nullarbor Limestone along north-south trending joint patterns has resulted in narrow, saline drainage floors infilled with colluvium, up to 10 km long, separated by partially deflated, parallel, low stony ridges.

Land management: The chenopod shrubland is prone to preferential grazing by herbivores. Where palatable perennial shrub cover is substantially reduced the vegetation is replaced by seasonally dependent grassland. Overgrazing can be avoided by good land management, including control of total grazing pressure. Large tracts of grassland increase the risk of fire. Myall woodland adjacent to or with speargrass understorey is particularly vulnerable. Firebreaks, in areas adjacent to dense grassland may preserve intact myall chenopod woodland from wildfires.

Traverse condition summary:
(144 assessments)

Vegetation—very good 1%, good 85%, fair 13%, poor 1%.

No.	Landform	Traverse recordings	Inventory sites
1.	Stony limestone plain	63	2
2.	Marginal slope to drainage floor	81	2
	Total	144	4



Virginia land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	50%	**Stony limestone plains**—level to gently inclined low ridges, forming undulating plains, stony mantle with Recrystallised Limestone outcrop and mixed-sized calcareous fragments.	Calcareous loamy earths at various depths (521, 542).	Scattered *Acacia papyrocarpa* (myall) woodland over an understorey dominated by mixed chenopods (MXCS) or *Austrostipa scabra* (speargrass) grassland (MSOG).
2.	50%	**Marginal slope to drainage floors**—smooth, level to gently inclined, narrow (< 0.7 km wide), open depressions (up to 10 km long) between gently undulating stony ridges (unit 1).	Calcareous loamy earths (542) and deep clays (622) with saline subsoils. Minor calcareous shallow loams (521).	Scattered to moderately closed low shrubland of *Atriplex vesicaria* (bladder saltbush) and *Maireana sedifolia* (PXCS) or co-dominated with *Tecticornia* spp. (samphires) (PXHS). *Acacia papyrocarpa* is occasionally present (MHXS).

Virginia land system: *Drainage floor supporting chenopod shrubland; in the background is a low ridge with scattered myall woodland.*

WEEBUBBIE LAND SYSTEM (416 km^2, 0.4% of the survey area)

(modified from Mitchell, McCarthy and Hacker 1979)

Gently undulating stony limestone plains supporting eucalypt and melaleuca woodland on rises and grassland on the lower slopes, closed drainage floors and claypans.

Land zone: Hampton Tableland.

Land type: 7

Geology: Miocene Nullarbor Limestone and Quaternary colluvium.

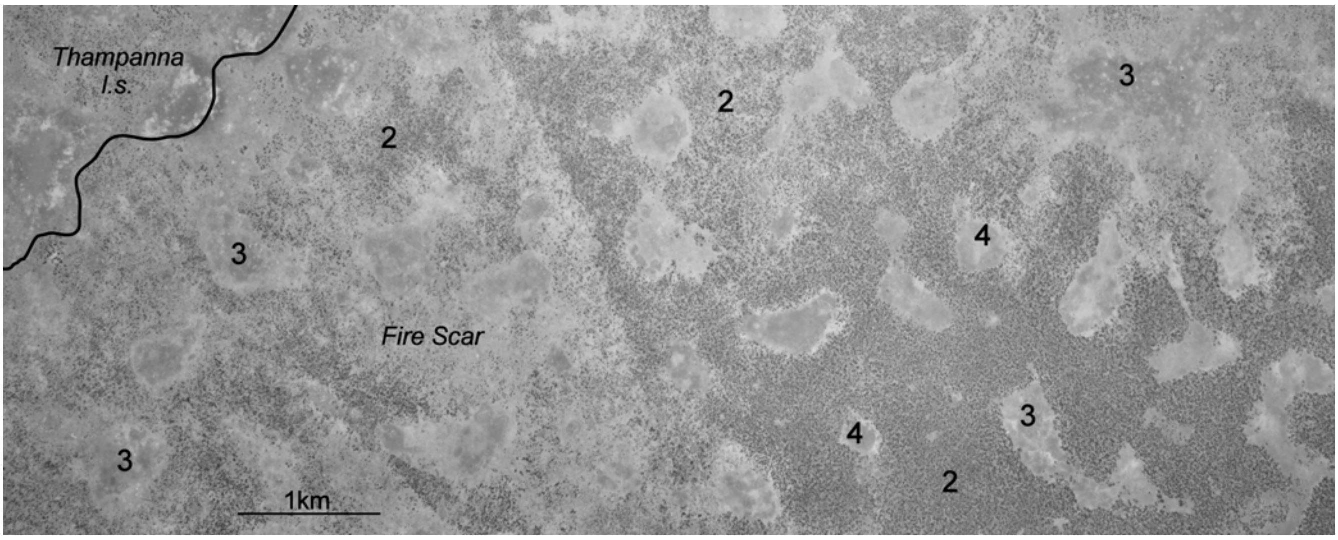
Geomorphology: Erosional surfaces; differential weathering of Nullarbor Limestone has formed small oval to circular, closed drainage foci separated by stony plains and low ridges with up to 3 m relief; marine-eroded scarp forms southern edge of Bunda Plateau.

Land management: The drainage foci may once have supported a mosaic of grassland and shrubland but are now reduced to primarily grassland through the combined effects of rabbits, stock and fire. The fire susceptibility of these areas is high. Though the adjacent woodland does not support an abundance of grasses the edges at drainage foci and the system's northern margin are vulnerable to fire as grasses encroach inwards threatening the integrity of the woodland leading to fragmentation.

Traverse condition summary:
(14 assessments)

Vegetation—good 79%, fair 21%.

No.	Landform	Traverse recordings	Inventory sites
1.	Scarp	–	–
2.	Stony limestone plain	9	1
3.	Closed drainage floor	–	–
4.	Claypan	5	1
	Total	14	2



Weebubbie land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Scarp**—marine-eroded scarp or cliff with colluvial lower slopes. Steep slopes or vertical faces with abundant stony fragments and outcrop of Nullarbor Limestone.	Shallow calcareous aeolian sands (421).	Moderately closed patches of woodland of *Eucalyptus gracilis* (yorrell), *E. yalatensis* (yalata mallee) and *Melaleuca lanceolata* with variable mid to low shrubland of *Atriplex nummularia* (old man saltbush) and *Westringia rigida* (EXSW) amidst stony outcrop.
2.	74%	**Stony limestone plains**—gently undulating limestone plains with low rises (up to 3 m relief), extensive mantle of calcareous fragments.	Calcareous shallow loams (521).	Scattered to moderately closed woodland of *Eucalyptus gracilis*, *E. yalatensis* and *Melaleuca lanceolata* with variable understorey of mixed shrubs commonly featuring *Atriplex nummularia*, *Cratystylis conocephala* (false bluebush), *Eremophila weldii*, *Halgania andromedifolia*, *Olearia calcarea*, *Maireana erioclada, Pomaderris myrtilloides* and *Westringia rigida* (EXSW).
3.	20%	**Closed drainage floors**—level, smooth surface, irregular to circular rarely exceeding 2 km in extent.	Deep calcareous red earths (542).	Open grassland dominated by *Austrostipa scabra* (speargrass) and *Austrodanthonia caespitosa* (wallaby grass) (SWOG).
4.	5%	**Claypans**—closed, circular to oval drainage focus, up to 0.8 km in extent.	Deep clays (622).	Bare or vegetated by open grassland dominated by *Austrostipa scabra* and *Austrodanthonia caespitosa* (SWOG).

Weebubbie land system: *Claypan supporting speargrass and wallaby grass surrounded by eucalypt woodland.*

WOORLBA LAND SYSTEM (554 km², 0.5% of the survey area)

Level to gently inclined clay floored depressions supporting chenopod shrubland or grassland, forming drainage foci for surrounding systems.

Land zone: Mardabilla Plain.

Land type: 5

Geology: Quaternary colluvium, occasional Miocene Nullarbor Limestone.

Geomorphology: Depositional surfaces; level to gently inclined depressions, forming drainage foci for surrounding areas. Surrounding slopes adjacent to neighbouring land systems are commonly gently inclined but can be steep to moderately inclined.

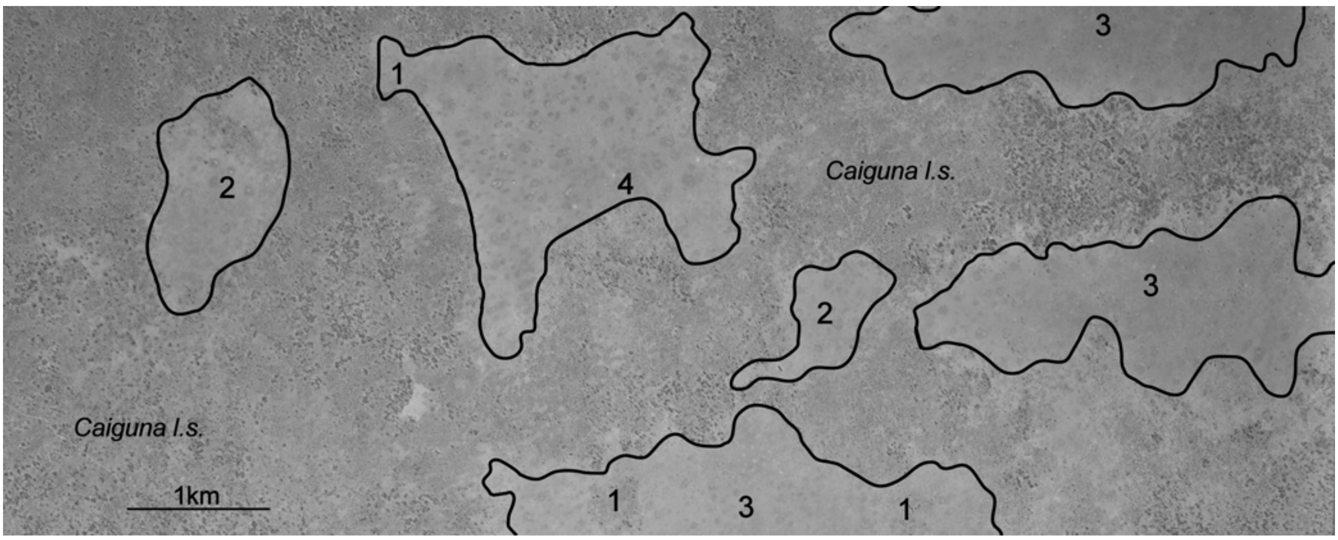
Land management: The chenopod vegetation is highly preferred by herbivores due to its position in the landscape. The soil of drainage foci can retain greater moisture after rainfall events and areas are often chosen for dam construction. Due to the regular occurrence of dams and the proximity to good quality dam water overgrazing of palatable flora can occur. Continuous heavy grazing reduces the floristic diversity of the depression to unpalatable and seasonally dependent shrubs and annuals. Heavy grazing can be avoided by good land management, including control of total grazing pressure.

Some depressions solely support grassland and are susceptible to fire, particularly following favourable seasons when there is a high fuel load. Such areas can carry fire along the lower-lying topography burning intact vegetation on the depression's margin, at times burning across adjacent systems into the next depression causing fragmentation of the adjacent woodland and shrubland. Strategic firebreaks in such areas may preserve intact vegetation communities.

Traverse condition summary:
(163 assessments)

Vegetation—very good 23%, good 56%, fair 14%, poor 4%, very poor 3%.

No.	Landform	Traverse recordings	Inventory sites
1.	Marginal slope to depression floor	74	3
2.	Clay floored depression	20	3
3.	Clay plain	53	2
4.	Saline drainage focus	16	2
	Total	163	10



Woorlba land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	5%	**Marginal slopes to depression floors**—commonly very gently inclined, seldom steep or moderately inclined, slopes of calcrete or Nullarbor Limestone grading down to level loam plains with sparse outcrop, occasional mantle of calcareous fragments.	Calcareous shallow loams (521).	Scattered low shrubland dominated by *Maireana sedifolia* (pearl bluebush) (PBLS) or co-dominated with *Atriplex nummularia* (old man saltbush) and *A. vesicaria* (bladder saltbush) (PXCS).
2.	35%	**Clay floored depressions**—level, closed drainage depression, variable in size and shape, receiving drainage from unit 1 or surrounding systems.	Deep, often saline, calcareous clay loams (542) or light clays (622).	Scattered to moderately closed low shrubland dominated by *Atriplex vesicaria* (BSSL) or co-dominated with *Atriplex nummularia* and *Maireana sedifolia* (PXCS) or replaced by *Austrodanthonia caespitosa* (wallaby grass) and *Austrostipa scabra* (speargrass) grassland (SWOG). Occasionally very scattered *Myoporum platycarpum* (sugarwood) is present (SWCS).
3.	35%	**Clay plains**—level plain, receiving drainage from unit 1 or surrounding systems.	Clay loams (542) of variable depth, deep types with saline subsoils.	As for unit 2.
4.	25%	**Saline drainage foci**—commonly occur within units 2 or 3 as closed drainage sumps, though occasionally can dominate most of depression.	Saline clay loams (542) to light clays (622).	Scattered to moderately closed low halophytic shrubland of *Atriplex nummularia*, *A. vesicaria*, *Maireana sedifolia* and *Tecticornia* spp. (samphires) (PXHS).

Woorlba land system: *Clay floored depression supporting bladder saltbush shrubland. Background is of eucalypt woodland on calcrete rise on adjacent Caiguna land system.*

WURRENGOODYEA LAND SYSTEM (1946 km², 1.6% of the survey area)

Coastal dunes supporting eucalypt coastal heath woodland.

Land zones: Hampton Tableland and Roe Plains.

Land type: 14

Geology: Quaternary (Pleistocene) aeolian siliceous sands containing sheet and nodular calcrete.

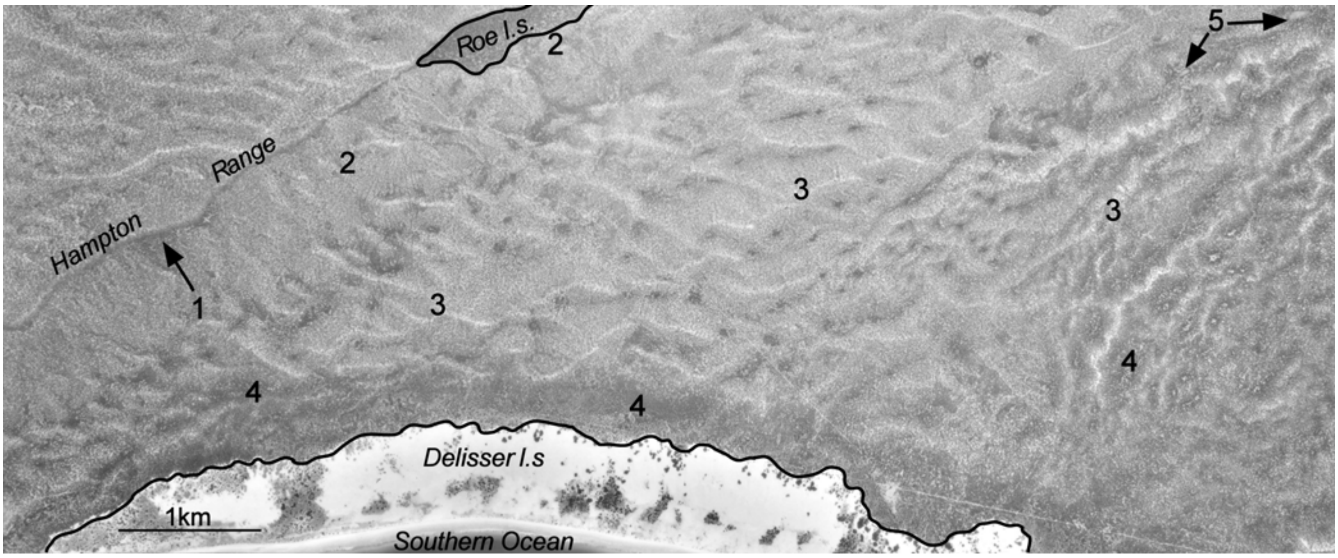
Geomorphology: Depositional surfaces; attenuated parabolic and nested parabolic sand dunes and swales with no organised drainage. Sand dunes partially consolidated by a concentrated horizon of calcium carbonate forming a thin layer of sheet or nodular calcrete at or close to the surface. Sand ramps linking the Bunda Plateau and the Roe Plains formed when the wind-built ramps at the base of the cliffs during a past sea regression.

Land management: Dunes are stable when vegetated but are susceptible to wind erosion if vegetation is reduced due to disturbance through fire or vehicle-induced track erosion.

Traverse condition summary:
(23 assessments)

Vegetation—very good 91%, good 9%.

No.	Landform	Traverse recordings	Inventory sites
1.	Scarp	1	1
2.	Sand (dune) ramp	–	–
3.	Dune	10	12
4.	Interdunal swale	12	1
5.	Interdunal saline depression	–	–
	Total	23	14



Wurrengoodyea land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Scarp**—marine-eroded scarp or cliff. Steep slopes or vertical faces with abundant stony fragments and outcrop of Abrakurrie Limestone.	Shallow calcareous aeolian siliceous sands (421).	Dwarfed moderately closed low woodland of *Eucalyptus discreta* and *E. incrassata* with a scattered understorey of *Beaufortia empetrifolia, Hakea nitida and Melaleuca lanceolata* (ECHW).
2.	3%	**Sand (dune) ramps**—steeply sloping partially consolidated wind-built sand ramps.	Calcareous deep sands (442) to pale deep sands (444).	Moderately closed woodland of *Eucalyptus discreta* and *E. incrassata* with a scattered scrub understorey of *Beaufortia empetrifolia, Hakea nitida and Melaleuca lanceolata* (ECHW) or moderately closed woodland dominated by mallee-form *Eucalyptus* and *Melaleuca* species (EMEW).
3.	70%	**Dunes**—partially consolidated parabolic dunes with gentle to steeply inclined slopes with a calcrete horizon developed close to the surface. The highest dunes are up to 90 m.	Pale deep sands (444) and some deep calcareous aeolian sands (442).	Scattered to closed Eucalyptus species woodland with Callitris sp. over a scattered to closed low heath shrubland commonly consisting of *Adenanthos forrestii, Acacia cochlearis, Beaufortia empetrifolia, B. micrantha, Boronia crassifolia, Bossiaea leptacantha, Conostephium drummondii, Hibbertia nutans, Lysinema ciliatum* and *Pultenaea heterochila* (EHEW).
4.	25%	**Interdunal swales**—gently inclined sandy sheets partially consolidated by a shallow calcrete horizon, calcrete nodules and fragments sparsely cover the surface.	Calcareous aeolian sands (442). Rarely pale shallow sand (422).	Scattered to moderately closed woodland or tall scrubland dominated by various mallee-form *Eucalyptus* and *Melaleuca* species (EMEW or EMCW) or scattered to closed *Eucalyptus* woodland with *Callitris* sp. over scattered to closed low heath shrubland (EHEW).
5.	1%	**Interdunal saline depressions**—small level saline flats between interdunal swales (unit 4).	Deep saline or gypsiferous clays (622).	Most depressions have no vegetation, though some support a very scattered low shrubland of *Carpobrotus modestus* (inland pigface) and *Tecticornia* spp. (samphires) (SAMP).

Wurrengoodyea land system: *Dune supporting eucalypt woodland over coastal heathland.*

WYLIE LAND SYSTEM (52 km^2, 0.1% of the survey area)

Part of narrow coastal plain with interdunal saline depressions between partially consolidated coastal dunes backed to the escarpment by sand ramps supporting banksia coastal heath woodland.

Land zone: Israelite Plain.

Land type: 14

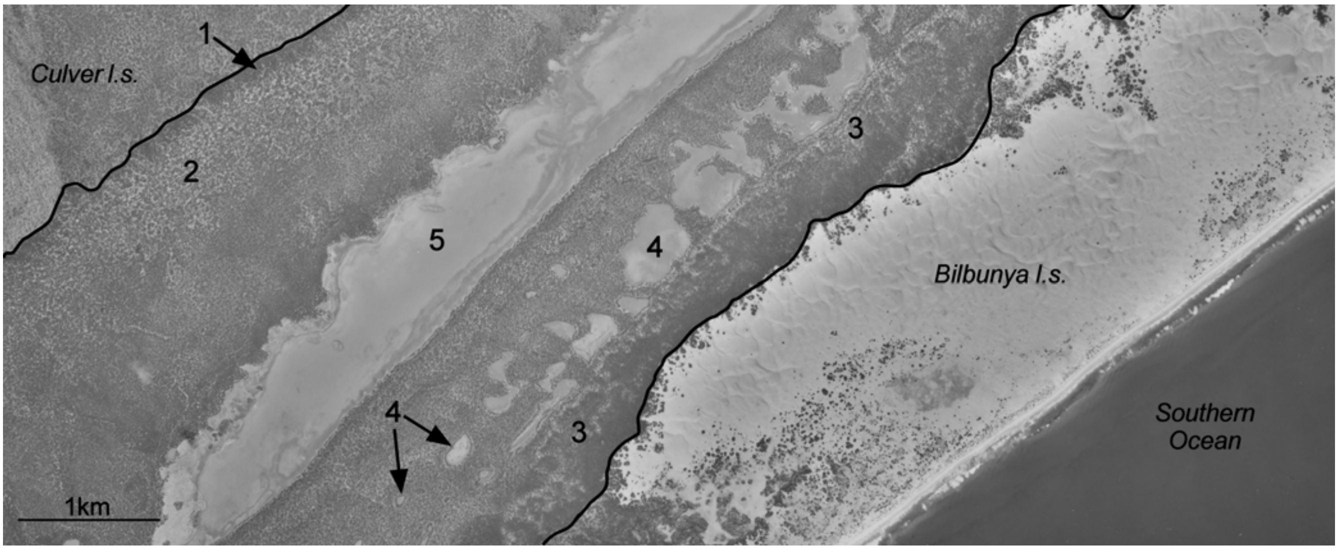
Geology: Quaternary (Pleistocene) aeolian siliceous sand overlying sheet and nodular calcrete or aeolian calcarenite and interdunal depressions with saline and gypsiferous lagoonal deposits of silt and clay.

Geomorphology: Depositional surfaces; partially consolidated sand dunes containing sheet or nodular calcrete at or close to the surface; interdunal chains of old coastal lagoons with saline, gypsiferous soils. Sand ramps link the Bunda Plateau and the Israelite Plain, formed when the wind-built ramps at the escarpment base when beaches were exposed during a past sea regression.

Land management: Dunes are stable when vegetated but are susceptible to wind erosion if vegetation is reduced due to disturbance through fire or vehicle-induced track erosion.

