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An inventory and condition survey of the Pilbara region, Western Australia

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Front cover: Gregory Gorge on the Fortescue River

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This survey could not have been conducted without the co-operation, advice and assistance of pastoralists throughout the area.

Definition

The Pilbara region, as used in this report, includes the following 1:250,000 map sheets: Balfour Downs, Marble Bar, Nullagine, Robertson, Roy Hill, Pt Hedland and Yarrie, and parts of the Collier, Dampier, Mandora, Mt Bruce, Newman, Onslow, Pyramid, Roebourne, Turee Creek, Yarraloola and Wyloo.

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An inventory and condition survey of the Pilbara region, Western Australia.

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Contents

Summary

Scope of the survey

1. The area surveyed by field work during 1995, 1996, 1997 and 1999 covers about 181,723 km^2 and includes the following 1:250,000 scale map sheets: the entire Balfour Downs, Marble Bar, Nullagine, Robertson, Roy Hill, Pt Hedland and Yarrie sheets, most of the Mt Bruce, Newman, Pyramid and Yarraloola sheets and small parts of the Collier, Dampier, Mandora, Onslow, Roebourne, Turee Creek and Wyloo sheets.

   Seven towns fall within the area, namely Pt Hedland in the north, Onslow and Pannawonica to the west, Wittenoom in the centre, Marble Bar and Nullagine in the centre east and Newman in the south-east. Several major river catchments occur in the survey area including the De Grey, Turner and Yule in the north, and the Fortescue and Robe in the west. All rivers are ephemeral and flow generally north-west to the Indian Ocean.

2. Pastoralism is the most extensive land use in the area. Forty-four pastoral leases fall wholly or partly within the survey area and collectively occupy about 105,240 km^2 (58% of the area).

   Areas set aside for nature conservation at the time of survey covered approximately 16,629 km^2 (9% of the area) consisting of the Karijini and Millstream-Chichester National Parks, the Mungaroona Range and Cane River Nature Reserves and the Meentheena pastoral lease which has been purchased by the Department of Conservation and Land Management (CALM), destocked and is to be incorporated into the conservation estate.

   The Aboriginal reserves of Abydos, Jigalong, Woodstock and Yandeyarra, and the special lease for Aboriginal use, Callawa, occupy about 9,740 km^2 (5% of the area).

   Mining is an important land use which is largely confined to ironstone ranges and greenstone belts throughout the survey area.

   There are also large tracts of unallocated Crown land which account for about 48,840 km^2 (27% of the area).

   The remaining 1% of the survey area is made up of town commons and various reserves.

3. This report provides a regional inventory and descriptive reference of land resources to accompany a land system map. The report 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, site type ecology, land systems and resource condition (in terms of pastoral impact) of the survey area. 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 site types. These are derived from 12,445 visual traverse assessments, which are shown on the accompanying land system map. Severely degraded and eroded areas have been mapped.

5. The report deals specifically with resource description and assessment, recognising the widespread impact of pastoralism on resources in the process. A companion report[1] focusing on pastoral resources and pastoral management has also been produced, based on the findings of this rangeland survey. Pastoralists are encouraged to refer to both reports.

Land characteristics

6. The survey area exhibits a characteristically arid or semi-arid climate. Rainfall averages between about 250 and 400 mm a year, mostly falling during the summer period December to March from thunderstorm or cyclonic activity. Temperatures in the summer months are very high (maxima often exceed 40˚C, minima about 25˚C), especially in inland areas. Winters are milder with temperatures in the daily range of about 28˚C maxima to 13˚C minima.

7. Geologically, the area is dominated by granite terrain of the Pilbara Block in the north; the rugged sedimentary Hamersley Basin in the south; and the sedimentary rocks overlain by eolian sands of the Canning Basin to the east. Drainage is mostly through major river catchments and is exoreic (i.e. flows into the ocean). The exception to this is the Savory Creek which drains eastwards into Lake Disappointment.

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[1] Van Vreeswyk, Payne and Leighton. (2004). Pastoral resources and their management in the Pilbara region of Western Australia. Department of Agriculture, Western Australia Miscellaneous Publication No. 21/2004.

8. Lands within the area have been described and mapped into 20 broad land types comprised of 102 land systems. Forty-six of the systems are described for the first time, the others having been described previously in other surveys. Their individual extent varies greatly, and almost half the area comprises just six land systems (Little Sandy, Macroy, Newman, Nita, Rocklea and Uaroo). The land system approach is a natural 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. The survey area has several natural characteristics that help protect the landscape against inappropriate land use practices. These include widespread stony mantles on pediments, extensive nearly level plains subject to episodic sheet flow with tall shrub strata largely unaffected by grazing and extensive sandy plains with moderately dense spinifex grasslands. The local areas in which the landscape is most susceptible to inappropriate land use practices are floodplains and alluvial plains.

Soils

10. Twenty-one broad Soil Groups have been identified within the survey area. The most outstanding characteristic of the soils is the predominant red colour. Stony mantles and shallowness are also dominant features.

11. The most extensive soils are shallow stony soils on hills and ranges and sands on sandplains. In the south the soils are predominantly red earths overlying hardpan on level to gently inclined plains. Lower flood plains have cracking and non-cracking clay soils. Duplex (texture-contrast) soils occur in localised areas on saline alluvial plains and elsewhere. These soils support the most preferentially grazed vegetation and are highly susceptible to erosion.

Vegetation

12. The flora of the area is diverse, with 1,137 vascular species being recorded during the survey; 1,094 of these species were native. Forty-one of the 95 plant species on the Declared Rare and Priority Flora listing for the survey area were collected. Perennial plant species that have restricted distributions or are rare and endangered, or any combination of these characteristics, are most frequently (though rarely) found on gilgaied alluvial plains and stony basaltic uplands.

13. Vegetation/soil associations considered at the scale of the land unit have been classified and described as 44 major site types within 11 broad site type groups. Ecological assessments are made for each site type. The site types include hummock grasslands, tussock grasslands, sclerophyll shrublands, and shrublands and woodlands with a tussock grass understorey. The most common genera are *Acacia, Aristida, Ptilotus, Senna* and *Triodia. Triodia pungens* (soft spinifex), *Acacia inaequilatera* (kanji bush), *Chrysopogon fallax* (ribbon grass) and the introduced grass *Cenchrus ciliaris* (buffel grass) are the most ubiquitous perennials while *Aristida contorta* (wind grass) is the most widespread annual species.

14. Intensive sampling at 102 condition sites within 4 sensitive site types revealed the patterns of variation that exist, partly as natural variation but otherwise as a consequence of changes related to cumulative impact by grazing animals and pastoral management.

Resource condition

Soil erosion

15. Accelerated soil erosion is not widespread but is a serious problem in localised areas on a few susceptible vegetation/soil types. Perennial vegetation on eroded areas is invariably degraded. Erosion problems have started and accelerated primarily as a consequence of loss of ground cover by overgrazing or other disturbance or where natural processes (such as overland sheet water flow) have been fragmented or disrupted. However, many hill and plain land units with stony surface mantles or rock outcrop are resistant to erosion.

16. Assessments made at 12,445 points whilst traversing the survey area showed that 6.5% of traverse points had some form of accelerated erosion. Slight or minor erosion was recorded at 3.7%, moderate erosion was recorded at 1.6% and severe or extreme erosion was recorded at 1.2% of the points. The most susceptible soil types are duplexes on areas with some slope, which are subject to sheet flows after rainfall events. The most common forms of erosion were scalding and surface sheeting. Eroded areas are mainly plains with patchy vegetation or which are denuded, with deflated or no topsoil and exposed saline subsoils or inert hardpan remaining as the land surface. Localised gully erosion was evident on some disturbed areas, such as along tracks, on some hardpan plains and at old minesites. However, the preponderance of shallow soils (<50 cm deep over parent rock or hardpan) has meant that erosion is not generally characterised by spectacular gullying.

17. Areas of severe degradation and erosion (sde) larger than 40 ha were mapped following aerial photo-interpretation and ground truthing; the total of these areas was approximately 310 km^2, which represents about 0.2% of the survey area. Severely degraded and eroded areas were identified on 25 of the 102 land systems, representing 10 of the 20 land types. The sde is largely confined to susceptible and preferentially grazed land units in particular land systems. Cane, Christmas and Jurrawarrina land systems have the highest proportions (7.1%, 5.3% and 5.0% respectively) of total area mapped as being severely degraded and eroded. Turee, Cowra, Paradise and Coolibah land systems have 3.6%, 3.1%, 2.9% and 2.6% respectively of their area mapped as severely degraded and eroded.

Vegetation condition

18. In terms of impact on perennial vegetation by pastoral usage, approximately 77% of traverse records indicated that vegetation was in good or very good condition, 11% indicated fair condition and 12% indicated poor or very poor condition. Taken overall, these summary data show that the vegetation in this survey area is generally in better condition than that recorded from most other regional rangeland surveys in Western Australia.

19. The most frequently observed impacts of pastoralism were loss in perennial species richness and perennial plant density. Decrease in perennial plant cover is a reliable indicator of grazing impact in tussock grasslands and in chenopod shrublands. These broad vegetation types are grazed preferentially and are often associated with soils that are susceptible to erosion. Hence, it was in tussock grasslands and chenopod shrublands that major alterations to vegetation and consequent accelerated soil erosion were most frequently observed. Increases in shrubs well suited to exploiting overgrazed situations were uncommon and they generally did not form dense thickets that might exclude the re-emergence of previous species as has been reported in previous rangeland survey reports (e.g. Payne, Curry and Spencer 1987[2]). A dramatic exception is on the delta of the Fortescue River where the serious woody weed mesquite (*Prosopis sp.*) has established dense stands. The exotic grasses buffel grass (*Cenchrus ciliaris*) and Birdwood grass (*Cenchrus setigerus*) have displaced native grasses and low shrubs on some coastal plains. They have also colonised previously severely degraded floodplains and levees of many of the major river systems in the survey area.

20. Disturbance as a result of mining or mining exploration was recorded at 42 traverse points, which represent 0.3% of traverse assessments and indicates the generally localised nature of mining impacts. About 4,877 ha of mine dumps from current mining activity and eroded spoil dumps from old mining activity, representing 0.03% of the survey area, were identified and mapped.

Management implications and recommendations

21. Within the survey area about 12% of the land currently used for pastoralism is in poor condition but not severely degraded and eroded. These areas, with mainly intact soil surfaces, present the best prospects for economically feasible regeneration of perennial vegetation, by appropriate management, in the short to medium term.

22. Areas identified as being severely degraded and eroded (sde) should be removed from pastoral use, as continued use will only exacerbate the problem. Given the generally low economic return per hectare, regeneration works on such areas are unlikely to be economically justifiable by pastoralists. Where regeneration is to be attempted, consideration of catchment and sub-catchment characteristics and processes will improve the chances of success.

23. Numerous land systems, site 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 agency, is actively purchasing pastoral leases and taking them out of pastoral production as a conservation initiative. However, 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 is recommended.

24. The map and contents of this report describe the environment in a spatial context, which is useful for planning future regional conservation strategies or systems of reserves. Resource condition assessments highlight types of land most extensively and severely modified by pastoral land use, and where they exist in a relatively intact state. Furthermore the map, and land system and site type descriptions are useful for planning ecological monitoring on the basis of representativeness or

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[2] Payne, A.L., Curry, P.J. and Spencer, G.F. (1987). An inventory and condition survey of the Carnarvon Basin, Western Australia. Western Australian Department of Agriculture, Technical Bulletin No. 73.

sensitivity to change. The map and report also provide essential biological information for pastoralists and other stakeholders with interests in accessing rangeland resources. For example mining companies preparing environmental impact reviews and pastoralists preparing property development and management plans.

25. It is difficult to evaluate the ecological sustainability of current land management without undertaking exhaustive monitoring of resources and management. 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 erosion. In contrast, there have been 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, conservative pastoralism can be ecologically sustainable in most land systems.

26. At present resource monitoring is confined largely to measurements of perennial shrub density and size, and soil surface stability. 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. At a broader scale, 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.

Introduction

Rangeland surveys

The findings presented in this report are those of a regional survey of lands in the Pilbara region of Western Australia. The survey was undertaken by a joint team from the Department of Agriculture, Western Australia and the Department of Land Administration (now Department of Land Information) between 1995 and 1999.

This survey is the eleventh of its type in a program of arid land classification, mapping and resource evaluation in the State. Other surveys in the program have been undertaken in the Gascoyne River catchment (Wilcox and McKinnon 1972), the West Kimberley (Payne *et al.* 1979), the Ashburton River catchment (Payne, Mitchell and Holman 1988), part of the Nullarbor Plain (Mitchell, McCarthy and Hacker 1988), the Carnarvon Basin (Payne, Curry and Spencer 1987), the Roebourne Plains (Payne and Tille 1992), the Murchison River catchment (Curry *et al.* 1994), the north-eastern Goldfields (Pringle, Van Vreeswyk and Gilligan 1994), the Sandstone-Yalgoo-Paynes Find area (Payne *et al.* 1998) and the Broome coastal plain (Cotching, unpublished).

The survey area

An area of 181,723 km^2 was covered in the Pilbara survey which extends from latitude 19˚30' S in the north to 24˚ S in the south, and longitude 115˚ E in the west to 121˚30' E in the east (Figure 1). Several major river systems occur in the area, including the De Grey, Fortescue, Robe, Turner and Yule.

In the north and west the survey area is bounded by the Indian Ocean and the area previously surveyed in the Roebourne Plains survey (Payne and Tille 1992), in the north-east by the Broome coastal survey (Cotching, unpublished) and in the south by the area previously surveyed in the Ashburton River catchment (Payne, Mitchell and Holman 1988). The eastern limit of the survey area is defined by longitude 121˚30' E (Figure 2).

The survey area includes all or part of the Ashburton, De Grey, East Pilbara and Roebourne/Port Hedland Land Conservation Districts, and the towns of Marble Bar, Newman, Nullagine, Onslow, Pannawonica, Port Hedland and Wittenoom. Forty-four leasehold pastoral stations, four Aboriginal reserves and one special lease for Aboriginal use are wholly or partly covered by this survey. The area also includes the Karijini and Millstream-Chichester National Parks, the Mungaroona Range and Cane River Nature Reserves and the Meentheena pastoral lease which has been purchased by the Department of Conservation and Land Management (CALM), destocked and is to be incorporated into the conservation estate (Figure 3).

A survey covering the Roebourne Plains (Payne and Tille 1992) was commissioned by the Commissioner of Soil Conservation in response to concerns over dust pollution around the town of Karratha. Information in this Pilbara report excludes the area covered by the Roebourne Plains survey, although the accompanying land system map shows the land systems mapped in the Roebourne Plains survey for completeness.

A survey investigating the impact of the Ophthalmia Dam on the floodplains of the Fortescue River was undertaken by the Department of Agriculture in 1990 (Payne and Mitchell 1992). That survey falls within the Pilbara survey area.

Purpose of the survey

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

The report and the accompanying map 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 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, habitats or conservation values for land use planning. Maps at other than the published scale can be generated as required.

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

Contents of the report

The first part of this report provides a brief review of particular aspects of the land use and biophysical features of the survey region. In many instances little detailed information has been published for the region and these chapters draw together the disparate information which is available. The Land use history, Climate, Geology and hydrogeology and Declared plants and animals chapters serve as an introduction to the later more detailed Soils, Vegetation, Site type ecology and Land systems chapters.

No review of the fauna of the Pilbara is presented. This aspect will be covered by the Department of Conservation and Land Management as part of the Pilbara Biological Survey which is being undertaken over the period 2002 to 2007.

The second part of the report includes a Methodology chapter which explains the survey procedure and chapters reporting on the findings of the survey. The Geomorphology chapter describes landforms and discusses how they are distributed and how they were formed. It also considers land use impacts on the landforms and landscape processes.

Other major chapters in this part discuss land systems, soils, vegetation and site type ecology. They provide information on landform, soil and vegetation at the land unit level, and used in conjunction with the map provide a comprehensive inventory of biophysical resources.

The Resource condition chapter provides a detailed assessment of land use impacts on the vegetation and soil resources of the survey area.

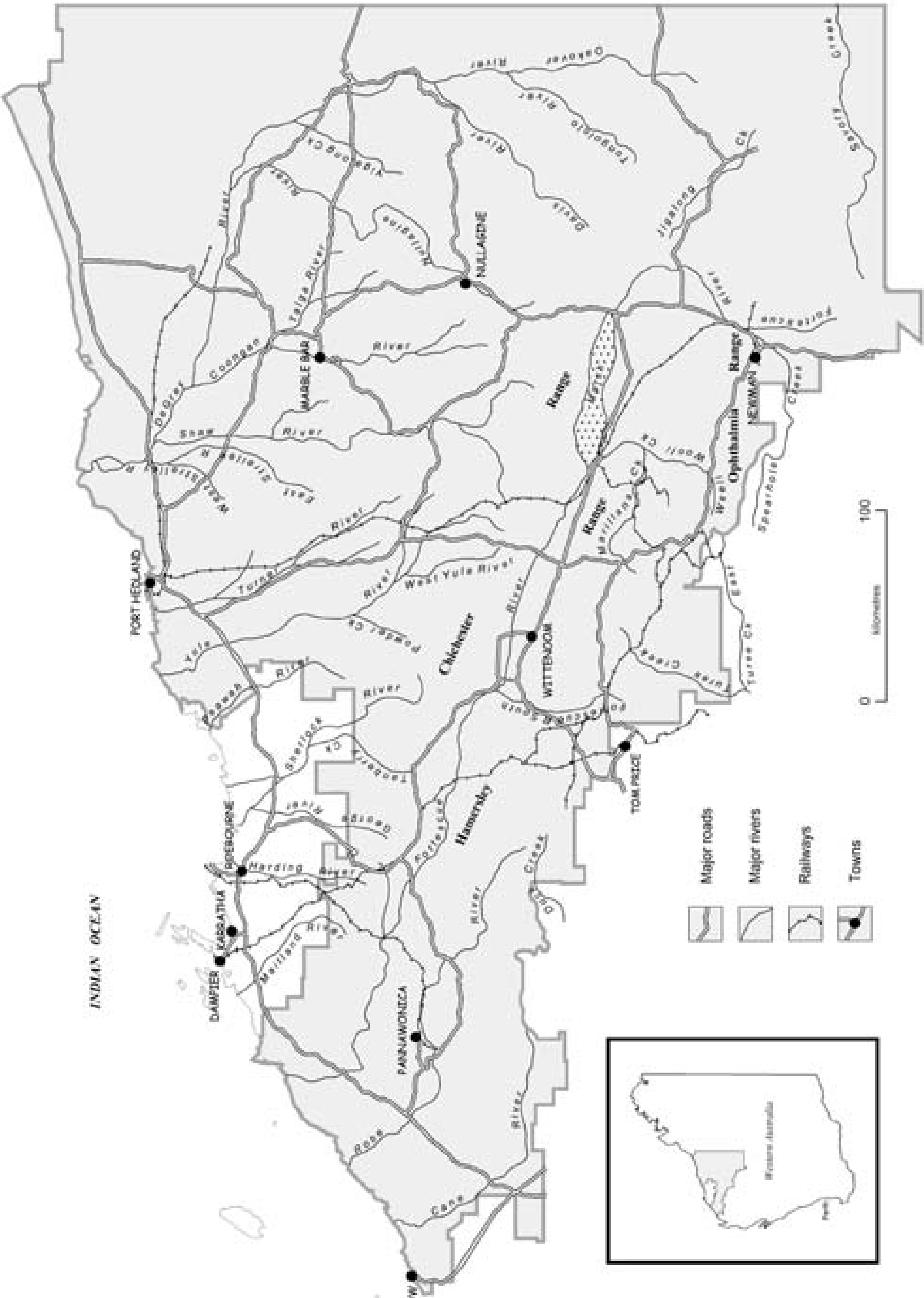

Figure 1. Location map and major features of the Pilbara survey area

Plant species lists and the land system map comprise the Appendices. The species lists contain information too detailed to include within the main report but provide background information for future research. The land system map is a separate attachment.

A companion report (Van Vreeswyk, Payne and Leighton 2004) which is directed to the pastoral industry was produced using the survey findings and provides general information that will assist in pastoral lease management planning. Reports for 42 pastoral leases and Jigalong and Yandeyarra aboriginal reserves are presented. Pastoral lease plans at 1:100,000 scale showing resource, topographical and cultural information were produced and provided to lease holders.

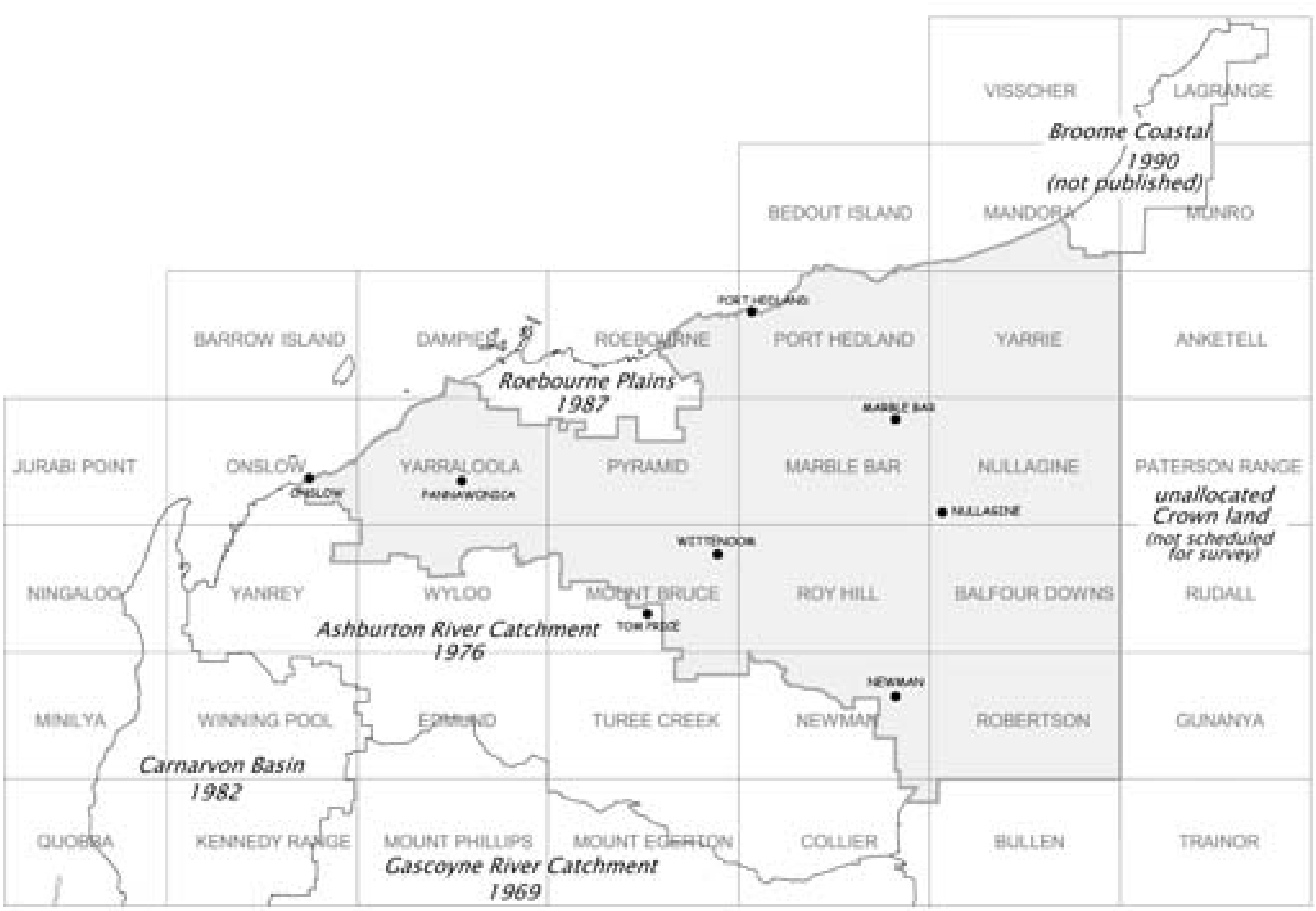

Figure 2. The 1:250,000 map sheets covering the survey area and showing adjacent survey areas (with field work start dates)

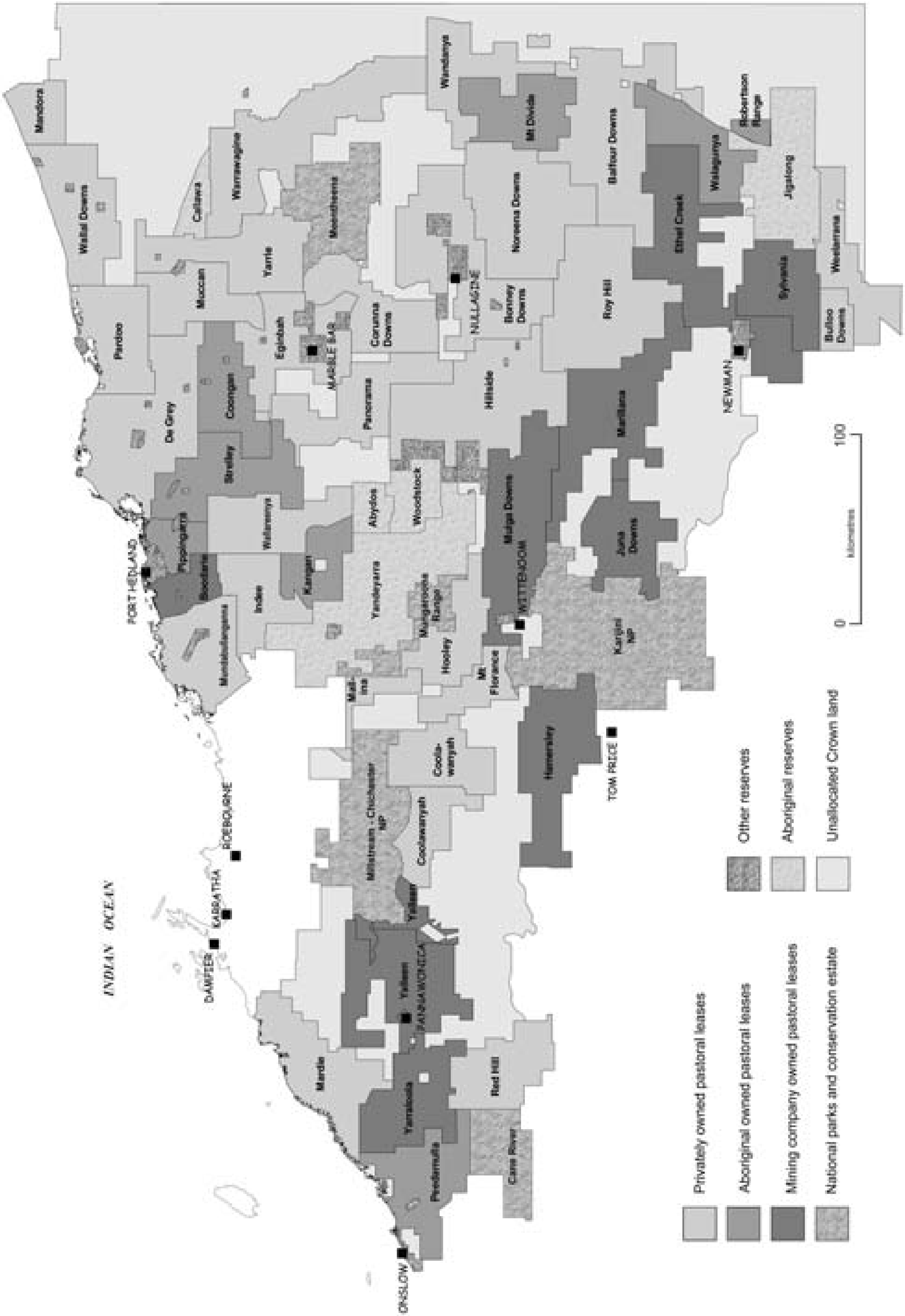

Figure 3. Land tenure in the survey area

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Review

A brief land use history (P. Hennig[1])

Climate (K.A. Leighton[2])

Geology and Hydrogeology (S. L. Johnson[3])

Declared plants and animals (A. Longbottom[4])

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[1] Rangelands Program, Department of Agriculture, Western Australia

[2] Geographic Services Branch, Department of Land Information, Western Australia

[3] Department of Environment, Western Australia

[4] Production Resource Protection Services, Department of Agriculture, Western Australia

A brief land use history

P. Hennig

Early European exploration

Europeans first encountered the Pilbara area in 1628, when a vessel in the command of Captain De Witt ran aground near Cape Thouin, (about 40 km west of Port Hedland) on route to the Dutch East Indies. After a cursory inspection of the coast he gave it the name of De Witt Land (Anon.).

Generally the prospect of a barren and isolated area did not encourage initial exploration beyond the immediate south-west corner of Western Australia. Yet within 30 years of the establishment of the European colony a need grew to supply pioneers with land suitable for livestock grazing and new agricultural enterprises.

The first European explorers to pass by the Pilbara were in ships under the command of Captain King in *The Mermaid* in 1818 and Captains Wickham and Stokes in *HMS Beagle* between 1838 and 1841. Their role was to carry out an important series of surveys of what was then known as 'the North-west' coast, identifying shipping harbours and reporting on coastal lands. In 1861 Frank T. Gregory was sent to report on country inland of the north-west coast (Figure 1), previously reported by King and Stokes as unfavourable. Gregory's party used Nickol Bay (near present day Karratha) as a base and observed several large areas of land suitable for pastoral purposes. The party also discovered and named the Ashburton, Fortescue, Sherlock, Yule, Harding, George, Strelley, De Grey and Oakover Rivers.

Pastoralism, mining and township settlement

The Governor of the time knew of the difficulties associated with pioneering. To encourage settlement, special land regulations to encourage squatting were created (Webb and Webb 1983). Settlers were offered about 40,000 hectares of freehold grants upon compliance with certain stocking conditions. The applicants were to select blocks of about 8,000 hectares with the lease running for eight years.

In 1863 Walter Padbury, realising the potential of the land for grazing livestock, chartered a vessel in order to visit the area. The ship was commanded by a Swedish mariner Peter Hedlund, after whom the town would later be named (Hedland-Thomas 2003). Although Nickol Bay was a safe anchorage for ships in the area, Tien Tsin Harbour was the most accessible port. This harbour was located at the mouth of the Harding River and was later renamed Cossack.

Charles Nairn, on behalf of his brother-in-law Walter Padbury, established the first pastoral lease in the area in 1863. Nairn brought livestock 260 km overland from the harbour at Cossack to establish De Grey station. Later that year, S. Hall and John Wellard took up land on the Harding River.

In 1864 the town of Roebourne was established about 15 km inland from Cossack, but the distance between the harbour and town proved unacceptable. A new townsite with a good natural harbour became a high priority.

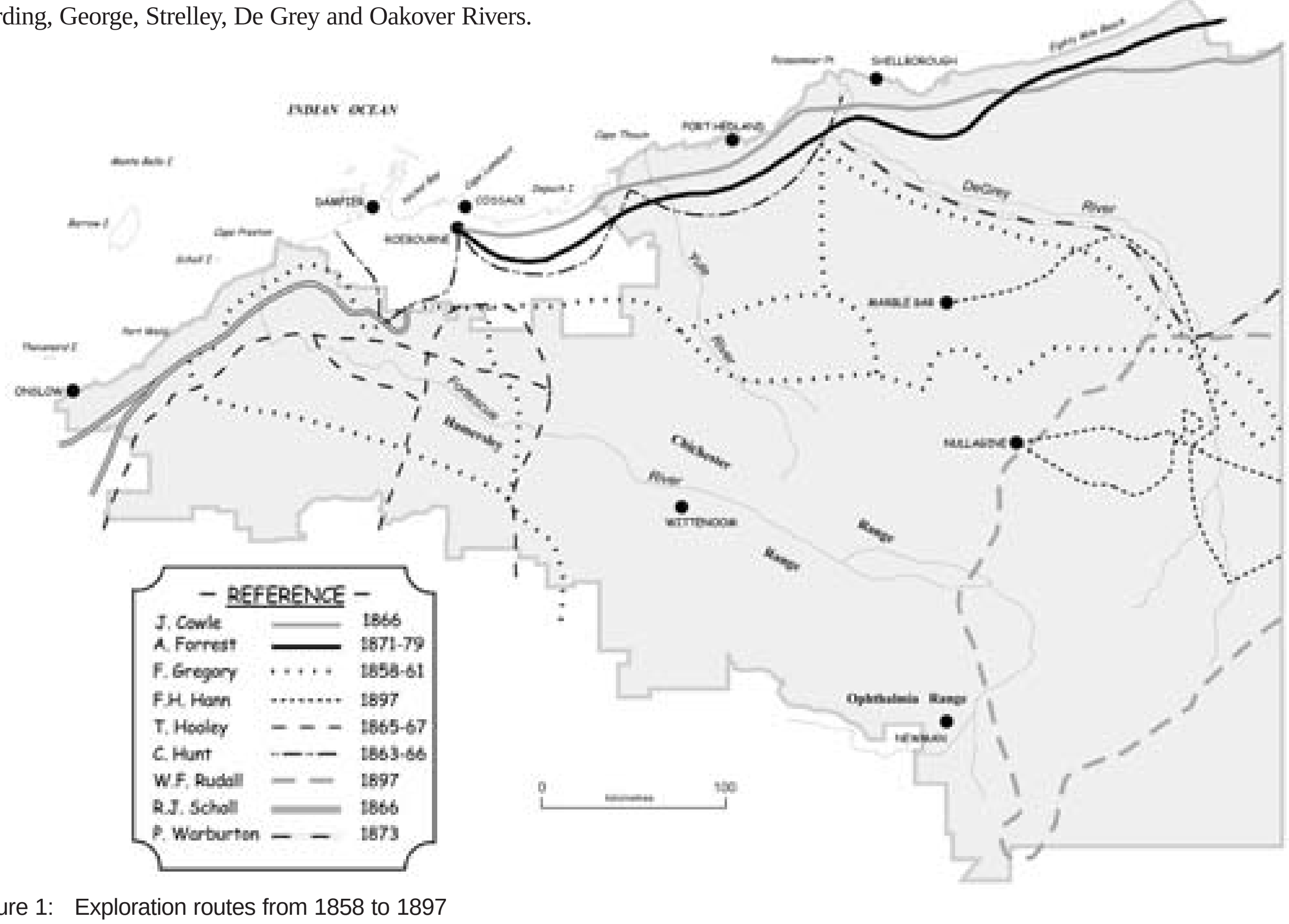

Figure 1: Exploration routes from 1858 to 1897

Throughout 1886 Mr. R.J. and T.C. Scholl organized several expeditions from Roebourne to examine land around the Ashburton, Harding, Sherlock and Fortescue Rivers. They were successful in discovering good pastoral land in the area and are attributed with encouraging settlement in the area. With the establishment of Roebourne as the administration centre for the region, settlers landing at Cossack took up land in the immediate vicinity.

In 1864 John and Emma Withnell (and Emma's sister Fanny Hancock) took up land at Mt Welcome in the Roebourne area and later moved to the Sherlock River. Fanny Hancock was an ancestor of mining magnate, (the late) Lang Hancock (Carter 1971). In 1865 about forty thousand hectares of land known as 'the Pyramid run' was selected. Around this time attempts were also made to establish the pastoral enterprise of Mundabullangana.

Outstations, mostly built at the far end of properties were used part time as the base for livestock mustering or accommodation. Most outstations were built using local materials.

Coastal shipping at this stage was the primary form of transport for importing stock and equipment to the area. It was however, expensive, unreliable and often unsuccessful. Ships lost at sea and livestock losses on route exacerbated the problem of isolation. To encourage alternatives, the government of the day offered about 40,000 hectares of pastoral land in the north-west to the first person to drive livestock overland into the northern districts. In 1866 Mr. E.T Hooley made a successful journey taking about 3 months to drove about 1,900 sheep from the Geraldton area to Nickol Bay (during the trip only 8 sheep were lost). The discovery of this overland stock route ultimately made the transport of stock cheaper and safer. However, shipping, even with the associated problems, remained the preferred method of transporting stock and goods for some time.

In 1863 the area had produced 8 bales of wool; by 1868 about 300 bales had been produced. By the end of 1867 about 24,000 square kilometres of land was being used to graze about 38,000 sheep. As land was taken up from the original settlements including the De Grey lands, the quest for suitable pastoral country progressed eastward.

The original settlers often only had the maps and diaries of early explorers to guide them in selecting parcels of land. Hence physical landscape features such as rivers or prominent hills were used as reference points for land selection. So as to maintain order in land selection, authorities insisted that all parcels of land should be rectangular in shape with parallel sides running north south and east west.

With a port established at Cossack, there was also a requirement for a safe port further north. Charles Wedge found the present day Port Hedland area (formerly known as Mangrove Harbour), unsatisfactory due to sandbars across the tidal creeks and the lack of good supplies of fresh water. An area about 100 km to the north-east at Condon Creek was the preferred option. This port was closer to the De Grey stations and provided fresh water. Although officially called Condon the settlement was gazetted as Shellborough. As pearls were discovered in the area in 1857, the small community catered for both the pastoral and pearling industries. Later, Condon became an important part of the supply route for the mining centres of Nullagine and Marble Bar.

The conditions for the early pastoralists were harsh. Drought, wild dogs, plagues of grasshoppers and mice, financial hardship and a lack of labour led to the abandonment of many leases. Over the early decades the pastoral industry was forced to consolidate with many small leases being amalgamated into larger properties. Due to drought in 1884-5 and a constant drain on financial resources, Padbury abandoned the De Grey property in 1868. This lease was re-established by Anderson, Grant and others in 1869. Between 1869 and 1870, 23 pastoral leases had lapsed, reducing the area under grazing by about one quarter, yet stock numbers continued to increase (Withnell Taylor 1980). Other stations established at that time were Mundabullangana, by the McKay brothers, and Boodarie.

Much of the early expansion in the Pilbara was due to mineral discoveries. As early as 1872 rich copper and lead deposits were found near Roebourne and one year later about 60 tonnes of copper ore was shipped from Cossack. In 1877 rich gold bearing quartz was reported near Roebourne, (but never verified) while 5 years later A. McCrae found a gold nugget weighing 14 pennyweight (about 21 grams) while riding from Roebourne to Cossack.

The government encouraged prospectors and in 1886 the Legislative Council provided financial assistance to anyone who was prepared to prospect for gold in the area of the upper De Grey, Fortescue and Oakover Rivers.

In 1888 gold was discovered at Mallina (adjacent to Whim Creek) and tin was discovered in small creeks east of Marble Bar. Further discoveries of gold at Marble Bar and Nullagine

Eight gold stamping batteries were built to service the Nullagine area during the gold rush heyday.

resulted in the proclamation of the Pilbara Goldfield. The Government rewarded Mr. J.H. Wells, N.W. Cooke and H. and J. Withnell for the discovery of the Pilbara Goldfield.

Cyclones were, and still are, an occupational hazard in the Pilbara. In 1872, a cyclone over Roebourne damaged or destroyed all the buildings in the town and pastoralists on the Nickol River lost about 5,000 sheep. Similarly, in 1882 another cyclone over Roebourne and Cossack destroyed many buildings, and many sheep were lost on the stations with the floods that followed.

Livestock originally brought into the area obtained water from permanent or semi-permanent freshwater pools in the major river systems. The early pastoralists were fully aware that this was only a short-term supply. To avoid complete land degradation and to fully utilize the land, wells to supply stock water were placed away from the rivers. De Grey station was the first property to introduce windmills and fencing for livestock control. Prior to this, sheep were shepherded during the day and often driven into makeshift yards at night. Shearing was conducted using hand operated blade shears, the wool was washed and scoured in fresh water pools in the rivers, and then sent direct to the London wool mills from Shellborough or Cossack. Wool price slumps in 1877 and 1890-92 coincided with droughts, and again caused hardship for the industry.

The arrival of European settlers had a dramatic effect on the Aboriginal population. Initial conflict, the introduction of new diseases, displacement, a drastic change of lifestyle and poor treatment by some of the new settlers resulted in the Aboriginal population being regarded as inferior to Europeans. In 1864 the Land Regulations Act allowed Aboriginals to enter pastoral leases in search of game, but many pastoralists still restricted access to water, food and cultural sites. With this restriction to their nomadic lifestyle, many Aboriginals began to work on stations in return for food and shelter.

Station labour was essentially Aboriginal or Asian. Pastoralists found it difficult to encourage many European workers to the area due to the isolation. Pioneers have noted the great contribution Aboriginals made to the early years of the pastoral industry. Many properties could not have existed without the support and loyalty of the local inhabitants.

Even though communications via the telegraph system were unreliable (as the lines were often damaged by storms), there was a great need for telegraph lines in the area as transport (by camels, donkeys and bullocks) was slow. Telegraph lines were opened from Geraldton to Roebourne and Roebourne to Cossack in 1885 with a Telegraph Office opened at Condon in 1889. In 1887 Cossack and Roebourne were declared municipalities with a Post Office at Condon in 1895.

By the mid 1890s the port at Condon began silting up, thus restricting shipping. A new port site was sought to service the De Grey area and the new mining area of Nullagine with a population of about 3,000.

The area of Port Hedland was surveyed again in 1895 and in 1896 became the new port for the northern Pilbara. The town prospered at the turn of the century with much increased mining, pearling and pastoral activity. The ports of Condon and Cossack eventually closed down.

The twentieth century

By the turn of the century most land except the most rugged ranges and the eastern deserts were under pastoral lease (Figure 2).

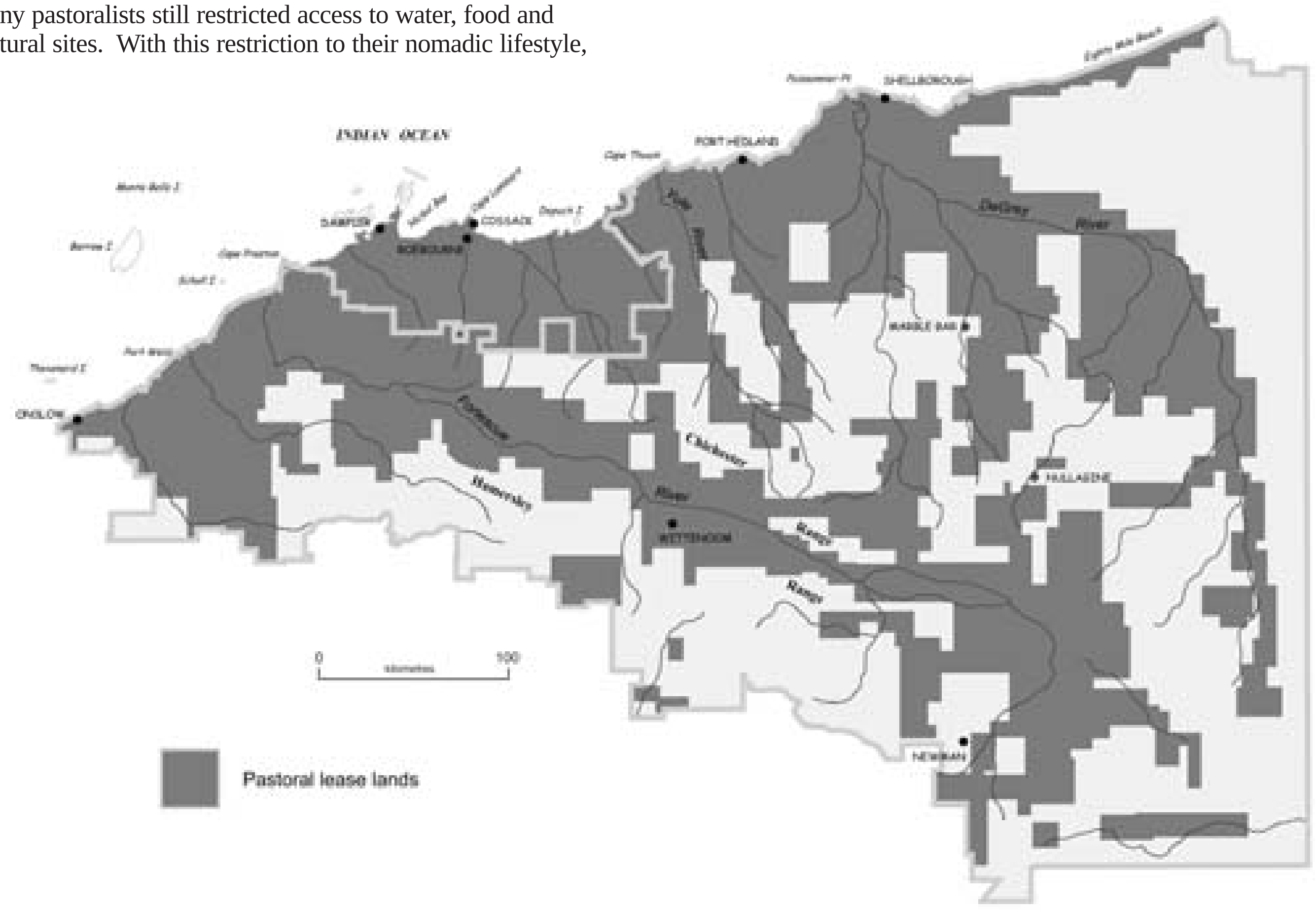

Figure 2: Lands held under pastoral lease on December 31, 1903

The first few years of the twentieth century saw drought conditions for the pastoral industry. Livestock numbers were very high around this time, with some of the largest properties carrying up to 70,000 sheep. This falsely reflected a perception that the land could easily support large numbers of stock. The Western Australian Yearbook of 1902-04 indicates the expectation of the time, quoting the North-West Division as being "…fairly well watered, and stock thrive and increase wonderfully". Also, "It is capable, in the best portions, when fenced in, of carrying a sheep to two acres" (about one hectare). As early as 1863, Charles Nairn noted "…the spinifex very quickly sprouts after being burnt and in that state is eaten by stock, so in case of all the grass country becoming burnt we shall very likely find spinifex a good standby…" (Withnell Taylor 1980). However, history suggests the effects of excess grazing pressure on saltbush and bluebush shrublands were not well understood by the first generations of pastoralists.

The Port Hedland to Marble Bar railway was completed in 1911. This was a boon to local pastoralists as the steam locomotives not only provided transport, but also required water at regular intervals, resulting in many water wells being developed. A telephone line was also constructed along the line with the local pastoralists paying for their own connections.

While mining activity began to decrease by about 1910, the pastoral industry recovered from the earlier drought with a run of good seasons. However the advent of World War 1 saw many men leaving the area and industry. Mining and pastoralism then went through a lean time as labour and finances became less.

Throughout the next fifteen years the local economies were still largely based on pastoralism, mining and pearling. Although asbestos was discovered in the Hamersley Range in 1917, it was considered unviable to mine due to the remoteness of the area. By the 1920s livestock grazing on the immediate main river frontages had caused a depletion of the indigenous grasses alongside the main channels. A perennial plant called buffel grass (*Cenchrus ciliaris*) was introduced by accident to the area (from Afghan camel packsaddles) establishing on the Port Hedland town common and later on the alluvial soils of the river systems. This grass adapted to certain parts of the Pilbara environment and quickly colonized many riverbanks to the detriment of native grasses but also offered protection from soil erosion. Birdwood grass (*Cenchrus setigerus*), closely related to buffel was introduced to Mundabullangana station from a sample of seeds sent to the station from India.

The pastoral industry suffered a long drought from 1935 to 1942. This drought was the most serious in pastoral industry history and the effect was to have long lasting implications. The severity of the drought was made even worse due to the effects of the Great Depression. This recession started in 1929 and saw worldwide overproduction of agricultural commodities dumped on the market causing sudden dramatic price drops affecting all sections of the economy. Sheep numbers in the Pilbara had fluctuated significantly in the previous 30 years, but after the drought and depression, the previous (unsustainable) high numbers were never regained.