Traverse condition summary:
(not traversed)

No.	Landform	Traverse recordings	Inventory sites
1.	Scarp	–	1
2.	Sand (dune) ramp	–	–
3.	Dune and swale	–	–
4.	Interdunal depression	–	–
5.	Lagoonal depression	–	–
	Total	–	1



Wylie land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Scarp**—marine-eroded scarp or cliff. Steep slopes or vertical faces with abundant stony fragments and outcrop of Toolinna Limestone.	Shallow calcareous aeolian siliceous sands (421).	Dwarfed closed low shrubland of *Adenanthos forrestii, Banksia media*, *Beaufortia micrantha, Boronia crassifolia, Conostephium drummondii, Eucalyptus incrassata*, *Melaleuca quadrifaria* and *Pultenaea heterochila* (BCHS).
2.	20%	**Sand (dune) ramps**—steeply sloping partially consolidated wind-built sand ramps.	Deep calcareous aeolian siliceous sands (442).	Moderately closed to closed low woodland of *Banksia media*, *Eucalyptus incrassata* and *Melaleuca* species with closed mid to low shrubland of *Adenanthos forrestii, Beaufortia micrantha, Boronia crassifolia, Conostephium drummondii* and *Pultenaea heterochila* (BCHS).
3.	50%	**Dunes and swales**—partially consolidated dunes with gentle to moderately inclined slopes with a calcrete horizon developed close to the surface.	Deep calcareous aeolian sands (442).	Scattered to moderately closed low woodland to tall scrubland of *Banksia media*, *Eucalyptus incrassata* and *Melaleuca* species with closed mid to low heathland (BCHS), becoming progressively more open and dominated by low coastal shrubs and sedges (COAS) closer to the coast as dunes become more mobile.
4.	9%	**Interdunal depressions**—level saline flats up to 0.6 km wide and of variable length between dunes (unit 3). Subject to occasional inundation.	Saline and gypsiferous clays (622) with some shallow sands or loams.	Most depressions have no vegetation, though some occur with a very scattered low shrubland of *Carpobrotus modestus* (inland pigface) and *Tecticornia* spp. (samphires) (SAMP).
5.	20%	**Lagoonal depressions**—level, long narrow interdunal saline flats up to 0.9 km wide. Subject to occasional inundation.	Saline and gypsiferous clays (622) with some shallow sands or loams.	As for unit 4.

***Wylie land system:** Partially consolidated sand ramp against Wylie scarp, supporting banksia coastal heath shrubland. Bilbunya dunes in the background.*

ZANTHUS LAND SYSTEM (619 km², 0.5% of the survey area)

Level sandy loam calcrete plains supporting mallee woodland over spinifex hummock grassland.

Land zones: Nyanga Plain and Carlisle Plain.

Land type: 1

Geology: Quaternary aeolian and residual sandy loam overlying Quaternary (Pleistocene) – Neogene (Pliocene) calcrete over Miocene Nullarbor Limestone.

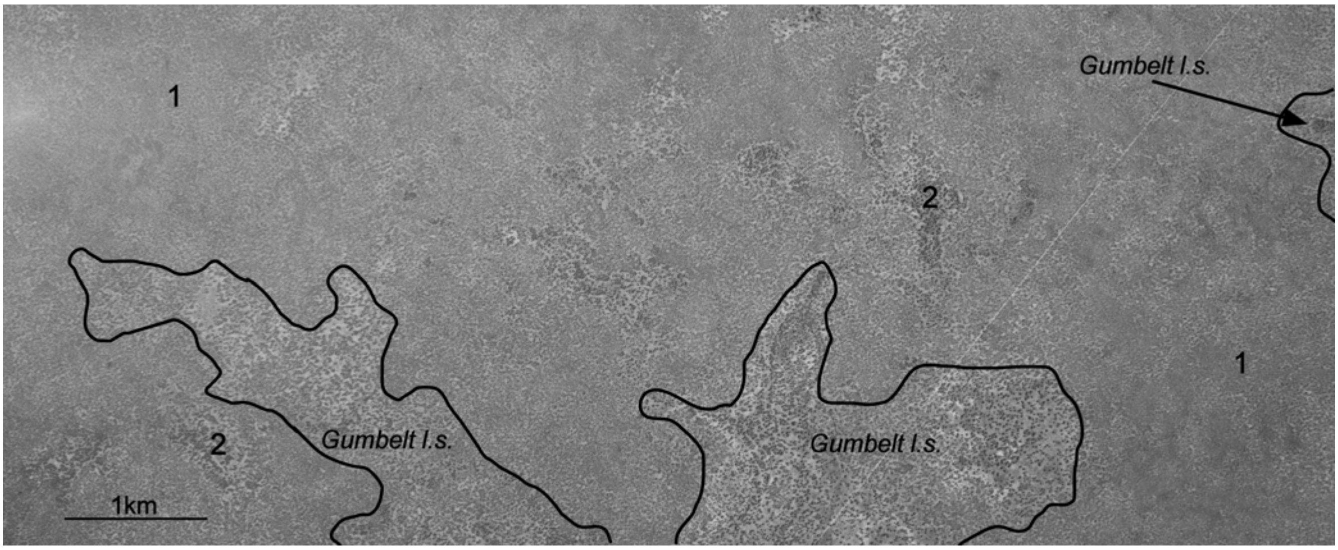
Geomorphology: Depositional land surfaces; level plains of residual sandy loam containing nodular calcrete near the surface, overlain by shallow deposits of aeolian sand; small irregular drainage foci, < 0.7 km in extent; no organised drainage pattern.

Land management: Spinifex hummock grassland is highly flammable and subject to occasional wildfires. During the hotter months in conjunction with strong winds wildfires can cause considerable damage to adjacent less fire-adapted plant communities, as well as infrastructure. Firebreaks in these areas may localise the impact of wildfires and facilitate their control. After fire wind erosion may occur, however regrowth after rains usually restores stability. In its unburnt state the system is not susceptible to soil erosion.

Traverse condition summary:
(49 assessments)

Vegetation—very good 61%, good 39%.

No.	Landform	Traverse recordings	Inventory sites
1.	Loamy plain overlain by aeolian sand	49	6
2.	Drainage focus	–	–
	Total	49	6



Zanthus land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	100%	**Loamy plains overlain by aeolian sand**—level to very gently inclined plains overlain by shallow sand sheets, calcrete nodules near the surface.	Red sandy earths (463) and variable depth calcareous loamy earths (542) with calcrete nodule substrates.	Scattered to closed mallee woodland of *Eucalyptus oleosa* subsp. *oleosa* (giant mallee) and *E. concinna* (Victoria desert mallee) over *Triodia scariosa* (spinifex) hummock grassland (MHGW), occasionally a tall to mid mixed scrub stratum is co-dominant with *Eucalyptus melanoxylon* (black morrel) (EXSW) or patches of *Casuarina pauper* (black oak) dominate the tree strata (CXSS).
2.	< 1%	**Drainage foci**—small irregular, shallow depressions.	Deep clay loams (542).	Scattered eucalypt woodland, commonly *Eucalyptus gracilis* (yorrell), over a chenopod understorey dominated by *Atriplex nummularia* (old man saltbush), *A. vesicaria* (bladder saltbush) and *Maireana sedifolia* (pearl bluebush) (EXSW).

Zanthus land system: *Loamy plain with aeolian deposits supporting giant mallee and spinifex hummock grassland.*

References

Mitchell, AA, McCarthy, R & Hacker, RB 1979, *A range inventory and condition survey of part of the Western Australian Nullarbor Plain, 1974*, Agriculture Western Australia, Technical Bulletin No. 47.

Payne, AL, Mitchell, AA & Hennig, P 1998, *Land systems of the Kambalda area and surrounds*, a report prepared for Western Mining Corporation Resources Ltd, Agriculture Western Australia.

Resource condition

PA Waddell

One objective of rangeland surveys in Western Australia is the assessment of grazing impacts on natural resources, focusing on the use of land for pastoralism. Other land use impacts have not been addressed in a similarly detailed manner primarily because pastoralism is the most extensive land use. Land uses such as mining activity were found to be localised.

In the context of this report resource condition has been determined by assessing the bio-physical indicators: perennial vegetation and soil surface condition, both of which provide measures of ecosystem change. There are three methods of assessing resource condition:

- visual traverse assessments at kilometre intervals
- collection of ecological data during field work from inventory sites
- aerial photo interpretation and ground verification.

Summary of traverse assessments

Traverse assessments were used to assess resource condition in the survey area, as described in the Methodology chapter. Range condition was assessed within a 50 m radius around the vehicle at 1 km intervals along pre-selected traverse routes. These assessments were visual subjective ratings using objective assessment criteria. The rating system is described in the Methodology chapter.

In the survey area a total of 6997 traverse points were described and assessed for various biophysical parameters; these are summarised in Table 22. Within the boundaries of pastoral leases 6276 traverse points were assessed for range condition.

A total of 91.6 per cent of all traverse assessments indicated vegetation was in the very good, good or fair categories. This may be regarded as acceptable condition. The remaining 8.4 per cent of regular traverse assessments showed obvious signs of pastoral overgrazing resulting in a poor or very poor condition assessment, with considerable loss of palatable perennial plants or general loss of perennial plants or marked increases in cover by unpalatable species.

Table 22 **Summary of vegetation condition derived from traverse assessments**

Perennial vegetation condition	Proportion (%) of traverse assessments
Very good	8
Good	58
Fair	26
Poor	7
Very poor	1

With these findings it is important to consider the irreversible alteration of vegetation communities due to various ecological disturbances. Some vegetation communities have undergone ecological changes so dramatic the original perennial species have been replaced by an annual component. In the 1974 Western Australian Nullarbor Plain survey Mitchell, McCarthy and Hacker (1979) describe many land systems as having chenopod shrubland communities; this information supports findings from Beard's (1975) Nullarbor vegetation survey. During 2005–2007 whilst re-traversing various routes of the 1974 survey there was an absence of chenopod shrubland in areas where it had been previously recorded as dominant. The elimination of large areas of chenopod shrubland from areas in which it formerly occurred is likely the combination of 'drought', fire and rabbit impact. Past biological surveys in the region (Beard 1975, 1990; McKenzie & Robinson 1987) comment on the effect of rabbit grazing in altering the landscape. Accepting these changes as permanent (Beard 1975; Davey 1978; Mitchell, McCarthy & Hacker 1979; Westoby, Walker & Noy-Meir 1989) some areas now in irreversible transition were assessed on their present form rather than speculating on their former state. This has resulted in some habitat types describing the present features and composition of an area as the stable state, rather than considering it as a former state in poor condition.

It is also necessary to consider these findings in the context of a biased sampling technique. In attempting to achieve a representative coverage across the survey area large portions of some leases were traversed through relatively undeveloped country. Lease development is strongly influenced by the nature of the terrain which limits suitable dam sites or the presence, quality and reliability of aquifer water. In terms of the overall condition of the native vegetation, the bias may be considerable as

*Mixed chenopod shrubland: pearl bluebush (*Maireana sedifolia*) dominates the stony plain whilst bladder saltbush (*Atriplex vesicaria*) dominates the low-lying corridors between the stony rises.*

*The same land unit patterns where the chenopod cover has been replaced by the dominance of speargrass (*Austrostipa scabra*).*

many areas not developed for pastoral use are traversed, particularly when attempting to use routes that did not require backtracking. In addition 721 of the 6997 traverse points were assessed outside pastoral lease boundaries with the majority of these considered in good or very good vegetative condition.

Reconnaissance trips and early traverse ratings recognised a high level of erosion across many habitat types with the associated dilemma of attributing the cause. In some locations pastoral activities have contributing to overgrazing resulting in accelerated erosion, especially the large piospheres radiating from water points. However, away from water points it is difficult to differentiate natural erosion cells that are a feature of the Nullarbor karst against pastoral induced erosion cells. Forms of erosion away from water points were assessed on their origin—anthropogenic or karst induced—and this was taken into account when determining a condition rating. Where erosion was attributed to pastoral activities this contributed to downgrading of a site's rating.

Wind rather than water is the primary mechanism driving accelerated erosion where vegetation cover has reduced through grazing or fire. Wind scalds were the most common type of erosion observed, regularly exposing fresh rock faces and root bases. Extensive soil loss has occurred around some water points. In localised areas scalding and microterracing was also common particularly near sinkhole entrances at the karst surface.

Around some water points there has been wide-spread soil loss through wind erosion. The lack of surface weathering and lichen on freshly exposed rock surfaces indicates the recent nature of the erosion.

Surface disturbance through continual grazing pressure has resulted in extensive soil redistribution; rocks perched on residual soil pedestals provide some indication of the severity of the erosion.

Patterns of soil and vegetation condition

Plant growth is restricted by the availability of water with distribution influenced by land unit relief, soil depth and salinity. Soil erosion and vegetation condition are often closely related. A reduction in total shrub and/or grass coverage results in a decline in vegetation condition leaving soil surfaces increasingly exposed to the erosive effects of wind and water, unless the surface is inherently resistant. Due to factors controlled by geology and climate Nullarbor soil development is limited with both nutrients and stored seed only found in the top 20–30 mm of the soil profile (Gillieson, Wallbrink & Cochrane 1996). In such a wind-blown landscape the importance of vegetation cover and cryptogamic crusts are paramount in reducing erosion.

Since the introduction of pastoralism the Nullarbor has experienced widespread soil erosion (Gillieson, Cochrane & Murray 1994), with considerable soil losses recorded through the droughts of the early 1970s and 1980s. Whilst vegetation recovery may take decades, the replacement of lost soil is unlikely to occur in such a short geological period, particularly if the soil loses its ability to support regeneration. Wind erosion has reduced the capacity of the soil to support perennial vegetation, leaving surfaces bare during dry seasons or dominated by annual species. To prevent this form of permanent damage land users should monitor the condition of the soil surface and cryptogamic crusts as well as preserving vegetation cover. Gillieson, Wallbrink and Cochrane (1996) state that at least 15 per cent projected foliar cover is necessary to prevent wind erosion.

Good condition areas

Figure 28 shows the distribution of traverse assessments within pastoral lease boundaries of very good or good vegetation condition. A large proportion of these points occurred in habitat types which are either largely unaffected by grazing, such as eucalypt woodlands in the west and south-west of the survey area, or in undeveloped or very recently developed pastoral areas, such as myall woodlands of the calcrete Nyanga Plain. On the stony Nullarbor Plain away from the summer grazing radius of stock vegetation condition was also generally considered to be in good condition. Areas outside of present day pastoral lease boundaries were assessed during the 1974 Western Australian Nullarbor Plain survey (Mitchell, McCarthy & Hacker 1979) and are not included in Figure 28.

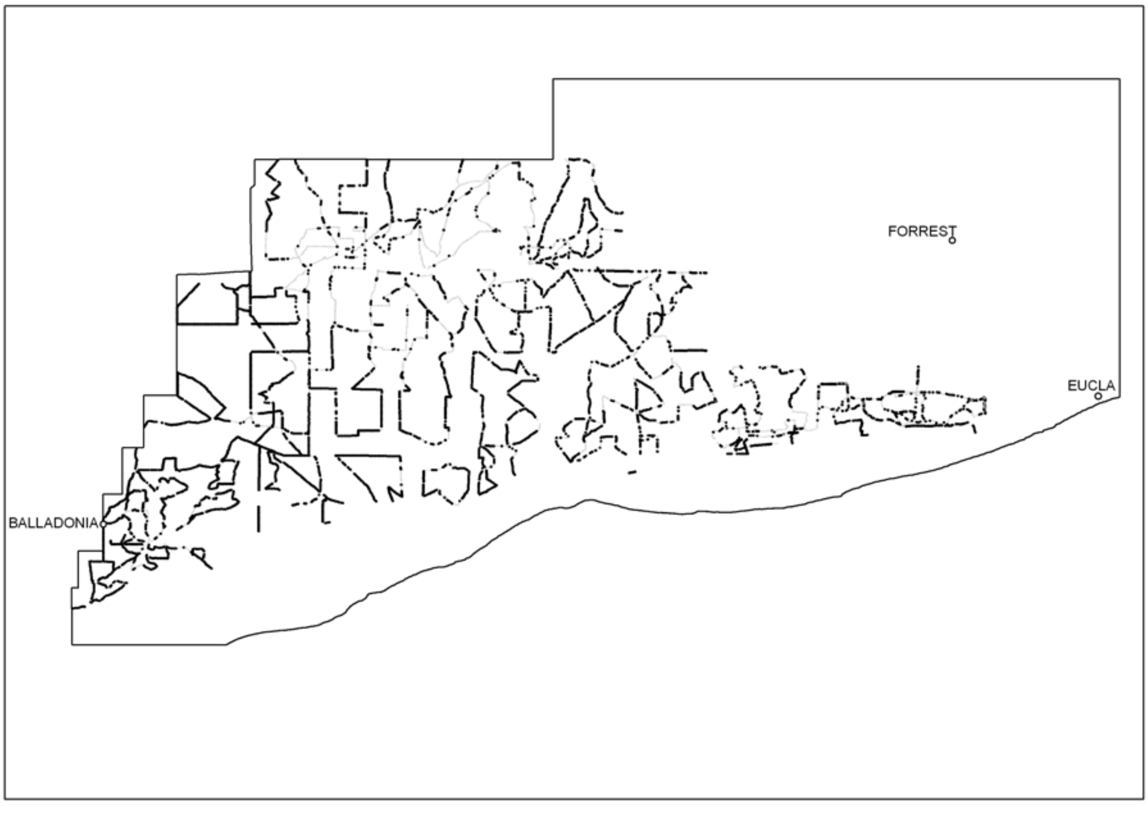


Figure 28 **Traverse assessments of very good to good vegetation condition with no erosion**

Poor condition areas

Figure 29 shows the distribution of traverse assessments within pastoral lease boundaries of poor or very poor vegetation condition. In regional terms the areas most adversely impacted by grazing are in the different forms of karst depressions which form corridors of linear depressions (chenopod shrubland or drainage focus communities) and 'dongas' (donga grove and gilgai grassy shrubland communities). These areas are preferentially grazed and commonly contain water point infrastructure. Soils are generally unstable and susceptible to wind erosion when disturbed by stock trampling and loss of vegetative cover.

Severely degraded and eroded areas

Past rangeland surveys have identified areas of eroded soil surfaces larger than 40 ha in extent and mapped them as being severely degraded and eroded (Pringle, Van Vreeswyk & Gilligan 1994; Payne et al. 1998; Van Vreeswyk et al. 2004). These are areas typically with little or no perennial vegetation remaining, as interpreted from aerial photographs with their extent verified in the field. Much of this degradation occurs in areas characterised by alluvial plains, river plains and wash plains. Such areas are highly productive and historically overgrazed. Accelerated erosion in these land types is exacerbated by the incised nature of the drainage in these regions. However as an areic drainage system the Nullarbor region predominantly experiences surface water loss via percolation through karst landforms into underground drainage systems. This process has largely protected the Nullarbor surface from the effects of water erosion in overgrazed areas as seen at all catchment scales in other areas of Western Australia (Pringle & Tinley 2003; Pringle, Watson & Tinley 2006).

Within the survey area severely degraded and eroded areas are restricted to water point environs. Overgrazing around water points developed on fragile landforms such as karst depressions has resulted in extensive bared piospheres. The loss of perennial vegetation in conjunction with regular stock movement exacerbates the extent of piosphere degradation. Through deflation, such areas are losing their ability to provide suitable conditions for seedling germination and establishment of perennial plants. Dust clouds are common near piospheres especially during dry periods.

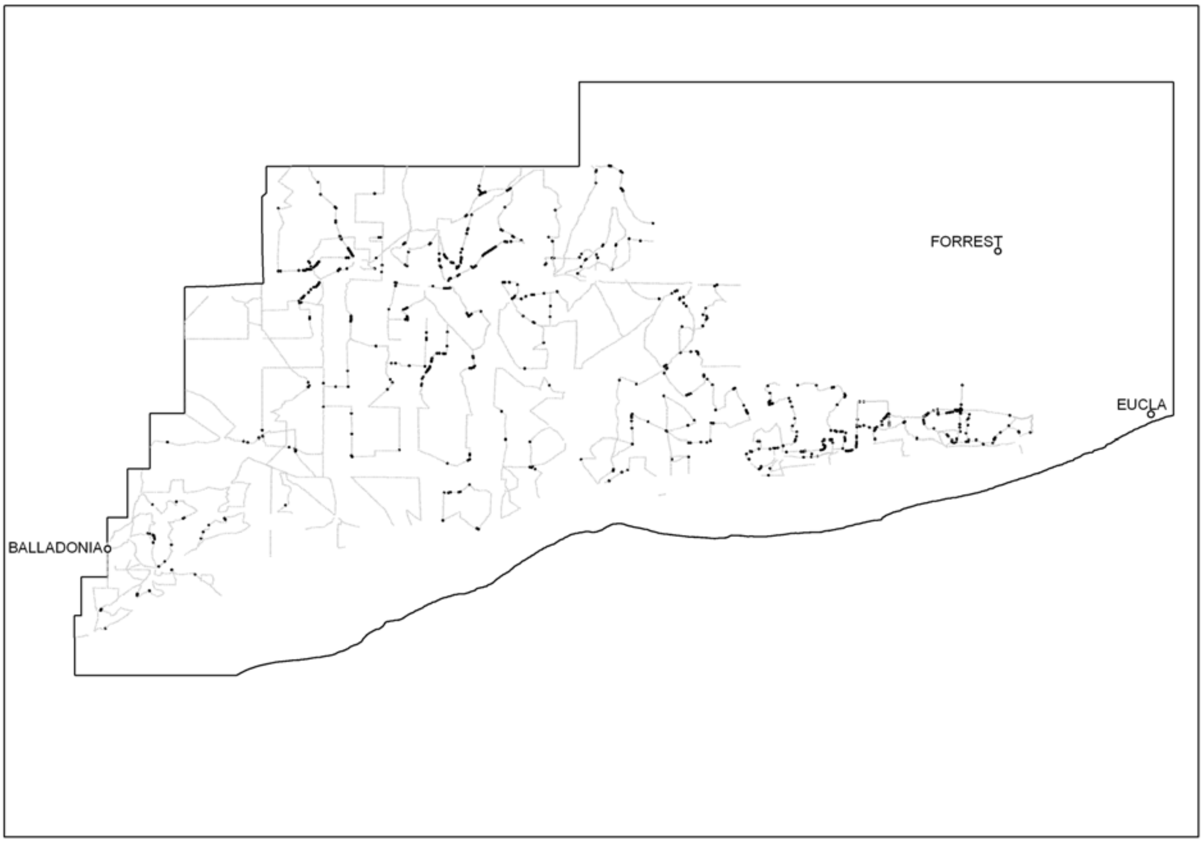
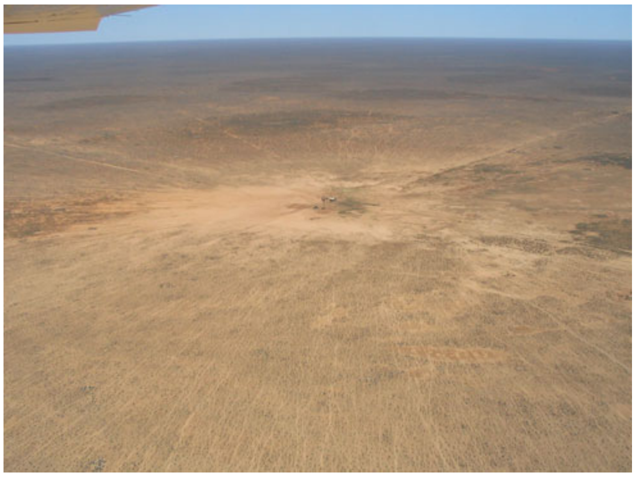


Figure 29 **Traverse assessments of poor to very poor vegetation condition**

Stock concentration at water points particularly during dry periods leads to piosphere development. Poorly developed soils become increasingly susceptible to wind erosion in the absence of perennial vegetation.