In 1939 Australia had entered World War 2. In 1942 Western Australia received the first bombing raid by the war time enemy in the Kimberley township of Broome. So serious was the threat of an enemy attack on Port Hedland, many women and children were evacuated to the inland stations. Port Hedland was bombed on two occasions resulting in one casualty. The Royal Australian Air Force set up a secret wartime air base at Corunna Downs station near Marble Bar which was used to conduct long range bombing attacks on enemy sites in Indonesia. During the war the British government bought Western Australia's entire wool clip for the war effort. The Second World War stimulated the demand for many minerals including tin, silver, manganese and tungsten. This boosted mining activity in the Pilbara. In 1943 mining began for blue asbestos at Wittenoom Gorge.

The Wittenoom blue asbestos mine started operation in 1943 and ceased in 1966. Due to public health issues related to raw asbestos fibres, the Government withdrew all services from the town in 1979.

The combined effects of the depression, drought and the war resulted in abandonment of many mining and pastoral leases. Labour was again difficult to hire due to the war effort, financing was unavailable, and equipment was difficult to obtain. Following the war, wool prices began to improve and sheep numbers rose to about half of the pre-depression years.

The development of pastoral land had, since its inception, fostered an increase in kangaroo and euro populations through the introduction of artificial stock watering points. Before pastoralism, kangaroo populations fluctuated with seasons, and droughts controlled the numbers through the processes of natural selection. By the 1950s the increasing kangaroo populations were causing concern, as there was an estimated ratio of ten kangaroos to one sheep. After a five year biological study, a one-off poisoning program was introduced to reduce the overall numbers and to reduce the pressure on the pastures of the rangeland. The program succeeded in assisting the regeneration of depleted vegetation. However, gains from the program were negated by a sharp fall in wool and cattle prices.

For many years pastoral properties had difficulties attracting workers of European origin, so many stations maintained a population of local Aborigines as workers. Shelter and basic food commodities were provided, but wages were low and rights restricted. In and endeavour to redress this, a collective of people called the Nomad group was formed to help the Aboriginal people restore their culture, self esteem and independence from a social system which was considered to be providing insufficient welfare. Many Aboriginal station labourers were encouraged to strike for better conditions in 1946-47. From this time the Nomad group briefly turned to mining and later to independent pastoralism, which they still operate today.

The most significant period of economic development in the Pilbara was in the beginning of the 1960s. Areas rich in iron ore in the Pilbara were reported as early as 1890 by geologists, but the Federal Government considered there was only sufficient quantity to supply the domestic market, and therefore banned all iron exports. Because of governmental restrictions the mining industry focussed energies toward other minerals. Manganese was one such mineral found in significant quantity south of Warrawagine station. The Woodie Woodie deposit was mined in the early 1950s with the first export shipment leaving Port Hedland in 1953. At this time local authorities noted the need for a larger, more efficient port for the area. Even with an export embargo imposed on iron ore, prospectors Lang Hancock and Stan Hildich were to make significant mineral discoveries during the 1950s.

In 1951 despite the protests from the townships and the primary industries, the Port Hedland to Marble Bar railway was closed due to high maintenance and running costs.

With increased geological surveys and mineral discoveries came a realization the reserves of iron ore were extensive, and there was a high demand from overseas markets

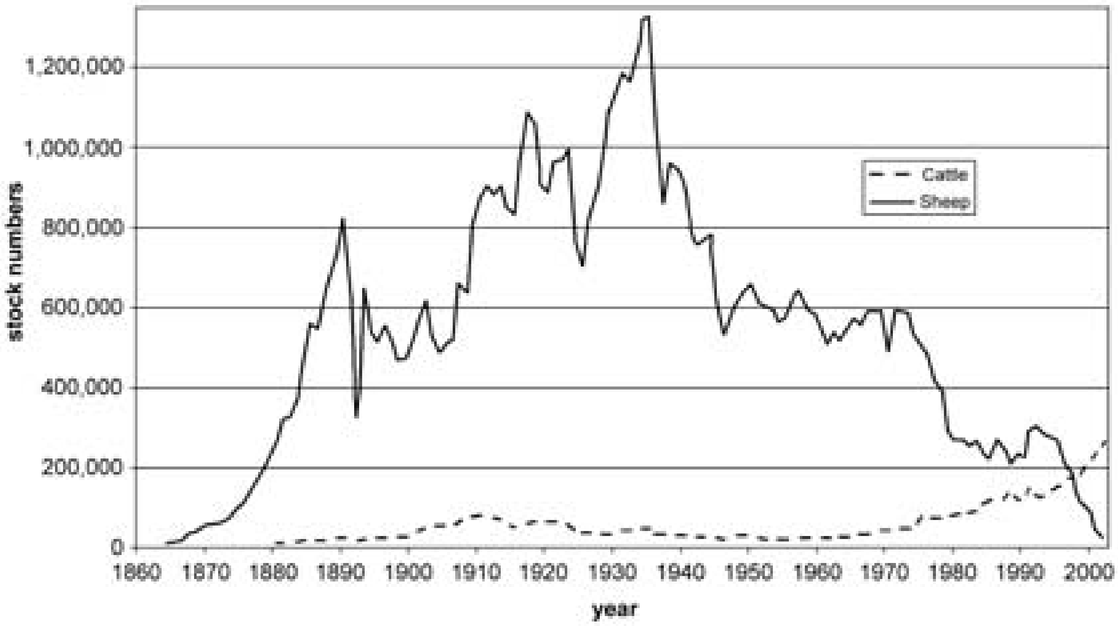

Figure 3: Sheep and cattle numbers in the Pilbara from 1864 to 2002 (source: Australian Bureau of Statistics and the Pastoral Lease Information System)

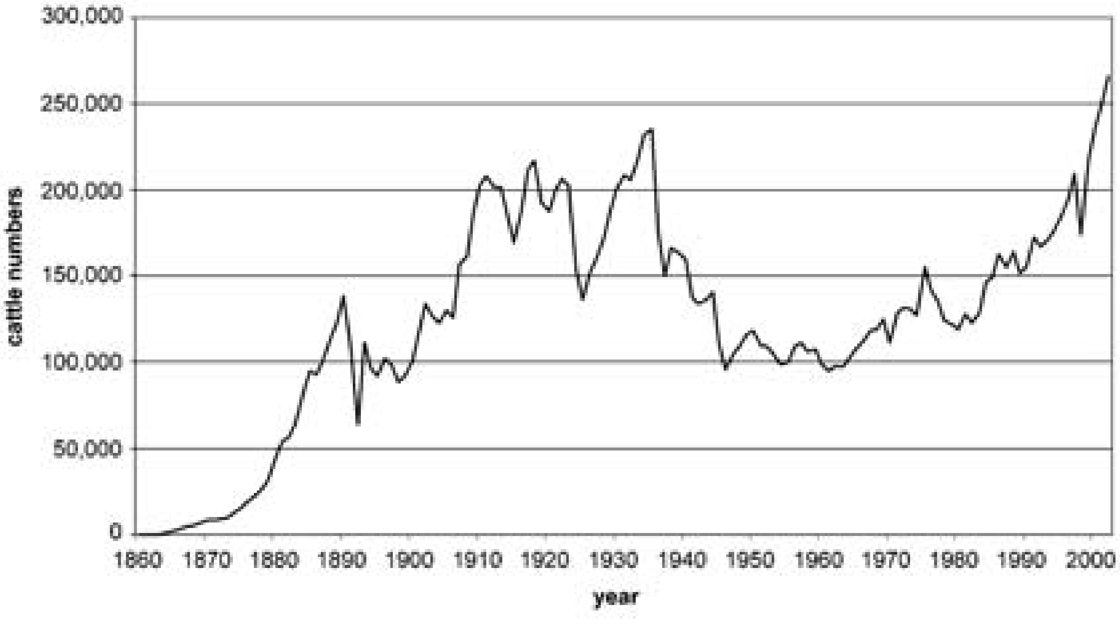

Figure 4: Total sheep and cattle numbers in the Pilbara from 1864 to 2002 expressed as cattle units where 7 dry sheep units equals 1 cattle unit

(particularly Japan). The lifting of the iron ore embargo signalled the beginning of the iron ore boom. With the lifting of the embargo, Hancock and Hildich allied themselves with international companies to develop the start of one of the world's richest iron ore producing areas. The 1960s saw the formation of the Goldsworthy and Mt Newman Mining Companies, and by the end of the decade iron ore was being exported in huge quantities. Further mining of major iron ore deposits resulted in other towns being established, namely Shay Gap, Pannawonica, Paraburdoo and Tom Price. The development of the Pilbara mining industry provided much needed improvements to services to the pastoral community. During this time a large solar salt plant was developed at Port Hedland and the Pilbara now produces about 70% of Australia's salt exports. Oil exploration in the 1950s led to the region's first commercially viable oil production operation on Barrow Island in 1964. In 1984 natural gas production commenced from the North Rankin Field and off-shore oil production commenced from the Harriet Field on the North West Shelf. A direct result of mining development and expansion was vastly improved roads, communications and community services.

Newer technologies and progress however also held some disadvantages for the wool industry. During the 1960s development of large quantities of synthetic fibres (essentially derived from crude oil based products) successfully competed against wool in the open markets. This caused a significant reduction in the price of wool. The pastoral industry responded by increasing the numbers of cattle, while still maintaining the sheep numbers of the 1960s (Figures 3 and 4). In 1968 the Pastoral Award set a basic wage for all station employees. As a consequence many stations were unable to retain large workforces. Stations up to this time employed a high number of Aboriginal workers, and as a result of the Award, many workers left the stations and moved into the major towns. Depressed wool prices in the 1970s saw the industry largely abandon sheep grazing enterprises, relying more on cattle that were realising good prices at the time. The turn-around to cattle enterprises was a permanent change and currently very few sheep are grazed on stations.

Over time there was also a major shift in the dominance of the pastoral wool industry. In 1930 there were about 10 million sheep in Western Australia, half of which were on pastoral properties. By 1971 the sheep population was about 35 million, yet only about 9 percent (3.15 million) were outside the southern agricultural districts.

A recessionary time in the late 1980s led to world wool price plunges in 1991, and the abandonment of the Australian Wool Reserve Price Scheme. Cattle prices also fell at this time due to an oversupply of beef on the world markets.

With the advent of changing technologies, the pastoral industry has sort to offset increased costs by embracing modern aids to ensure more efficient practices such as the use of small aircraft and solar powered water supplies.

In recent years mining, Aboriginal or conservation interests have purchased numerous pastoral leases. There are currently nine pastoral stations held by Aboriginal interests, with one special lease and four reserves. Nine stations are currently held by mining interests and two stations were recently purchased for the purpose of conservation areas in the Pilbara. Some properties are choosing to diversify to derive supplementary income to compensate for low pastoral returns. With the advent of improved vehicles, roads and services in the arid zone, tourism is becoming increasing popular. Improved availability of four wheel drive vehicles and heightened interests in conservation, bush walking, and small time prospecting have resulted in many people visiting the area during the cooler months of the year. Many stations now cater for tourists wishing to sample the outback or station lifestyle, or experience the scenic aspects of the land.

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Climate

K.A. Leighton

The Pilbara rangeland survey area falls within two bioclimatic regions (Beard 1990), semi-desert: tropical and desert: summer rain. The semi-desert: tropical region is characterised by 9 to 11 months of dry weather and only the inland higher rainfall areas and the cooler areas nearer the coast fall into this category. The desert: summer rain region is characterised by up to 12 months of dry weather and higher temperature and lower rainfall areas are in this category.

Beard defined dry by analysing the relationship between the monthly temperature and rainfall of the area. Reading from specially configured graphs (Figure 1 shows the Wittenoom relationship). If the rainfall line falls below the temperature line that month is considered dry i.e. precipitation is inadequate to sustain plant growth. The number of dry months then determines the bioclimate classification. The classification boundaries will accord very well with the natural zones of regional vegetation maps (Beard 1990).

In general it is the availability of moisture together with the soil characteristics that determines plant growth. The presence of moisture is a product of the prevailing climate. The Pilbara often experiences considerable variations in rainfall but is rarely subjected to long periods of drought. With year round temperatures that are consistently high any diminished rainfall will limit plant growth. This relationship between rainfall, temperature and plant growth is explored later in this chapter.

In terms of climatic zones based on temperature and humidity the Bureau of Meteorology (BOM) has classified the Pilbara into two zones: hot humid summer with a warm winter; and, hot dry summer with a mild winter. The map of this classification (Figure 7) shows that this boundary roughly runs parallel to the coast and shows that the bulk of the survey area is contained within the hot dry summer region.

The combined effect of all the meteorological variables of temperature, rainfall, humidity, wind, solar radiation and the human variables of metabolic heart rate and clothing insulation is expressed as the ‘socio-climate’ (Colls and Whitaker 1995). The quantification of the socio-climate of the area (the relative strain index) provides a relative indication of the attraction of the physical environment for settlement. The number of discomfort days per year in the Pilbara ranges from 100 in the southern and coastal areas to 200 in northern areas, while by comparison in the Kimberley the number exceeds 200 and Perth has 10 to 25. Obviously the presence of more compelling reasons for settlement other than socio-climate factors (e.g. socio-economic) will ultimately determine habitation choice.

Sources of climate data

The Perth office of the BOM is the principle source of weather data for stations in Western Australia. Some of their data are available in comprehensive form direct from their website (www.bom.gov.au). Not all recording stations are represented here but the extra information necessary to complete the analysis of the Pilbara area was readily available for nominal cost by direct application to the Perth office.

Within the Pilbara there is very good archive of meteorological data some of which dates back over 100 years. Not all stations record all weather attributes as this requires more specialist equipment and a greater commitment from the recorder but there is a good distribution over the area that allows a reasonable analysis of the data.

As can be seen from Figures 2 and 7 there are considerably more stations that record rainfall (and for longer) than other attributes such as temperature, humidity and wind. Not all station data was used for general analysis, those used were chosen for the completeness and length of record and their distribution through the survey area. Perth BOM is in the process of compiling a more comprehensive Pilbara climate publication as a part of its Western Australia Climatic Survey series. Some of the information from the draft of this report is presented in abridged form in this chapter.

The Internet provides ready access to weather and climate information to the general user. The BOM has a very comprehensive site that provides many different data sets often presented in user-choice format. That is, the user can

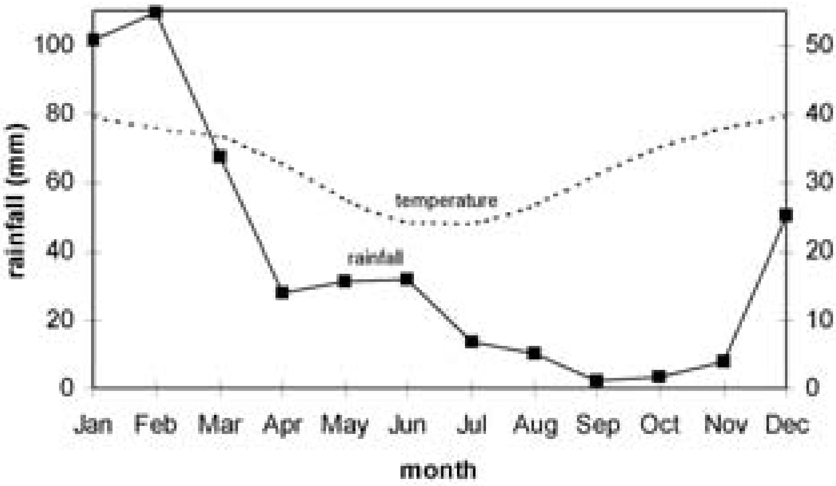

Figure 1. Relationship between monthly temperature and rainfall at Wittenoom townsite for the definition of dryness

Table 1. Climate data recording centres used in the text: their position, history and some climatic extremes

Rainfall recording centre	Latitude (°S)	Longitude (°E)	Elevation (m)	Open date	Actual years of rainfall observations	Highest recorded annual rainfall (mm)	Lowest recorded annual rainfall (mm)	Median rainfall (mm)
Bonney Downs	-22.18	119.93	480	1907	96	801 (2000)	47 (1944)	267
De Grey	-20.18	119.19	15	1888	100	845 (1988)	1 (1924)	260
Mandora	-19.74	120.84	7	1913	90	1,011 (2000)	19 (1924)	332
Mardie	-21.19	115.98	11	1885	115	856 (1995)	9 (1936)	234
Mt Florance	-21.79	117.86	450	1886	114	927 (1999)	92 (1972)	339
Red Hill	-21.98	116.06	150	1898	100	891 (1973)	43 (1944)	348
Roebourne Post Office	-20.78	117.14	12	1887	114	1,060 (1900)	3 (1891)	282
Sylvania	-23.59	120.05	600	1950	34	799 (1998)	4 (1977)	234
Warrawagine	-20.85	120.69	152	1897	95	937 (2000)	62 (1924)	281

Temperature recording centre	Latitude (°S)	Longitude (°E)	Elevation (m)	Open date	Actual years of temperature observations	Highest recorded daily max. (°C)		Lowest recorded daily min. (°C)	
						January	July	January	July
Mandora	-19.74	120.84	7	1962	34	46.8	35.7	18.8	-0.6
Marble Bar	-21.18	119.75	182	1957	42	48.8	33.9	18.9	2.2
Mardie	-21.19	115.98	11	1957	42	48.9	34.3	16.1	2.9
Newman Post Office	-23.36	119.73	544	1965	31	46.0	29.4	16.0	-2.0
Port Hedland Airport	-20.37	118.63	6	1942	57	47.5	33.9	18.1	3.2
Roebourne Post Office	-20.78	117.14	12	1923	80	48.4	33.6	18.6	4.4
Wittenoom	-22.24	118.34	463	1949	50	47.6	31.1	14.1	1.6

select historical and predictive maps based on various time-frames. This chapter can provide limited insight into the Pilbara climate but used in conjunction with other (web available) data the land manager should find some practical application of the information. Other websites that provide useful climate and weather references are the Queensland Department of Natural Resources and Mines at www.longpaddock.qld.gov.au and WA Water and Rivers Commission at www.wrc.wa.gov.au.

Table 1 lists some attributes of the rainfall and temperature recording centres used in this report for the analysis of the Pilbara climate.

Major climatic patterns

Throughout this chapter reference will be made to seasonal analysis. The BOM defines the seasons as Summer - December through February, Autumn - March through May, Winter - June through August, and Spring - September through November. For the Pilbara the wet season is defined as the period extending from December through to the end of March.

Winter/Spring patterns (June to November)

Throughout the year Australia's weather pattern is dominated by the west to east passage of high pressure systems commonly referred to as anti-cyclones. In winter and spring these systems move slowly along a mean latitude of 29˚S. This is some 6˚ (700 km) south of the southern extent of the survey area and therefore provides little rain to this area. The winds tend to predominate from the east and south-east and occasionally join up with mid-level moisture from the Indian Ocean creating a north-west cloudband that can produce significant falls of rain across the continent into Victoria.

Daily winter temperatures remain mild throughout the Pilbara with night temperatures sometimes dropping to near zero inland. Generally only the southern coastal areas (around Onslow) receive any benefit from winter rain systems (extended cold fronts) from the south. Humidity is low throughout. Universally spring is the driest season with only about 2% of the annual rainfall received in that time.

Summer/Autumn patterns (December to May)

In summer the high pressure systems drop to lower latitudes around 37˚S which promotes the formation of a semi-permanent heat low over the Pilbara. This commonly interacts with low-level moisture to generate thunderstorms that will vary in size and intensity, will often form in the afternoon and will regularly produce heavy rainfall and local flooding.

The Pilbara also stands in the path of tropical cyclones. Few years pass without some effect of cyclones being felt over the area. The widespread flooding after heavy rain that is always associated with these systems can create problems with infrastructure but the native vegetation flourishes after summer. Cyclones are an integral part of the Pilbara environment and whilst they can severely disrupt human activity the physical environment is mostly resilient.

Climatic factors

Rainfall

As for most of the Australian continent a 'normal' rainfall year in the Pilbara seldom exists. With much of the annual precipitation coming from local thunderstorms and cyclone events rainfall can be highly variable across relatively small distances. The frequency of these events means that most places can expect an average rainfall over a longer period.

In quantifying rainfall the terms average (or mean) and median are commonly used but often misunderstood. The median represents the most common value of a set of records. In a series of years typical of the Pilbara the rainfall in mm might look like 530, 30, 270, 50, 40, 130, 180 where the median would be 130, that is there are three values lower and three higher than 130. The average or mean value however is 176. The median is often quoted as giving a better indication of yearly rainfall as it is not influenced by extreme rainfall events. Typically the difference between the median and the average annual rainfall in the Pilbara is about 30 mm with the median always being the lower figure. The two values will converge as the number of records increase.

Within the Pilbara the BOM were able to supply rainfall data for 153 recording stations. Figure 2 shows the distribution of these stations and categorises them into functioning and non-functioning sites grouped according to the number of years of recorded data. Currently there are 72 stations still operating, 19 of which have been recording for more than 100 years and 21 which have been recording for more than 50 years. There is a broad mix of locations of sites including pastoral lease homesteads, townsites, airports, mining facilities and a few automatic weather stations. Mt Florance pastoral lease started recording in 1886 and is the longest, currently operating station.

The wide distribution of comprehensive data means that nine selectively chosen stations will quite reasonably represent the historical patterns of the region. Table 2 summarises the annual rainfall data for these stations and Figure 3 shows this graphed against a map of the area.

Figure 2 shows the rainfall variability for the wet season (from the BOM website) and is compiled from the relationship between the 90th, 50th, and 10th percentiles over the three month period. The coastal strip northward to Port Hedland shows the highest variability – Figure 4 shows that this area also has a higher proportion of winter rain. Winter rainfall is highly variable across the area, broadly increasing from south to north.

Figure 4 shows both the proportion of seasonal rain and the wettest six months. All stations except Mardie in the west are dominated by summer rainfall, the trend getting stronger inland and further north. The convective nature of summer rain means that large amounts can be received in a single fall and such falls can be very localised. Autumn rain is still significant across the area often as a product of late cyclones that often decay into large rain bearing depressions. Winter rain typically comes from either elongated southern latitude fronts or the interaction of the these fronts and mid-level moisture from the Indian Ocean creating the moisture-laden north-west cloudbands that can extend across the continent. On average about two bands occur each month and last about four days and can bring significant rainfall throughout the interior. Spring rain is universally restricted to rain in November preceding the opening of the wet season in December.