Land systems most likely to exhibit bared piospheres are those with limestone plains and poorly developed soils rather than calcrete plains with loam soils of variable depth. This corresponds with underground water supplies occurring more often below limestone than calcrete surfaces. Severely degraded and eroded piospheres areas were identified in 12 of the 54 land systems, representing 5 of the 15 land types. Ten of the land systems with severely degraded and eroded areas occur on the 'deflated limestone plains' land surface type. Two land systems occur on the land surface type designated 'limestone plains with deeper soil than found on deflated limestone plains' (Table 23).

Severely degraded and eroded areas are generally not found in land types characterised by: (a) calcrete plains (land types 1, 2, 3 and 4); (b) depressions within calcrete plains (land type 5); (c) granite outcrop (land type 6); (d) limestone plains with deeper soils (land types 7 and 9—excluding the two land systems mentioned in Table 23); (e) coastal landforms (land types 8, 13 and 14) or; (f) salt lakes (land type 15).

Comparison with other regional surveys

Table 24 summarises the resource condition in the survey area compared with previous rangeland survey areas. The resource condition classes were determined by combining the perennial vegetation condition rating and extent of accelerated soil erosion for each traverse assessment, using the matrix shown in Table 25. As the resource condition of different survey areas has changed since the survey it is not

Table 23 **Summary of land systems with severely degraded and eroded areas in the form of piospheres**

Land surface type	Land type	Description and land systems
Limestone plains with deeper soil than deflated limestone plains	7	**Level to gently undulating calcareous plains with eucalypt–melaleuca–myall woodland and chenopod shrubland** Land system—Thampanna.
	9	**Recrystallised (weathered) limestone plains with myall woodland and bluebush shrubland or bindii grassland** Land system—Kanandah.
Deflated limestone plains	10	**Deflated limestone plains with myall woodland and chenopod shrubland or bindii grassland** Land system—Shakehole.
	11	**Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland** Land systems—Arubiddy, Balgair, Gafa, Kybo, Moonera and Nightshade.
	12	**Deflated limestone plains with regular karst drainage depressions (dongas) surrounded by bindii grassland** Land systems—Bullseye, Kinclaven and Nurina.

statistically valid to make direct comparisons between surveys. Survey areas differ in the amount of pastoral leasehold land, Unallocated Crown Land and conservation reserves they contain which significantly influences condition rating. For this reason the total of severely degraded and eroded areas (as mapped) and total average of the resource condition classes from all surveys are not presented.

As previously mentioned, some areas are considered to be in an irreversible state of transition; such areas were assessed on their present form rather than speculating on their former state. This inevitably has resulted in a greater proportion of area considered in better condition than had the former poor condition state been assessed. A significant proportion of ratings occurred in areas largely unaffected by grazing, or in undeveloped or only very recently developed areas, such as eucalypt woodlands.

Note: Information presented in Table 24 should not be used as an indication of the present day pasture resource condition of Western Australian pastoral lands. The condition of pasture resources has altered from previous surveys.

Condition of land systems

The average number of traverse assessments for soil and vegetation condition per land system is 152; however this varies from zero to 1045. Table 21 in the Land systems chapter shows the sampling intensity for each system. Baxter, Bilbunya, Carlisle, Colville, Oasis, Ponton, Rabbit and Wylie were not traversed. Delisser and Lefroy were assessed less than five times; for these, sampling intensity is too low for reasonable comparison with other systems. Table 26 shows the condition for each land system based on traverse assessments.

Table 24 **Resource condition summaries for regional rangeland surveys**

Region surveyed (year survey commenced)	Total area (km²)	No. of traverse assessments	Severely degraded and eroded area (as mapped)		Resource condition classes (% of traverse assessments)		
			km²	%	Good	Fair	Poor
Gascoyne (1969)	63 400	2 426	1 205*	1.9*	32	53	15
West Kimberley (1972)	89 600	4 532	2 000*	2.2*	20	50	30
Eastern Nullarbor (1974)	47 400	1 273	0	0	50	10	40
Ashburton (1976)	93 600	8 608	534	0.6	50	34	16
Carnarvon Basin (1980)	74 500	10 952	647	0.9	45	32	23
Murchison (1985)	88 360	13 441	1 560	1.8	21	37	42
Roebourne Plains (1987)	10 216	1 172	233	2.3	51	27	22
North-eastern Goldfields (1988)	100 570	10 470	452	0.4	39	32	29
Sandstone–Yalgoo–Paynes Find (1992)	94 710	9 435	145	0.2	45	32	23
Pilbara (1995)	181 723	12 448	310	0.2	77	11	12
Lower Murchison (2002)	13 039	836	9	0.1	78	9	13
Western Nullarbor (2005)	118 358^	6 997	0	0	66	26	8
All areas surveyed	928 076^^	82 590					

* Not mapped, estimate only.
^ Includes 47 400 km² from 1974 eastern Nullarbor survey.
^^ Excludes 47 400 km² from 1974 eastern Nullarbor survey.

Table 25 **Matrix used to determine resource condition classes good, fair and poor based on combined vegetation condition and extent of soil erosion scores**

Extent of soil erosion	Condition of vegetation		
	Very good or Good	Fair	Poor or Very poor
Nil	**Good** (1)	**Fair** (2)	**Poor** (3)
Slight or Minor	**Good** (1)	**Fair** (2)	**Poor** (3)
Moderate	**Fair** (2)	**Poor** (3)	**Poor** (3)
Severe or Extreme	**Poor** (3)	**Poor** (3)	**Poor** (3)

Table 26 **Range condition based on vegetation plus soil condition (derived from traverse assessments)**

Land system	No. of assessments	Good or very good	Fair	Poor or very poor
Arubiddy	210	143	57	10
Balgair	195	130	56	9
Balladonia	31	18	9	4
Baxter	0	–	–	–
Bilbunya	0	–	–	–
Boonderoo	14	14	0	0
Bullseye	15	4	6	5
Caiguna	201	184	14	3
Carlisle	0	–	–	–
Chowilla	21	12	8	1
Colville	0	–	–	–
Culver	48	45	2	1
Damper	35	35	0	0
Delisser	2	2	0	0
Gafa	138	95	38	5
Gumbelt	381	363	14	4
Haig	115	74	35	6
Jubilee	8	0	7	1
Kanandah	223	62	129	32
Kinclaven	542	130	316	96
Kitchener	56	4	41	11
Koonjarra	186	145	33	8
Kyarra	62	43	11	8
Kybo	174	103	48	23
Lefroy	3	3	0	0
Lowry	16	11	4	1
Moodini	51	32	16	3
Moonera	319	233	69	17
Moopina	7	6	1	0
Morris	49	43	6	0
Mundrabilla	127	115	11	1
Nanambinia	114	73	32	9
Naretha	139	42	80	17
Nightshade	286	221	54	11
Nurina	204	106	86	12
Nyanga	1045	849	161	35
Oasis	0	–	–	–
Pondana	188	89	67	32
Ponton	0	–	–	–
Rabbit	0	–	–	–
Reid	38	32	3	3
Roe	64	61	2	1
Seemore	15	9	6	0
Shakehole	355	212	92	51
Skink	85	67	16	2
Thampanna	723	348	227	148
Toolinna	55	54	1	0
Vanesk	64	48	13	3
Virginia	144	124	18	2
Weebubbie	14	11	3	0
Woorlba	163	129	23	11
Wurrengoodyea	23	23	0	0
Wylie	0	–	–	–
Zanthus	49	49	0	0
	6997	4596	1815	586

The average resource condition score for each of the land systems which were sufficiently traversed was derived as follows: Average resource condition score = [(% of traverse records in good resource condition x 1) + (% of traverse records in fair resource condition x 2) + (% of traverse records in poor condition x 3)] ÷ 100.

Table 27 shows these land systems ranked according to their average resource condition score.

Table 27 **Land systems ranked according to resource condition score**

Land system	No. of. assessments	Resource condition			Average resource* condition score
		% Good (1)	% Fair (2)	% Poor (3)	
Boonderoo	14	100	0	0	1.00
Damper	35	100	0	0	1.00
Wurrengoodyea	23	100	0	0	1.00
Zanthus	49	100	0	0	1.00
Toolinna	55	98	2	0	1.02
Gumbelt	381	95	4	1	1.06
Roe	64	95	3	2	1.07
Culver	48	94	4	2	1.08
Caiguna	201	91	7	2	1.11
Mundrabilla	127	90	9	1	1.11
Morris	49	88	12	0	1.12
Moopina	7	86	14	0	1.14
Virginia	144	86	12	2	1.16
Weebubbie	14	79	21	0	1.20
Nyanga	1045	81	15	4	1.23
Skink	85	79	19	2	1.23
Reid	38	84	8	8	1.24
Koonjarra	186	78	18	4	1.26
Nightshade	286	77	19	4	1.27
Woorlba	163	79	14	7	1.28
Vanesk	64	75	20	5	1.30
Moonera	319	73	22	5	1.32
Gafa	138	69	27	4	1.35
Arubiddy	210	68	27	5	1.37
Lowry	16	69	25	6	1.37
Balgair	195	66	29	5	1.39
Seemore	15	60	40	0	1.40
Haig	115	64	30	6	1.42
Moodini	51	63	31	6	1.43
Kyarra	62	69	18	13	1.44
Nanambinia	114	64	28	8	1.44
Chowilla	21	57	38	5	1.48
Nurina	204	52	42	6	1.54
Kybo	174	59	28	13	1.54
Shakehole	355	60	26	14	1.54
Balladonia	31	58	29	13	1.55
Pondana	188	47	36	17	1.70
Thampanna	723	48	31	21	1.73
Naretha	139	30	58	12	1.82
Kanandah	223	28	58	14	1.88
Kinclaven	542	24	58	18	1.94
Bullseye	15	27	40	33	2.06
Kitchener	56	7	73	20	2.13
Jubilee	8	0	87	13	2.13

* Note where 1 = good resource condition, 2 = fair resource condition and 3 = poor resource condition.

Of the 44 land systems sufficiently traversed, 32 were closest to good resource condition (average score between 1.0 and 1.5) and 12 were closest to fair condition (average score between 1.5 and 2.5). Of these 12 land systems, all except Jubilee have areas associated with historical Nullarbor pastoral operations. The difficulty in finding reliable sources of good stock water dictated where early infrastructure development occurred. During dry periods stock concentrate in specific areas and early pastoralists had limited options for moving stock to areas of better feed or to rest country from grazing.

Condition of land systems according to pastoral potential

Land systems were grouped according to their pastoral potential (Table 28). This is discussed in the Station reports chapter. The average resource condition score for the groups is summarised in Table 29. All pastoral potential groups are close to good condition. The good condition of much of the Nullarbor region is possibly a reflection of the short pastoral history in comparison to the rest of Western Australia's pastoral areas, with large areas still relatively undeveloped. The difficulty in obtaining reliable or good quality water has also reduced the extent of pastoral impact. Degraded piospheres around water points are a common feature but away from these degraded areas the country tends to be in good condition.

As in other rangeland areas of Western Australia the very low and low pastoral potential groups were in best condition. They consist of land systems characterised by coastal cliffs, sandy soils either sparsely vegetated or dominated by low mallee and/or heath or spinifex, hyper-saline drainage foci and calcrete plains dominated by annual pasture. Generally livestock do not preferentially graze these landscapes or they occur within Unallocated Crown Land far from pastoral leases.

The good resource condition of moderately high and moderate pastoral potential groups reflects the general resilience of the dominant vegetation types of these land systems, such as the 'Pearl bluebush low shrubland', 'Open bindii grassland' or 'Speargrass, wallaby grass open grassland'. These extensive vegetation types are relatively resilient in grazing systems where stocking rates (demand) match seasonal feed on offer (supply).

However, within these land systems it is generally the smaller land units, such as karst depressions, which are more productive. Karst depressions are preferentially grazed and frequently include water points. These commonly support donga groves or saltbush communities which are more sensitive to grazing pressure and have fragile soils which are inherently susceptible to erosion.

In some instances the overall good condition of the more uniform vegetation types (e.g. ungrazed pearl bluebush communities) masks declining condition within more sensitive areas. The continual decline of these sensitive areas will lead to a general impoverishment and habitat simplification of the Nullarbor landscape. This trend will result in pastoral production systems being self-limiting.

Table 28 **Land systems in each pastoral potential group**

Pastoral potential	Land systems			
Moderately high	Arubiddy Balgair Chowilla Gafa Kanandah Koonjarra	Kybo Lefroy Moodini Moonera Moopina Mundrabilla	Nanambinia Thampanna Pondana Reid Seemore Shakehole	Vanesk Virginia Weebubbie Woorlba
Moderate	Balladonia Boonderoo Bullseye Caiguna Carlisle Colville	Gumbelt Haig Jubilee Kinclaven Kitchener Kyarra	Lowry Morris Naretha Nightshade Nurina Nyanga	Oasis Roe Skink
Low	Culver Damper	Ponton Rabbit	Toolinna Wurrengoodyea	
Very low	Baxter Bilbunya	Delisser	Wylie	Zanthus

Table 29 **Average resource condition scores for land systems grouped according to pastoral potential (derived from traverse assessments)**

Pastoral potential	Area (km^2)	No. of assessments	Resource condition (%)			Average resource condition score
			Good (1)	Fair (2)	Poor (3)	
Moderately high	34 267	3 483	64	26	10	1.36
Moderate	78 336	3 350	66	27	7	1.41
Low	2 642	90	99	1	0	1.01
Very low	3 099	74	100	0	0	1.00
Total	118 344*	6 997	66	26	8	1.34

* This summary does not include the 14 km^2 of lake bed, which has no pastoral potential.

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Resource management

PA Waddell

Managing ecological disturbances

In the Nullarbor region, pastoralism forms the major land use in terms of area. Whilst the condition and ecological integrity of landscapes is significantly affected by grazing many other factors impact at a local to broadscale level. Such factors include fire, seasonal variation, rabbit plagues, weed invasions, infrastructure placement (i.e. roads, tracks, the Trans-Australian Railway line) and to a minor degree, mining activities. As well, there is natural variation within vegetation communities which needs to be taken into account when assessing rangelands for any particular use.

Salient factors responsible for influencing the ecology of Nullarbor landscapes include fire, rabbit plagues and pastoralism, including increased kangaroo numbers resulting from increased water supply (Gillieson, Wallbrink & Cochrane 1996; Landsberg et al. 1997). In combination with arid climatic conditions these factors have contributed to extensive alteration to Nullarbor vegetation communities.

This chapter discusses some management implications and considerations for the maintenance and improvement of managed Nullarbor habitats.

Fire

Bushfires are a natural feature of the Nullarbor. The landscape is especially susceptible after favourable seasonal conditions have encouraged ephemeral growth. Grasses such as *Austrostipa scabra* (speargrass) can produce volatile fuel loads after winters of above-average rainfall. This growth, when dry, can readily carry fire in the following summer.

Lightning strikes during summer thunderstorms can start fires. Though Aboriginal people occupied the areas near the coast, the Roe and Israelite plains, and the Great Victoria Desert they tended to avoid the treeless portion of the Nullarbor Plain (Tindale 1940; Gillieson 1993). Burning was probably initiated near the coast but the extent elsewhere on the Bunda Plateau is unknown (Wright 1971). Beard (1975) states that 'the Nullarbor Plain seems always to have been substantially fire free since a fire would only travel following a good season, when there is a dense growth of tall grass. Occurrence of old fire-tender tree species of *Acacia* on the plain (*A. papyrocarpa, A. aneura*) indicates freedom from fire'. However, since European settlement fire frequency on the Nullarbor has increased, particularly following the development of the Trans-Australian Railway line and the use of steam trains, and in more recent times with accidental and deliberate roadside fires (Davey 1978; Gillieson 1993; Gillieson, Wallbrink & Cochrane 1996).

The composition of many of the principal vegetation communities has been adversely affected by the increased fire frequency. Chenopod shrubland is not adapted to regular fires. The degree of damage caused by a fire is also linked with the fire temperature. A cool, moderate burn may not kill *Maireana sedifolia* (pearl bluebush), though its recovery is slow, however *Atriplex vesicaria* (bladder saltbush) will not withstand any type of fire (Fitzgerald 1976; Graetz & Wilson 1984). After fire chenopod regeneration is by seed alone; if grazing pressure is not reduced to allow post-fire recovery there is a risk of completely exhausting the seed bank (Hodgkinson & Griffin 1982).

Mitchell, McCarthy and Hacker (1979) describe how before European settlement and rabbit plagues the vegetation was thought to exist as a mosaic pattern in a state of cyclic equilibrium alternating between chenopod shrublands and grass dominated patches. The mosaic pattern occurred as a patchwork of burnt and unburnt areas in response to intermittent fires burning non-uniformly. Summer fires occurring after periods of abundant seasonal rainfall can eliminate shrubs. This was observed in the Kalgoorlie–Nullarbor districts following severe fires in 1974–75 when extensive shrub and tree communities were destroyed (Fitzgerald 1976; Lay 1976). The period required for shrub regeneration is likely to be long since eliminated shrubs are replaced by faster growing grasses, rendering burnt patches more susceptible to subsequent burning. Though the grass phase tends to be maintained once established, Mitchell, McCarthy and Hacker (1979) conclude that shrub recolonisation of burnt areas eventually occurs, though at a time scale determined by the seasonal conditions and burning history of the area. However, this cyclic state of vegetation mosaic in various stages of

regeneration became disrupted with the introduction of rabbits, later combined with an increased fire frequency and in some cases finally compounded by livestock grazing. The various states and transitions of the Nullarbor Plain chenopod shrubland have been summarised by Gillieson, Wallbrink and Cochrane (1996) (Figure 30).

There has also been extensive alteration to the woodland communities that border the Nullarbor Plain. The encroachment of grassland into woodland margins has increased the fire susceptibility of these habitats. On the Hampton Tableland areas of myall and mallee woodland on limestone hummocks (low rises) have become surrounded by grassland in the depression corridors. Similar scenarios have occurred on the land systems bordering the Nyanga Plain. In some instances fire has completely burnt out the perennial vegetation on the rises. Grazing and subsequent fires have altered the area, tending to favour the expansion of grassland. Fire sensitive myall have been killed. Grasses growing at the base of myall lead to the trunk being burnt out with the upper branches lying splayed on the ground.

Grazing by stock and rabbits eliminates seedling germination and the seed bank becomes exhausted. In some instances the only evidence of past woodland is dead branches on the ground. After the next favourable season when grasses are again prolific if a fire occurs through the area all woody debris is consumed, removing visual evidence the area once supported any woodland at all. In some areas on the Hampton Tableland fire tolerant mallees such as *Eucalyptus yalatensis* (yalata mallee) have also been eliminated due to intense or frequent fires. The evidence of these former wooded habitats comes from charred roots in hollows surrounded by up-ended root-heaved rocks.

Pastoral development has provided a means to manage fire. The accessibility through tracks and fencelines allowed pastoralists the opportunity to fight fires where before they had no way of getting to the fire. Nullarbor pastoralists comment that if they can get to a fire early, whilst it is still a narrow finger, before a wind change turns the fire into a front they have a chance to extinguish it. Infrastructure development has also provided pastoralists with the

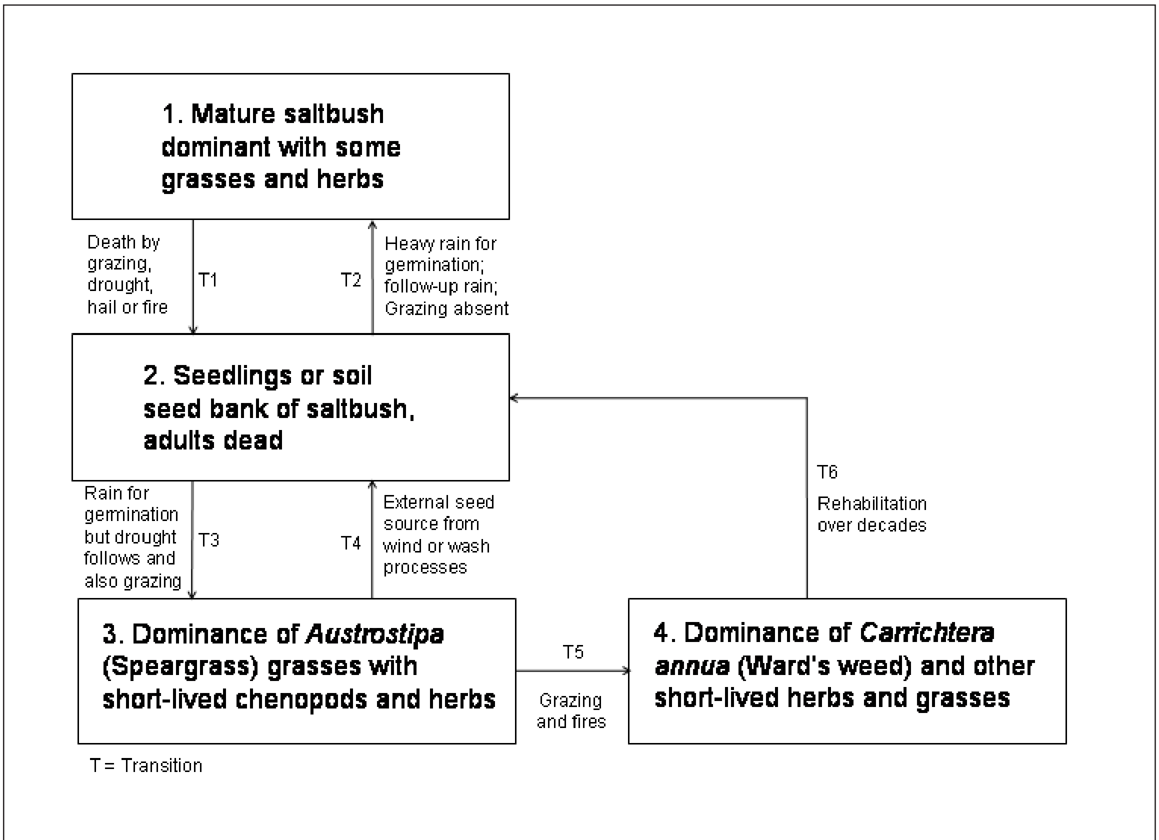


Figure 30 **State and transition model of the dynamics of the Nullarbor Plain chenopod shrubland (Gillieson, Wallbrink & Cochrane 1996); modified from a general model by Westoby, Walker and Noy-Meir (1989).**

Fire sensitive myall is killed when its trunk base is burnt. Upper branches remain splayed around the trunk base. Dead limbs accumulate leaf litter creating an improved microhabitat for other plants. This process provides an increased fuel source for subsequent fires that will eliminate any evidence of the old tree once burnt. Recruitment is reduced through grazing.