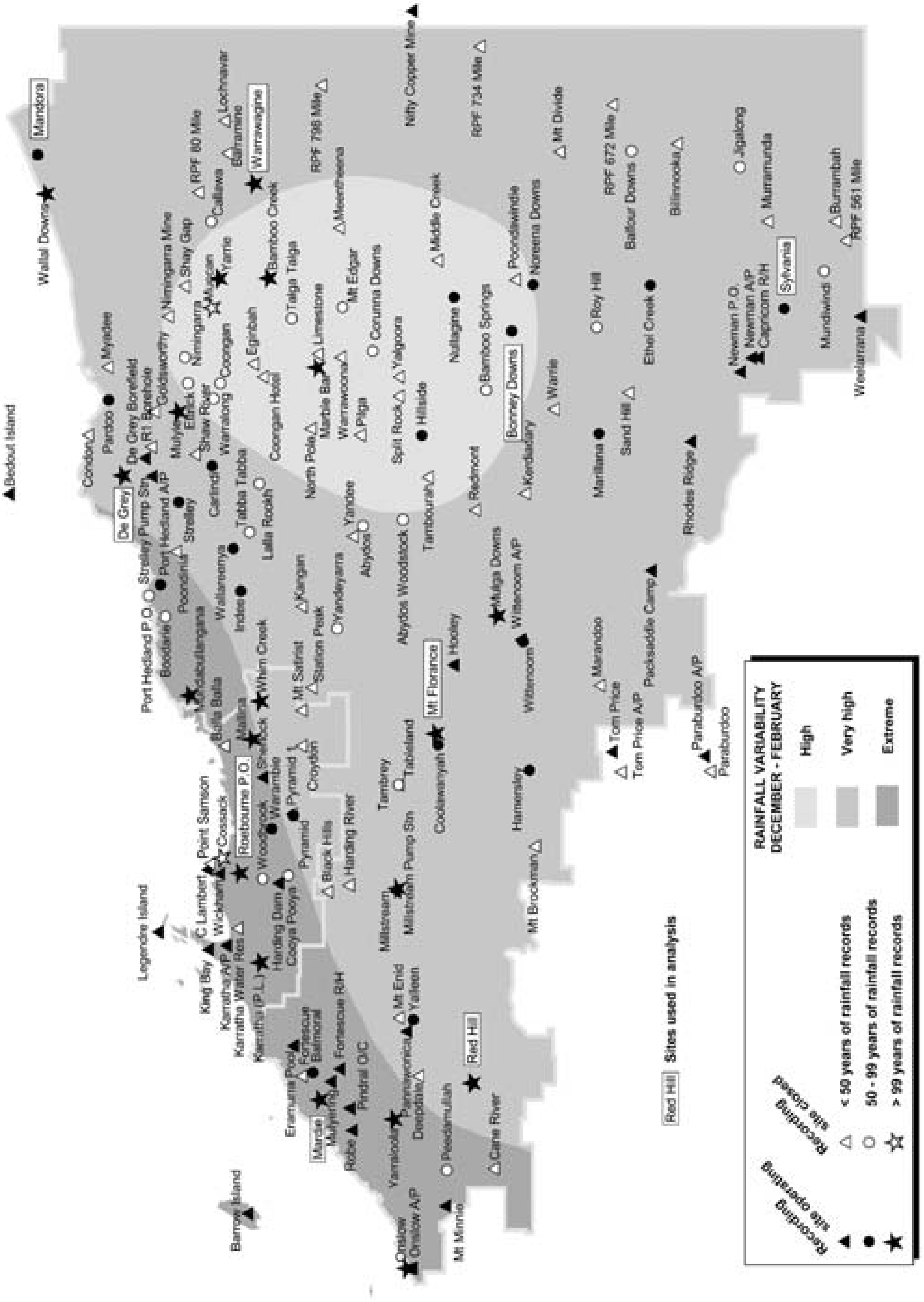

Figure 2. Rainfall recording sites and wet season rainfall variability

Table 2. Summary of monthly rainfall data for selected sites

Bonney Downs	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly rainfall (mm)	66	72	49	23	22	21	9	7	1	4	10	35
Median (5th decile) monthly rainfall (mm)	46	51	19	7	10	6	2	0	0	0	3	23
Highest monthly rainfall (mm)	401	649	287	175	153	141	71	66	21	59	88	296
Mean number of rain days	not available											

De Grey	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly rainfall (mm)	66	75	58	24	28	24	8	4	1	1	3	18
Median (5th decile) monthly rainfall (mm)	30	50	20	0	8	8	0	0	0	0	0	0
Highest monthly rainfall (mm)	451	431	463	283	187	158	83	47	26	65	109	233
Mean number of rain days	3	4	3	1	2	2	1	0	0	0	0	1

Mandora	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly rainfall (mm)	81	96	69	21	27	18	8	3	1	1	7	33
Median (5th decile) monthly rainfall (mm)	51	63	35	0	6	0	0	0	0	0	0	9
Highest monthly rainfall (mm)	627	430	486	215	214	191	100	74	24	31	160	272
Mean number of rain days	6	6	4	1	2	1	1	0	0	0	0	2

Mardie	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly rainfall (mm)	37	59	49	18	39	39	14	8	1	1	1	9
Median (5th decile) monthly rainfall (mm)	8	30	17	1	16	20	5	0	0	0	0	0
Highest monthly rainfall (mm)	241	675	330	180	212	275	151	117	64	24	32	171
Mean number of rain days	3	4	3	1	3	3	2	1	0	0	0	1

Mt Florance	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly rainfall (mm)	84	89	67	23	21	27	13	7	2	3	9	31
Median (5th decile) monthly rainfall (mm)	53	66	37	3	8	13	2	0	0	0	2	20
Highest monthly rainfall (mm)	667	449	448	245	168	228	170	107	75	81	101	362
Mean number of rain days	6	6	4	2	2	2	1	1	0	0	1	3

Red Hill	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly rainfall (mm)	65	83	61	22	34	38	16	8	1	1	7	22
Median (5th decile) monthly rainfall (mm)	45	62	34	6	14	16	7	0	0	0	0	9
Highest monthly rainfall (mm)	324	437	300	195	245	237	193	94	37	36	94	186
Mean number of rain days	not available											

Roebourne Post Office	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly rainfall (mm)	59	67	62	30	29	30	14	5	1	1	1	10
Median (5th decile) monthly rainfall (mm)	17	40	19	2	11	16	4	0	0	0	0	1
Highest monthly rainfall (mm)	368	325	408	552	225	309	135	98	40	31	31	129
Mean number of rain days	3	5	3	1	3	3	2	1	0	0	0	1

Sylvania	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly rainfall (mm)	40	80	33	18	21	18	11	8	4	1	5	34
Median (5th decile) monthly rainfall (mm)	27	36	14	9	9	3	0	0	0	0	0	10
Highest monthly rainfall (mm)	201	354	213	104	105	122	110	80	38	28	46	578
Mean number of rain days	3	4	2	2	2	2	1	1	0	0	1	2

Warrawagine	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean monthly rainfall (mm)	70	76	58	17	19	23	9	6	1	3	9	37
Median (5th decile) monthly rainfall (mm)	44	58	37	1	0	3	0	0	0	0	0	18
Highest monthly rainfall (mm)	287	360	401	223	174	190	92	60	29	76	66	405
Mean number of rain days	not available											

Figure 3. Mean monthly and annual rainfall and number of rain days (rain days not collated at all recording stations)

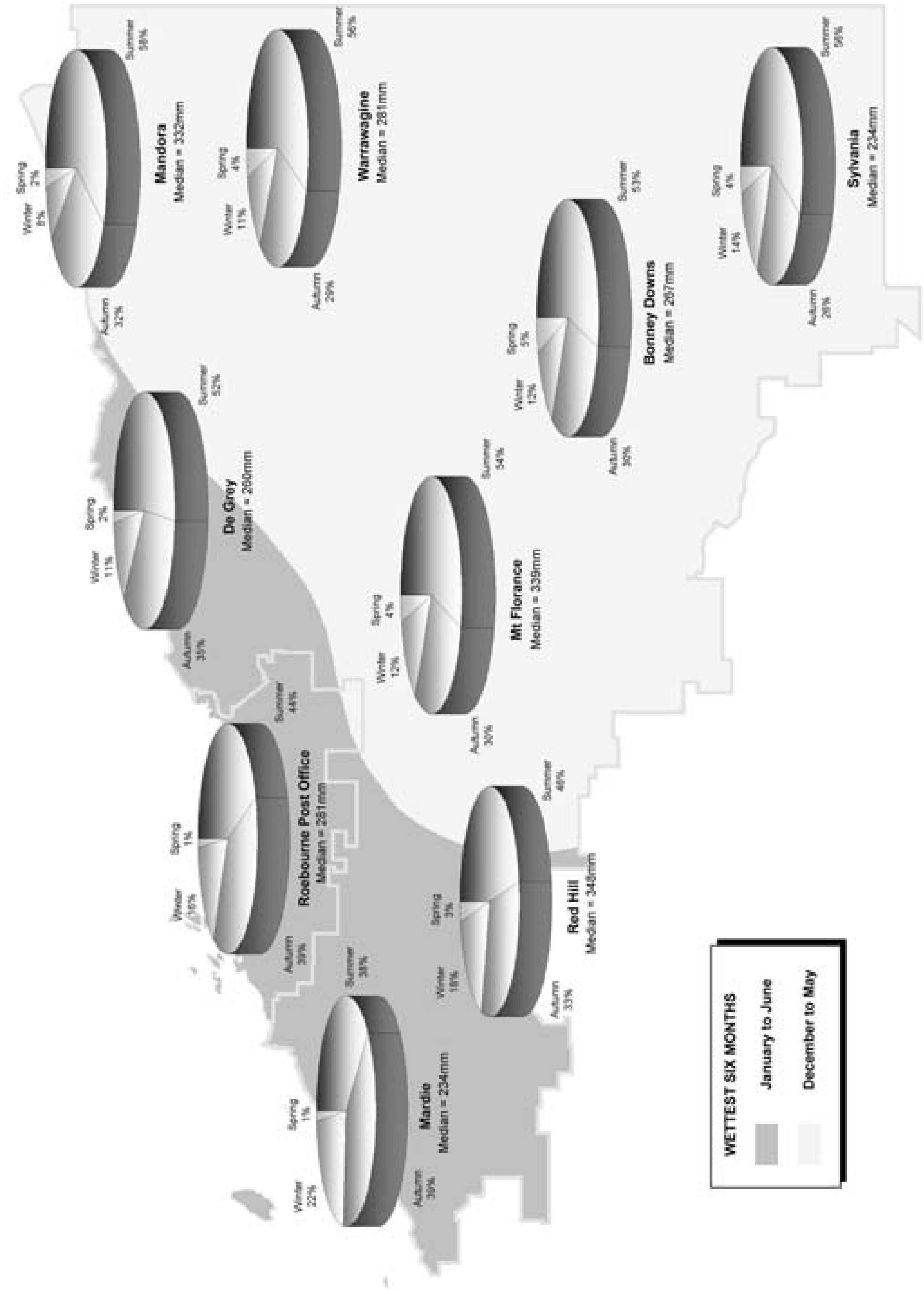

Figure 4. Proportions of seasonal rainfall and wettest six months

Figure 3 graphs the mean monthly rainfall for the nine stations against the average number of rain days. In all cases February is the wettest month in the Pilbara while September and October are the driest. The slightly bimodal pattern of rain ensures, in good years, that the vegetation growing season is prolonged (refer to the discussion on effective rainfall later in this chapter).

Annual average Pilbara rainfall follows a roughly inland to coastal and southern to northern increasing trend. Figure 5 shows the annual average rainfall isohyets based on the records of all recording centres. The complicating factor for a smooth interpretation of the isohyets is the topography. The Hamersley Ranges has a higher rainfall than the closely adjacent lower plains areas. To the north Mandora and Shay Gap rainfall is more peripherally influenced by the northern monsoon of the Kimberley. Rainfall within the eastern inland (marginal desert) area is not as well documented due to the lack of recording stations.

The cyclonic or thunderstorm nature of rainfall in the Pilbara associated with the rocky sloping topography of much of the upper catchments often produces considerable run-off and widespread flooding in the major river systems. It is not uncommon for wide areas of the Pilbara to become inaccessible during the wet season, and together with high temperatures and humidity human activity is generally lowest at this time. Management of pastoral, transport and mining activities must accommodate this period or suffer the consequence of prolonged disruption.

Widespread flooding from cyclonic summer rains may damage roads, railway lines and other infrastructure, isolate homesteads, threaten cattle and cause soil erosion. The photo shows flooding around the old Cooya Pooya homestead on the Harding River after cyclone Monty in March 2004. (Photo courtesy of WaterCorp, Karratha)

The Pilbara has some impressive rainfall statistics including the state record for the highest daily fall at Whim Creek of 747 mm on 3 April 1898. The highest annual rainfall of 1,344 mm was recorded in 1999 at Wittenoom which coincidentally enjoys the highest average annual rainfall in the region of 452 mm.

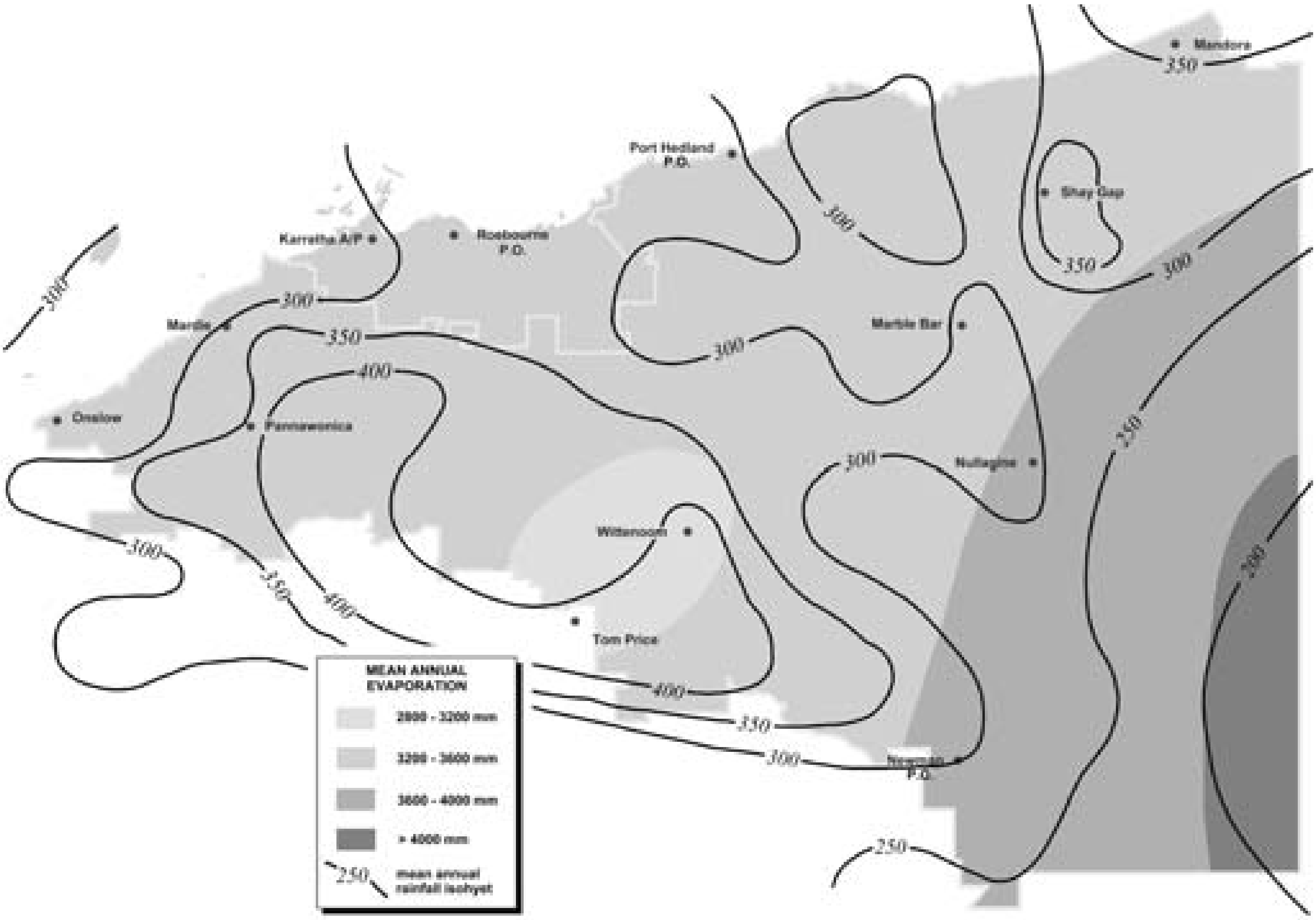

Figure 5. Interpreted mean annual rainfall isohyets and evaporation

Drought

The term ‘drought’ is widely used to describe periods of decreased rainfall. These periods can be long or short term; are commonly seen as recurrent in nature; can be localised or widespread in area and more recently have been recognised as being caused by variations in the Southern Oscillation Index (SOI) over the Pacific Ocean. The BOM considers that a serious deficiency has occurred if the rainfall is within the lowest 10% recorded for a specific period (usually three months or more). A severe rainfall deficiency exists in a district if the rainfall is in the lowest 5% of records.

The drought risk map (Figure 6) categorises the susceptibility of the survey area to drought. The categories are calculated from the percentile variations of the average annual rainfall (Colls and Whitaker 1995).

By graphing the annual average rainfall for the Pilbara it becomes evident that there were few extended periods when the whole area was affected by either serious or severe drought. However, local areas have been fairly regularly affected. Below average rainfall of 5 years or greater have occurred around 1903, 1912, 1925, 1938, 1950 and 1992.

The amount of available soil moisture, which in turn is influenced more by the frequency of rainfall rather than the total amount falling will also influence the severity of a drought and its affect on plant growth. Low rainfall on its own does not necessarily constitute a drought if that rainfall comes at opportune times for peak growth periods rather than as a single event.

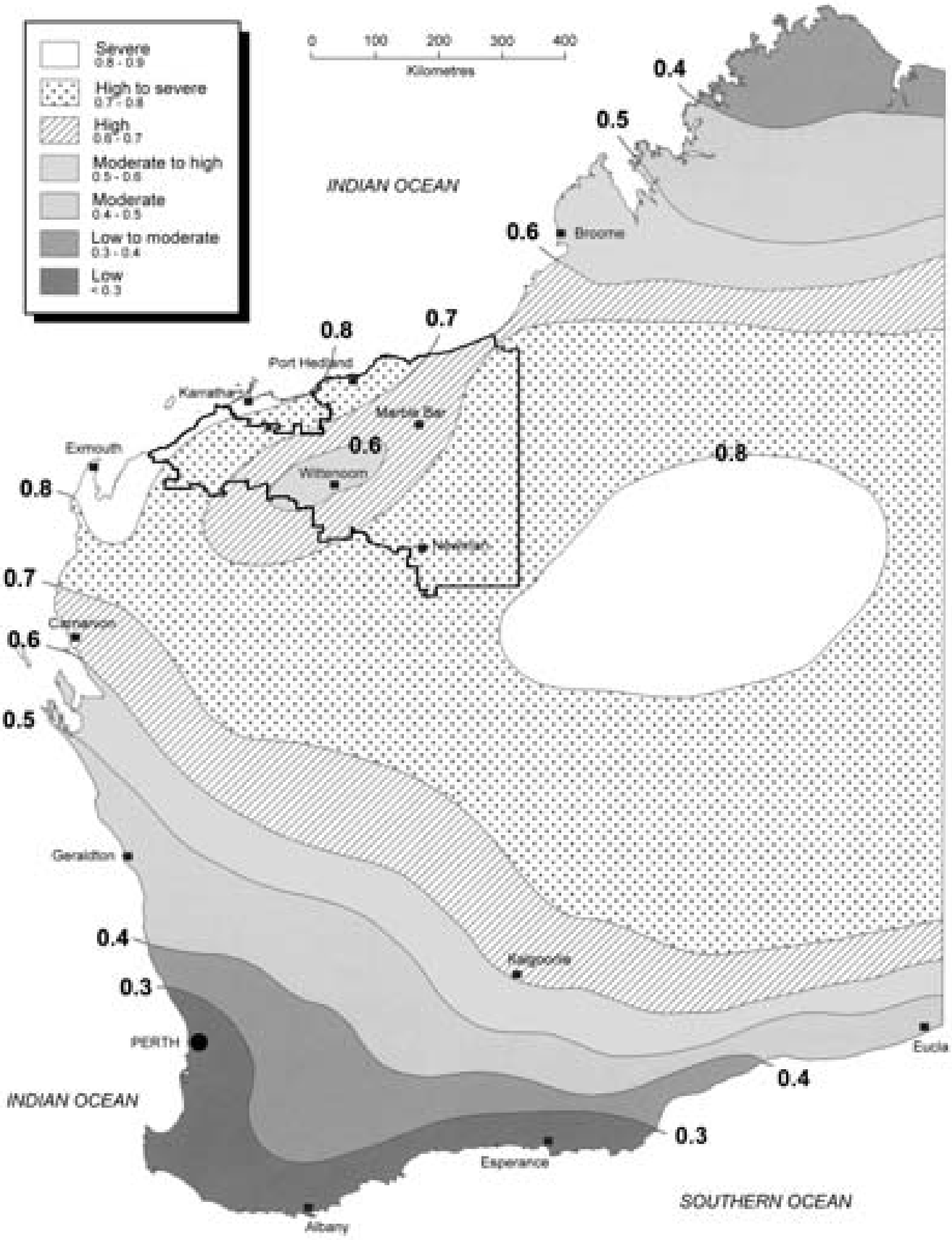

Figure 6. Drought risk index in WA based on percentiles of annual rainfall (after Colls and Whitaker 1995)

Studies quoted in Reynolds, Watson and Collins (1983) indicate that in WA, 54 years in 100 will experience drought conditions, i.e. any continuous three month period will lie below the 10 percentile rainfall value. Given that within much of the survey area the drought risk index is high to severe (see Figure 6) it is clear that drought mitigation measures should be part of normal pastoral management. The only effective counter to lessen the effect of extended periods of low rainfall is to adopt management strategies that minimise losses when the problem arises (Reynolds, Watson and Collins 1983).

In 1965 the BOM implemented a Drought Watch Service (DWS) as a key component to assist with national drought management in rural Australia. Access to the DWS data, analysis and reporting is available through the BOM website.

Temperature

Within the Pilbara area the BOM was able to supply temperature data for 31 recording stations. Figure 7 shows the distribution of these stations and categorises them into functioning and non-functioning sites grouped according to the number of years of recorded data. Currently there are 21 stations still operating, 10 of which have been recording for more than 30 years. There is a broad mix of locations of sites including pastoral lease homesteads, townsites, airports, mining facilities and a few automatic weather stations. Cossack, Onslow and Marble Bar share honors for the length of records however Cossack is now no longer operational. In contrast to rainfall recording, the more technical nature of thermometers, their installation and recording regime mean that fewer sites routinely record temperature.

As with the distribution of the rainfall recording centres, eight sites have been selected across the Pilbara for a regional temperature synopsis. Table 3 summarises the temperature data for these stations and Figure 8 plots this against a map of the area. The regional variation in the data is a product of their proximity to the coast and the latitude. As can be seen from Figure 8 the pattern of mean daily maximum and minimum temperatures along the coast are almost identical. It is only as the sites are located further inland that the graph shape created by the monthly averages becomes more concave indicating a greater variation in summer and winter temperature gradient.

Marble Bar has the hottest average daily temperatures for the three months over summer of 40.7˚C max. and 25.7˚C min. with the area between Wittenoom and Pannawonica averaging slightly cooler daily averages of around 40˚C max. and 25˚C min. Marble Bar is nationally recognized as being the hottest town in Australia with frequently sustained periods of temperatures on consecutive days staying well above the old 100˚F (37.8˚C) mark (160 days in summer of 1923/24). Over the whole year Marble Bar averages 98 days above 40˚C and 275 days above 30˚C. Next hottest is Pannawonica which averages 64 days above 40˚C, whilst Mardie (near the coast) averages 273 days above 30˚C. Summer daily temperatures vary about 15˚C between day and night averages inland, and about 12˚-13˚C adjacent to the coast.

In winter the zonal east-west prevailing temperature belt moves more northerly towards the coast so that the hottest centres (although considerably milder than summer temperatures) are Marble Bar, Port Hedland and Mardie with temperatures in the daily range of 28˚C max. to 13˚C min. Mandora, being under a more northern temperature influence, has the hottest three monthly winter daily averages of 29.4˚C and 13.4˚C. Conversely, Newman shows a more southern weather trend with winter average temperatures dropping to 23.1˚C max. and 9.2˚C min.

The summer-winter seasonal variation between averages is about 13˚-15˚C inland and about 7˚-10˚C adjacent to the coast.

As expected autumn and spring temperatures fall evenly between the extremes. The drop in temperature between the months of April and May of 5˚C and the rise of 4˚C between August and September are greater than between any other two month period. By May there would be few instances where the temperature or humidity could be considered excessive and conditions are much more comfortable than in the early and late part of the year.

For inland locations the hottest months are December/January while on the coast this comes about a month or two later due to the dampening influence of the ocean. The effect of the monsoon in the northern portion is more noticeable where the onshore winds, cloud cover and rain moderate the temperature. At Mardie weaker onshore winds in January than further north on the coast create hotter conditions. Strong afternoon sea breezes along the coast provide little relief inland where prevailing winds tend to be strongly over the land from the east. The highest maximum recorded in the region was 50.5˚C at Mardie (19 February 1998).

Universally throughout the Pilbara the coldest month is July. However, Mandora still averages 10 days in July over 30˚C, whilst Mardie averages 5.5 days and Newman none. The lowest recorded temperature was –2.2˚C at Nullagine (20 July 1965). Typically lower daily minimum temperatures can be expected inland to the south-east, and in some more elevated positions.

Frosts occur very infrequently in the Pilbara. The right combination of saturated air and very low temperature is most likely to occur only in the lower south-east, and usually only after the passage of a winter depression followed by strong southerly winds.

Dew and fog

The dew point is the temperature at which water vapour starts to condense from the air. For this to happen, relative humidity needs to be 100%. If the dew point and air temperature are similar in the late afternoon, when the air gets cooler fog is likely during the night. High dew point indicates high water vapour content and therefore a better chance of rain and thunderstorms, whereas low dew point indicates low water vapour. When the dew point falls to 0˚C it is called the frost point.

Along the Pilbara coast the daily dew points show little variation. In winter both the 9am and 3pm average dew points are about 8˚C, while in summer they average about 20˚C. Mandora has slightly different seasonal (9am and 3pm) averages of between 6˚C in winter to 23˚C in summer.

Inland the seasonal variation is more distinct with winter 9am averages around 4˚C dropping to 2˚C at 3pm. Summer averages for 9am are around 13˚C and dropping to 11˚C at 3pm.

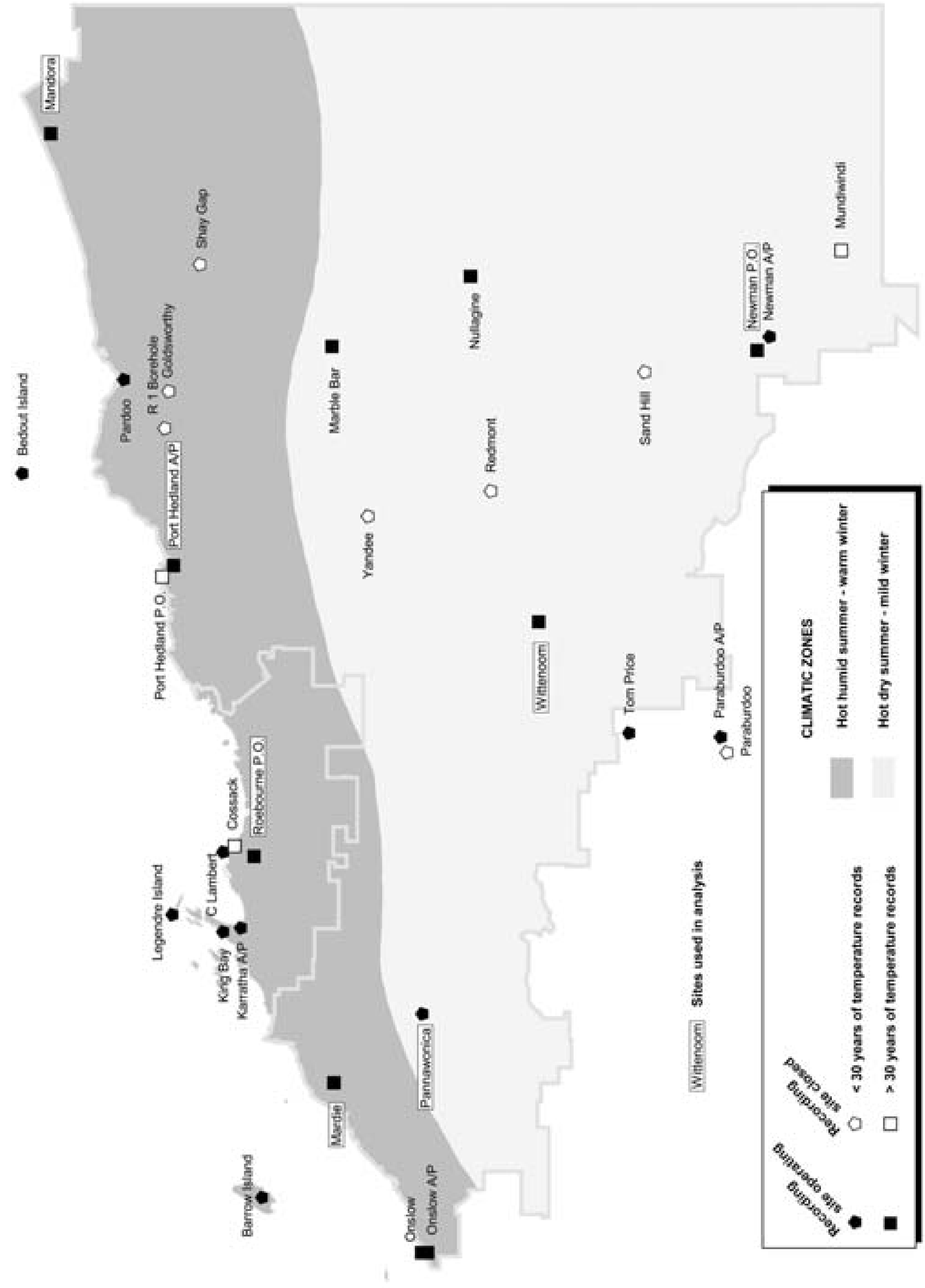

Figure 7. Temperature recording sites and climatic zones

Table 3. Summary of monthly temperature data for selected sites

Mandora	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp. (°C)	36.0	35.4	36.7	35.9	31.8	28.9	28.9	30.5	33.7	35.5	36.1	36.6
Mean daily minimum temp. (°C)	25.3	25.1	23.9	20.7	16.7	14.2	12.7	13.5	15.9	18.9	21.7	24.3
Mean number of days temp. >40°C	3.3	3.4	4.7	1.5	0	0	0	0	0.4	4.4	5.4	5.5
Mean number of days temp. >30°C	27.4	25.3	28.5	25.2	21.4	10.1	9.5	17.0	24.1	25.6	26.5	27.1
Mean daily 9 am relative humidity	60	64	52	39	40	41	37	35	30	35	41	49
Mean daily 3 pm relative humidity	58	58	48	34	33	32	28	27	29	38	45	50

Marble Bar	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp. (°C)	41.0	39.8	39.1	36.0	30.7	27.1	26.8	29.6	33.9	37.5	40.5	41.5
Mean daily minimum temp. (°C)	26.1	25.6	24.7	21.3	16.6	13.1	11.8	13.3	16.7	20.3	23.6	25.5
Mean number of days temp. >40°C	19.8	13.9	13.0	2.7	0	0	0	0	0.4	8.6	16.9	22.5
Mean number of days temp. >30°C	30.0	27.1	30.4	27.8	18.9	5.9	5.1	13.6	26.3	30.2	29.5	30.5
Mean daily 9 am relative humidity	45	50	41	35	40	44	39	33	27	26	27	34
Mean daily 3 pm relative humidity	27	30	25	24	27	28	25	21	17	16	16	20

Mardie	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp. (°C)	38.1	37.5	37.7	36.0	31.4	28.0	27.6	29.4	32.3	35.0	36.5	37.8
Mean daily minimum temp. (°C)	24.8	25.1	23.9	20.9	16.7	13.9	11.6	12.3	14.1	17.1	19.8	22.8
Mean number of days temp. >40°C	9.7	7.3	8.8	2.1	0.1	0	0	0	0.1	3.4	6.6	8.8
Mean number of days temp. >30°C	30.3	27.2	30.4	28.7	22.2	6.8	5.5	13.3	22.7	27.0	28.7	30.1
Mean daily 9 am relative humidity	52	61	56	50	51	57	51	46	39	35	37	43
Mean daily 3 pm relative humidity	44	50	43	35	36	38	33	30	28	31	34	39

Newman Post Office	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp. (°C)	38.8	37.2	35.8	31.6	26.2	22.4	22.2	24.8	29.4	33.6	36.5	38.5
Mean daily minimum temp. (°C)	25.3	24.4	22.5	18.5	13.3	9.6	8.0	10.2	13.7	18.0	21.5	24.1
Mean number of days temp. >40°C	12.9	7.8	3.1	0	0	0	0	0	0	0.2	3.9	9.8
Mean number of days temp. >30°C	29.4	26.4	29.2	21.7	4.9	0.2	0	2.3	13.4	24.8	27.7	29.4
Mean daily 9 am relative humidity	35	41	37	41	49	56	50	43	30	25	24	30
Mean daily 3 pm relative humidity	22	26	23	26	32	34	29	24	17	14	14	19

Pannawonica	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp. (°C)	40.8	39.3	38.4	35.0	30.5	26.9	26.5	28.9	32.5	36.1	38.5	40.4
Mean daily minimum temp. (°C)	25.1	25.2	24.4	21.2	17.1	14.2	12.5	13.8	16.1	19.0	21.6	24.2
Mean number of days temp. >40°C	15.8	12.1	8.5	0.4	0	0	0	0	0.1	3.0	8.7	15.4
Mean number of days temp. >30°C	25.7	24.7	25.4	24.1	15.0	2.5	2.3	9.4	20.5	24.7	24.3	24.4
Mean daily 9 am relative humidity	48	53	44	41	44	49	46	39	32	28	29	39
Mean daily 3 pm relative humidity	27	30	25	24	28	31	28	22	17	15	16	24

Port Hedland Airport	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp. (°C)	36.3	36.1	36.8	35.1	30.4	27.5	27.0	29.0	32.3	34.6	36.1	36.6
Mean daily minimum temp. (°C)	25.4	25.3	24.4	21.3	17.2	14.1	12.2	13.1	15.3	18.2	21.1	23.9
Mean number of days temp. >40°C	4.6	4.3	5.1	1.0	0	0	0	0	0.1	2.7	5.6	5.8
Mean number of days temp. >30°C	30.5	27.2	30.4	28.3	17.5	5.0	3.1	10.8	22.7	26.7	28.5	30.7
Mean daily 9 am relative humidity	56	59	51	41	42	44	41	37	32	33	37	45
Mean daily 3 pm relative humidity	51	53	45	37	36	36	32	31	31	35	39	46

Roebourne Post Office	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp. (°C)	38.6	37.9	37.5	35.2	30.2	26.9	26.5	28.9	32.5	35.4	37.9	38.9
Mean daily minimum temp. (°C)	26.2	26.1	25.3	22.1	18.3	15.3	13.5	14.6	16.8	19.6	22.6	24.9
Mean number of days temp. >40°C	12.2	8.7	9.2	1.9	0	0	0	0	0.2	5.0	9.9	12.9
Mean number of days temp. >30°C	30.2	27.4	30.4	28.4	18.5	4.6	3.0	12.3	24.6	29.4	29.7	30.7
Mean daily 9 am relative humidity	52	57	51	45	47	51	47	41	36	33	35	41
Mean daily 3 pm relative humidity	40	44	38	34	37	40	34	30	26	27	29	33

Wittenoom	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily maximum temp. (°C)	39.5	37.8	36.9	33.0	27.4	24.3	24.0	26.5	31.0	35.0	37.9	39.5
Mean daily minimum temp. (°C)	26.0	25.2	24.4	21.1	16.1	12.9	11.4	13.2	16.8	20.5	23.5	25.4
Mean number of days temp. >40°C	16.4	9.4	5.1	0.2	0	0	0	0	0	1.0	7.2	15.7
Mean number of days temp. >30°C	30.3	26.9	29.5	24.6	8.4	0.8	0.2	4.3	19.3	29.1	29.4	30.6
Mean daily 9 am relative humidity	39	46	38	39	43	48	44	37	28	24	25	30
Mean daily 3 pm relative humidity	25	31	26	27	31	33	29	25	18	16	16	20

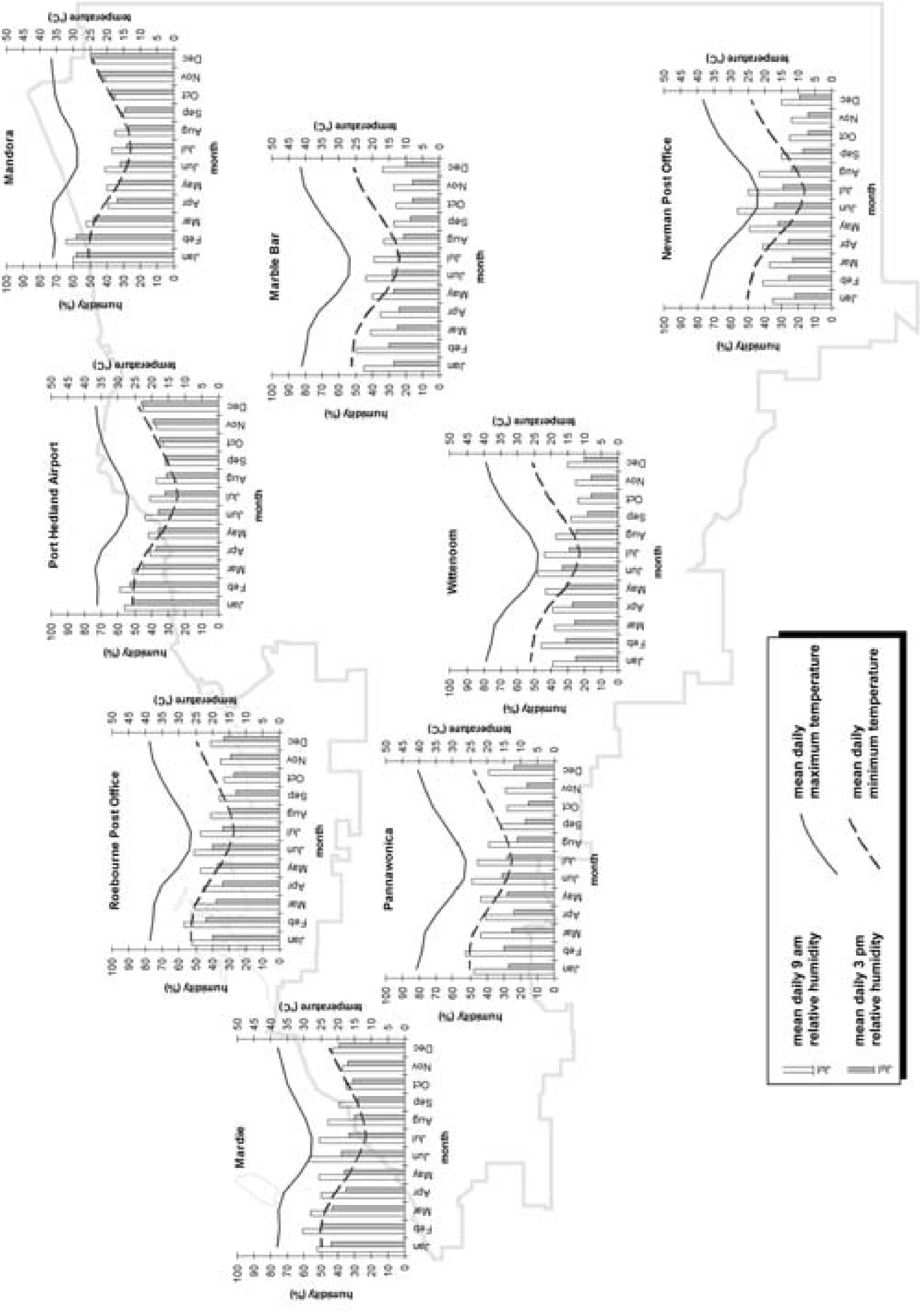

Figure 8. Mean monthly relative humidity and temperatures

In all areas of the Pilbara the mean minimum temperatures are well above the respective dew points so dew would not normally be expected. The likelihood of dew is greater inland in the south-east under similar conditions, but not as cold, that create frost. Dew can be of significant benefit to plant growth in arid environments.

Fog is rare throughout the Pilbara being confined more frequently along the coast in the early morning between the months of July to September. Fog forms when warm air flows over cold ground generally around dawn when it is coolest, and usually indicates a fine day will follow.

Humidity

Mean relative humidity expresses the amount of moisture in the air as a percentage of the maximum that can be held at the same temperature. At 0% the air is completely dry and at 100% it is saturated and can hold no more unless the temperature increases. If the air cools some of the moisture condenses into liquid (as rain or dew) leaving the air still saturated at a lower temperature.

The Pilbara, for much of the year, is located in part of the driest area of the continent. Except for the most southern (Newman) and northern (Port Hedland and Mandora) locations there is little difference between the February and June relative humidity values. The biggest fluctuations happen in autumn and spring. Being inversely proportional to temperature, relative humidity will always be greater at dawn, and least when temperatures are high in the afternoon.

Along the coast, and throughout the year, the 9am relative humidity varies between 30-60%; inland the variation is between 25-50%. Lowest humidity is around September-October; highest humidity is February and June, except Port Hedland (February), and Newman (June) (refer to Figure 8). Localities close to the ocean will always have higher humidity especially during times when prevailing winds originate over the water.

At 3pm, inland, the relative humidity universally drops about 30-40%. Along the coast, however, the seasonal presence of a sea breeze and the latitude of the recording station determine the drop in the afternoon value. In winter, being the dry season, humidity along the coast drops about 25% during the day. In the summer wet season it drops about 15% at Mardie but only about 5% north of Port Hedland.

In hot weather comfort is closely related to the amount of moisture in the air. In dry conditions the air has the capacity to evaporate moisture from the skin and so create a cooling effect, so even in very hot temperatures one can remain reasonably comfortable. When the air is moist there is less capacity for evaporation to occur and the human cooling system becomes less effective (BOM, 1972).

Relative humidity is determined by comparing simultaneous readings of a standard dry bulb thermometer and one that has the bulb wrapped in wet muslin. The evaporation of water from the muslin has a cooling effect so the temperature indicated by the wet bulb thermometer will be less than the temperature indicated by a dry-bulb thermometer. The rate of evaporation depends on the humidity of the air – evaporation being slower when the air is already full of water vapour.

Many people find conditions becoming uncomfortable when the wet bulb temperature reaches 21˚C. Marble Bar has 183 days at this temperature; Onslow has 185; Port Hedland 195 and Wittenoom 100. At a wet bulb temperature of 24˚C most people are uncomfortable – Marble Bar has 99 days over this temperature, Onslow 115, Port Hedland 125 and Wittenoom 38. Port Hedland has 93 days over 27˚C and 10 of these exceed 29˚C wet bulb temperatures – more than triple the rate for the other centres.

Evaporation

Evaporation is the single most important contributing factor to water loss in arid Australia. It therefore has considerable influence on water conservation both in terms of plants and animals.

Parts of the Pilbara have the highest average annual evaporation in Australia and, as for much of the continent, this is considerably higher than the average rainfall. Figure 5 shows that in the south-east sector, whilst rainfall amounts to less than 200 mm, annual evaporation is in excess of 4,000 mm (20 times as much). With an annual rainfall of over 400 mm Wittenoom records one of the highest annual rainfalls in the Pilbara and is located within an area of lowest annual evaporation of 3,000 mm (7.5 times higher). On average, for most of the Pilbara, the annual evaporation rate is about 10 times higher than the rainfall.

In November and December, with the onset of the wet season, daily evaporation rates range from about 11 mm at the coast to 14 mm inland. Increased cloud, humidity and rain in January to February reduce the daily evaporation even though temperatures are peaking. With the onset of cooler months the evaporation rate declines to a more uniform average of 5 mm in July across the Pilbara.

Sunshine and cloud

A 150 km swath running east from Port Hedland to the WA-NT border receives more than 10 annual average daily sunshine hours, the highest in Australia. The seasonal variations within the Pilbara are small from 10 hours per day in October/November to 8-9 in June.

Cloud cover is greatest during January and February with an average of 12 cloud free days per month near the coast. Further inland this reduces to 6-8 days cloud free. Daily variation in cloud cover is minimal near the coast but increases inland during the afternoon especially during the warmer months. In spring and early winter the area is regularly influenced by northwest cloud bands which can typically extend across the continent from the Pilbara coast to Victoria. October has the most number of clear days with 25 cloud free days near the coast reducing to 20 days further inland. After October there is a rapid build-up of cloud with the approaching wet season.

Prevailing winds

For most of the cooler part of the year and over most of the Pilbara winds tend to be easterly or south-easterly, influenced by the passage of winter high pressure (or anti-cyclone) systems that are moving eastwards across the continent. In the afternoon in coastal locations these winds change to a more northerly direction. In spring these winds weaken as a semi-permanent heat low develops over the area and along the coast the wind direction becomes more variable. In these coastal areas, especially in the warmer months, the wind direction often reverses in the afternoon and sea breezes from the north-west dominate.

Figures 9 and 10 show the patterns of winds for summer and winter recorded at 9am and 3pm. They show that inland wind patterns are relatively constant throughout the year in terms of strength and direction. In Newman there are a greater proportion of calms in winter mornings and summer afternoons. Throughout the year the coastal locations have more calm periods in the morning than afternoon.

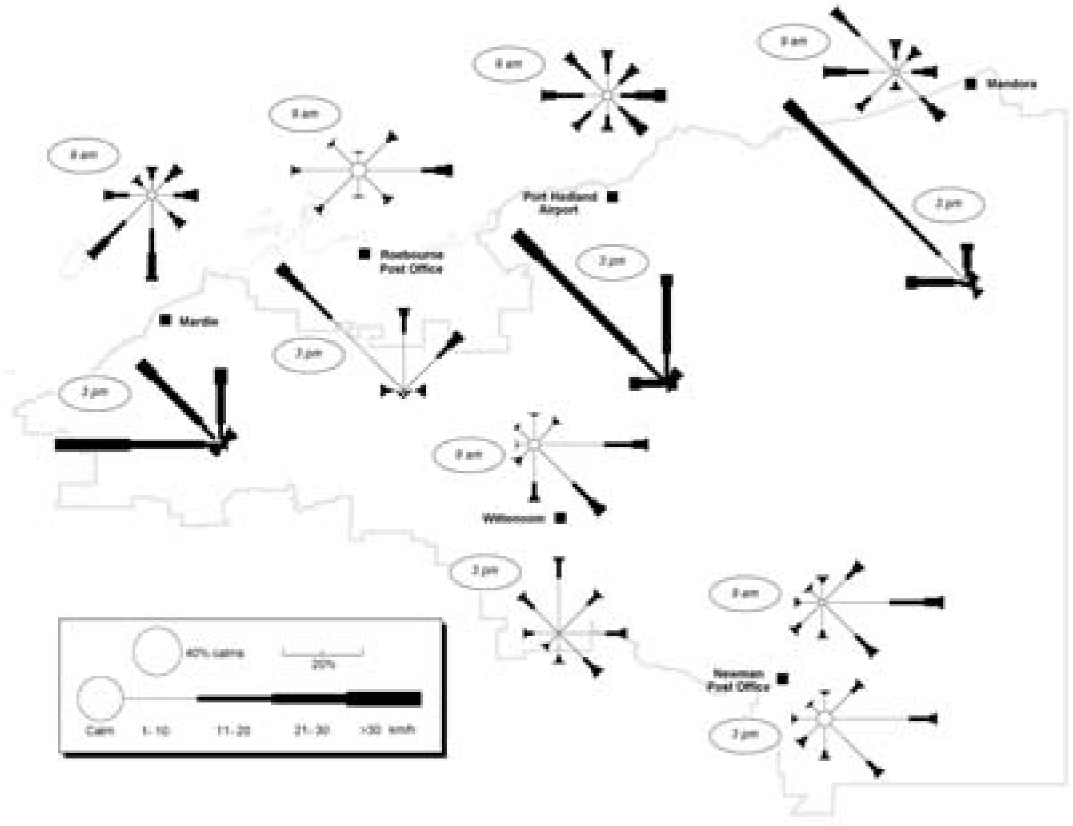

Figure 9. Summer wind roses for 9am and 3pm

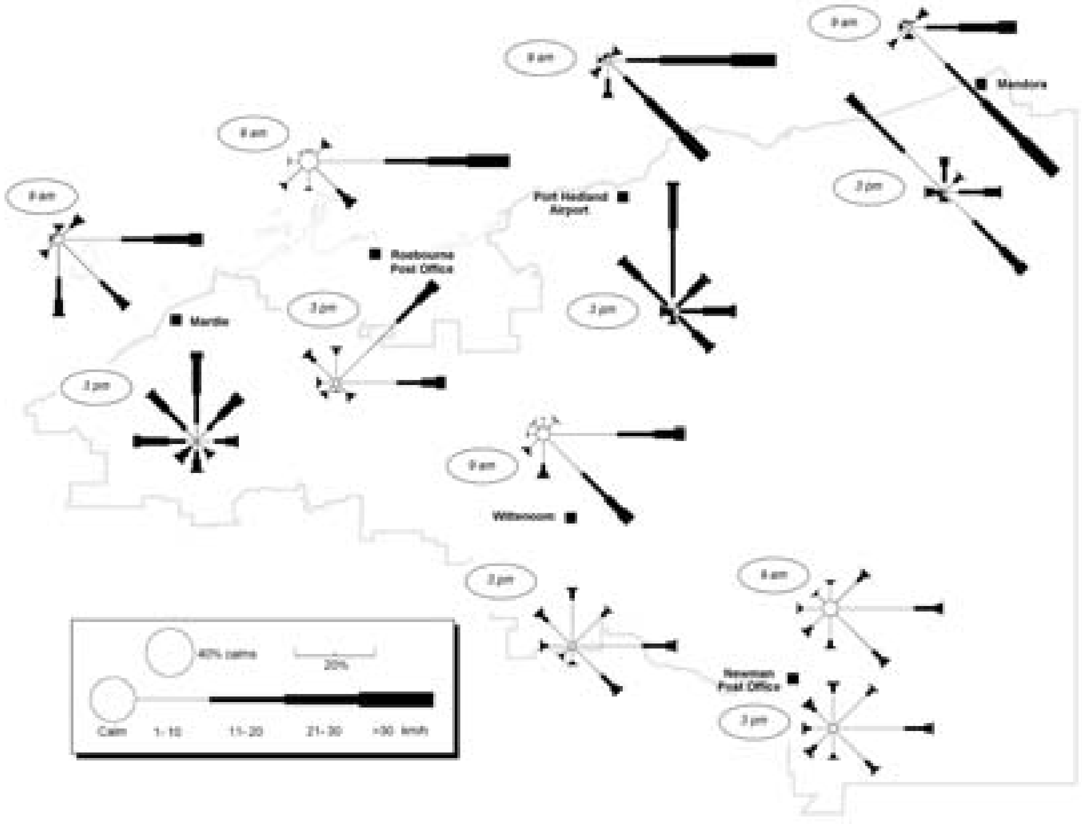

Figure 10. Winter wind roses for 9am and 3pm

Tropical cyclones

The Pilbara coast is in one of the most cyclone-prone areas of the world (see Figure 11). BOM records, which date back to 1910, indicate that 235 cyclones have crossed the coast, while another 160 stayed out to sea but passed close by. On average 2.5 cyclones per year cross the coast accompanied by strong to destructive winds often in excess of 170 km/h, and heavy rain. In any one year the maximum number of cyclones has been 6 (1965, 1981, 1984).