*To accommodate growing mallee roots rocks are displaced. Even fire tolerant yalata mallee (*Eucalyptus yalatensis*) can be killed by frequent or intense fires. Subsequent fires consume all wooded material on the ground. Where mallees have been eliminated or reduced it is possible to see the past extent of the woodland by charred roots in hollows with root-heaved rocks.*

option to amalgamate paddock flocks in exceptionally good seasons to intensely graze the dense swards of speargrass in selected paddocks in an attempt to reduce the threat of extensive fires.

Rabbits

The various condition statements in the previous chapter largely assume that the causal agent for any decline from good or optimal condition is grazing pressure. In plant communities that are highly preferred by herbivores this is demonstrably the case. Rabbits are not reliant on surface water sources and so can have huge, widespread impacts (Wilson et al. 1992). Earlier rabbit plagues warrant particular mention due to the extent their grazing effect had in altering the condition and state of Nullarbor vegetation communities. The alteration of large tracts of land from chenopod shrubland to bindii grassland through the Nullarbor and Nyanga Plains is considered to be largely a result of excessive rabbit populations in conjunction with increased fire frequency.

Rabbits (*Oryctolagus cuniculus*) were introduced into Australia in 1859 and by 1896 were present in Eucla (Mason 1897). By the 1940s rabbits were so abundant as to support a commercial trade. Since then rabbit numbers have fluctuated with seasonal conditions. The release of the viruses myxomatosis (1954, 1966) and rabbit calicivirus (1995) reduced numbers significantly though their numbers continue to fluctuate sporadically across the region (Nullarbor pastoralists' 2006 pers. com.).

Rabbits are well adapted to arid and semi-arid areas. Past Nullarbor biological surveys (Beard 1975; Mitchell, McCarthy & Hacker 1979; McKenzie & Robinson 1987) have stated the extent to which rabbits are responsible for the declining condition of the Nullarbor vegetation. Gilfillan (1999) lists how rabbit foraging has reduced the recruitment of trees such as *Acacia papyrocarpa, A. burkittii* and *A. oswaldii* by eating seedlings, and decreased palatable herbs and grasses leading to an increase in unpalatable annuals and subshrubs. The reduced ground cover results in increased erosion.

Recovery of plant populations has been severely impeded by rabbits after fire or extended dry seasons. Deterioration of perennial vegetation communities has resulted with changes in species composition through increasing the annual component, particularly grasses, invariably resulting in increased susceptibility to fire. Beard (1975) stated that even if the rabbit population permanently decreased degraded areas of the Nullarbor were unlikely to regenerate.

Viruses such as rabbit calicivirus and myxomatosis have been successful in reducing rabbit numbers. However there is the possibility that rabbit populations may again build up as individuals within populations gain resistance to rabbit calicivirus. Long-term rabbit control has proven more successful when a combination of biological control and physical methods (i.e. warren ripping or blasting) are used (Edwards & Dobbie 1999).

Pastoralism

Pastoralism began in the south of the Western Australian Nullarbor region in the late 1870s and in the central and northern portion in the 1960s. The Nullarbor pastoral industry has developed despite long seasons of aridity and extreme temperatures with unreliable rainfall and a landscape with unstable shallow soils that support mainly perennial shrub vegetation constrained by water availability. Underground water availability and quality are major limiting factors to pastoral development.

The effects of grazing on the palatable components of the vegetation and on soil status provide the basis for determination of condition assessments for rangelands under pastoral use. Extensive literature on the relative impact of different grazing systems throughout the world, suggests that deriving an appropriate stocking rate in alignment with the available utilisable forage is the major factor to sustainable pastoral productivity in the management of semi-arid and arid environments. Rangeland forage availability is spatially heterogeneous and variable over time, therefore carrying capacity will vary correspondingly and stocking rates should be flexible in response to seasonal forage availability and existing conditions rather than being fixed.

Throughout the survey area the environmental consequences of grazing were obvious. Most noticeable effects included a decline in the number and vigour of palatable plants in preferred communities, fenceline effects between

paddocks and piospheres around water points resulting in reduced biomass, diversity and soil loss. Accelerated erosion is closely associated with sites of artificial water supplies due to the direct (trampling) and indirect (loss of vegetative cover) effects of excessive grazing (Lange 1969; Gillieson, Cochrane & Murray 1994; Gillieson, Wallbrink & Cochrane 1996).

Donga fenceline effect. The grazed side is dominated by seasonally dependent, unpalatable annuals with a significant reduction in palatable shrubs and grasses. The heavy utilisation of the grazed side left the surface compacted and flat. The ungrazed side has a good diversity of shrubs and palatable grasses; the donga surface remained irregular due to gilgai processes.

Heavy grazing by livestock alters the species composition of the vegetation, favouring the establishment of unpalatable species with the resulting loss of species richness, density and cover that rarely equals that of the previous vegetation community. Through competition for water perennial chenopod shrubland suppresses herbage species, however the loss of perennial chenopods is followed by a substantial increase in annual species and weeds (Graetz & Wilson 1984). Near water points the soil surface has often become so degraded that soil crusts are absent and the surface is compacted. The only plants are seasonally dependent annuals or subshrubs and for dongas there is limited or no recruitment of trees.

Seasonal conditions, temperature and the salt content of feed and water influence the volume of water stock require, in turn determining the piosphere extent surrounding water points (Lange 1969; Pringle & Landsberg 2003). When stock graze on saline feed and drink saline water (> 5000 ppm), regularly the case on the Nullarbor, the daily water requirement is greatly increased. The longer stock stay near water points, affected by their inability to travel before needing to return, the level of degradation around water points expands (Tongway, Sparrow & Friedel 2003). Ongoing erosion of such areas can be reduced, and the dietary intake for stock improved, by relocating water points away from their existing locations (Burnside, Williams & Curry 1990).

Relocating existing or new water points should consider resilient land surfaces such as stony rises or plains rather than fragile surfaces such as claypans, drainage depressions and dongas. Stony surfaces offer more resistance to trampling.

Overlapping grazing radii of closely spaced water points leads to continuous grazing as herbivores can spend more time in favoured areas. This leads to the deterioration of preferentially grazed habitats such as donga groves, tree-based clumps and drainage focus shrublands. New water point installation should consider grazing radii and distance from other water points where radii do not overlap.

Stocking rates need to be maintained within utilisable forage availability to prevent landscape degradation. Permanent monitoring systems provide the systematic means of making informative management decisions. Monitoring sites provide visual evidence which can be reassessed and long-term effects of management actions can be demonstrated.

Maintaining floristic diversity and heterogeneity

With climate models predicting the likelihood of increasingly hotter and drier years the productivity of pastoral operations will become more reliant on perennial plants. Chenopod shrublands and bindii grasslands dominate the vast, open Nullarbor Plain. Within the Nullarbor landscape chenopod shrubs provide ‘long-lived resilient structures’, which contribute minimally to production and only during dry seasons (Graetz & Wilson 1984). The loss of chenopod shrubs leads to either an increase in annual species, unpalatable shrubs or exposes the soil surface to erosion. Biodiversity is primarily threatened by feral herbivores and domestic stock which eat out critical habitats and the dry season refugia (Morton et al. 1995).

The majority of the Nullarbor Plain is geomorphically and floristically finely patterned. The limited floristic diversity renders the Nullarbor extremely seasonally dependent for pastoral purposes. The irreversible transition of extensive areas of chenopod shrubland and lightly wooded myall chenopod woodland into open bindii grassland has further simplified Nullarbor landscapes. The long-term carrying capacity of ecosystems is significantly reduced by degradation of the perennial vegetation communities as systems increasingly lose the ability to support grazing animals during dry periods. Around water points grazing is strongly patterned with obvious piospheres due to overgrazing (Cridland & Stafford Smith 1993). However, away from water points high stock numbers carried through dry seasons are subtly contributing to the broad homogenisation and simplification of the Nullarbor region as the seed store of palatable flora is reduced, with the exception of *Austrostipa scabra* (speargrass) (Hunt 2001).

Much of the floristic diversity in the landscape is associated with scattered fertile patches within greater resource-poor areas. Fertile patches commonly are based around trees restricted to dongas where they form groves or as isolated stands on the Nullarbor Plain. The scenario is similar for the Nyanga Plain and the Hampton Tableland. On the Nyanga Plain *Acacia papyrocarpa* (myall) woodlands occur over chenopod or bindii understorey; within the myall woodlands tree-based clumps develop into groves around *Alectryon oleifolius* (mingah), *Eremophila longifolia* (berrigan), *Myoporum platycarpum* (sugarwood), *Santalum acuminatum* (quandong) and *S. spicatum* (sandalwood). On the Hampton Tableland tree-based clumps develop around such trees as *Eucalyptus gracilis* (yorrell), *E. oleosa* subsp. *oleosa* (giant mallee) and *Eucalyptus yalatensis* (yalata mallee). In both physiographic regions tree-based clumps also develop under myall and *Casuarina pauper* (black oak) on convexities. Morton et al. (1995) discussed the value of such fertile patches, especially during extended dry seasons, and the threat posed by introduced herbivores. Animal activity will always be focused on fertile patches, however their small size and patchy distribution create problems for their management in isolation from the surrounding large expanses of less fertile country.

Tree-based clumps

Tree habitats are important in influencing ecosystem processes and patterns within arid environments (Slatyer 1975). They have a key role in forming the nucleus of 'tree-based clumps' or 'perch-base thickets' (Tinley 2005). Tree-based clumps refer to the growth of bird dispersed bush thickets typically around and beneath the canopy of 'perch' trees and large shrubs, but also on and around rock outcrops and termitaria. Tinley (2005) and Russell (2007) list the specific benefits provided by bush clumps and thickets as enhanced:

- plant species richness
- landscape and habitat structural complexity
- biomass productivity
- source of seed (seed bank)
- connectivity of habitat patches for birds and small mammals
- resistance and resilience to extended dry periods.

Woody plants with brightly coloured, fleshy fruits or arillate seeds attractive to birds are predominant components of bush clumps. The seed dispersal process by frugivorous birds of berry-bearing or fleshy-fruited plants is critical to their formation. Greater seed dispersal under trees results in higher shrub densities within the sub-canopy patch compared to the interpatch. Primarily due to perch tree utilisation by frugivorous birds results in higher dissemination of bird droppings below tree canopies (Ridley 1930; Tester et al. 1987). The typical components of the bird-formed bush-clump in the Nullarbor region include: *Acacia tetragonophylla* (curara), *Chenopodium curvispicatum, Enchylaena tomentosa* (ruby saltbush), *Eremophila longifolia*, *Lycium australe* (water bush), *Nitraria billardierei* (nitre bush), *Pimelea microcephala*, *Pittosporum angustifolium* (native willow), *Rhagodia* spp. and *Scaevola spinescens* (currant bush).

Tree-based clumps provide favourable growing conditions beneath canopies, leading to the establishment of refugia for plants and animals during dry periods; improving the carrying capacity of arid landscapes (Slatyer 1962, 1975; Tester et al. 1987; Garner & Steinberger 1988; Tongway & Ludwig 1990). Greater plant diversity tends to occur within bush clumps. Shelter and the shade microhabitat provided below the sub-canopy advantage plants

compared to unsheltered seedlings attempting establishment in exposed interpatches where soil evaporation rates are higher (Tester et al. 1987).

Bush clumps are important in patch-interpatch water and nutrient capture and cycling processes (Ludwig & Tongway 1995). Trees accumulate branch and leaf litter around their bases. Such debris protects the tree base area from erosion by obstructing ground surface winds and water sheet flow. In this way wind and water dispersed material, (i.e. soil, leaf litter, seeds, animal scats, general debris) accumulate around the tree base. This process maintains and enriches local soil with nutrients particularly organic carbon and nitrogen, increases microbial activity facilitating nutrient cycling and contributes to greater soil moisture (Garner & Steinberger 1988; Tongway & Ludwig 1990); creating improved conditions for seedling germination and establishment. As tree-based clumps develop, progressive successional tendency results in enhanced changes of cover, pattern and structure, function, composition, productivity and resilience (Tinley 2005), until a disturbance reverses the process e.g. fire, overgrazing.

In arid landscapes perch-based thickets also provide refuge for palatable plants from herbivores. Many plants and grasses found within bush clumps are palatable. During dry periods herbivores are increasingly dependent on browse for survival. Palatable plants in the open are selected first, but as dry conditions persist or where grazing pressure is intense then less palatable plants will also be consumed. Tree-based clumps provide herbivores with a source of browse which remained sheltered whilst exposed plants are dying from heat stress or overgrazing, and they offer a potential refuge to palatable plants from overgrazing. Importantly they are core habitats for seed redispersal after disturbance events. Seed dispersal by birds is an essential ecological process in maintaining species diversity and the structuring of vegetation within landscapes (Kollmann 2000). Tree-based clumps provide a measure of landscape health, with the composition and structure of clumps or thickets an indication of grazing pressure and overall rangeland condition. (See tree-based clump condition monitoring photographic guide.)

*Isolated myall (*Acacia papyrocarpa*) tree-based clump on the edge of the Nullarbor Plain.*

*Curara (*Acacia tetragonophylla*) and native willow (*Pittosporum angustifolium*) within a donga.*

*Yalata mallee (*Eucalyptus yalatensis*) on the Hampton Tableland.*

The trees pictured above all support Chenopodium curvispicatum *and ruby saltbush (*Enchylaena tomentosa*) in areas dominated by seasonally dependent, short-lived plants. The tree-based clumps provide the only suitable forage reserve during dry periods and the major source of protein which enables ruminants to utilise remnant cellulose on the open plain.*

The repeated browsing of foliage and bark, breaking of limbs and eventually the central crown can ultimately kill individual trees. Heavy browsing of tree-based clumps by large herbivores can eliminate a browse source from an area through the development of high browse lines out of reach of younger or other herbivore species. The continual physical breakdown of a tree leading to its eventual death through loss of vigour has much greater implications to the local ecosystem than just the death of the tree. The loss of tree-based clump nuclei results in reduced diversity of habitat, species composition and carrying capacity. In an open plains environment the loss of shade also impacts directly on animal condition.

Tree-based clumps can be used as valuable early warning indicators of landscape health. Monitoring sites in these preferentially grazed habitats provide an effective way to monitor range condition. Particularly if the linkage between the condition of smaller, sensitive focus areas and the condition of the surrounding larger landscape units can be established. Monitoring sites may also be used to assess utilisation levels of key indicator species.

Fenced exclosures infrequently distributed would preserve these important habitats and serve to maintain their ecological role as a seed source of palatable perennial shrubs within the surrounding landscape.

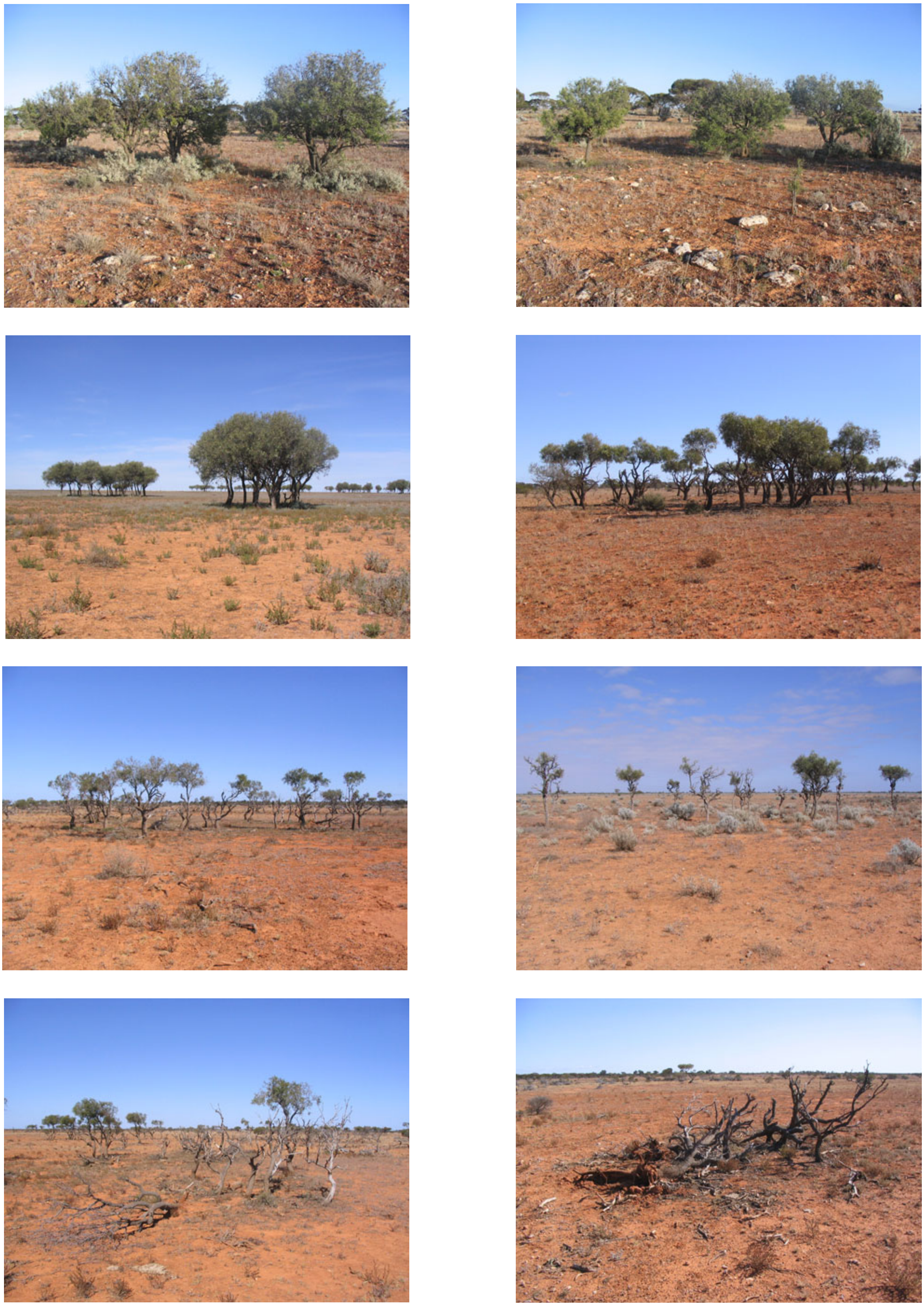
Tree-based clump condition monitoring photographic guide

*Browsing sequence for curara (*Acacia tetragonophylla*) and native willow (*Pittosporum angustifolium*). Dense bush clumps exist under the canopy of nucleus trees or tall shrubs. Grazing pressure initially opens up the bush clump understorey with continual grazing eliminating all shrubs. Excessive browsing begins to break down the nucleus tree through livestock seeking shade and feed.*

*Good condition yalata mallee (*Eucalyptus yalatensis*) tree-based clumps*

*Poor condition yalata mallee (*Eucalyptus yalatensis*) tree-based clumps*

*Good to poor condition native willow (*Pittosporum angustifolium*) tree-based clumps*



*Good to poor condition mingah or bullock bush (*Alectryon oleifolius*) tree-based clumps*

*High browse lines as seen in these mingah trees (*Alectryon oleifolius*) have reduced the potential forage availability making this source of browse out of reach of other herbivores or younger individuals.*

Donga groves

Dongas are predominantly found in the north of the survey area. They are rounded, shallow, closed depressions below the level of the surrounding stony plain. They commonly have flat clay floors up to several hundred metres across with gently sloped margins, so the whole depression may be up to 2 km in diameter. The clay floors of dongas often contain gilgai or crabhole soil structure with irregular surfaces.

Vegetation associated with dongas regularly consists of a sparse tree cover or clumps of small groves over a variety of perennial shrubs, annual herbs and grasses. In the pastoral areas water point location is commonly associated with dongas to the detriment of the associated vegetation. These areas have significant regional ecological value and are important in 'arid proofing' the northern Nullarbor as a source of browse during dry periods. Deterioration in donga grove condition is occurring within the grazing radii of water points as continuous grazing breaks down bush clumps and reduces the floristic diversity. When water points are situated in dongas herbivores are less inclined to browse elsewhere and so spend more time there. Animals preferentially frequent these habitats for food and shelter. Mature trees and shrubs become browsed out of reach and there is no juvenile recruitment in the lower stratum. When these mature trees eventually die, or are killed, there are no established younger trees to replace them. This reduces the ecological value of dongas in their ability to provide habitat and to support grazing animals through dry periods. The sustainable benefits donga groves can offer to local ecosystems will be lost.

The centripetal drainage of the surrounding landscape into dongas causes sediment accumulation and improves the soil moisture of such land units. This provides favourable conditions for plant growth, supporting a diverse variety of perennial trees and shrubs and annual herbs. Donga groves provide a valuable source of browse and support annual plant growth for longer than the surrounding stony limestone plains. They offer shelter to animals and other plants, providing important habitat refugia within the exposed and arid surroundings of the plain.

The structure and diversity of donga groves provide an indication of their condition. In good condition dongas have an abundance of the palatable grasses *Eragrostis dielsii* and *E. setifolia* surrounding compact groves of tree-based clumps. These are composed of the same array of berry and arillate woody plants dispersed by frugivorous birds mentioned previously.

In deteriorating conditions there is an increasing abundance of *Acacia tetragonophylla* (curara) associated with a decline in the density of the understorey. Prominent browse lines develop as a result of grazing. The replacement of grasses by short-lived herbs leads to soil loss as the donga becomes more open and exposed to wind erosion (Gillieson, Wallbring & Cochrane 1996). In poor condition dongas can be reduced to sparse stands of aged trees surrounded by undesirable annuals such as *Carrichtera annua* (Ward's weed), *Salsola tragus* (roly poly), *Salvia verbenaca* (introduced sage) and declared weeds such as *Carthamus lanatus* (saffron thistle), *Emex australis* (doublegee) and *Xanthium spinosum* (Bathurst burr). The physical breakdown and deterioration of donga groves leads to a reduction in the overall carrying capacity of the simplified landscape as it loses its ability to support herbivores during medium to long-term dry periods.

Due to the fragility of donga vegetation communities and their ecological importance consideration should be given to establishing new water points on the resilient stony surfaced plain rather than directly in the donga. This would reduce the time herbivores spend in dongas; lessening the intensity of grazing and

Dongas in good condition. Diverse, dense grass coverage with good bush clump development; near optimal species composition.

Dongas in declining condition. Obvious reductions in palatable species and heavy browse lines evident.

Dongas in poor condition. Few palatable species remain and cover is greatly reduced. Excessive grazing has led to tall shrubs and trees being broken down.

trampling within the donga and assisting in preserving vegetation diversity for dry periods when there is a shortage of suitable browse on the plain. During favourable seasons when the plains have an abundance of feed donga habitats can receive a respite from intense grazing, which is less likely when a permanent water point is present.

Fixed point photographic monitoring sites in dongas within the grazing radius of permanent water sources, as well as in areas remote from water, provide an effective method to monitor range condition of these habitats.

Strategic fencing and exclosures

As it is not realistic to fence off all areas of critical habitat and fertile patches land managers need to prioritise their actions. Morton et al. (1995) suggest a hierarchy of reserve units which serve to protect important areas during critical periods, while making other areas available at other times. Within lands under pastoral lease they recommend the following principles:

- Identify reserve blocks of critical, core habitats purely for conservation.
- Identify important patches in the remaining country requiring special management at critical times to ensure their preservation and ecological function within the landscape.
- Sustainable land management practices should be encouraged across the remaining country.

Numerous land systems, habitat types and declared rare or priority flora species are not represented or are poorly represented on lands set aside for nature conservation within the survey area. The Government, through its conservation department, is actively purchasing portions of pastoral leases and taking them out of pastoral production as a conservation initiative. As such excisions in the Nullarbor District are small and tend to be associated with

protecting cave entrances it is unlikely all threatened species and ecosystems could ever by reserved. Local community participation in addressing these deficiencies is recommended as it is likely to improve the chances of achieving both specific and broad nature conservation goals (Pringle & Riches 1996; Pringle & Tinley 2000; Biograze 2000).

Throughout the Nullarbor region preferentially grazed areas are patchily distributed. These areas are predominantly in the different forms of karst depressions separated by low stony limestone undulations or tree groves that provide the nuclei for bush clump development.

Within the greater uniformity of the Nullarbor Plain these areas commonly support plants of high nutritional value to grazing animals. Continual grazing of these areas reduces the forage reserve they can offer in dry times. The preference directed to these patchily distributed areas in conjunction with the high variability in seasonal conditions spatially and temporally makes these areas difficult to manage.

Pasture spelling through temporary water point closure, strategic internal paddock fencing and exclosures would help to preserve karst depression habitats, isolated woodland patches on calcrete rises within the plain and ecologically important grove habitats. The restriction of access to such areas during favourable seasons would assist in preserving important nutritional sources for use during dry seasonal conditions when the more uniform areas no longer provide a suitable forage reserve. The long-term preservation of core habitats provides a valuable seed source for redispersal after disturbance events.

Reduction of populations of feral animals and kangaroos

The ability of pastoral managers to apply landcare practices that improve land condition depends as much on their capacity to control grazing by feral animals (rabbits, horses and camels) and kangaroos as it does on the control of stock numbers and the areas stock graze. Controlling all populations of grazing animals on pastoral lease land is essential for maximising the potential of management for land conservation.

Research of kangaroo populations in the arid zone generally have shown that commercial harvesting programs have had no significant impact on numbers (Prince 1984; Pople & Grigg 1999; Hale 2004). Eradication is not seen as an appropriate or accepted goal for kangaroos anywhere. Ongoing research and development aimed at devising methods for effective managerial control through depriving animal access to (artificial) stock watering points offers the best prospect for success.

Complete withdrawal of grazing pressure to facilitate accelerated regeneration may be the desired option for land in poor condition, particularly where accelerated erosion is evident or a risk. However, as well as seasonal conditions, the speed of recovery will be influenced by the extent to which all grazing pressure is controlled within the paddock. Compensatory grazing pressure by feral animals and kangaroos through continual availability of artificial permanent water will also need to be managed.

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Appendices

1. Station summaries

2. Plant species lists

(i) Plant species recorded in the survey area

(ii) Common plants of the Bunda Plateau in the survey area

(iii) Common Nullarbor coastal zone plants in the survey area

3. Land system maps

Appendix 1—Station summaries

Station reports are presented alphabetically as tables for the 20 stations in the survey area.

Each station report consists of preliminary information including the land conservation district and shire in which the station falls. The area included is that which was legally defined as part of the pastoral lease(s) comprising each station at the time of the survey. The area does not include reserves, freehold land and Unallocated Crown Land within the pastoral lease. The station area is calculated from digitised mapping and is more accurate than the current stated legal area.

Each station report consists of three tables. The first table deals with land types, i.e. groups of similar land systems. It gives a general impression of the types of country and their extent on each pastoral lease. Land types and land systems are shown on the accompanying map sheets.

The second table provides more detailed information at a land system scale. For each land system (sorted into groups according to pastoral potential) there are details on area, number of traverse assessments and condition based on the traverse assessments.

The third table summarises the second table. Information is presented for land systems grouped according to pastoral potential.

Finally, summarised pastoral resource condition information for the station as a whole is presented. This includes the proportion of good, fair and poor condition vegetation condition and the potential carrying capacity.

Throughout the station reports the figures have been rounded to whole numbers.

For the purpose of this report, the categories of pastoral potential, based on estimated carrying capacity, have been adopted as shown in Table 30.

Table 30 **Categories of pastoral potential for land systems**

Category	Carrying capacity in good condition (ha/dry sheep equivalent)
High	6–9 ha/dse
Moderately high	10–14 ha/dse
Moderate	15–19 ha/dse
Low	20–29 ha/dse
Very low	≥ 30 ha/dse

The potential carrying capacity indicates the total grazing pressure a habitat can maintain on a sustainable, long-term basis from a community of herbivores. The potential carrying capacities are given in dry sheep equivalents (dse). One dry sheep equivalent is the feed energy required by a 45 kg liveweight Merino wether, to maintain its liveweight (Newman & Chapman 2001). The impact of other herbivores can be converted to different types and classes of stock using dse conversion rates in Table 31.

Table 31 **Relative feed requirements expressed as dry sheep equivalents (dse)** (adapted from Cooke-Yarborough 1990; Van Vreeswyk & Godden 1998; Dorges, Heuckle & Dance 2003).

Sheep (Merino)	**dse**
1 Merino wether (~ 45 kg)	1.0
1 Merino ewe (average for ewes producing 50% lambs)	1.3
1 Merino weaner (to 1 year)	0.7
1 Merino ram	1.5
Sheep (meat sheep)	
1 meat sheep wether (~ 45 kg)	1.0
1 meat sheep ewe (average for ewes producing 50% lambs)	1.4
1 meat sheep weaner (to 1 year)	1.0
1 meat sheep ram	1.5
Cattle	
1 steer/bullock (~ 270 kg)	7.0
1 year old steer or heifer (~ 140 kg)	6.0
1 cow (average for cows producing 50% calves)	9.8
1 weaner	4.2
1 bull	10.5
Other grazers	
1 camel (450 kg—635 kg)	11.0–14.0
1 horse (450 kg—635 kg)	11.0–14.0
1 kangaroo	0.7

* 7 dse = 1 cattle unit (cu)

For each land system the calculated potential carrying capacity (Pcc) was based on the proportion of its component land units and the associated vegetation habitat types in good condition. The potential carrying capacity indicates that which each land system can support on a long-term basis without damage to the rangeland resource. The potential carrying capacity is derived from the land unit area on each lease and estimated stocking rates. The potential carrying capacity assumes the capacity of the lease to produce forage has not been reduced and that water point distribution is sufficient to ensure that all pastures on the lease are able to be grazed throughout the year. Table 32 shows the potential carrying capacity for each of the Western Australian Nullarbor land systems in good vegetative condition. Areas of lake bed have been extracted from the land systems in which they occur and have been given a carrying capacity of zero.

It is the lessees' statutory obligation to ensure that overgrazing of pastures does not degrade the rangeland resource (inferred in Land Administration Act 1997 Section 108 Sub-section (4)). The actual number of stock run at *any one time* will vary according to factors such as:

- current seasonal conditions
- history of seasons prior to current season
- grazing pressure from non-domestic herbivores
- stock distribution
- class and status of stock
- range condition trend management requirements.

Historical information concerning the carrying capacity of Nullarbor pastures is limited. Nullarbor potential carrying capacities have been primarily based on carrying capacity information determined during the 1974 Western Australian Nullarbor Plain survey (Mitchell, McCarthy & Hacker 1979) in conjunction with information provided by past and present Nullarbor pastoralists. Where similarities existed with habitat types from previous southern rangeland surveys (Curry et al. 1994; Pringle, Van Vreeswyk & Gilligan 1994; Payne et al. 1998) carrying capacity information was compared against these locations. In such cases the potential carrying capacities had been based on results from grazing trials such as those at Boolathana (Holm 1994), Yerilla (Fletcher 1995), Coodardy (Yan, Holm & Mitchell 1996) or other literature (Lay 1975).

Productivity data was not solely used to determine carrying capacity estimates; climate, palatability and durability of the vegetation were also taken into account. Over recent decades throughout southern Australia the intensity and frequency of exceptionally hot years have been increasing and this trend is expected to continue. The projections of reduced annual rainfall averages are likely to result in more exceptionally dry years and fewer exceptionally wet years (Hennessy et al. 2008). Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed those stated as the potential carrying capacity during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return. Carrying capacity estimates were checked against the opinions of experienced rangeland advisors and past lease inspection reports.

The vegetation condition summaries are based on the composition and condition of the perennial vegetation. The vegetation condition classes are defined as:

Good For the land unit-vegetation type, the composition and cover of shrubs, perennial herbs and grasses is near optimal; free of obvious reductions in palatable species or increases in unpalatable species. Perennials present include all or most of the palatable species expected; some less palatable or unpalatable species may have increased, but the total perennial cover is not very different from the optimal.

Fair Moderate losses of palatable perennials and/or increases in unpalatable shrubs or grasses, but most palatable species and stability desirables still present; foliar cover is less than on comparable sites rated very good or good unless unpalatable species have increased.

Poor Conspicuous losses of palatable perennials or few, if any palatable perennials remain, foliar cover is either decreased through general loss of perennials or is increased by the invasion of unpalatable species.

Rangeland forage availability is heterogeneous in space and variable over time, therefore carrying capacity will vary correspondingly. **This suggests that it is inappropriate for the potential carrying capacity figures alone to be used for commercial or regulatory purposes.**

Individual station reports presented in this report are for the following leases:

Arubiddy, Balgair, Balladonia, Boonderoo, Gunnadorah, Kanandah, Kinclaven, Koonjarra, Kybo, Madura, Moonera, Mundrabilla, Nanambinia, Noondoonia, Point Culver, Pondana, Rawlinna, Vanesk, Virginia and Woorlba.

Table 32 **Western Australian Nullarbor land system pastoral potential and carrying capacity (ha/dse)**

Pastoral potential	Land system	Good condition (ha/dse)
Moderately high	Moodini	11
	Moopina	11
	Woorlba	11
	Arubiddy	12
	Koonjarra	12
	Lefroy	12
	Mundrabilla	12
	Nanambinia	12
	Thampanna	12
	Weebubbie	13
	Balgair	14
	Chowilla	14
	Gafa	14
	Kanandah	14
	Kybo	14
	Moonera	14
	Pondana	14
	Reid	14
	Seemore	14
	Shakehole	14
	Vanesk	14
	Virginia	14
Moderate	Balladonia	15
	Bullseye	15
	Haig	15
	Kinclaven	15
	Morris	15
	Nightshade	15
	Nurina	15
	Roe	15
	Skink	15
	Caiguna	16
	Carlisle	16
	Kitchener	16
	Lowry	16
	Naretha	16
	Nyanga	16
	Oasis	16
	Colville	17
	Gumbelt	17
	Jubilee	17
	Kyarra	17
	Boonderoo	19
Low	Rabbit	20
	Ponton	21
	Culver	23
	Damper	23
	Toolinna	24
	Wurrengoodyea	25
Very low	Baxter	30
	Wylie	30
	Bilbunya	50
	Delisser	50
	Zanthus	50

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ARUBIDDY STATION

Pastoral lease 3114/1080

Lease area: About 314 394 ha (legal); 316 541 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
2	Calcrete plains with eucalypt woodland and mixed scrub understorey	1	460	0.2
3	Calcrete plains with myall woodland and mixed shrubland	1	681	0.2
7	Level to gently undulating calcareous plains with eucalypt–melaleuca–myall woodland and chenopod shrubland	1	15 889	5.0
8	Undulating calcareous plains with eucalypt woodland, mixed scrub and heathland	1	4 563	1.4
9	Recrystallised (weathered) limestone plains with myall woodland and bluebush shrubland or bindii grassland	1	1 156	0.4
10	Deflated limestone plains with myall woodland and chenopod shrubland or bindii grassland	1	18 292	5.8
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	5	274 751	86.8
13	Level calcarenite plains with eucalypt–melaleuca–myall woodlands and mixed shrubland	2	749	0.2

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	11	Arubiddy	90 387	28.6	106	71	26	3	12	7 532
Moderately high	11	Balgair	1	^ 0.0	0	0	0	0	14	0
Moderately high	11	Moonera	123 845	39.1	94	84	15	1	14	8 846
Moderately high	13	Mundrabilla	646	0.2	4	100	0	0	12	54
Moderately high	11	Pondana	2 065	0.7	4	100	0	0	14	148
Moderately high	10	Shakehole	18 292	5.8	30	43	43	13	14	1 307
Moderately high	7	Thampanna	15 889	5.0	9	78	11	11	12	1 324
Moderate	2	Caiguna	460	0.1	0	0	0	0	16	29
Moderate	9	Lowry	1 156	0.4	12	58	33	8	16	72
Moderate	11	Nightshade	58 453	18.5	111	75	22	4	15	3 897
Moderate	3	Nyanga	681	0.2	2	100	0	0	16	43
Moderate	13	Roe	103	^ 0.0	0	0	0	0	15	7
Low	8	Culver	4 563	1.4	0	0	0	0	23	198

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	251 125	79	247	73	23	4	19 210
Moderate	60 853	19	125	74	22	4	4 047
Low	4 563	2	0	0	0	0	198
Total	316 541	100	372	74	22	4	23 457

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity / total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

^ Indicates minor value not reported in tables.

Station summary

Number of traverse points	372
Pastoral resource condition:	
Perennial vegetation	
% good	74
% fair	22
% poor	4

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing. 23 457 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

BALGAIR STATION

Pastoral lease 398/703

Lease area: About 289 316 ha (legal); 289 657 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas; Kalgoorlie–Boulder

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
3	Calcrete plains with myall woodland and mixed shrubland	1	1 089	0.4
4	Calcrete plains with sparse myall and bindii grassland or chenopod shrubland	1	27 171	9.4
9	Recrystallised (weathered) limestone plains with myall woodland and bluebush shrubland or bindii grassland	1	5 376	1.8
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	3	216 430	74.7
12	Deflated limestone plains with regular karst drainage depressions (dongas) surrounded by bindii grassland	2	39 591	13.7

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	11	Balgair	183 098	63.2	181	67	28	5	14	13 078
Moderately high	11	Moonera	13 542	4.7	5	80	20	0	14	967
Moderately high	11	Pondana	19 791	6.8	18	67	33	0	14	1 414
Moderate	4	Haig	27 171	9.4	38	63	37	0	15	1 811
Moderate	12	Kinclaven	19 409	6.7	41	32	46	22	15	1 294
Moderate	9	Lowry	5 376	1.8	4	100	0	0	16	336
Moderate	12	Nurina	20 182	7.0	17	65	29	6	15	1 345
Moderate	3	Nyanga	1 089	0.4	2	100	0	0	16	68

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	216 430	75	204	67	28	4	15 459
Moderate	73 227	25	102	53	37	10	4 854
Total	289 657	100	306	62	31	7	20 313

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity / total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	306
Pastoral resource condition:	
Perennial vegetation	
% good	62
% fair	31
% poor	7

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing. 20 313 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

BALLADONIA STATION

Pastoral lease 3114/1147

Lease area: About 125 751 ha (legal); 125 128 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas

Approximate area of various reserves, freehold and Unallocated Crown Land excluded from the managed area = 2428 ha.

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
2	Calcrete plains with eucalypt woodland and mixed scrub understorey	2	79 492	63.5
3	Calcrete plains with myall woodland and mixed shrubland	1	31	< 0.1
5	Large depressions within calcrete plains with chenopod shrubland or bindii grassland	1	13 833	11.1
6	Low granite outcrop protruding through calcrete plains with fringing acacia–dodonaea–eremophila shrubland	1	6 500	5.2
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	1	25 058	20.0
15	Salt lakes and fringing alluvial plains with halophytic shrubland	1	214	0.2

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	15	Lefroy	214	0.2	3	100	0	0	12	18
Moderately high	11	Nanambinia	25 058	20.0	70	57	31	11	12	2 088
Moderately high	5	Woorlba	13 833	11.1	67	85	13	1	11	1 258
Moderate	6	Balladonia	6 500	5.2	19	63	26	11	15	433
Moderate	2	Caiguna	69 181	55.3	94	90	10	0	16	4 324
Moderate	2	Gumbelt	10 311	8.2	20	90	5	5	17	607
Moderate	3	Nyanga	31	< 0.1	0	0	0	0	16	2

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	39 106	31	140	71	22	6	3 364
Moderate	86 022	69	133	86	11	2	5 366
Total	125 128	100	273	79	16	5	8 730

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	273
Pastoral resource condition:	
Perennial vegetation	
% good	79
% fair	16
% poor	5

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing. 8730 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

BOONDEROO STATION

Pastoral lease 3114/1097

Lease area: About 308 923 ha (legal); 308 096 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas; Kalgoorlie–Boulder

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
1	Calcrete plains overlain by aeolian sandy loam with eucalypt woodland and spinifex grasses	1	32 162	10.4
2	Calcrete plains with eucalypt woodland and mixed scrub understorey	1	70 707	22.9
3	Calcrete plains with myall woodland and mixed shrubland	1	149 367	48.5
5	Large depressions within calcrete plains with chenopod shrubland or bindii grassland	1	18 190	5.9
9	Recrystallised (weathered) limestone plains with myall woodland and bluebush shrubland or bindii grassland	1	2 551	0.8
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	1	24 474	7.9
15	Salt lakes and fringing alluvial plains with halophytic shrubland	2	9 240	3.0
Nil	Lake bed	1	1 405	0.6

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	9	Kanandah	2 551	0.8	0	0	0	0	14	182
Moderately high	5	Koonjarra	18 190	5.9	13	100	0	0	12	1 516
Moderate	15	Boonderoo	6 899	2.2	14	100	0	0	19	363
Moderate	2	Gumbelt	70 707	22.9	35	100	0	0	17	4 159
Moderate	11	Kitchener	24 474	7.9	46	4	72	24	16	1 530
Moderate	3	Nyanga	149 367	48.5	208	89	9	2	16	9 335
Low	15	Ponton	2 341	0.8	0	0	0	0	21	111
Very low	1	Zanthus	32 162	10.4	19	100	0	0	50	643
Nil		Lake bed	1 405	0.6	0	0	0	0	0	0

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	20 741	7	13	100	0	0	1 698
Moderate	251 447	81	303	78	17	5	15 387
Low	2 341	1	0	0	0	0	111
Very low	32 162	10	19	100	0	0	643
Nil	1 405	1	0	0	0	0	0
Total	308 096	100	335	80	15	5	17 839

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity / total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points 335

Pastoral resource condition:

Perennial vegetation

% good 80

% fair 15

% poor 5

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing. 17 839 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

GUNNADORAH STATION

Pastoral lease 3114/1005

Lease area: About 333 010 ha (legal); 334 675 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Kalgoorlie–Boulder

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
3	Calcrete plains with myall woodland and mixed shrubland	1	99 938	29.9
4	Calcrete plains with sparse myall and bindii grassland or chenopod shrubland	2	35 785	10.7
12	Deflated limestone plains with regular karst drainage depressions (dongas) surrounded by bindii grassland	3	198 952	59.4

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderate	12	Bullseye	38 856	11.6	15	27	40	33	15	2 590
Moderate	4	Haig	12 348	3.7	35	57	34	9	15	823
Moderate	12	Kinclaven	60 068	17.9	60	27	68	5	15	4 004
Moderate	4	Kyarra	23 437	7.0	49	73	14	12	17	1 379
Moderate	12	Nurina	100 028	29.9	148	47	47	7	15	6 669
Moderate	3	Nyanga	99 938	29.9	108	72	21	6	16	6 246

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderate	334 675	100	415	54	38	8	21 711
Total	334 675	100	415	54	38	8	21 711

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	415
Pastoral resource condition:	
Perennial vegetation	
% good	54
% fair	38
% poor	8

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing. 21 711 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

KANANDAH STATION

Pastoral lease 3114/1189

Lease area: About 359 230 ha (legal); 357 854 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Kalgoorlie–Boulder

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
1	Calcrete plains overlain by aeolian sandy loam with eucalypt woodland and spinifex grasses	1	7 587	2.1
2	Calcrete plains with eucalypt woodland and mixed scrub understorey	1	11 828	3.3
3	Calcrete plains with myall woodland and mixed shrubland	1	202 401	56.6
5	Large depressions within calcrete plains with chenopod shrubland or bindii grassland	1	4 594	1.3
9	Recrystallised (weathered) limestone plains with myall woodland and bluebush shrubland or bindii grassland	1	111 922	31.3
10	Deflated limestone plains with myall woodland and chenopod shrubland or bindii grassland	1	328	0.1
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	1	2 191	0.6
12	Deflated limestone plains with regular karst drainage depressions (dongas) surrounded by bindii grassland	1	17 003	4.7

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	9	Kanandah	111 922	31.3	155	19	60	21	14	7 994
Moderately high	5	Koonjarra	4 594	1.3	13	69	15	15	12	383
Moderately high	10	Seemore	328	0.1	0	0	0	0	14	23
Moderate	2	Gumbelt	11 828	3.3	13	100	0	0	17	696
Moderate	12	Kinclaven	17 003	4.7	39	31	64	5	15	1 133
Moderate	11	Kitchener	2 191	0.6	6	33	67	0	16	137
Moderate	3	Nyanga	202 401	56.6	131	63	31	6	16	12 650
Very low	1	Zanthus	7 587	2.1	1	100	0	0	50	152

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	116 844	33	168	23	57	20	8 400
Moderate	233 423	65	189	58	37	5	14 616
Very low	7 587	2	1	100	0	0	152
Total	357 854	100	358	42	46	12	23 168

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	358	
Pastoral resource condition:		
Perennial vegetation		
% good	42	
% fair	46	
% poor	12	
Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing.		23 168 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

KINCLAVEN STATION

Pastoral lease 3114/1171

Lease area: About 496 581 ha (legal); 497 630 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Kalgoorlie–Boulder

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
3	Calcrete plains with myall woodland and mixed shrubland	1	76 864	15.4
4	Calcrete plains with sparse myall and bindii grassland or chenopod shrubland	1	2 433	0.5
9	Recrystallised (weathered) limestone plains with myall woodland and bluebush shrubland or bindii grassland	1	46 105	9.3
10	Deflated limestone plains with myall woodland and chenopod shrubland or bindii grassland	1	41 196	8.3
12	Deflated limestone plains with regular karst drainage depressions (dongas) surrounded by bindii grassland	2	331 032	66.5

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	9	Kanandah	46 105	9.3	68	47	53	0	14	3 293
Moderately high	10	Seemore	41 196	8.3	15	60	40	0	14	2 943
Moderate	12	Kinclaven	319 103	64.1	345	19	60	21	15	21 273
Moderate	4	Kyarra	2 433	0.5	0	0	0	0	17	143
Moderate	12	Nurina	11 929	2.4	0	0	0	0	15	795
Moderate	3	Nyanga	76 864	15.4	52	90	10	0	16	4 804

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	87 301	18	83	49	51	0	6 236
Moderate	410 329	82	397	28	53	19	27 015
Total	497 630	100	480	32	53	15	33 251

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity / total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	480
Pastoral resource condition:	
Perennial vegetation	
% good	32
% fair	53
% poor	15

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing.	33 251 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

KOONJARRA STATION

Pastoral lease 3114/1227

Lease area: About 325 118 ha (legal); 325 534 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
1	Calcrete plains overlain by aeolian sandy loam with eucalypt woodland and spinifex grasses	1	15 925	4.9
2	Calcrete plains with eucalypt woodland and mixed scrub understorey	1	57 808	17.8
3	Calcrete plains with myall woodland and mixed shrubland	1	186 672	57.3
5	Large depressions within calcrete plains with chenopod shrubland or bindii grassland	2	63 064	19.4
9	Recrystallised (weathered) limestone plains with myall woodland and bluebush shrubland or bindii grassland	1	2 065	0.6

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	5	Koonjarra	61 650	19.0	127	72	23	5	12	5 138
Moderately high	9	Virginia	2 065	0.6	7	100	0	0	14	148
Moderately high	5	Woorlba	1 414	0.4	4	75	25	0	11	128
Moderate	2	Gumbelt	57 808	17.8	36	100	0	0	17	3 400
Moderate	3	Nyanga	186 672	57.3	188	79	17	4	16	11 667
Very low	1	Zanthus	15 925	4.9	17	100	0	0	50	319

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	65 129	20	138	74	41	15	5 414
Moderate	244 480	75	224	82	14	4	15 067
Very low	15 925	5	17	100	0	0	319
Total	325 534	100	379	80	16	4	20 800

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	379
Pastoral resource condition:	
Perennial vegetation	
% good	80
% fair	16
% poor	4

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing. 20 800 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

KYBO STATION

Pastoral lease 398/427

Lease area: About 283 280 ha (legal); 283 193 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas; Kalgoorlie–Boulder

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
4	Calcrete plains with sparse myall and bindii grassland or chenopod shrubland	1	8 317	2.9
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	4	244 305	86.3
12	Deflated limestone plains with regular karst drainage depressions (dongas) surrounded by bindii grassland	1	30 571	10.8

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	11	Balgair	10 600	3.7	14	64	36	0	14	757
Moderately high	11	Gafa	63 753	22.5	46	72	24	4	14	4 554
Moderately high	11	Kybo	117 118	41.4	159	63	25	12	14	8 365
Moderately high	11	Moonera	52 834	18.7	41	68	24	7	14	3 774
Moderate	4	Haig	8 317	2.9	18	89	11	0	15	555
Moderate	12	Nurina	30 571	10.8	32	75	22	3	15	2 038

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	244 305	86	260	65	25	9	17 450
Moderate	38 888	14	50	80	18	2	2 593
Total	283 193	100	310	68	24	8	20 043

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	310
Pastoral resource condition:	
Perennial vegetation	
% good	68
% fair	24
% poor	8

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing.	20 043 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

MADURA STATION

Pastoral lease 3114/832

Lease area: About 366 194 ha (legal); 367 048 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas

Approximate area of various reserves, freehold and Unallocated Crown Land excluded from the managed area = 2944 ha.