Many of the storms originate in the Timor Sea then travel in a west to south-west direction roughly parallel to the coastline. At about the latitude of the Pilbara some will recurve and travel south-easterly and disruptively cross the coast, others will continue paralleling the coast and degrade, yet others will recurve westerly and fade out in the Indian Ocean. Cyclones that cross the Pilbara coast are often more severe than those that cross the Kimberley coast further north. During the extra time it takes to reach Pilbara latitudes the cyclones have had more time to develop and reach severe proportions. Those that cross the coast generally keep following a south-easterly trend until they degrade to a rain-bearing depression. Seldom do many cross the continent to the Southern Ocean – most are spent in the central desert region of WA. Figure 12 shows the classic form of a tropical cyclone associated with a continental cloud band and, somewhat uncharacteristically, another cyclone forming in close proximity.

Cyclones have the potential to cause widespread damage through destructive wind gusts and flooding from rain or tidal surge. Infrastructure is particularly at risk during the cyclone season but domestic livestock is also vulnerable when insufficient warning make it impossible to move stock to more sheltered areas. The unpredictable nature of cyclones virtually precludes pastoral lessees from executing timely precautionary strategies to save livestock – most effort is focussed on preserving critical infrastructure.

Damage to infrastructure, such as this windmill, caused by cyclonic winds is an annual risk.

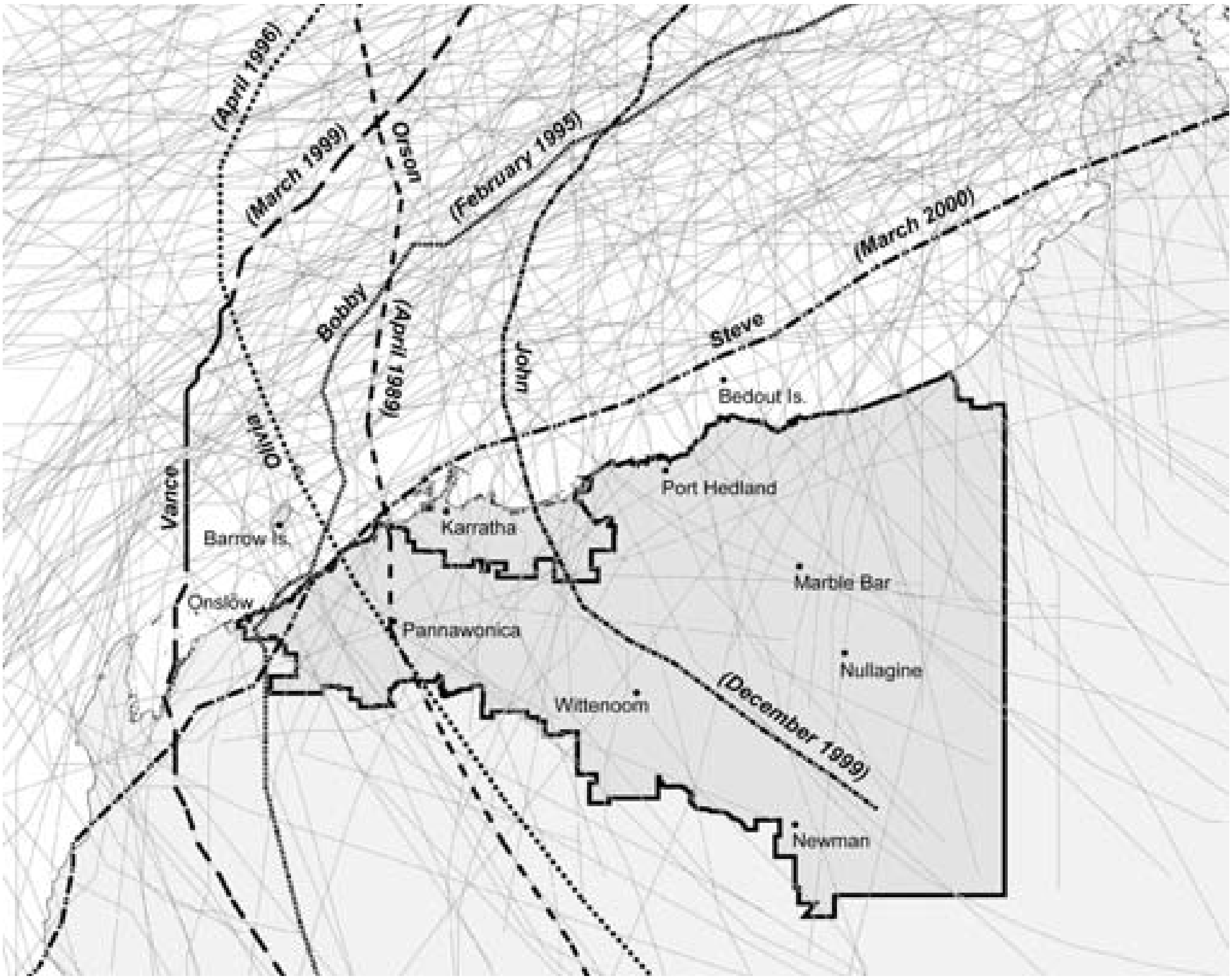

Figure 11. Tropical cyclone paths from 1910-2002, with some of the more recent significant ones highlighted

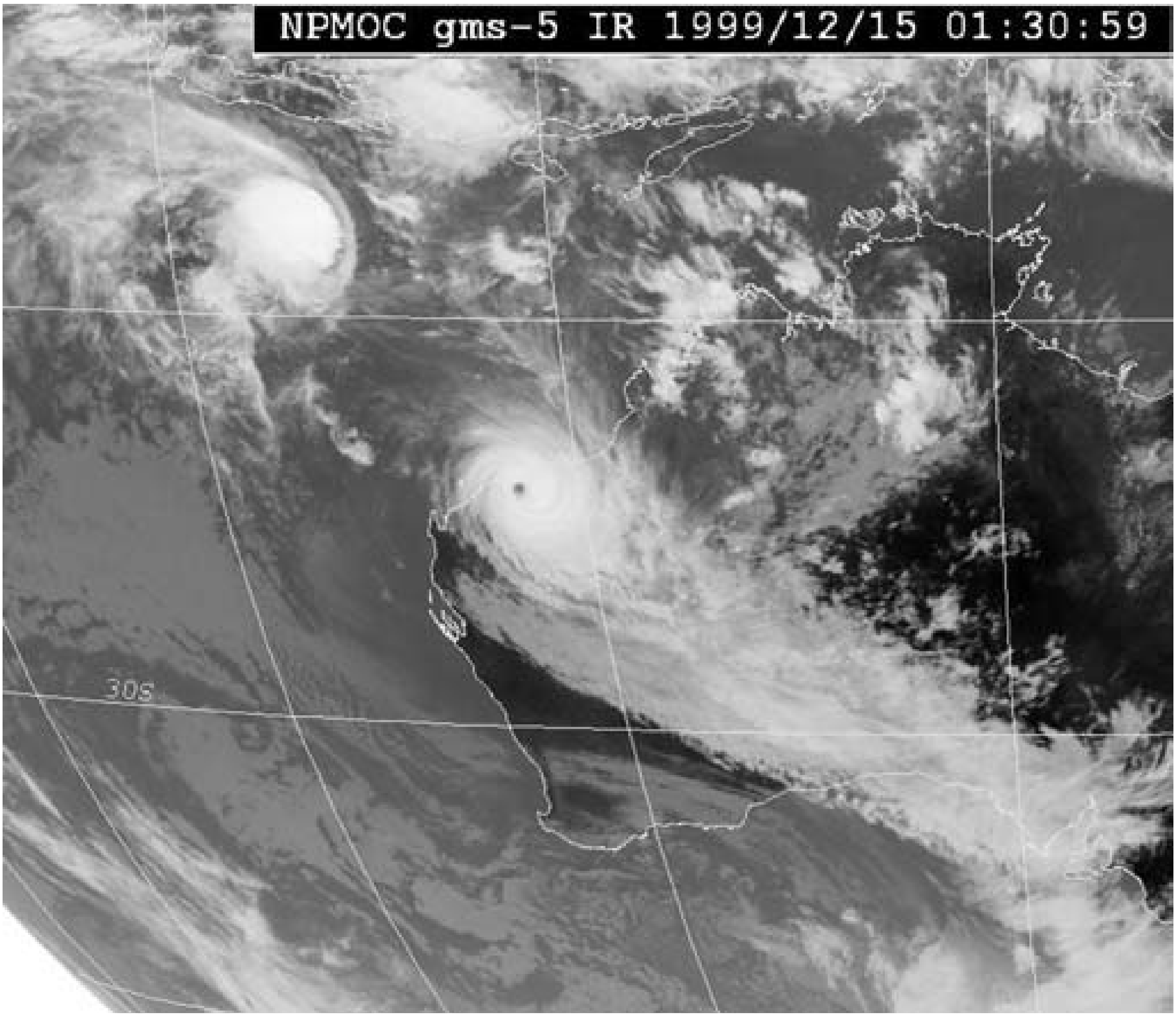

Figure 12. Severe TC John at 9:30am on 15 December 1999 – a category 5 storm when it crossed the coast near Whim Creek travelling south-east at 15-20 km/h. To the north-west is TC Ilsa – a category 2 storm travelling east-south-east at 30 km/h (source: Japanese Geostationary Meteorological Satellite (GMS - 5) image from www.bom.gov.au)

Notwithstanding the destructive nature of cyclones, they are critical for supplying up to 50% of average annual rainfall. Unfortunately rain tends to be banded and whilst intensive rain will fall along the cyclone track, the outer margins of the storm will receive only modest falls with the extremities receiving no benefit. The topography of the Pilbara, being mostly hard surfaced with numerous tributary creeks and rivers, means that major river systems will run from rain falling somewhere within the catchment. Local to widespread flooding is common in the lower reaches of most river systems.

The tropical cyclone season extends from November through to May. The historical monthly distribution since 1910 shows that November has hosted 4 cyclones, December 41, January 54, February 49, March 63, April 16 and May 3. Cyclones that develop in the early months of the season are more likely to cross the coast in the northern parts of the Pilbara and as the season progresses so the paths cross the coast further south. The most destructive cyclones typically occur in January to March.

One of the strongest cyclones to affect mainland Australia was *Vance* of March 1999 which tracked southwards down Exmouth Gulf (see Figure 12). It caused extensive damage to the town of Exmouth and created a 4 m tidal surge that inundated parts of Onslow town and severely breached salt concentrator ponds in the same vicinity. Further west there was severe coastal sand dune erosion and widespread denudation of vegetation on pastoral lands. The highest ever wind gust in Australia of 267 km/h was recorded at Learmonth. *Vance* continued across WA in a south-westerly direction causing widespread flooding in the Goldfields, severed the highway and rail link to the eastern states, and caused gale force winds over parts of South Australia and Victoria.

Cyclone warnings, severe weather alerts and emergency procedures are posted on the BOM website at www.bom.gov.au and the Emergency Management Australia website at www.ema.gov.au

Southern oscillation index (SOI)

Many weather phenomena can be attributed to the Southern Oscillation – that is the air pressure difference along the equator within the Pacific Ocean. The SOI is particularly useful in predicting, some months ahead, the onset of the monsoon season in the Australian tropics. It has been found that the patterns of tropical cyclones correlate to the SOI. A strongly negative SOI (below –10) characterises an El Nino event and an increased probability of drier conditions. Typically during this period there will be fewer cyclones, the season is likely to start later and they are more likely to cross the WA coast. La Nina events happen when the SOI is strongly positive (above +10) and often give rise to an earlier start to the cyclone season. However, the influence of the Southern Oscillation is otherwise very limited in the Pilbara region as it is located too far south of the equator and is distant from the Pacific Ocean. Figure 13 shows the weakly correlated relationship between the Pilbara average rainfall for the November to February wet season and the corresponding SOI for the period 1972-2002.

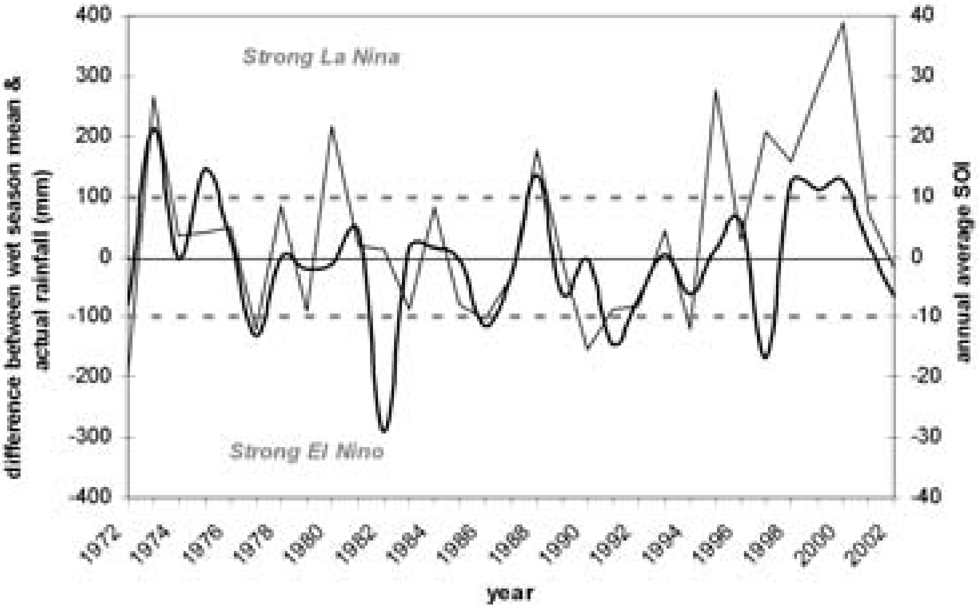

Figure 13. Relationship between Pilbara wet season average rainfall and SOI (thick line is SOI trace)

Rainfall effectiveness and estimated periods of plant growth

The availability of soil moisture is the most dominant factor influencing plant growth in the arid and semi-arid regions. Rainfall, from which most soil moisture is derived, is most effective for plant growth if it comes as a combination or series of episodic falls. This is far preferable than receiving the average or total annual rainfall as one or a few major events that are likely to cause more damage than good. Assessing the effectiveness of rainfall for plant growth needs to consider, among other things, the frequency (as well as the amounts falling) of rainfall events. Growing conditions are also influenced by temperature which, if extreme, will retard growth.

In the Pilbara the native vegetation has adapted to making good use of summer rainfall and higher temperatures. Many of the plants are endemic to the area and do not grow well in the more moderate climate regimes of the southern areas of the state. For much of the area the rainfall is weakly bimodal in nature which tends to promote growth throughout the year.

The WATBAL computer model (Fitzpatrick, Slatyer and Krishnan 1967) measures rainfall effectiveness in terms of availability of sufficient soil moisture to promote vegetation growth. The model takes into account rainfall and potential losses from transpiration, evaporation, percolation and run-off. Historical climate data for nine centres within the survey area was analysed to produce an estimate of the annual number of pentads (five-day periods) of likely vegetation growth. If there is a store of water remaining in the soil at the conclusion of the pentad then plant growth is considered to have occurred.

Table 4 lists the average start date of the growing season (taken from about 90 years of observations) for winter and summer for each of nine well-spaced recording centres. In this table winter is defined as the months May to October and summer as the months November to April as these periods are expected to better reflect growth seasons than the BOM season definitions. Table 4 also lists the average length of each seasonal growing period, the longest recorded growing season and the percentage of effective growing seasons for winter and summer over the 90 year period. The definition of what constitutes an effective period is somewhat arbitrary. Previous rangeland reports (Payne *et al.* 1998) used a minimum 30 day period of positive soil moisture for winter, or a 20 day period for summer but this model does not take into account regional variations in soil, topography and the adaptation of plant species to seasonal conditions. It is thought that local knowledge would provide a better guide to quantifying the minimum length for an effective season. However, for ease of comparison between centres the 30 and 20 day periods have been adopted in Table 4.

Table 4. Growing season statistics for winter and summer seasons at selected sites

	Winter season				Summer season			
Recording centre	Average start date	Average length of growing season (days)	Longest recorded growing season (days)	% of effective seasons (>30 growth days)	Average start date	Average length of growing season (days)	Longest recorded growing season (days)	% of effective seasons (>20 growth days)
Bonney Downs	3 Jun ± 24 days	25 ± 22	90 (1955)	32	17 Feb ± 28 days	45 ± 28	115 (1941)	55
Bulloo Downs	1 Jun ± 28 days	25 ± 22	75 (1998)	29	18 Feb ± 50 days	30 ± 25	75 (1999)	40
Mandora	25 May ± 21 days	20 ± 20	70 (1998)	18	29 Jan ± 47 days	55 ± 30	130 (1968)	80
Mardie	30 May ± 25 days	40 ± 24	90 (1973)	53	14 Feb ± 30 days	30 ± 21	95 (1933)	55
Mt Florance	2 Jun ± 24 days	30 ± 22	75 (1931)	31	8 Feb ± 44 days	50 ± 26	150 (1999)	76
Pardoo	1 Jun ± 26 days	25 ± 22	95 (1955)	28	3 Feb ± 30 days	40 ± 26	100 (1996)	70
Red Hill	30 May ± 24 days	40 ± 29	110 (1973)	51	8 Feb ± 28 days	45 ± 26	120 (1933)	67
Roebourne	1 Jun ± 24 days	26 ± 20	70 (1910)	27	11 Feb ± 45 days	35 ± 25	90 (1945)	64
Warrawagine	3 Jun ± 26 days	20 ± 20	70 (2000)	19	3 Feb ± 25 days	41 ± 26	105 (1942)	57

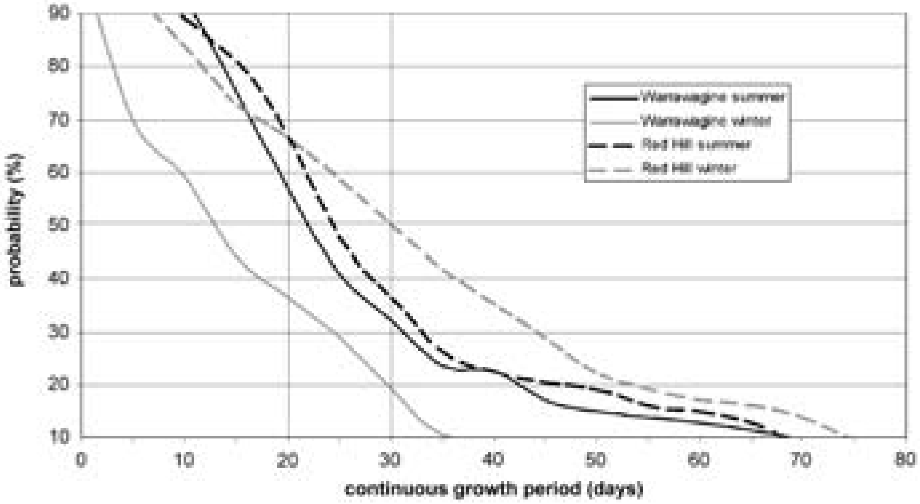

Figure 14. The probability of attaining defined periods of continuous growth for two centres

Most of the Pilbara is much more likely to have an effective summer season than an effective winter season. Regionally the western centres of Mardie and Red Hill, and the more central locality of Mt Florance are the only ones to have an average winter growing season in excess of 30 days. For the former the probability of an effective winter season is about 50% whereas for Mt Florance this is only about 30%. By contrast, during summer, most centres show a probability of much better than 50% of having an effective growth season. Mandora has the longest average summer growing season of 55 days and the highest probability of receiving an effective season at 80%. Except for Mardie all centres record longer growing seasons in summer.

Figure 14 shows the probability of receiving a defined period of continuous growth days. The four series have been compiled for summer and winter seasons at Warrawagine and Red Hill observing stations. It demonstrates that both northern (Warrawagine) and south-western (Red Hill) parts of the survey area are more likely to have effective summer seasons than effective winters. Effective winters are much more common in the south-west than in the north.

It can be interpreted from the graph that:

- there is about a 20% probability of Warrawagine having an effective 30 day continuous winter growth season.
- there is about a 50% probability of Red Hill having an effective 30 day continuous winter growth season.
- there is about a 56% probability of Warrawagine having an effective 20 day continuous summer growth season.
- there is about a 66% probability of Red Hill having an effective 20 day continuous summer growth season.

The pastoral management implications which climate determines are discussed in the companion publication entitled ‘Pastoral resources and their management in the Pilbara area, Western Australia’ (Van Vreeswyk, Payne and Leighton 2004).

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Geology and hydrogeology

S. L. Johnson

Introduction

The Pilbara region is a major mineral province with numerous large scale iron ore mine operations. It is also an important pastoral area for grazing cattle and small numbers of sheep.

The population of the Pilbara is presently around 45,000. The population is very mobile with the staff of many mining operations using a fly-in-fly-out system. Most inhabitants live in and around the major centres of Karratha and Port Hedland. Small numbers of people also live on the pastoral stations, smaller mining centres and Aboriginal communities scattered through the area.

The availability of groundwater is extremely important for town, mining and community water supplies, which utilise potable groundwater from various hydrogeological environments. The pastoral industry is dependent on groundwater and surface water sources for watering of cattle and sheep.

This section of the report outlines the geology and hydrogeology of the Pilbara. It aims to provide a regional overview of the nature and occurrence of groundwater resources from all available data held by the Water and Rivers Commission, and to assist in the location of groundwater supplies for the pastoral and mining industries.

Previous investigations

A comprehensive description of the geology in the Pilbara can be obtained from Memoir 3 (Geological Survey of Western Australia 1990). More detailed descriptions of the geology are contained in the respective 1:250,000 Geological Series Explanatory Notes published by the Western Australian Geological Survey.

Balleau (1973) provided the first regional description of the hydrogeology and groundwater resources for the Pilbara, as well as discussing the extent of previous groundwater investigations. A hydrogeological reconnaissance of basement rocks and surficial units throughout the West Pilbara was undertaken by Davidson (1975) with descriptions of groundwater salinity, recharge and potential bore yields from various aquifers. Barnett and Commander (1986) conducted groundwater exploration in the vicinity of the Millstream calcrete aquifer to assess the hydrogeology of the western Fortescue River valley.