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
7	Level to gently undulating calcareous plains with eucalypt–melaleuca–myall woodland and chenopod shrubland	2	197 754	53.9
10	Deflated limestone plains with myall woodland and chenopod shrubland or bindii grassland	1	133 330	36.3
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	3	11 506	3.1
13	Level calcarenite plains with eucalypt–melaleuca–myall woodlands and mixed shrubland	2	24 458	6.7

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	11	Gafa	5 198	1.4	0	0	0	0	14	371
Moderately high	11	Kybo	561	0.1	0	0	0	0	14	40
Moderately high	7	Moodini	10 495	2.9	45	64	33	2	11	954
Moderately high	13	Mundrabilla	22 315	6.1	44	80	18	2	12	1 860
Moderately high	10	Shakehole	133 330	36.3	109	57	26	17	14	9 524
Moderately high	7	Thampanna	187 259	51.0	249	43	32	24	12	15 605
Moderate	13	Roe	2 143	0.6	12	92	0	8	15	143
Moderate	11	Skink	5 747	1.6	0	0	0	0	15	383

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	359 158	98	447	52	29	18	28 354
Moderate	7 890	2	12	92	0	8	526
Total	367 048	100	459	53	29	18	28 880

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	459
Pastoral resource condition:	
Perennial vegetation	
% good	53
% fair	29
% poor	18

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing. 28 880 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

MOONERA STATION

Pastoral lease 3114/1243

Lease area: About 324 821 ha (legal); 344 852 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
7	Level to gently undulating calcareous plains with eucalypt–melaleuca–myall woodland and chenopod shrubland	1	47 065	13.6
10	Deflated limestone plains with myall woodland and chenopod shrubland or bindii grassland	1	80 585	23.4
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	3	217 202	63.0

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	11	Arubiddy	48 177	14.0	68	71	26	3	12	4 015
Moderately high	11	Kybo	10 068	2.9	15	20	53	27	14	719
Moderately high	11	Moonera	158 957	46.1	123	55	34	11	14	11 354
Moderately high	10	Shakehole	80 585	23.4	102	69	22	10	14	5 756
Moderately high	7	Thampanna	47 065	13.6	57	56	35	9	12	3 922

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	344 852	100	365	61	30	9	25 766
Total	344 852	100	365	61	30	9	25 766

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	365
Pastoral resource condition:	
Perennial vegetation	
% good	61
% fair	30
% poor	9

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing.	25 766 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

MUNDRABILLA STATION

Pastoral lease 3114/915

Lease area:	About 384 901 ha (legal); 383 872 ha (computed)
Area surveyed:	Whole lease
Land Conservation District:	Nullarbor–Eyre Highway
Shire(s):	Dundas

Approximate area of various reserves, freehold and Unallocated Crown Land excluded from the managed area = 84 ha.

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
7	Level to gently undulating calcareous plains with eucalypt–melaleuca–myall woodland and chenopod shrubland	3	198 452	51.7
10	Deflated limestone plains with myall woodland and chenopod shrubland or bindii grassland	2	74 589	19.4
13	Level calcarenite plains with eucalypt–melaleuca–myall woodlands and mixed shrubland	2	101 198	26.4
14	Coastal plains, cliffs, dunes, lagoonal deposits and beaches; varied vegetation	2	9 441	2.5
15	Salt lakes and fringing alluvial plains with halophytic shrubland	1	192	^ 0.0

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	10	Chowilla	787	0.2	0	0	0	0	14	56
Moderately high	7	Moodini	1 680	0.4	6	50	17	33	11	153
Moderately high	7	Moopina	55	^ 0.0	0	0	0	0	11	5
Moderately high	13	Mundrabilla	62 895	16.4	40	93	8	0	12	5 241
Moderately high	10	Shakehole	73 802	19.2	95	53	29	18	14	5 272
Moderately high	7	Thampanna	196 717	51.2	391	49	31	20	12	16 393
Moderate	13	Roe	38 303	10.0	4	75	25	0	15	2 554
Low	15	Damper	192	0.1	0	0	0	0	23	8
Low	14	Wurrengoodyea	9 439	2.5	0	0	0	0	25	378
Very low	14	Delisser	2	^ 0.0	0	0	0	0	50	0

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	335 936	87	532	61	21	18	27 120
Moderate	38 303	10	4	75	25	0	2 554
Low	9 631	3	0	0	0	0	386
Very low	2	0	0	0	0	0	0
Total	383 872	100	536	53	29	18	30 060

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

^ Indicates minor value not reported in tables.

Station summary

Number of traverse points	536	
Pastoral resource condition:		
Perennial vegetation		
% good	53	
% fair	29	
% poor	18	
Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing.		30 060 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

NANAMBINIA STATION

Pastoral lease 3114/429

Lease area: About 46 266 ha (legal); 46 296 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
2	Calcrete plains with eucalypt woodland and mixed scrub understorey	1	42 027	90.8
5	Large depressions within calcrete plains with chenopod shrubland or bindii grassland	1	1 187	2.6
6	Low granite outcrop protruding through calcrete plains with fringing acacia–dodonaea–eremophila shrubland	1	2 954	6.4
15	Salt lakes and fringing alluvial plains with halophytic shrubland	1	128	0.2

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	15	Lefroy	128	0.2	0	0	0	0	12	10
Moderately high	5	Woorlba	1 187	2.6	14	79	21	0	11	108
Moderate	6	Balladonia	2 954	6.4	2	50	0	50	15	197
Moderate	2	Caiguna	42 027	90.8	56	95	4	2	16	2 627

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	1 315	3	14	79	21	0	118
Moderate	44 981	97	58	93	3	3	2 824
Total	46 296	100	72	90	7	3	2 942

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	72
Pastoral resource condition:	
Perennial vegetation	
% good	90
% fair	7
% poor	3

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing. 2942 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

NOONDOONIA STATION

Pastoral lease 3114/1229

Lease area: About 126 670 ha (legal); 126 762 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas

Approximate area of various reserves, freehold and Unallocated Crown Land excluded from the managed area = 196 ha.

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
1	Calcrete plains overlain by aeolian sandy loam with eucalypt woodland and spinifex grasses	1	816	0.6
2	Calcrete plains with eucalypt woodland and mixed scrub understorey	2	94 065	74.3
3	Calcrete plains with myall woodland and mixed shrubland	1	17 540	13.8
5	Large depressions within calcrete plains with chenopod shrubland or bindii grassland	2	10 527	8.3
6	Low granite outcrop protruding through calcrete plains with fringing acacia–dodonaea–eremophila shrubland	1	2 707	2.1
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	1	1 107	0.9

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	5	Koonjarra	1 152	0.9	5	60	40	0	12	96
Moderately high	11	Nanambinia	1 107	0.9	5	80	20	0	12	92
Moderately high	5	Woorlba	9 375	7.4	34	85	6	9	11	852
Moderate	6	Balladonia	2 707	2.1	10	50	40	10	15	180
Moderate	2	Caiguna	5 267	4.2	4	75	25	0	16	329
Moderate	2	Gumbelt	88 798	70.1	118	91	8	1	17	5 223
Moderate	3	Nyanga	17 540	13.8	19	100	0	0	16	1 096
Very low	1	Zanthus	816	0.6	5	100	0	0	50	16

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	11 634	9	44	82	11	7	1 040
Moderate	114 312	90	151	89	10	1	6 828
Very low	816	1	5	100	0	0	16
Total	126 762	100	200	87	10	3	7 884

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	200
Pastoral resource condition:	
Perennial vegetation	
% good	87
% fair	10
% poor	3

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing. 7884 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

POINT CULVER

Pastoral lease 398/745

Lease area: About 57 616 ha (legal); 57 584 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
2	Calcrete plains with eucalypt woodland and mixed scrub understorey	2	42 171	73.2
5	Large depressions within calcrete plains with chenopod shrubland or bindii grassland	1	3 542	6.2
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	2	11 871	20.6

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	11	Nanambinia	11 514	20.0	25	64	32	4	12	959
Moderately high	5	Woorlba	3 542	6.2	5	100	0	0	11	322
Moderate	2	Caiguna	40 394	70.1	25	100	0	0	16	2 525
Moderate	2	Gumbelt	1 777	3.1	0	0	0	0	17	105
Moderate	11	Nightshade	357	0.6	0	0	0	0	15	24

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	15 056	26	30	70	27	3	1 281
Moderate	42 528	74	25	100	0	0	2 654
Total	57 584	100	55	84	14	2	3 935

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	55
Pastoral resource condition:	
Perennial vegetation	
% good	84
% fair	14
% poor	2

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing.	3935 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

PONDANA STATION

Pastoral lease 3114/803

Lease area: About 186 479 ha (legal); 186 580 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas; Kalgoorlie–Boulder

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
2	Calcrete plains with eucalypt woodland and mixed scrub understorey	1	161	0.1
3	Calcrete plains with myall woodland and mixed shrubland	1	20 751	11.1
10	Deflated limestone plains with myall woodland and chenopod shrubland or bindii grassland	1	21 443	11.5
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	3	144 225	77.3

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	11	Moonera	44 959	24.1	37	95	5	0	14	3 211
Moderately high	11	Pondana	87 515	46.9	92	35	39	26	14	6 251
Moderately high	10	Vanesk	21 443	11.5	7	57	43	0	14	1 532
Moderate	2	Gumbelt	161	0.1	0	0	0	0	17	9
Moderate	11	Naretha	11 751	6.3	4	0	75	25	16	734
Moderate	3	Nyanga	20 751	11.1	18	50	44	6	16	1 297

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	153 917	82	136	52	30	18	10 994
Moderate	32 663	18	22	41	50	9	2 040
Total	186 580	100	158	51	33	16	13 034

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	158
Pastoral resource condition:	
Perennial vegetation	
% good	51
% fair	33
% poor	16

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing.	13 034 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

RAWLINNA STATION

Pastoral lease 3114/1224

Lease area: About 271 980 ha (legal); 272 411 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Kalgoorlie–Boulder

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
2	Calcrete plains with eucalypt woodland and mixed scrub understorey	1	3 593	1.3
3	Calcrete plains with myall woodland and mixed shrubland	1	22 807	8.4
9	Recrystallised (weathered) limestone plains with myall woodland and bluebush shrubland or bindii grassland	1	419	0.2
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	3	187 467	68.8
12	Deflated limestone plains with regular karst drainage depressions (dongas) surrounded by bindii grassland	1	58 125	21.3

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	9	Kanandah	419	0.2	0	0	0	0	14	30
Moderately high	11	Pondana	55 502	20.4	74	55	34	11	14	3 964
Moderate	2	Gumbelt	3 593	1.3	0	0	0	0	17	211
Moderate	12	Kinclaven	58 125	21.3	57	44	42	14	15	3 875
Moderate	11	Kitchener	13 146	4.8	4	0	100	0	16	822
Moderate	11	Naretha	118 819	43.6	92	28	58	14	16	7 426
Moderate	3	Nyanga	22 807	8.4	13	54	46	0	16	1 425

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	55 921	21	74	55	34	11	3 994
Moderate	216 490	79	166	35	52	13	13 759
Total	272 411	100	240	41	47	12	17 753

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	240
Pastoral resource condition:	
Perennial vegetation	
% good	41
% fair	47
% poor	12

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing.	17 753 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

VANESK STATION

Pastoral lease 3114/1223

Lease area: About 595 322 ha (legal); 587 613 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas; Kalgoorlie–Boulder

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
2	Calcrete plains with eucalypt woodland and mixed scrub understorey	2	9 425	1.6
3	Calcrete plains with myall woodland and mixed shrubland	1	178 414	30.4
5	Large depressions within calcrete plains with chenopod shrubland or bindii grassland	1	16 065	2.7
9	Recrystallised (weathered) limestone plains with myall woodland and bluebush shrubland or bindii grassland	1	69 522	11.8
10	Deflated limestone plains with myall woodland and chenopod shrubland or bindii grassland	1	79 126	13.5
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	4	235 061	40.0

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points[#]	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	11	Arubiddy	60 666	10.3	36	56	31	14	12	5 055
Moderately high	5	Koonjarra	16 065	2.7	8	100	0	0	12	1 339
Moderately high	11	Moonera	29 290	5.0	19	100	0	0	14	2 092
Moderately high	10	Vanesk	79 126	13.5	55	76	18	5	14	5 652
Moderately high	9	Virginia	69 522	11.8	32	84	9	6	14	4 966
Moderate	2	Caiguna	6 672	1.1	4	0	50	50	16	417
Moderate	2	Gumbelt	2 753	0.5	1	100	0	0	17	162
Moderate	11	Naretha	24 123	4.1	43	37	56	7	16	1 508
Moderate	11	Nightshade	120 982	20.6	107	74	20	7	15	8 065
Moderate	3	Nyanga	178 414	30.4	121	79	15	6	16	11 151

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	254 669	43	150	77	16	7	19 104
Moderate	332 944	57	276	70	24	7	21 303
Total	587 613	100	426	72	21	7	40 407

[#] Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	426
Pastoral resource condition:	
Perennial vegetation	
% good	72
% fair	21
% poor	7

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing. 40 407 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

VIRGINIA STATION

Pastoral lease 398/771

Lease area: About 244 226 ha (legal); 240 678 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
2	Calcrete plains with eucalypt woodland and mixed scrub understorey	2	32 375	13.5
3	Calcrete plains with myall woodland and mixed shrubland	1	48 498	20.2
5	Large depressions within calcrete plains with chenopod shrubland or bindii grassland	2	3 413	1.4
9	Recrystallised (weathered) limestone plains with myall woodland and bluebush shrubland or bindii grassland	1	97 323	40.4
10	Deflated limestone plains with myall woodland and chenopod shrubland or bindii grassland	1	10 147	4.2
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	1	48 922	20.3

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	5	Koonjarra	1 896	0.8	7	100	0	0	12	158
Moderately high	10	Vanesk	10 147	4.2	2	100	0	0	14	725
Moderately high	9	Virginia	97 323	40.4	105	86	14	0	14	6 952
Moderately high	5	Woorlba	1 517	0.6	8	75	13	13	11	138
Moderate	2	Caiguna	8 956	3.8	3	100	0	0	16	560
Moderate	2	Gumbelt	23 419	9.7	27	100	0	0	17	1 378
Moderate	11	Nightshade	48 922	20.3	52	85	15	0	15	3 261
Moderate	3	Nyanga	48 498	20.2	77	96	4	0	16	3 031

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	110 883	46	122	86	13	1	7 973
Moderate	129 795	54	159	93	7	0	8 230
Total	240 678	100	281	90	10	0	16 203

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	281	
Pastoral resource condition:		
Perennial vegetation		
% good	90	
% fair	10	
% poor	0	
Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing.		16 203 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

WOORLBA STATION

Pastoral lease 3114/1002

Lease area: About 315 026 ha (legal); 315 249 ha (computed)

Area surveyed: Whole lease

Land Conservation District: Nullarbor–Eyre Highway

Shire(s): Dundas

Summary of land types

No.	Land type	No. of land systems	Area (ha)	% of station
1	Calcrete plains overlain by aeolian sandy loam with eucalypt woodland and spinifex grasses	1	1 363	0.4
2	Calcrete plains with eucalypt woodland and mixed scrub understorey	2	197 000	62.5
3	Calcrete plains with myall woodland and mixed shrubland	1	84 312	26.7
5	Large depressions within calcrete plains with chenopod shrubland or bindii grassland	2	18 703	6.0
11	Deflated limestone plains with open bluebush and saltbush shrublands or bindii grassland	1	13 871	4.4

Rangeland inventory and condition summary

Pastoral potential	Land type	Land system	Total area		No. of traverse points#	Perennial vegetation (%)			Condition ha/dse	Pcc (dse)*
			ha	%		Good	Fair	Poor		
Moderately high	5	Koonjarra	3 149	1.0	13	100	0	0	12	262
Moderately high	11	Nanambinia	13 871	4.4	14	93	7	0	12	1 156
Moderately high	5	Woorlba	15 554	5.0	31	58	29	13	11	1 414
Moderate	2	Caiguna	1 456	0.5	0	0	0	0	16	91
Moderate	2	Gumbelt	195 544	62.0	118	96	3	2	17	11 503
Moderate	3	Nyanga	84 312	26.7	79	95	5	0	16	5 270
Very low	1	Zanthus	1 363	0.4	1	100	0	0	50	27

Pastoral resource summary

Pastoral potential	Total area		No. of traverse points	Perennial vegetation (%)			Pcc (dse)*
	ha	%		Good	Fair	Poor	
Moderately high	32 574	10	58	76	17	7	2 832
Moderate	281 312	89	197	95	4	1	16 864
Very low	1 363	1	1	100	0	0	27
Total	315 249	100	256	91	7	2	19 723

Where there are inadequate observations for a land system the carrying capacity calculations are based on averages for the land system over the whole survey area.

* Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition and lease is fully developed.

Station summary

Number of traverse points	256
Pastoral resource condition:	
Perennial vegetation	
% good	91
% fair	7
% poor	2

Potential carrying capacity/total grazing pressure (dse) over the dry season, assuming all land systems are in good condition, and that the lease is fully developed for grazing. 19 723 dse

Climate scenarios predict more exceptionally dry years and fewer exceptionally wet years. Therefore this probability has been factored into the calculated potential carrying capacities for Western Australian Nullarbor land systems. Whilst it is likely that total herbivore grazing pressure may exceed the figure stated above during exceptionally wet years the landscape cannot support such numbers on a long-term basis once average drier seasonal conditions return.

Appendix 2(i)—Plant species recorded in the survey area

Key to table at end of chapter.

Family Botanical name	Name id.	Collection no.	Growth form	Total sites	Physiographic regions: Hampton Tableland	Israelite Plain	Mardabilla Plain	Nullarbor Plain	Nyanga Plain	Roe Plains
Adiantaceae										
Cheilanthes austrotenuifolia	31	WNB255	F	-			●			
Cheilanthes lasiophylla	37	WNB259	F	1			●			
Aizoaceae										
Carpobrotus modestus	2796		PH	9	●			●	●	●
Carpobrotus virescens	2798	WNB081	PH	4	●					●
Disphyma crassifolium	2799	WNB274	LS	2			●			
Gunniopsis calcarea	2802	WNB003	LS	27			●	●	●	●
Gunniopsis quadrifida	2807		LS	1	●		●			
**Mesembryanthemum crystallinum*	2813		AH	35			●	●	●	
**Mesembryanthemum nodiflorum*	2814		AH	3			●	●		
Tetragonia eremaea	2822		AH	3	●			●	●	●
Tetragonia implexicoma	2823	WNB126	PH	4						●
Amaranthaceae										
Ptilotus exaltatus	2721		AH	2			●		●	
Ptilotus holosericeus	2732		PH	-			●		●	
Ptilotus obovatus	2747	WNB185	LS	59	●		●	●	●	●
Ptilotus symonii	2764	WNB036	LS	10	●		●	●		●
Anacardiaceae										
**Schinus molle* var. *areira*	17056		TR	-				●		
Apocynaceae										
Alyxia buxifolia	6565	WNB121	MS	2					●	
Asclepiadaceae										
**Gomphocarpus fruticosus*	6587		PH	-					●	
Marsdenia australis	12949	WNB181	C	15				●	●	
Asparagaceae										
Lomandra sp.	21187		PH	3	●					●
Thysanotus baueri	1322	WNB188	PH	3	●		●			
Asphodelaceae										
**Asphodelus fistulosus*	1364		AH	1					●	
Aspleniaceae										
Pleurosorus rutifolius	65	WNB260	F	-			●			
Asteraceae										
Angianthus conocephalus	7825	WNB148	AH	15	●		●	●	●	●
**Arctotheca populifolia*	7839		PH	-						●
Asteridea athrixioides	7846	WNB064	AH	5	●			●		
Brachyscome ciliaris	7871	WNB204	AH	8	●		●	●	●	●
Brachyscome lineariloba	7880	WNB169	AH	2	●					●
Calocephalus knappii	7893		AH	1					●	
Calotis breviradiata	7899	WNB240	AH	-				●		
Calotis hispidula	7903	WNB015	AH	2	●			●	●	●
Calotis multicaulis	7905	9239	AH	11	●		●	●	●	
**Carduus nutans*	7908	9306	AH	1	●					

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					Hampton Tableland	Israelite Plain	Mardabilla Plain	Nullarbor Plain	Nyanga Plain	Roe Plains
**Carthamus lanatus*	7911		AH	1				●		
**Centaurea melitensis*	7916		AH	2	●		●	●	●	●
Centipeda crateriformis	19758	WNB247	AH	-			●			
Cephalipterum drummondii	7922		AH	1				●		
Cratystylis conocephala	7949	WNB119	MS	85	●		●	●	●	●
Cratystylis subspinescens	7951		LS	1					●	
Ermophyllum ramosum subsp. *ramosum*	14377		AH	-				●		●
Erodiophyllum elderi	7971	9244	AH	5				●	●	
Isoetopsis graminifolia	8087	9231	AH	3	●		●	●	●	●
Kippistia suaedifolia	8094	WNB118	LS	1						●
Leucophyta brownii	16449	WNB091	LS	1						●
Minuria cunninghamii	8107	WNB110	PH	8	●			●	●	
Minuria leptophylla	8110	WNB244	PH	-	●			●	●	
Olearia axillaris	8127		TS	3		●	●			●
Olearia calcarea	8129	WNB160	LS	62	●		●	●	●	●
Olearia dampieri subsp. *eremicola*	15450		MS	-	●					●
Olearia muelleri	8140	WNB040	LS	14						●
Olearia picridifolia	8144	9187	LS	2	●					
Olearia ramosissima	8146	WNB075	LS	8	●			●		●
**Oncosiphon suffruticosum*	20661	WNB252	AH	1			●			
Podolepis canescens	8172	WNB043	AH	14	●				●	●
Podolepis capillaris	8173		AH	-			●			
Rhodanthe chlorocephala	13239		AH	2	●			●	●	
Rhodanthe floribunda	13301	9219	AH	46	●		●	●	●	
Rhodanthe haigii	13293	WNB084	AH	-					●	●
Rhodanthe nullarborensis	13295	WNB197	AH	1			●	●	●	
Schoenia ayersii	13285	9251	AH	-						
Senecio glossanthus	8207	9363	AH	-					●	●
Senecio magnificus	8213	WNB235	PH	-					●	
Senecio pinnatifolius	20161		AH	15	●			●		●
Senecio quadridentatus	8217	WNB243	PH	4	●		●			
Senecio spanomerus	25889	WNB025	PH	8					●	●
**Sonchus oleraceus*	8231		AH	17	●			●	●	●
Trichanthodium skirrophorum	12652	WNB079	AH	8	●			●	●	●
Vittadinia dissecta	8264		AH	-	●					
Vittadinia dissecta var. *hirta*	11788	9399	AH	-	●					
Vittadinia humerata	8268	9158	AH	6	●		●	●	●	
Vittadinia nullarborensis	8269	WNB023	AH	4	●		●	●		
**Xanthium spinosum*	8287		AH	7	●			●	●	
Boraginaceae										
Halgania andromedifolia	6684	WNB103	LS	6	●					
Heliotropium asperrimum	6700	9321	PH	1	●					
**Heliotropium europaeum*	6710		AH	-				●		
Brassicaceae										
Arabidella trisecta	2992	WNB011	AH	4	●			●		
**Brassica tournefortii*	3000		AH	-	●			●		●
**Cakile maritima*	3002	WNB327	AH	1						●
**Carrichtera annua*	3008		AH	111	●		●	●	●	●
**Lepidium africanum*	3018	WNB246	AH	-	●					
Lepidium fasciculatum	3026	WNB031	AH	1				●		
Lepidium phlebopetalum	3037	WNB193	AH	1				●		
Lepidium rotundum	3044	WNB337	LS	1				●	●	●
Lepidium sp.	22409	WNB027	AH	19				●	●	
Menkea sp.	22410		AH	1					●	

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Phlegmatospermum cochlearinum	3057	WNB192	AH	1				●		
**Sisymbrium erysimoides*	3069		AH	10	●			●	●	●
**Sisymbrium irio*	3070	WNB033	AH	-	●			●	●	●
Caesalpiniaceae										
Senna artemisioides	17645	9245	MS	-	●		●	●	●	●
Senna artemisioides subsp. *petiolaris*	12281	WNB187	MS	1				●	●	
Senna artemisioides subsp. *x artemisioides*	17558	WNB305	MS	25	●		●	●	●	
Senna artemisioides subsp. *x coriacea*	12275		MS	37	●			●	●	●
Senna cardiosperma	18430	9255	TS	4	●				●	
Campanulaceae										
Wahlenbergia communis	7385	WNB263	PH	2			●			
Casuarinaceae										
Allocasuarina helmsii	1730	WNB105	TR	12	●				●	●
Allocasuarina scleroclada	1737	WNB301	TS	1	●					
Casuarina pauper	12658	9385	TR	24	●			●	●	
Chenopodiaceae										
Atriplex acutibractea	2449	WNB022	PH	70	●		●	●	●	
Atriplex acutibractea subsp. *karoniensis*	11489	WNB253	AH	-			●			
Atriplex cinerea	2452		LS	1	●					●
Atriplex codonocarpa	2453		AH	1					●	
Atriplex cryptocarpa	2454	WNB024	LS	14	●			●	●	
Atriplex holocarpa	2459		PH	-				●	●	
Atriplex isatidea	2463	WNB116	MS	2		●				●
Atriplex nummularia	2469		MS	140	●	●	●	●	●	●
Atriplex pumilio	2472	WNB257	PH	-			●			
Atriplex semilunaris	2476	WNB182	AH	-			●			
Atriplex stipitata	2479	WNB225	LS	2			●		●	
Atriplex vesicaria	2481		LS	239	●	●	●	●	●	●
Chenopodium curvispicatum	2487	WNB019	LS	86	●		●	●	●	
**Chenopodium murale*	2494	WNB032	AH	2				●	●	
Dissocarpus paradoxus	2499		PH	-					●	
Dysphania cristata	33501	9279	AH	1				●		
Dysphania kalpari	2502	WNB238	AH	-					●	
Dysphania melanocarpa forma *leucocarpa*	33596	WNB196	AH	14	●			●	●	
Enchylaena tomentosa	2511		LS	143	●		●	●	●	●
Eriochiton sclerolaenoides	2514	9397	PH	113	●		●	●	●	●
Maireana brevifolia	2537		LS	-			●			
Maireana erioclada	2542	9159	LS	107	●		●	●	●	●
Maireana georgei	2544	WNB130	LS	13	●		●	●	●	●
Maireana oppositifolia	2553	WNB332	LS	6	●				●	●
Maireana pentatropis	2555	9432	LS	14	●		●		●	●
Maireana radiata	2561		LS	29	●		●	●	●	●
Maireana sedifolia	2563		LS	173	●		●	●	●	●
Maireana thesioides	2566	WNB237	LS	-					●	
Maireana tomentosa	2567	WNB077	LS	12	●			●	●	●
Maireana trichoptera	2568	WNB076	LS	91	●		●	●	●	●
Maireana turbinata	2570	WNB155	LS	27	●		●	●	●	
Rhagodia crassifolia	2580	WNB142	LS	37	●	●	●	●	●	●
Rhagodia preissii	2584		TS	1	●				●	●
Rhagodia preissii subsp. *preissii*	11254	9213	MS	1	●				●	●
Rhagodia spinescens	2585	WNB232	MS	-				●	●	

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Rhagodia ulicina	2586	WNB216	LS	9	●		●	●	●	
Salsola tragus	18599		AH	150	●		●	●	●	●
Sclerolaena brevifolia	2599	WNB203	LS	8	●		●	●	●	●
Sclerolaena cuneata	2606	9430	PH	1			●		●	
Sclerolaena densiflora	2607		PH	5	●			●		●
Sclerolaena diacantha	2609		PH	133	●		●	●	●	●
Sclerolaena fimbriolata	2613	9417	PH	-					●	
Sclerolaena obliquicuspis	2625		PH	113	●		●	●	●	●
Sclerolaena patenticuspis	2627	9163	PH	116	●		●	●	●	●
Tecticornia disarticulata	31492	WNB334	LS	3	●					●
Tecticornia doleiformis	31918		LS	51			●	●	●	●
Threlkeldia diffusa	2644	WNB073	PH	7	●					●
Colchicaceae										
Wurmbea tenella	1403	9411	PH	6	●					
Cucurbitaceae										
**Citrullus lanatus*	7370		AH	6				●	●	
**Cucumis myriocarpus*	7372	WNB201	AH	-						●
Cupressaceae										
Callitris preissii	96		TR	4					●	●
Cyperaceae										
Ficinia nodosa	20216	WNB093	PS	3		●				●
Gahnia deusta	903	WNB324	PS	1	●					
Gahnia lanigera	906	9176	PS	8	●					●
Isolepis congrua	911	9380	AS	1					●	
Lepidosperma sp. A2 Island Flat	16264	WNB008	PS	2	●					●
Mesomelaena stygia	956		PS	1	●					
Mesomelaena stygia subsp. *stygia*	11473	9195	PS	-	●					
Schoenus caespititius	979	9196	PS	2		●				
Schoenus lanatus	997	9207	PS	3	●					●
Schoenus subflavus subsp. hispid culms	16267	9199	PS	3	●					
Tetraria capillaris	1034	9297	PS	9	●					
Dilleniaceae										
Hibbertia nutans	5149	WNB096	LS	5		●				●
Epacridaceae										
Acrotriche cordata	6295	WNB323	LS	3	●					●
Acrotriche patula	6297	WNB312	LS	3	●					●
Conostephium drummondii	6345	9198	LS	7	●	●			●	●
Leucopogon sp.	22492	WNB326	LS	1	●					
Lysinema ciliatum	6456	WNB088	LS	3					●	
Styphelia hainesii	6472	WNB318	MS	1						●
Euphorbiaceae										
Beyeria lechenaultii	4598	WNB268	MS	1	●		●			
Euphorbia drummondii	4626	9233	AH	128	●		●	●	●	●
**Euphorbia paralias*	4636	WNB092	PH	2	●	●				●
Euphorbia tannensis subsp. *eremophila*	12097	WNB194	PH	2				●	●	
Frankeniaceae										
Frankenia densa	5196	WNB129	LS	10	●			●	●	
Frankenia sessilis	5211	WNB171	LS	2	●					●

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Gentianaceae										
*Centaurium erythraea	6539	WNB245	AH	1	●				●	
Geraniaceae										
*Erodium aureum	4331	9375	PH	21				●	●	
*Erodium cicutarium	4333	WNB170	AH	4	●			●	●	●
Erodium cygnorum	4335		AH	8				●	●	
Pelargonium australe	4342	WNB261	PH	-			●			
Goodeniaceae										
Goodenia affinis	7488	9173	PH	3	●					
Goodenia concinna	7499	WNB262	PH	1	●		●			
Goodenia krauseana	7519		AH	-			●			
Goodenia pinnatifida	7535	9226	AH	14	●			●	●	
Lechenaultia formosa	7575	WNB065	LS	1	●					●
Scaevola bursariifolia	7601	WNB183	LS	2	●					●
Scaevola collaris	7604	WNB220	PH	1					●	
Scaevola crassifolia	7606		LS	3		●				●
Scaevola spinescens	7644	WNB016	MS	32	●		●	●	●	●
Velleia arguta	7653	9221	PH	-	●			●		
Haloragaceae										
Haloragis gossei	6174	9262	AH	-					●	
Myriophyllum balladoniense	6186		Q	-			●			
Hypoxidaceae										
Hypoxis glabella var. _glabella_	11699	9302	PH	1	●					
Lamiaceae										
*Marrubium vulgare	6881		PH	-						
Prostanthera serpyllifolia subsp. _serpyllifolia_	11953	WNB159	LS	3	●					
*Salvia verbenaca	6929	WNB112	PH	4				●	●	
Teucrium racemosum	6936	WNB017	PH	2				●		
Westringia rigida	9247	WNB059	LS	43	●		●	●	●	●
Lauraceae										
Cassytha melantha	2953	WNB094	C	8	●	●				
Loranthaceae										
Amyema melaleucae	2378	9217	Mi	2	●					●
Amyema quandang var. _quandang_	11827	9276	Mi	4				●	●	
Lysiana sp.	21335		Mi	1					●	
Lythraceae										
*Lythrum hyssopifolia	5281		AH	-			●			
Malvaceae										
Abutilon oxycarpum subsp. _prostratum_	16918		PH	1				●		
Lawrencia spicata	4958	WNB333	PH	2				●		●
Lawrencia squamata	4959		LS	34	●		●	●	●	●
*Malva parviflora	4961		AH	-					●	
Malva preissiana	31351	WNB001	AH	7	●		●	●	●	
*Malvastrum americanum	4962		PH	6	●			●	●	
Sida calyxhymenia	4970	WNB018	MS	16			●	●	●	
Sida intricata	4981	WNB200	PH	1				●		

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Sida spodochroma	16924	WNB179	PH	86	●		●	●	●	●
Marsileaceae										
Marsilea hirsuta	76	9381	F	2	●				●	
Mimosaceae										
Acacia anceps	3213	WNB090	MS	7	●	●			●	
Acacia ancistrophylla var. *ancistrophylla*	14584	WNB231	MS	4					●	
Acacia aneura	3217	9273	TR	13				●	●	
Acacia bracteolata	16114		LS	-	●					
Acacia burkittii	3248	9246	TS	17				●	●	
Acacia camptoclada	3251	9259	LS	2					●	
Acacia cochlearis	3262	WNB165	LS	3					●	●
Acacia cupularis	12672	WNB320	MS	1	●					●
Acacia cyclops	3282	WNB066	TS	4	●					●
Acacia densiflora	3292	WNB219	TS	2					●	
Acacia erinacea	3324	WNB102	LS	16	●		●			
Acacia excentrica	3328	WNB100	LS	1	●					
Acacia hemiteles	3366	WNB217	TS	8				●	●	
Acacia ligulata	3419	WNB215	TS	6			●		●	
Acacia merrallii	3440	9361	MS	3	●		●			●
Acacia mutabilis subsp. *angustifolia*	16133	WNB082	LS	1					●	
Acacia nyssophylla	3463		MS	8	●		●		●	
Acacia oswaldii	3473	WNB135	TS	34	●			●	●	●
Acacia papyrocarpa	3481		TR	70	●			●	●	●
Acacia rigens	3522	9264	TS	1					●	
Acacia salicina		WNB202	TR	1				●		
Acacia saligna	3527	WNB271	TS	-			●			
Acacia sulcata var. platyphylla	13506	WNB303	MS	1	●					
Acacia tetragonophylla	3577		TS	30				●	●	
Acacia xerophila	3605	WNB236	LS	1					●	
Myoporaceae										
Eremophila alternifolia	7180	WNB051	TS	9	●		●	●	●	●
Eremophila caperata	13807	WNB248	TS	1					●	
Eremophila decipiens	7193	WNB049	MS	17	●		●	●	●	●
Eremophila decipiens subsp. *decipiens*	14895	WNB314	LS	1	●		●			
Eremophila dempsteri	7195	WNB107	TS	21	●		●	●	●	●
Eremophila dendritica	17588	9243	LS	-					●	
Eremophila deserti	7198	WNB085	MS	20	●		●			●
Eremophila glabra	7215		MS	10	●		●	●	●	●
Eremophila ionantha	7226	WNB224	MS	1			●		●	
Eremophila latrobei	7230		MS	6				●	●	●
Eremophila latrobei subsp. *glabra*	17169	WNB186	MS	4				●	●	
Eremophila latrobei subsp. *latrobei*	17576	WNB213	MS	1					●	
Eremophila longifolia	7234		TR	23	●			●	●	
Eremophila maculata	7237	WNB002	MS	4				●	●	
Eremophila oblonga	14632	WNB254	LS	3			●		●	
Eremophila parvifolia	7251	WNB060	LS	4	●		●		●	●
Eremophila pustulata	7259		LS	1					●	
Eremophila scoparia	7267	WNB109	MS	34	●		●	●	●	●
Eremophila serrulata	7269	WNB206	MS	-				●	●	
Eremophila sp. (aff. *latrobei*)		WNB014	MS	5				●	●	
Eremophila weldii	7283	WNB050	LS	14	●			●		●
Myoporum platycarpum	7293		TR	72	●		●	●	●	●

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Myoporum platycarpum subsp. *platycarpum*	18259	9368	TR	7	●		●		●	●
Myrtaceae										
Beaufortia empetrifolia	5383	9202	MS	4					●	●
Beaufortia micrantha	5388	WNB095	LS	4	●					●
Calothamnus gracilis	5409	WNB290	TS	1		●				
Calytrix tetragona	5483	WNB302	LS	1	●		●			
Darwinia diosmoides	5510	WNB284	LS	1	●	●				
Eucalyptus brachycalyx	10757	WNB152	Ma	10	●	●			●	●
Eucalyptus concinna	5596	WNB227	Ma/TR	2			●		●	
Eucalyptus conglobata	5600	9289	Ma	9	●		●			●
Eucalyptus cooperiana	5604	WNB304	Ma	3	●	●	●		●	
Eucalyptus discreta	5624	WNB063	Ma	10				●	●	●
Eucalyptus diversifolia	5626	WNB153	Ma	8	●					●
Eucalyptus eremophila	5637	9404	Ma/TR	-			●		●	
Eucalyptus fraseri subsp. *fraseri*	14277	9336	TR	1			●			
Eucalyptus fraseri subsp. *melanobasis*	14276	WNB265	TR	1			●		●	
Eucalyptus gracilis	5662	WNB042	Ma/TR	33	●		●	●	●	●
Eucalyptus incrassata	5675	WNB287	Ma	9	●	●	●		●	
Eucalyptus leptophylla	15682	9413	Ma	2						●
Eucalyptus melanoxylon	5711	WNB347	TR	3	●				●	
Eucalyptus oleosa	5726	WNB278	Ma	18	●		●			●
Eucalyptus oleosa subsp. *ampliata*	20308		Ma	7				●		●
Eucalyptus oleosa subsp. *oleosa*	20091	WNB218	Ma	6	●		●	●	●	●
Eucalyptus rigidula	5761	9401	Ma	-	●		●			
Eucalyptus salubris	5767	9373	Ma	2					●	
Eucalyptus sp. Fraser Range	29671	WNB228	Ma	2					●	
Eucalyptus surgens	13519	9316	Ma	-	●					
Eucalyptus urna	18293	9340	TR	4	●		●			
Eucalyptus yalatensis	5801	WNB307	Ma	29	●	●	●	●		●
Kunzea pulchella	5840		MS	1	●		●			
Melaleuca eleuterostachya	5908	9257	TS	1					●	
Melaleuca lanceolata	5922	9166	TS	50	●		●	●	●	●
Melaleuca pentagona var. *latifolia*	11686	WNB288	MS	2		●	●			
Melaleuca pulchella	5955	WNB285	MS	1		●				
Melaleuca quadrifaria	5957	WNB005	TS	24	●			●	●	●
Melaleuca uncinata	5984	9258	TS	1					●	
Verticordia sieberi	6117	WNB291	LS	1	●		●			
Nyctaginaceae										
Boerhavia repleta	2774	WNB266	PH	2			●	●		
Oxalidaceae										
**Oxalis corniculata*	4349	9232	AH	5				●	●	
Papilionaceae										
Bossiaea leptacantha	3712	9210	LS	3	●					●
Cullen cinereum	17117		PH	17				●	●	
Glycine rubiginosa	19924	WNB131	C	13				●	●	
Lotus cruentus	4061	WNB191	AH	12			●	●	●	
Medicago sp.	21591		AH	1					●	
Pultenaea elachista	4170	WNB281	LS	10	●	●				
Pultenaea heterochila	28286	WNB087	MS	9	●	●			●	
Swainsona affinis	12355	WNB156	PH	8	●			●	●	
Swainsona campestris	4218	WNB141	PH	-	●			●		

Family Botanical name	Name id.	Collection no.	Growth form	Total sites	Physiographic regions					
					Hampton Tableland	Israelite Plain	Mardabilla Plain	Nullarbor Plain	Nyanga Plain	Roe Plains
Swainsona formosa	12356		AH	2				●	●	
Swainsona microphylla	4235	WNB010	PH	1	●			●		
Templetonia retusa	4256		TS	9	●				●	●
Templetonia sulcata	4258	WNB184	TS	2	●					
Phormiaceae										
Dianella revoluta	1259		PH	18	●	●		●	●	●
Pittosporaceae										
Billardiera fusiformis	25798	WNB315	C	1	●					
Marianthus bicolor	19421	9214	C	3					●	●
Pittosporum angustifolium	19744		TR	48	●		●	●	●	●
Plantaginaceae										
Plantago drummondii	7300	9370	AH	-	●		●	●	●	
Poaceae										
Aristida contorta	207	WNB239	AG	1				●	●	
Aristida nitidula	217	9247	TG	-				●		
Austrodanthonia caespitosa	17950	9229	TG	111	●		●	●	●	●
Austrodanthonia setacea	17945		TG	5	●			●	●	●
Austrostipa acrociliata	17231	WNB039	TG	1	●		●			●
Austrostipa dongicola	17333	WNB199	TG	-				●	●	●
Austrostipa drummondii	17236	WNB080	TG	9	●		●	●		●
Austrostipa elegantissima	17237	WNB128	TG	6	●	●	●	●	●	●
Austrostipa eremophila	17238	WNB123	TG	-	●			●	●	
Austrostipa nitida	17246	WNB004	TG	2	●	●	●	●	●	●
Austrostipa platychaeta	17247		TG	46	●		●	●	●	●
Austrostipa scabra	17251	9162	TG	216	●	●	●	●	●	●
Bromus arenarius	247	WNB151	AG	-	●			●		
**Cenchrus ciliaris*	258		TG	-				●		
**Chloris gayana*	267		TG	-			●			
Cymbopogon ambiguus	279		TG	-				●		
Cymbopogon obtectus	281		TG	-			●			
Enneapogon avenaceus	356	9256	TG	1	●				●	
Enneapogon caerulescens	357	9395	TG	39				●	●	
Enneapogon cylindricus	358	9277	TG	42				●	●	
Enteropogon ramosus	368		TG	3					●	
Eragrostis australasica	369		TG	1					●	
Eragrostis dielsii	378	WNB189	TG	22	●		●	●	●	●
Eragrostis leptocarpa	388		TG	1			●			
Eragrostis setifolia	393	9376	TG	14	●		●	●	●	●
Eriachne aristidea	400		AG	1			●		●	
Eriachne pulchella subsp. *pulchella*	16486	WNB207	AG	1				●	●	
**Hordeum glaucum*	448	WNB211	AG	-				●		●
Panicum decompositum	503		TG	2				●	●	
Panicum effusum	504	WNB012	TG	2					●	
Paspalidium clementii	518		AG	-			●			
**Pentaschistis airoides*	543		AG	-			●			
**Rostraria pumila*	11151		AG	1	●			●		●
**Schismus barbatus*	597	WNB158	AG	-	●		●	●	●	●
Spinifex hirsutus	624		TG	1						●
Themeda triandra	673	WNB258	TG	-			●			
Triodia scariosa	699		TG	10	●				●	