Skidmore (1996) completed a quantitative assessment of the groundwater resources in the Pilbara Region, which was summarised by Wright (1997). Johnson and Wright (2001) provided a regional overview of groundwater resources and water management issues relating to the assessment of iron-ore mining developments in the central Pilbara.

There are various unpublished hydrogeological reports, held by the Water and Rivers Commission, on groundwater prospects for pastoralists, aboriginal communities, the Main Roads Department, and town water supplies for Karratha, Port Hedland and Newman. In addition, there are numerous consultants' reports on the availability of groundwater for various mining projects.

Physiography

The landscape is variable and shaped by the structure of the underlying geology and imposed weathering processes. The Pilbara has moderately high relief with a number of ranges, river valleys and peneplains which, in the north, fall away to form a gently sloping coastal plain. The rangelands are mostly rugged with prominent strike ridges and hills of outcropping rock separating deep valleys in which thick sequences of infill have locally accumulated. The Hamersley Range, marking the southern boundary of the study area, is the highest range in the State with Mt Meharry reaching a height of 1,249 m AHD (Australian Height Datum).

The Hamersley and Chichester Ranges are major topographic features that divide the two major river systems: the Fortescue and De Grey Rivers. All rivers are seasonal reflecting the erratic nature of rainfall and only flow after heavy rain. Pools and springs are often present in the river beds after the rivers cease to flow. The rivers mostly flow through single well-defined channels, but the channels often become poorly defined in a network of braided tidal creeks and salt flats at the coast.

A gently sloping coastal plain has developed in the north and west of the Pilbara Region. The plain rises gradually from sea level to about 50 m AHD and is around 20 to 60 km wide over most of the area. However, in the north, a broad alluvial plain associated with the De Grey, Coongan, Shaw and Oakover Rivers, merges with the coastal plain and extends about 120 km inland.

An eolian sandplain occurs in the north-east of the region and represents the westernmost extension of the Great Sandy Desert (Hickman 1983). The surface of the plain is characterised by east to south-east trending seif dunes, rare rocky outcrops, and occasional low breakaways. Surface drainages are absent over most of the plain.

Geology

The Pilbara Region has undergone a long geological evolution over a period of about 3,500 million years (Trendall 1990). Precambrian basement rocks, generated during phases of sedimentation, intrusion and volcanism, were deformed and metamorphosed due to movements in the Earth's crust. These rocks occupy most of the Pilbara and have been cut by intrusive dykes and veins. Later sea level changes and subsidence led to the deposition of large Phanerozoic sedimentary basins that overlie the western and eastern margin of the Pilbara (Figure 1). Erosion of the basement rocks and transportation by drainages has lead to the deposition of Cainozoic superficial units which now cover much of the basement rocks and the sedimentary basins.

Precambrian basement rocks: The Pilbara Craton contains the oldest rocks in the Pilbara and is subdivided into the Archaean granite-greenstone terrane in the north and the Archaean and Proterozoic Hamersley Basin in the south (Figure 1). The greenstone sequences cover approximately 40% of the granite-greenstone terrane and comprise

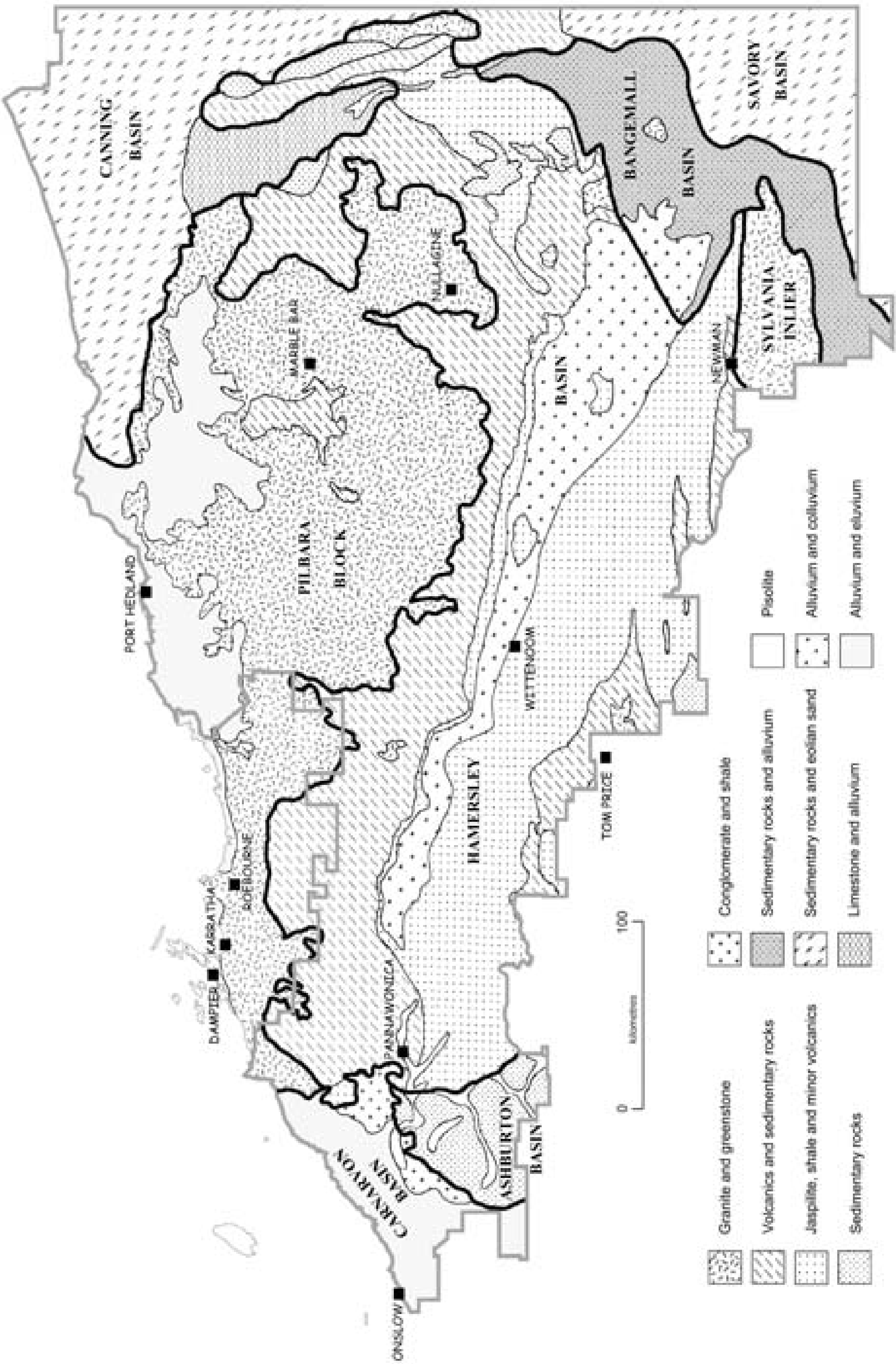

Figure 1. Generalised geology (adapted from Geological Survey of Western Australia, Memoir 3 1990)

metasedimentary and volcanic rocks that have been intruded by significant granitoid bodies. The granitic rocks comprise various deformed and metamorphosed granitic phases that are locally intruded by younger veins and dykes. The rocks of the complexes are exposed in the eastern Pilbara, but are poorly exposed in the west.

The Hamersley Basin overlies the older Archaean Pilbara Craton and comprises mafic and felsic volcanics, shale, siltstone, sandstone and conglomerate, as well as dolomite and banded iron formation. The sequence is extensively deformed with the rocks being faulted and folded.

Phanerozoic sedimentary basin: The Carnarvon Basin onlaps the western margin of the Pilbara Craton (Figure 1) and comprises a multi-layered sedimentary sequence overlying Proterozoic basement rocks. The sequence is mostly less than 500 m thick, but can be up to about 700 m thick in the south-west. In the Pilbara, the Carnarvon Basin comprises Late Devonian to Tertiary sediments of cavernous dolomite, claystone, shale, siltstone, sandstone, glauconitic sand and marly limestone.

Trealla Limestone is part of the Carnarvon Basin sequence and occurs in the subsurface beneath the Onslow coastal plain. It consists predominantly of fine-grained, crystalline limestone, clay and marl and is mostly about 15 m thick.

The Canning Basin covers much of the area to the north-east of the Pilbara. The south-western part of the basin onlaps the north-eastern margin of the Pilbara Craton (Figure 1) and extends into the Craton along a narrowing valley some 140 km long that coincides with the Oakover River. In the Pilbara, the Canning Basin sequence is Late Carboniferous to Cretaceous in age, more than 700 m thick and comprises shale, mudstone, sandstone, conglomerate, siltstone and minor coal. A thin veneer of Cainozoic deposits overlies the sequence.

Cainozoic deposits: A variety of Cainozoic units are deposited over the basement rocks and sedimentary basins. Jointed and cavernous pisolitic limonite (Robe Pisolite) has been deposited in the ancient Fortescue River valley and many of the valleys in the Hamersley Range. These are often located close to existing drainages and may be greater than 70 m thick. Pisolitic limonite also occurs in the subsurface of the Fortescue River valley.

Deposits of calcrete and minor silcrete occur throughout the Pilbara. They lie mostly in or adjacent to drainage channels, may be up to 65 m thick and outcrops may be up to 20 km wide. The deposits are thickest in the Fortescue River valley, in the vicinity of Millstream (Barnett and Commander 1986).

Eluvium comprises residual weathered material that remains *in-situ* and is developed to various depths over underlying basement rocks. Colluvial material of scree and talus is present over much of the western Pilbara and obscures the basement geology. It consists of poorly sorted clay, silt, sand and gravel that has been transported over short distances by gravity.

Rivers traverse the coastal plains and have deposited large amounts of Quaternary age, alluvial material. On the coastal plain near Port Hedland, the alluvium comprising clay, silt, sand and gravel overlies weathered Archaean basement rocks. It can be greater than 50 m thick close to major drainages, but decreases in thickness away from the major drainages where it merges with colluvial material. The alluvium present in the main drainages is mostly less than 1 km wide, but in some sections may be up to 10 km wide.

Hydrogeology

Source of data

The hydrogeological data used for this paper was obtained from detailed bore census carried out during regional geological mapping in the 1960s and 1970s. All groundwater information (water levels, depths, yields and salinities) for about 6,000 bores and wells is stored in the Water Information (WIN) database of the Department of Environment. The distribution of water points is relatively dense along the coast, along the major drainage features, and in the vicinity of mining operations and the towns of Karratha, Marble Bar and Port Hedland (Figure 2).

Groundwater occurrence

Groundwater occurs throughout the Pilbara. There is a regional watertable representing the level at which all pore spaces within rocks are saturated, and forms a subdued reflection of the topography. Although generally continuous through the region, the watertable is sometimes absent in high areas where the weathered and fractured zone is unsaturated, or where the fractures are poorly developed.

Pastoral water requirements of the area are met from small supplies of fresh to brackish groundwater in colluvium, alluvium and calcrete. Colluvial deposits that border the main trunk drainages provide a reliable source of shallow, good quality groundwater. Other smaller supplies are obtainable from the weathered bedrock profile, and from fractures and shear zones within the fresh bedrock. In many cases, the groundwater salinity is lower along the main drainage lines.

Groundwater availability

Groundwater is important to the pastoral and mining industry throughout the Pilbara. The area has low rainfall with erratic seasonal distribution and a high potential evaporation; hence, there is a surface water deficiency.

There are small supplies of fresh to brackish groundwater suitable for stock-watering throughout the Pilbara, however, it is more difficult to locate large supplies of potable groundwater for town and mine water supplies. The location of large groundwater supplies, irrespective of salinity, is dependent on the presence of suitable groundwater-yielding rock types and site-specific geological conditions, such as dissolution features, fractures or shear zones.

Groundwater occurs in various hydrogeological environments, ranging from surficial and sedimentary aquifers with intergranular porosity, to weathered and fractured aquifers. The different aquifers in the area are described below and summarised in Table 1. The relationship of groundwater within the various rock units and typical bore locations is shown in Figure 3.

Surficial aquifers

The unconsolidated surficial aquifers include both coastal and valley-fill alluvium. Groundwater in the Quaternary deposits of the coastal plain is mostly contained in alluvial,

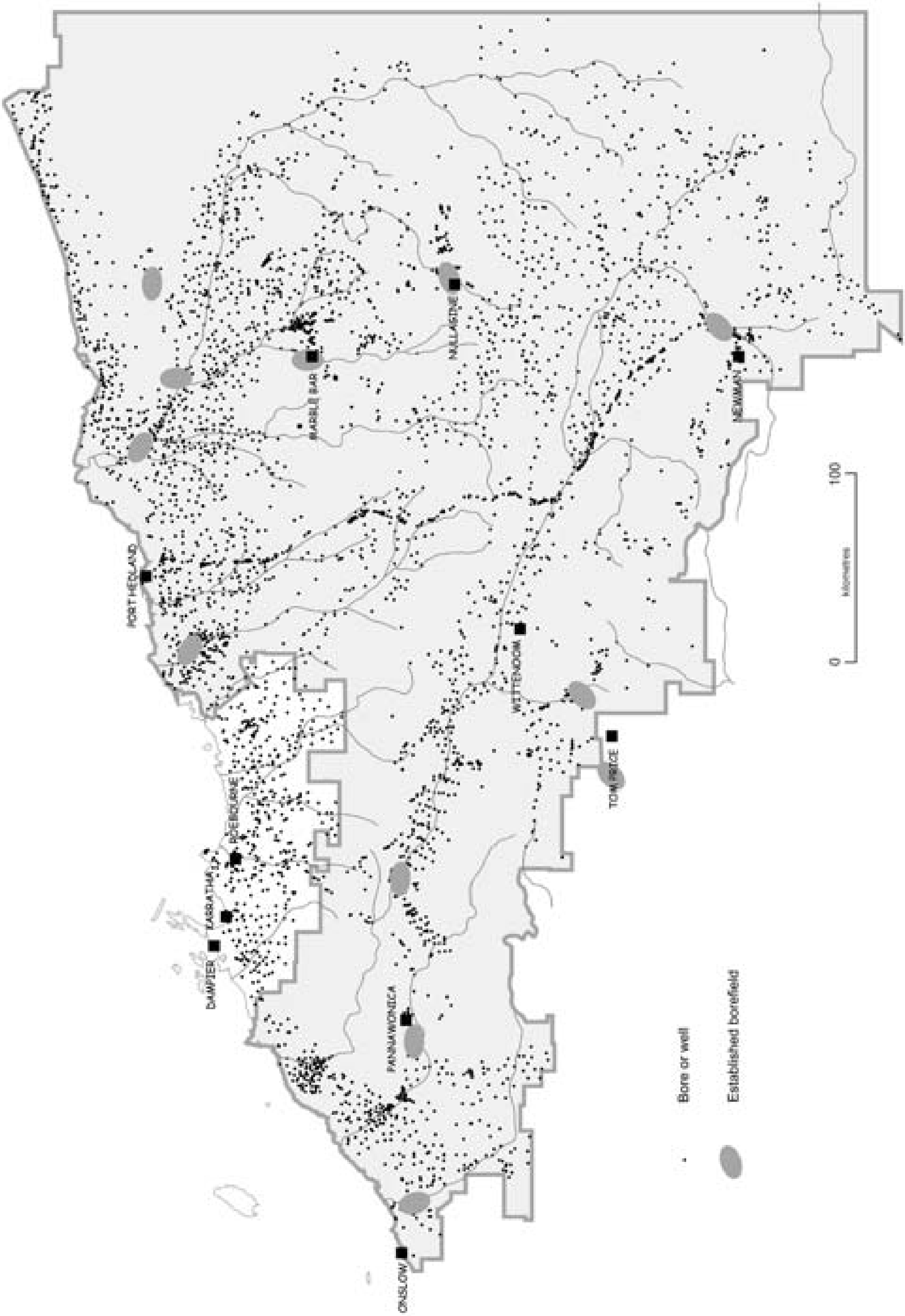

Figure 2. Bore and well distribution

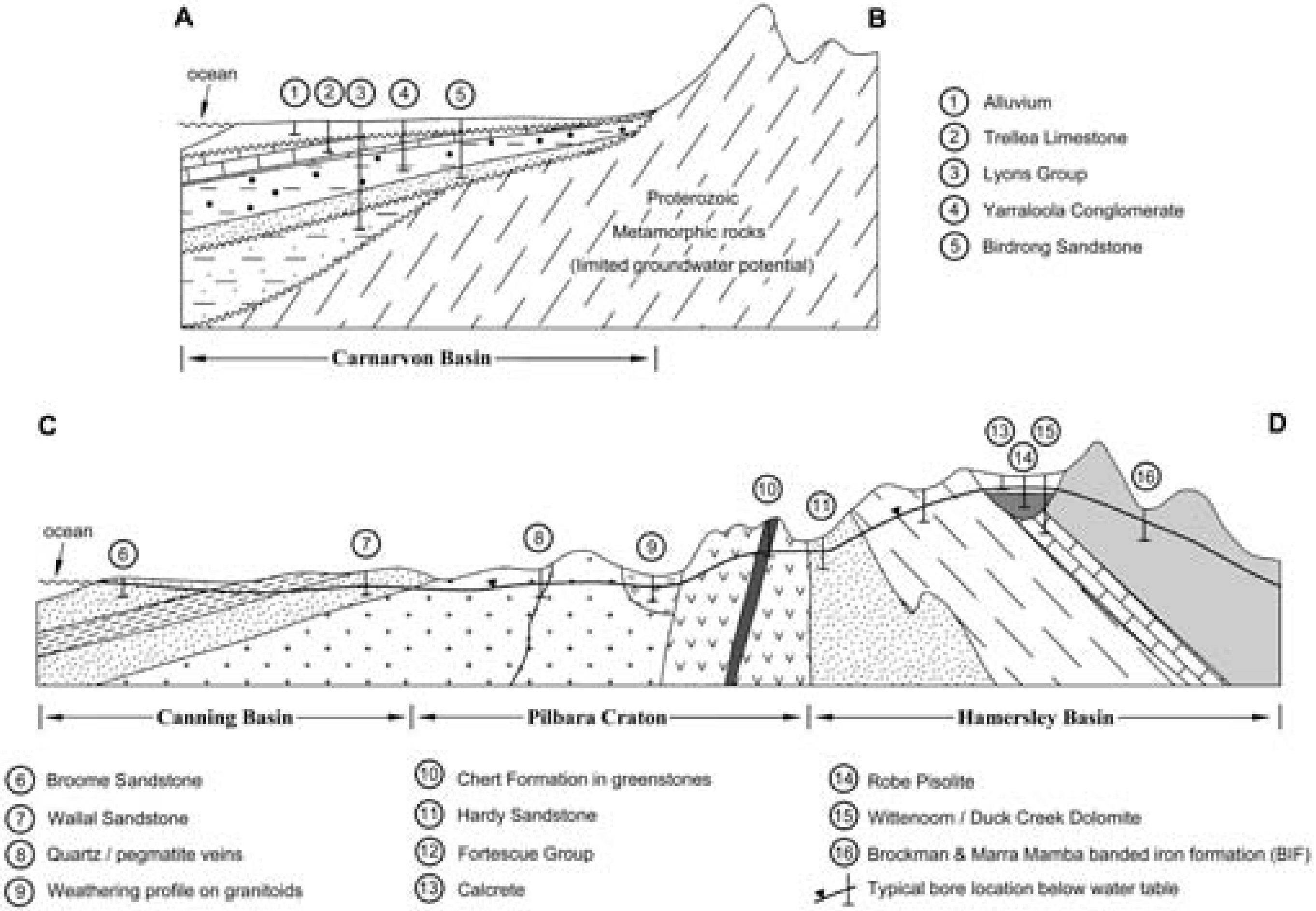

Figure 3. Schematic cross sections showing groundwater occurrence and typical bore locations (Note: Position of sections shown on Figure 4)

unconfined aquifers in which regional flow systems may be defined. Coastal dunes form local unconfined aquifers that are not of regional significance. There are areas of low salinity groundwater in the coastal alluvial aquifer, where the river drainages cross the coastal plain.

Large groundwater resources in the upland areas are stored in the valley-fill alluvium of the Fortescue River and valleys in the Hamersley Range. The valley-fill consists of colluvium and alluvium, up to 100 m thick, which often overlies pisolitic limonite and calcrete. Bore yields from the Fortescue River alluvium range between 100 and 500 m^3/day. Yields greater than 1,000 m^3/day are common, where bores are constructed in both the dolomitic basement rocks and overlying alluvium.

Groundwater recharge to the coastal plain and valley-fill alluvial aquifers occurs mostly by leakage from surface water flows and to a lesser extent by direct infiltration of rainfall. Minor recharge may also occur by lateral groundwater flow from the basement rock aquifers, where in hydraulic connection.

Groundwater is generally fresh, except away from the main rivers on the coastal plain. Salinity increases in the direction of groundwater flow, in areas of low permeability and with increasing depth. Groundwater salinities in the alluvial aquifers of the coastal plains range from fresh to saline. Groundwater in the valley-fill alluvium is fresh to brackish, except in the Marsh where saline groundwater has been encountered.

Chemically deposited aquifers

The calcrete and pisolitic limonite aquifers were chemically deposited within Tertiary drainages. Both aquifers are characterised by secondary permeability and large bore yields (in excess of 1,500 m^3/day).

Calcrete aquifer: Calcrete occurs within drainages as localised exposed mounds near discharge zones, such as river pools or springs. Many calcrete bodies are remnants of larger areas that have been dissected by recent drainages. The calcrete is up to 46 m thick at Millstream (Barnett and Commander 1986) but is generally less than 10 m thick.

The calcrete is characterised by secondary porosity with karstic features developed through the partial dissolution of calcrete via percolating surface water and groundwater movement. Groundwater recharge occurs mostly by leakage from streambeds during surface runoff and to a lesser extent by direct infiltration of rainfall.

Bore yields from the calcrete are generally between 50 and 100 m^3/day, although yields of up to 5,000 m^3/day have been obtained at Millstream (Water Authority 1992). Groundwater salinity is mostly fresh to marginal, but may be brackish during prolonged dry periods and where groundwater from basement rocks discharges into the aquifers. On the flanks of the Fortescue Marsh, the groundwater is hypersaline due to concentration via evaporation.