Family Botanical name	Name id.	Collection no.	Growth form	Total sites	Physiographic regions Hampton Tableland	Israelite Plain	Mardabilla Plain	Nullarbor Plain	Nyanga Plain	Roe Plains
Polygalaceae										
Comesperma volubile	4566	WNB067	C	5	●				●	●
Polygonaceae										
**Emex australis*	2409		AH	1				●		
Muehlenbeckia florulenta	16982		MS	4	●			●	●	●
Portulacaceae										
Calandrinia sp.	21411	WNB275	AH	1	●		●			
Primulaceae										
**Anagallis arvensis*	6480	WNB172	AH	1	●					●
Proteaceae										
Adenanthos cuneatus	1773	WNB300	MS	2	●		●			
Adenanthos forrestii	1784	9211	LS	5	●	●			●	●
Banksia media	1832	WNB286	TR	3	●	●	●			
Banksia speciosa	1850	WNB293	TR	1	●		●			
Grevillea acuaria	1949	9263	LS	1			●		●	
Grevillea nematophylla	2047	WNB139	TS	3				●	●	
Grevillea nudiflora	2050	WNB289	LS	1		●				
Grevillea pauciflora	2060		LS	1	●					●
Grevillea sparsiflora	2093	WNB310	MS	3	●					
Hakea cinerea	2139	WNB296	MS	1	●					
Hakea nitida	2187	9215	MS	5	●	●	●			●
Isopogon trilobus	2240	WNB292	MS	1	●		●			
Petrophile teretifolia	2313	WNB294	MS	1			●			
Stirlingia anethifolia	16375	WNB298	LS	1	●					
Synaphea oligantha	16772	WNB098	LS	2						
Restionaceae										
Desmocladus myriocladus	16471	WNB097	PH	4	●	●				●
Harperia eyreana	18294	9200	PH	1						●
Rhamnaceae										
Cryptandra sp.	22463	WNB325	LS	1	●					
Pomaderris forrestiana	4815	WNB146	MS	1	●					●
Pomaderris myrtilloides	4818	WNB101	LS	12	●				●	●
Spyridium microcephalum	4830	9205	LS	1	●					●
Spyridium tricolor	13556	9294	LS	4	●					●
Rubiaceae										
Opercularia loganioides	19210	WNB313	PH	1	●					
Psydrax attenuata	18206		TR	1					●	
Psydrax suaveolens	18155		TS	1	●				●	
Rutaceae										
Boronia crassifolia	4411	9191	LS	4	●	●				●
Geijera linearifolia	4481	WNB053	TS	57	●		●	●	●	●
Microcybe multiflora	4487		LS	2	●					●
Microcybe pauciflora	4488	WNB068	LS	-	●					
Microcybe pauciflora subsp. *pauciflora*	13785	WNB280	LS	2	●					
Philotheca fitzgeraldii	18536	WNB317	LS	1	●					

Family Botanical name	Name id.	Collection no.	Growth form	Total sites	Physiographic regions					
					Hampton Tableland	Israelite Plain	Mardabilla Plain	Nullarbor Plain	Nyanga Plain	Roe Plains
Santalaceae										
Exocarpos aphyllus	10977	9218	TS	30	●		●	●	●	●
Exocarpos sparteus	10765	WNB316	TS	4	●				●	●
Leptomeria pachyclada	2349	9326	MS	2	●		●			
Santalum acuminatum	2356	WNB163	TR	13	●		●		●	●
Santalum lanceolatum	2357		TR	2	●					
Santalum spicatum	2359		TR	4	●			●		
Sapindaceae										
Alectryon oleifolius	4739		TR	22	●		●	●	●	
Dodonaea amblyophylla	4753	9216	MS	1	●					
Dodonaea bursariifolia	4755	WNB282	MS	3	●					
Dodonaea caespitosa	4756		LS	1	●		●			
Dodonaea lobulata	4769		TS	11	●		●	●	●	
Dodonaea stenozyga	4780	9171	MS	22	●			●	●	●
Solanaceae										
Lycium australe	6967		LS	74	●			●	●	●
**Nicotiana glauca*	6974	WNB136	TR	-			●			●
Nicotiana goodspeedii	6975	WNB009	AH	14	●		●	●	●	●
Nicotiana occidentalis	6976	WNB125	AH	25	●			●	●	●
Nicotiana occidentalis subsp. *obliqua*	11331	9240	AH	1	●					
Solanum ellipticum	7006	WNB013	PH	43				●	●	
Solanum lasiophyllum	7018		LS	6	●		●	●	●	●
**Solanum nigrum*	7022		PH	2				●	●	
Solanum nummularium	7023		LS	44	●		●	●	●	
Solanum orbiculatum	7026		LS	3	●			●	●	
Solanum plicatile	7030	9400	LS	1	●		●			
Solanum symonii	7037		MS	1	●					●
Sterculiaceae										
Lasiopetalum compactum	5027	9299	MS	1	●					
Rulingia craurophylla	5056	WNB226	MS	1					●	
Tamaricaceae										
**Tamarix aphylla*	15741		TR	1					●	
Thymelaeaceae										
Pimelea ferruginea	5243		LS	1		●				
Pimelea microcephala	5256	9284	MS	12			●	●	●	
Pimelea serpyllifolia	5262	9177	LS	2	●	●				
Zygophyllaceae										
Nitraria billardierei	4366	WNB055	MS	50	●		●	●	●	●
Zygophyllum apiculatum	4385		PH	6	●				●	●
Zygophyllum aurantiacum	4386	WNB006	LS	32	●		●	●	●	●
Zygophyllum billardierei	4387	WNB072	PH	2						●
Zygophyllum compressum	4388	9412	AH	1			●			
Zygophyllum eremaeum	4389	9283	AH	3			●		●	
Zygophyllum glaucum	4391	WNB007	AH	29	●		●	●	●	●
Zygophyllum iodocarpum	4392	WNB041	AH	60	●			●	●	●
Zygophyllum ovatum	4394	9225	AH	14				●		●

Key to Appendix 2(i)

Family and botanical names

Species identifier from the Western Australian Herbarium.

* denotes naturalised species, not native to Western Australia.

Name identification

Unique species identification number from the Western Australian Herbarium.

Collection number

WNB numbers were collected within the survey area by the rangeland survey team during the survey.

Numbers from 9158 to 9432 were collected within the survey area by R Davis, Western Australian Herbarium, Department of Environment and Conservation.

Growth form

TR	tree
Ma	mallee
TS	tall shrub (> 2 m)
MS	mid shrub (1–2 m)
LS	low shrub (< 1 m)
PH	perennial herb
AH	annual herb
HG	perennial hummock grass
TG	perennial tussock grass
AG	annual grass
PS	perennial sedge
AS	annual sedge
C	creeper
Mi	mistletoe
F	fern
Q	aquatic plants

Total sites

The number of inventory sites at which the species was recorded.

Physiographic regions

Physiographic divisions of the Eucla Basin based on differences in geological history, topography, soil, vegetation and climate (Figure 31).

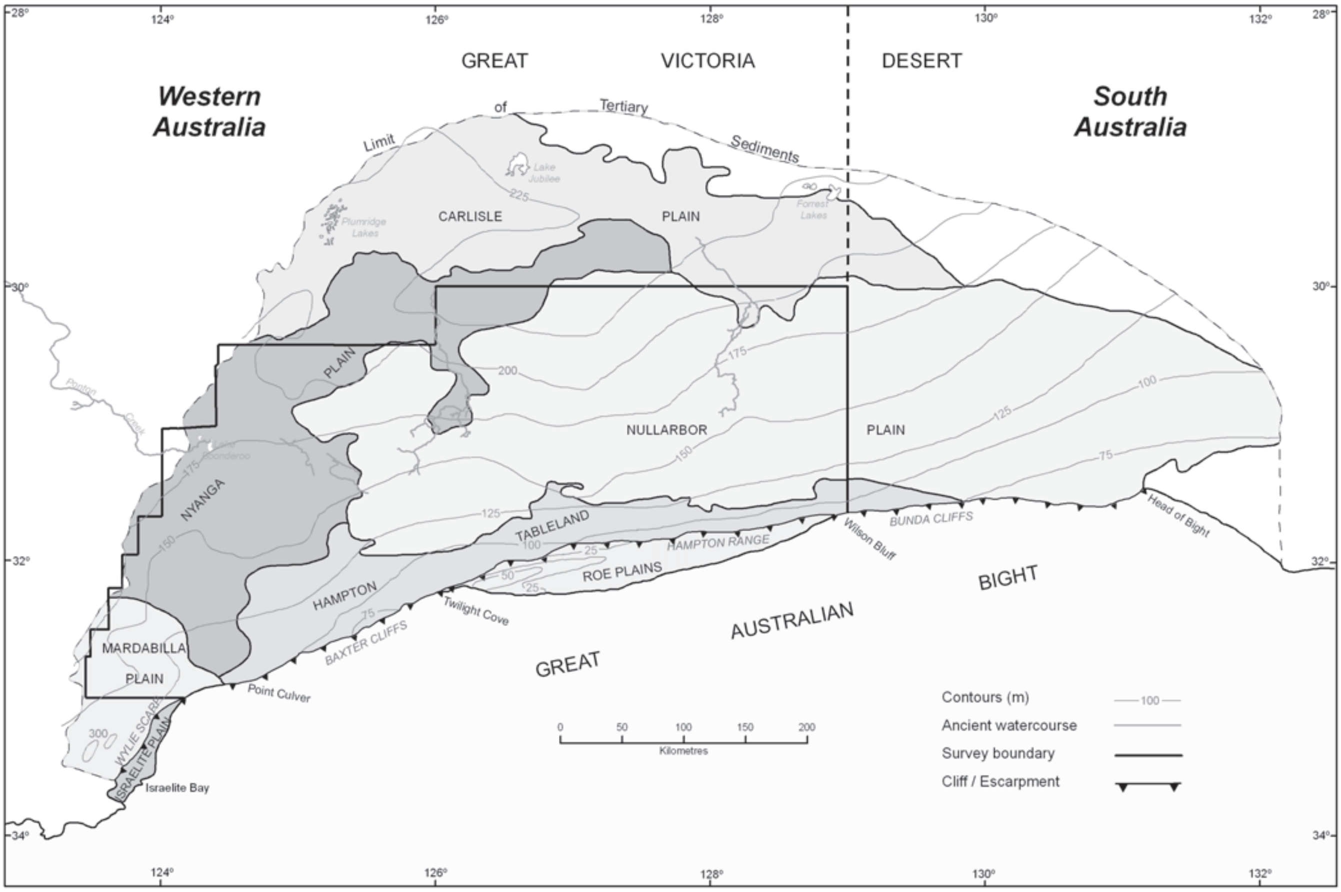

Figure 31 **Physiographic divisions of the Eucla Basin from Lowry and Jennings (1974)**

Appendix 2(ii)—Common plants of the Bunda Plateau in the survey area

The Bunda Plateau is subdivided into the following physiographic regions: Carlisle Plain, Hampton Tableland, Mardabilla Plain, Nullarbor Plain and Nyanga Plain.

Botanical name	Common name
Trees and mallees (commonly > 2 m)	
Acacia aneura	Mulga
Acacia papyrocarpa	Western myall
Alectryon oleifolius	Mingah or Bullock bush
Allocasuarina helmsii	
Casuarina pauper	Black oak
Eremophila longifolia	Berrigan
Eucalyptus concinna	Victoria desert mallee
Eucalyptus diversifolia	Soap mallee
Eucalyptus gracilis	Yorrell or White mallee
Eucalyptus oleosa	Giant mallee
Eucalyptus oleosa subsp. *oleosa*	Giant mallee
Eucalyptus yalatensis	Yalata mallee
Grevillea nematophylla	
Myoporum platycarpum	Sugarwood
Pittosporum angustifolium	Native willow
Santalum acuminatum	Sweet quandong
Tall shrubs (commonly > 2 m)	
Acacia burkittii	Fine leaf jam
Acacia ligulata	Umbrella bush
Acacia oswaldii	Miljee
Acacia tetragonophylla	Curara
Dodonaea lobulata	Bead hopbush
Eremophila alternifolia	Poverty bush
Eremophila dempsteri	
Exocarpos aphyllus	Naked lady
Geijera linearifolia	Oilbush
Melaleuca lanceolata	Rottnest teatree
Mid shrubs (commonly 1–2 m)	
Atriplex nummularia	Old man saltbush
Cratystylis conocephala	False bluebush
Eremophila decipiens	Slender fuchsia
Eremophila deserti	
Eremophila glabra	Black fuchsia
Eremophila scoparia	Broom bush
Muehlenbeckia florulenta	Lignum
Nitraria billardierei	Nitre bush
Pimelea microcephala	Shrubby riceflower
Scaevola spinescens	Currant bush
Senna artemisioides subsp. x *artemisioides*	
Senna artemisioides subsp. x *coriacea*	Desert cassia
Low shrubs (commonly < 1 m)	
Acacia erinacea	
Atriplex cryptocarpa	Rough saltbush
Atriplex vesicaria	Bladder saltbush
Chenopodium curvispicatum	Scrambling saltbush
Enchylaena tomentosa	Ruby saltbush
Eremophila weldii	
Frankenia densa	Nullarbor frankenia
Gunniopsis calcarea	
Lawrencia squamata	Grey fan leaf
Lycium australe	Water bush

Botanical name	Common name
Maireana erioclada	Rosy bluebush
Maireana georgei	Golden bluebush
Maireana pentatropis	Erect bluebush
Maireana radiata	Grey bluebush
Maireana sedifolia	Pearl bluebush
Maireana turbinata	
Olearia calcarea	Limestone daisy
Olearia muelleri	Goldfields daisy
Ptilotus obovatus	Cotton bush
Rhagodia crassifolia	Fleshy saltbush
Rhagodia ulicina	
Sida calyxhymenia	Tall sida
Solanum lasiophyllum	Flannel bush
Solanum nummularium	Money leaved solanum
Tecticornia disarticulata	
Tecticornia doleiformis	Samphire
Westringia rigida	Rigid westringia
Zygophyllum aurantiacum	Shrubby twinleaf
Perennial herbs	
Atriplex acutibractea	Toothed saltbush
Cullen cinereum	
Dissocarpus paradoxus	Curious saltbush
Eriochiton sclerolaenoides	Woolly bindii
Erodium aureum	Crowsfoot
Goodenia affinis	Silver goodenia
Maireana tomentosa	Felty leafed bluebush
Maireana trichoptera	Pink-seeded bluebush
Sclerolaena diacantha	Grey bindii
Sclerolaena obliquicuspis	Limestone bindii
Sclerolaena patenticuspis	Spear-fruit copperburr
Sida spodochroma	Dwarf sida
Solanum ellipticum	Potato bush
Wurmbea tenella	Eight Nancy
Zygophyllum apiculatum	Gallweed
Perennials grasses	
Austrodanthonia caespitosa	Wallaby grass
Austrostipa platychaeta	Cane speargrass
Austrostipa scabra	Speargrass
Enneapogon caerulescens	Limestone grass
Enneapogon cylindricus	Jointed nineawn
Eragrostis dielsii	Mallee lovegrass
Eragrostis setifolia	Neverfail
Triodia scariosa	Buck spinifex
Other plant forms	
Amyema quandang var. *quandang* (mistletoe)	
Carpobrotus modestus (succulent perennial herb)	Inland pigface
Comesperma volubile (creeper)	Love creeper
Dianella revoluta (lily)	Blueberry lily
Glycine rubiginosa (creeper)	
Lysiana sp. (mistletoe)	
Marsdenia australis (creeper)	Cogla
Marsilea hirsuta (fern)	Nardoo
Annual herbs	
Angianthus conocephalus	
Calotis multicaulis	Burr daisy
**Carrichtera annua*	Ward's weed
Dysphania melanocarpa forma *leucocarpa*	
Euphorbia drummondii	Balsam
Goodenia pinnatifida	Cut-leafed goodenia

Botanical name	Common name
Lepidium sp.	Peppercress
Lotus cruentus	Redflower lotus
**Mesembryanthemum crystallinum*	Ice plant
Nicotiana goodspeedii	Small-flowered tobacco
Nicotiana occidentalis	Native tobacco
Podolepis canescens	Large copperwire daisy
Rhodanthe floribunda	
Salsola tragus	Roly poly
Senecio pinnatifolius	
**Sisymbrium erysimoides*	Smooth mustard
Sonchus oleraceus	Common sowthistle
Zygophyllum glaucum	Pale twinleaf
Zygophyllum iodocarpum	Violet twinleaf
Zygophyllum ovatum	Dwarf twinleaf

* denotes naturalised species, not native to Western Australia

Appendix 2(iii)—Common Nullarbor coastal zone plants in the survey area

The Nullarbor coastal zone refers primarily to the Israelite and Roe Plains, but also includes the seaward margin of the Bunda Plateau where land systems immediately connected with the Baxter Cliffs, Hampton Range and Wylie Scarp are considerably influenced by coastal conditions.

Botanical name	Common name
Trees and mallees (commonly > 2 m)	
Acacia papyrocarpa	Western myall
Alectryon oleifolius	Mingah or Bullock bush
Allocasuarina helmsii	
Banksia media	Southern Plains banksia
Callitris preissii	Rottnest Island pine
Eucalyptus brachycalyx	Gilja
Eucalyptus conglobata	Port Lincoln mallee
Eucalyptus cooperiana	Many-flowered mallee
Eucalyptus discreta	
Eucalyptus diversifolia	Soap mallee
Eucalyptus gracilis	Yorrell or White mallee
Eucalyptus incrassata	Lerp mallee
Eucalyptus oleosa subsp. *ampliata*	
Eucalyptus oleosa subsp. *oleosa*	Giant mallee
Eucalyptus urna	
Eucalyptus yalatensis	Yalata mallee
Myoporum platycarpum	Sugarwood
Santalum acuminatum	Sweet quandong
Tall shrubs (commonly > 2 m)	
Acacia cyclops	Coastal wattle
Dodonaea stenozyga	
Eremophila dempsteri	
Exocarpos aphyllus	Naked lady
Exocarpos sparteus	Broom ballart
Geijera linearifolia	Oilbush
Melaleuca lanceolata	Rottnest teatree
Melaleuca pentagona var. *latifolia*	
Melaleuca quadrifaria	
Templetonia retusa	Cockies tongue
Mid shrubs (commonly 1–2 m)	
Acacia anceps	
Atriplex nummularia	Old man saltbush
Beaufortia empetrifolia	
Cratystylis conocephala	False bluebush
Eremophila decipiens	Slender fuchsia
Eremophila deserti	
Eremophila glabra	Black fuchsia
Hakea nitida	Frog hakea
Nitraria billardierei	Nitre bush
Pultenaea heterochila	
Scaevola spinescens	Currant bush
Low shrubs (commonly < 1 m)	
Acacia erinacea	
Acacia cochlearis	Rigid wattle
Adenanthos forrestii	
Atriplex vesicaria	Bladder saltbush
Beaufortia micrantha	Little bottlebrush
Boronia crassifolia	
Bossiaea leptacantha	
Conostephium drummondii	

Botanical name	Common name
Enchylaena tomentosa	Ruby saltbush
Eremophila parvifolia	Small-leaved eremophila
Eremophila weldii	
Frankenia densa	Nullarbor frankenia
Frankenia sessilis	
Gunniopsis calcarea	
Halgania andromedifolia	
Kippistia suaedifolia	
Lawrencia squamata	Grey fan leaf
Leucophyta brownii	
Lycium australe	Water bush
Maireana erioclada	Rosy bluebush
Maireana oppositifolia	
Maireana sedifolia	Pearl bluebush
Olearia axillaris	Coastal daisybush
Olearia calcarea	Limestone daisy
Olearia muelleri	Goldfields daisy
Olearia picridifolia	
Pimelea serpyllifolia	
Pomaderris forrestiana	
Pomaderris myrtilloides	
Prostanthera serpyllifolia subsp. *serpyllifolia*	
Pultenaea elachista	
Rhagodia crassifolia	Fleshy saltbush
Scaevola crassifolia	Thick-leaved fan-flower
Scaevola spinescens	Currant bush
Spyridium tricolor	
Tecticornia disarticulata	
Tecticornia doleiformis	Samphire
Westringia rigida	Rigid westringia
Zygophyllum aurantiacum	Shrubby twinleaf
Perennial herbs	
Heliotropium asperrimum	Rough heliotrope
Maireana tomentosa	Felty leafed bluebush
Sclerolaena diacantha	Grey bindii
Sclerolaena obliquicuspis	Limestone bindii
Sclerolaena patenticuspis	Spear-fruit copperburr
Sida spodochroma	Dwarf sida
Tetragonia implexicoma	Bower spinach
Threlkeldia diffusa	Coast bonefruit
Perennials grasses	
Austrodanthonia caespitosa	Wallaby grass
Austrostipa elegantissima	Feather speargrass
Austrostipa platychaeta	Cane speargrass
Austrostipa scabra	Speargrass
Spinifex hirsutus	Hairy spinifex
Triodia scariosa	Buck spinifex
Other plant forms	
Amyema melaleucae (mistletoe)	
Billardiera fusiformis (creeper)	Australian bluebell
Carpobrotus modestus (succulent perennial herb)	Inland pigface
Carpobrotus virescens (succulent perennial herb)	Coastal pigface
Cassytha melantha (creeper)	Large dodder-laurel
Comesperma volubile (creeper)	Love creeper
Dianella revoluta (lily)	Blueberry lily
Ficinia nodosa (perennial sedge)	Knotted club rush
Gahnia lanigera (perennial sedge)	Little sedge
Lepidosperma sp. A2 Island Flat (perennial sedge)	
Marianthus bicolor (creeper)	Painted marianthus
Mesomelaena stygia (perennial sedge)	

Botanical name	Common name
Schoenus caespititius (perennial sedge)	
Schoenus lanatus (perennial sedge)	Woolly bog-rush
Schoenus subflavus subsp. hispid culms (perennial sedge)	
Tetraria capillaris (perennial sedge)	Hair sedge
Annual herbs	
**Anagallis arvensis*	Pimpernel
Asteridea athrixioides	
Brachyscome ciliaris	
Brachyscome lineariloba	
**Cakile maritima*	Sea rocket
Calandrinia sp.	
**Carduus nutans*	Nodding thistle
**Carrichtera annua*	Ward's weed
**Erodium cicutarium*	Common storksbill
Euphorbia drummondii	Balsam
Lepidium sp.	Peppercress
**Oncosiphon suffruticosum*	
Nicotiana goodspeedii	Small-flowered tobacco
Podolepis canescens	Large copperwire daisy
**Rostraria pumila*	
Senecio pinnatifolius	
Sonchus oleraceus	Common sowthistle
Trichanthodium skirrophorum	
Zygophyllum glaucum	Pale twinleaf
Zygophyllum iodocarpum	Violet twinleaf
Zygophyllum ovatum	Dwarf twinleaf

* denotes naturalised species, not native to Western Australia