Pisolitic limonite aquifer, often referred to as Channel Iron Deposit (CID) aquifer, is utilised for groundwater supplies at

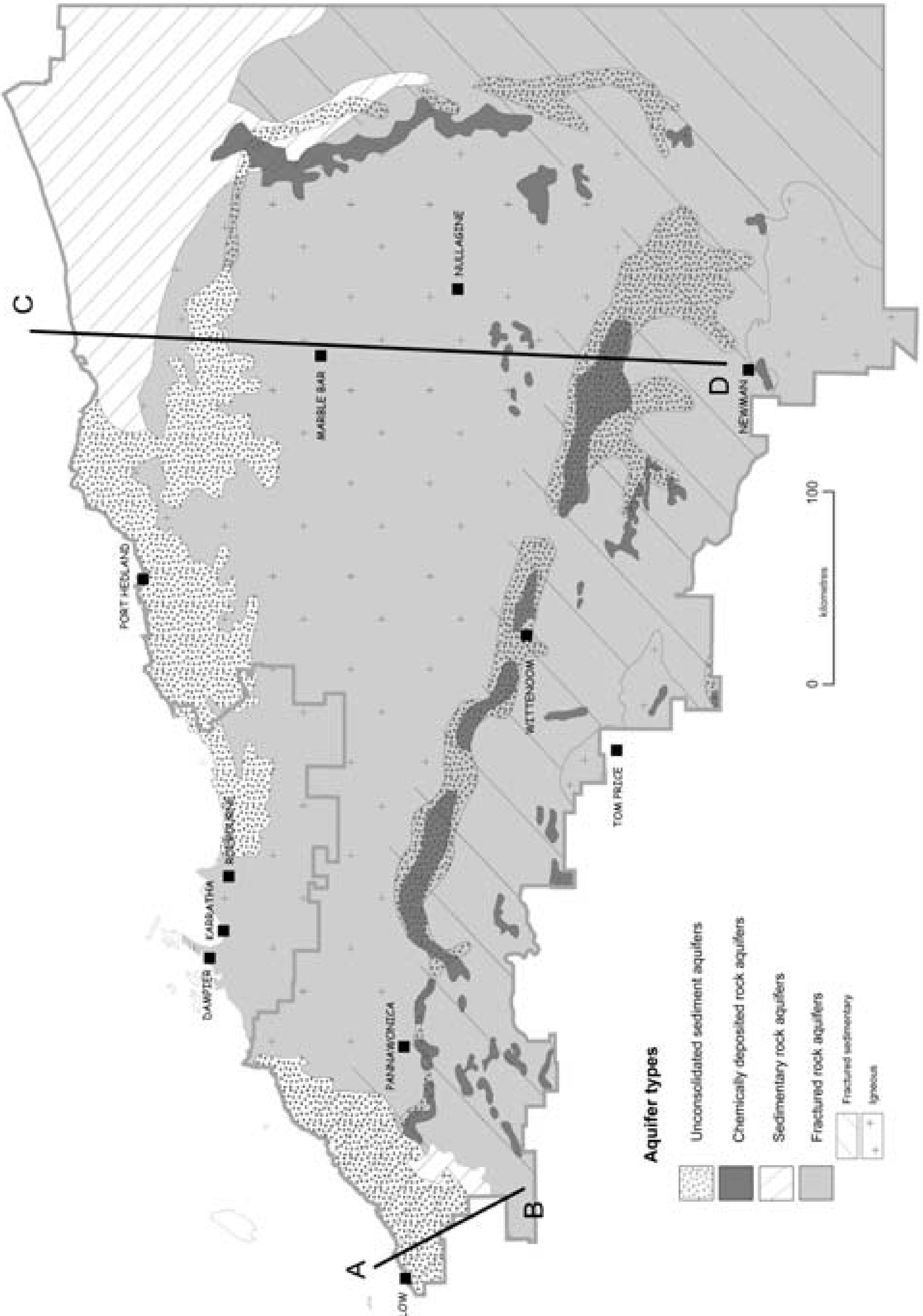

Figure 4. Aquifer types

the Robe River and Yandicoogina mining operations. The pisolite aquifer is up to 90 m thick within the BHP Yandi operations at Marillana Creek. The pisolitic limonite does not outcrop extensively and only constitutes an aquifer where it occupies channels incised into basement rocks by prior drainages. It is often unsaturated where it outcrops outside the drainages, but forms large local aquifers where it occurs below the drainages.

The aquifer is highly porous, vuggy and heterogeneous. Bore yields from the pisolite are often in excess of 1,500 m^3/day. Most production bores show a delayed yield response suggesting groundwater can become perched due to poor interconnection between pores or clay layers. Groundwater salinity is typically fresh to brackish.

Sedimentary aquifers

The sedimentary rock aquifers comprise the Carnarvon and Canning Basin aquifers, which are respectively positioned in the western and north-eastern parts of the Pilbara (Figure 4). The aquifers are both confined and unconfined with the primary porosity providing storage capacity. Recharge is by means of direct rainfall infiltration and leakage from drainages during surface water flows. Groundwater flow patterns in the sedimentary basins occur on a regional scale generally towards the coast.

Canning Basin

The Canning Basin contains three major aquifers; the unconfined Broome Sandstone aquifer, the confined Wallal Sandstone and Paterson Formation aquifers.

The *Broome Sandstone* aquifer is a major unconfined aquifer comprising the Cretaceous Broome Sandstone. It rests on the Jarlemai Siltstone over most of the area. Groundwater movement is towards the coast in a north and north-west direction from the recharge areas. Groundwater salinity is variable. There is a groundwater salinity increase along the groundwater flow path from less than 1,000 mg/L total dissolved solids (TDS) in the south to greater than 10,000 mg/L TDS in the north-west. Large diameter bores slotted over the fully saturated aquifer thickness may be capable of 1,000 m^3/day.

The *Wallal Sandstone* is a major confined aquifer comprising the Jurassic Wallal Sandstone. The groundwater is generally fresh, although salinity increases in the direction of groundwater flow. There is a rapid increase in salinity in the northwest in the vicinity of the De Grey River where groundwater salinity is greater than 10,000 mg/L. Most large diameter bores are capable of between 1,000 and 2,000 m^3/day.

The *Paterson Formation* is a possible major multilayer aquifer, but little is currently known about its hydrogeology. Groundwater in the aquifer is presumably recharged by infiltration of rainfall and surface water flows, as well as by inflow from adjacent basement rocks. Groundwater occurs as a consequence of primary porosity in the sand and sandstone beds within the Paterson Formation and is confined by clay and silt layers. Bore yields of about 500 m^3/day have been recorded from bores screened against about 10 m of the aquifer.

Carnarvon Basin

The Carnarvon Basin contains two major confined aquifers, namely the Yarraloola Conglomerate aquifer of Cretaceous age and the Lyons Group aquifer of Permian age. The aquifers underlie Cainozoic deposits on the Onslow coastal plain and rest on Proterozoic basement rocks. Groundwater in the aquifers is mostly under artesian pressure with temperatures ranging between 40 and 70˚C (Moors 1980).

The *Trealla Limestone aquifer* occurs in the subsurface throughout much of the coastal plain. It generally clayey and marl in nature, hence, it is a poor aquifer. The formation thickness is 15 m and bore yields are generally less than 100 m^3/day. Bore yields up to 900 m^3/day have been recorded in this formation, but these are not common.

The *Yarraloola Conglomerate aquifer* is comprised of the Yarraloola Conglomerate, Nanutarra Formation and Birdrong Sandstone. It overlies the Lyons Group aquifer and is confined by the Muderong Shale over most of the coastal plain. Groundwater recharge occurs mostly by leakage from the alluvial aquifers. The salinity of the groundwater beneath the Onslow coastal plain is fresh where the Yarraloola Conglomerate subcrops the alluvial deposits of the major drainages (300 to 900 mg/L). The salinity, however, increases with depth and along the direction of groundwater flow. Salinities at depth range from 6,000 to 40,000 mg/L TDS. Groundwater in the aquifer to the east of the coastal plain is mostly saline, but fresh and brackish groundwater occurs in narrow strips under and adjacent to the drainages. Bore yields in the coastal plain may be as high as 4,500 m^3/day.

The *Lyons Group aquifer* is a large confined aquifer comprising formations of the Lyons Group. Groundwater in the aquifer is saline suggesting relatively low rates of recharge. The salinity ranges from 6,000 to 36,000 mg/L TDS, but is mostly greater than 20,000 mg/L TDS. The aquifer has good potential for large supplies of saline groundwater from depths exceeding 100 m. Estimated artesian flow rates from bores of up to 5,000 m^3/day have been recorded, but bore yield data is scarce. Average yields in excess of 1,000 m^3/day may be expected from the aquifer.

Fractured-rock aquifers

Groundwater in the fractured-rock aquifer occurs where secondary porosity has developed in fractured and weathered zones or along bedding plane partings or joints. The rocks are tight outside the zones of secondary porosity and, in these zones, do not contain groundwater. Groundwater storage is, thus, mostly small, but may be large locally in solution voids. Groundwater recharge is episodic and affected by direct infiltration of rainfall over areas where the rocks are fractured, jointed and weathered. Recharge will also occur by leakage from surface flows, into the basement rocks or indirectly through superficial sediments where they overlie the basement rocks. Groundwater flow is largely controlled by local geological structures and weathering.

Fractured rock aquifers may be grouped into sedimentary and igneous rock aquifers and cover most of the area (Figure 4).

Fractured sedimentary-rock aquifers

The *dolomitic aquifer* (Wittenoom and Duck Creek Dolomite Formations) is prospective for groundwater, particularly where it underlies thick sequences of valley-fill in the Fortescue River and Hamersley Range. The dolomitic formations include mostly dolomite with minor chert and dolomitic shale. Hydrogeological data from the dolomite formations in the Oakover River and Ashburton River valleys are sparse, but groundwater prospects appear favourable. Groundwater is fresh to marginal with salinities ranging between 150 and 1,500 mg/L TDS. Some brackish groundwater may exist in shaly and less permeable sections. Bore yields from the dolomitic aquifers are variable depending on the intersected fracture and cavern density and range up to 1,600 m^3/day. Bores that abstract from both the thick valley-fill deposits and dolomite yield up to 5,500 m^3/day.

The *Banded Iron Formation (BIF)* aquifer has been identified as a local aquifer in the Hamersley Range. The BIF is comprised mostly of chert and jaspilite, with minor dolomitic shale. The upper sections of the Brockman and Marra Mamba Iron Formations, which also include minor interbedded shale, can be weathered and have well-developed solution features. Bore yields are variable and range up to 1,000 m^3/day. Yields greater than 1,500 m^3/day have been recorded, but most yields will probably be less than 500 m^3/day. Groundwater quality is mostly fresh to marginal with salinities ranging from 200 to 1,400 mg/L TDS. Brackish groundwater may occur in the discharge areas or where the fracture permeability of the rocks is low.

The *sandstone aquifer* comprising the Cliff Spring Formation (mostly agglomerate with some conglomerate and sandstone) and the Hardey Sandstone (sandstone grit and conglomerate, with some shale, mudstone, siltstone, tuff and basalt) are generally poor groundwater sources. The sandstone aquifer is only of local importance. Yields in the Cliff Springs Formation range between 100 and 250 m^3/day, while the Hardey Sandstone is poorly explored. Groundwater salinity is fresh to marginal (150 to 1,200 mg/L TDS) with a gradual increase in salinity along flow paths.

Igneous rock aquifers

The igneous rock aquifer includes mafic and felsic volcanic rocks of the Hamersley Basin and granitic and greenstone rocks of the Pilbara Craton.

The *mafic volcanic rocks* are not considered to have good potential for major groundwater supplies. Yields are generally less than 100 m^3/day, although well positioned and constructed bores may yield up to 500 m^3/day. Groundwater salinity is mostly fresh to brackish, indicating relatively rapid recharge. The *felsic volcanic rocks* form a poor aquifer, but sustainable yields may be located close to drainages.

In *granite and greenstone rocks*, the groundwater occurs mainly in the upper weathered zone and where intruded by quartz and pegmatite veins. Yields from granitic and greenstone rock aquifers are variable, site specific and range from dry to 2,000 m^3/day. The largest yields are likely to occur from the intrusive quartz veins and may not be sustainable away from the drainages. The granite aquifers are locally productive from intense fracturing, mostly around intrusive quartz veins. Elsewhere, the granite is a poor aquifer with yields seldom exceeding 100 m^3/day. The greenstone forms local aquifers with the best prospects in the more brittle and resistant units (BIF, quartzite and felsic volcanics), particularly where they underlie or are adjacent to drainages. Groundwater salinity in the granite-greenstone aquifers ranges from less than 500 mg/L along drainages to greater than 10,000 mg/L TDS.

Groundwater salinity and quality

Groundwater in the Pilbara is generally fresh (less than 1,000 mg/L TDS), particularly throughout the inland areas (Figure 5). There are areas of brackish to saline groundwater occurring within the interfluvial zone on the coastal plain and in the sediments of the Carnarvon Basin below the Onslow coastal plain (Skidmore, 1996).

The distribution of groundwater salinity at the watertable is shown by isohalines in Figure 5, although groundwater salinity may also increase with depth below the watertable. The areas with less than 1,500 mg/L TDS represent fresh or potable groundwater, 1,500-3,000 mg/L TDS – good stock-quality water, and 3,000-7,000 mg/L TDS – marginal stock-quality water.

Most groundwater analyses conducted in the Pilbara are from town water supplies operated by the Water Corporation and mining industry reports relating to mine and town water supplies (Table 2). Groundwater throughout the area is sodium chloride type, reflecting its derivation (through precipitation) from cyclic salts. Hardness is a water quality issue with the probable source of the calcium carbonate being from the calcrete and dolomitic formations. In most potable borefields, the water is treated by dosing with Calgon to ensure the calcium carbonate is maintained in solution.

High fluoride levels have been recorded in areas of tin mineralisation in the granitic country (Blockley 1980; Whincup 1976) and high levels of arsenic and sulphate occur in groundwater from areas of mineralisation in the greenstone sequences (Allen 1965). Cyanide has been recorded in groundwater close to gold ore treatment areas in the vicinity of Whim Creek (Allen 1965).

Nitrate levels above the recommended acceptable limits have been recorded in groundwater from the Cretaceous sediments of the Canning Basin (Leech 1979). Uranium levels above those recommended for drinking water (NHMRC 1996) can be located in the Yarraloola Conglomerate aquifer, where the Ashburton River enters the Onslow coastal plain. Groundwater from the Cretaceous sequence below the Onslow coastal plain may be accompanied by residual, biodegrading hydrocarbons and gas.

Groundwater resources

The most significant and exploitable groundwater resources of the Pilbara are contained in the alluvial aquifers on the coastal plains and calcrete aquifers along the major drainages. The greatest potential occurs where the valley-fill and calcrete aquifers can be exploited in conjunction with underlying fractured-rock aquifers, particularly the dolomitic units. Fractured-rock aquifers represent important local sources of groundwater. The Canning Basin contains the largest untapped groundwater resource in the region, however, its remoteness represents a major development constraint. The Wallal Sandstone aquifer is a substantial resource and has a larger storage than any aquifer in the Pilbara.

There are good prospects of locating large groundwater resources throughout the Pilbara. Skidmore (1996) estimated the groundwater resources throughout the Pilbara, in terms of storage and recharge of each aquifer type. Groundwater storage in the Pilbara was estimated at 126,000 x 10^6 m^3 with annual recharge contribution into the aquifers being about

Table 1. Summary of the Pilbara aquifers

Aquifer	Geological unit	Bore yield (m^3/day)	Aquifer potential*	Major occurrence
Unconsolidated sediment (surficial) aquifers				
Alluvial	Alluvium	<1,000	Major	Coastal plain
Valley fill	Colluvium	<1,500	Major	Inland drainage channels
	Eluvium	<1,500	Major	Inland drainage channels
Chemically deposited rock aquifers				
Calcrete	Calcrete	5,000	Major	Inland drainages
Pisolitic limonite	Robe Pisolite	1,500	Major	Inland drainages
Sedimentary rock aquifers				
Carnarvon Basin	Carnarvon Basin			
Trealla Limestone	Trealla Limestone	<1,000	Major	Onslow coastal plain
Yarraloola Conglomerate	Yarraloola Conglomerate	<1,000	Major	Onslow coastal plain
Lyons Group	Lyons Group	<1,000	Major	Onslow coastal plain
Canning Basin	Canning Basin			
Broome Sandstone	Broome Sandstone	<1,000	Major	Eolian sandplain
Wallal Sandstone	Wallal Sandstone	<2,000	Major	Eolian sandplain
Paterson Formation	Paterson Formation	<500	Inter	Oakover River valley
Fractured rock aquifers				
Fractured sedimentary	Hamersley Basin			
BIF	Brockman Iron Formation	<500	Inter	Hamersley Range
	Marra Mamba Iron Formation	<500	Inter	Hamersley Range
Dolomitic	Wittenoom Dolomite	2,000	Major	Hamersley Range
	Carawine Dolomite	2,000	Major	Fortescue River valley
Sandstone	Hardey Sandstone	<250	Inter	Hamersley Range
	Cliff Springs Formation	<250	Inter	Northern catchments
Igneous	Felsic Volcanics	<100	Minor	Chichester Range
Weathered rock	Mafic Volcanics	<100	Minor	Chichester Range
Intrusive rock	Granites	<100	Minor	Hamersley Range
	Greenstones	<100	Minor	Northern catchments

* Aquifer potential (based on individual bore yields) - Major >500 m^3/day; Intermediate 100-500 m^3/day; Minor <100 m^3/day

Table 2. Selected chemical analyses of groundwater – mg/L (except pH)

Locality	Millstream	Newman	Nullagine	Port Hedland	Tom Price	Yandicoogina
Wellfield (and aquifer)	Millstream (calcrete)	Orebody 18 (BIF -Brockman)	Gold Spec Mine (alluvium and granite)	De Grey (alluvium)	S. Fortescue (valley-fill and dolomite)	Dewatering (CID-Pisolitic limonite)
Depth (m)	15-25	152-157	19-33	40-70	83-196	72-93
SWL (m)	2-8	53-63	4-9	10-17	38-67	46-55
pH	7.3-8.0	7.9-8.3	6.5-7.1	7.5-7.9	7.4-7.7	7.2-8.6
TDS	80-1100	1,300-1,600	380-1,570	310-850	557-635	440-510
Hardness	345-524	n/a	36-275	100-310	256-301	250-270
Alkalinity	253-318	260-360	n/a	n/a	206-220	200-240
Ca	61-92	100-120	9-46	25-47	53-61	38-41
Mg	42-71	89-98	3-39	14-38	30-36	38-42
Na	54-110	210-330	16-165	65-240	38-54	58-64
K	8-18	16-17	1-2	2-5	9-11	5-6
HCO_3	n/a	320-440	65-260	165-335	n/a	238-580
Cl	104-263	380-570	18-195	53-270	118-145	76-83
SO_4	52-177	220-290	6-90	18-55	104-120	43-45
NO_3	1-2	0.1-3	1-5	1-4	15-25	2-3
SiO_2	23-59	n/a	45-80	47-61	16-21	47-51

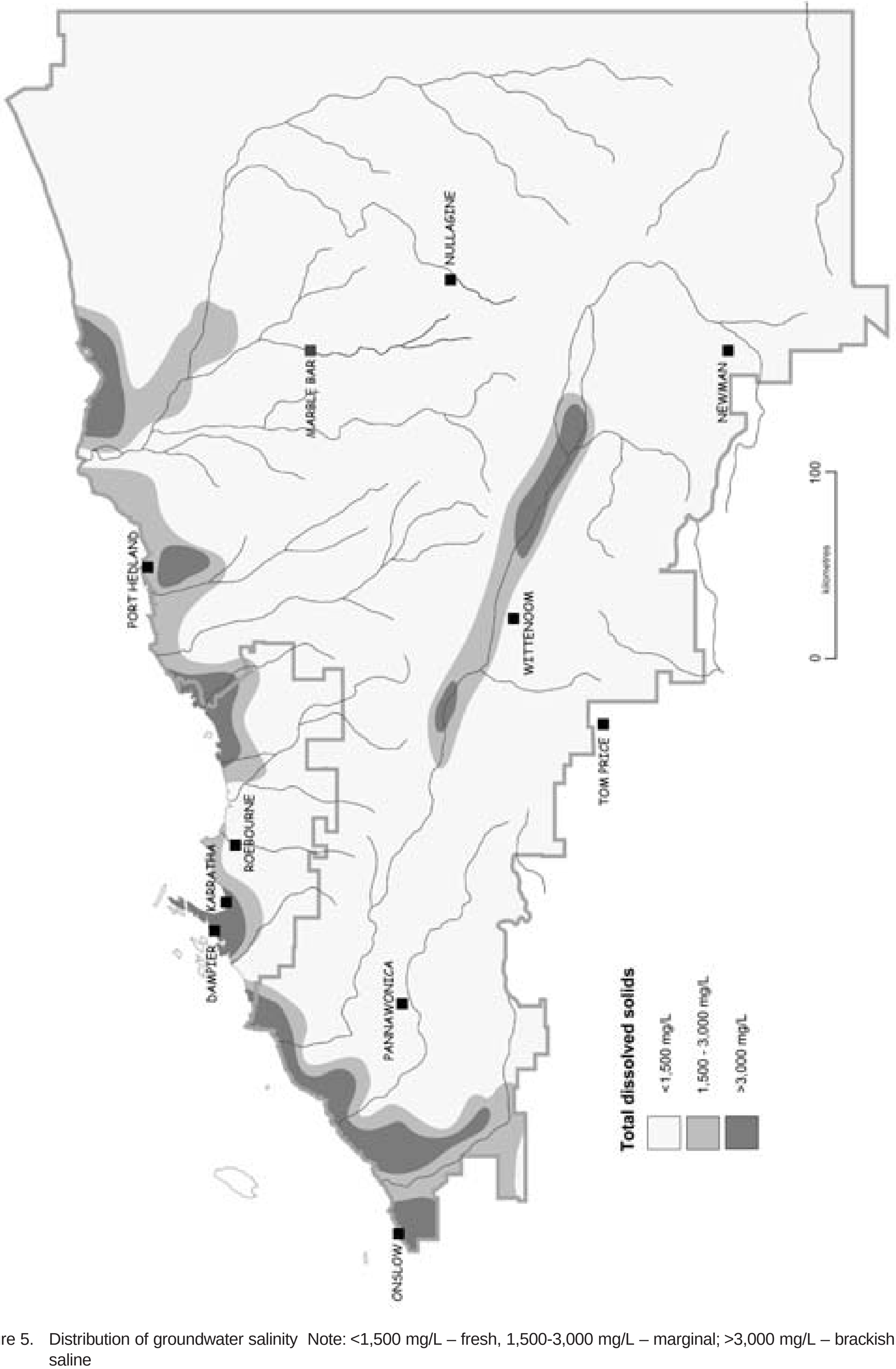

Figure 5. Distribution of groundwater salinity Note: <1,500 mg/L – fresh, 1,500-3,000 mg/L – marginal; >3,000 mg/L – brackish to saline

Table 3. Groundwater resources of the Pilbara

Aquifer type		Area (km^2)	Storage (x 10^6 m^3)	Recharge (x 10^6 m^3/yr)
Unconsolidated sediment (surficial)		36,000	56,000	397
Chemically deposited rock		6,000	12,800	>46
Sedimentary rock	Carnarvon Basin	7,000	21,900	unknown*
	Canning Basin	7,600	11,300	>63
Fractured rock	Sedimentary rocks	121,500	19,600	115
	Igneous rocks	75,900	4,600	42
Totals		254,000	126,000	>660

* Recharge occurs by leakage through overlying strata.

660 x 10^6 m^3/yr (Table 3). These groundwater resource estimates are based on data concentrated around populated centres and mines, although there are large unexplored areas. Figure 6 indicates the areas of greatest groundwater potential in the Pilbara taking quality and quantity aspects into consideration.

Groundwater utilisation

Consumptive water use in the Pilbara is largely dependent on the development and utilisation of groundwater resources. Groundwater usage falls into three main categories:

- Pastoral - pastoral stations, some of which are operated by mining companies, require water for livestock. Water is obtained from bores and permanent pools within ephemeral watercourses. The volume of water used for stock watering is negligible, when compared with abstraction for mining and town water supplies.
- Town - the town water supplies have been established and developed by the Water Corporation and mining companies.
- Mining - the main water usages are mineral processing, dust suppression and dewatering activities. An additional water supply is often required for the construction of road and rail infrastructure.

Pastoral industry

The pastoral industry is a minor groundwater user in the Pilbara. Shallow bores and hand-dug wells were initially constructed to meet the pastoral requirements for stock watering. Cattle and sheep stations are dependent on groundwater supplies and surface water features, such as pools or springs, for watering stock. It is difficult to determine the number of functioning bores and wells throughout the Pilbara with most abandoned or poorly maintained. Altogether there has probably been thousands of bores and wells constructed for pastoral purposes.

Most bores and wells tend to be concentrated in the low-lying areas of alluvium rather than the topographically higher, colluvial soils or areas of bedrock outcrop. In general, groundwater supplies are easily located, but many exploratory sites have been abandoned due to drilling problems or inadequate supplies.

Most bores and wells used by the pastoral industry are less than 30 m deep and are typically equipped with a windmill, which yields up to 10 m^3/day. Larger supplies in excess of 20 m^3/day are available from areas of calcrete and thick alluvium. Groundwater is generally fresh, although groundwater up to 7,000 mg/L TDS can be utilised for stock watering. Domestic supplies usually rely on rainwater tanks supplemented by potable groundwater, if available.

Town water supplies

Groundwater abstraction for town water supply purposes throughout the Pilbara is in excess of 20 million m^3/yr (Water and Rivers Commission 1996). The Water Corporation is the main water supplier, particularly for towns along the coast. Paraburdoo, Newman and Tom Price water supplies are owned and operated by mining companies. All schemes are wholly supplied from groundwater sources, except for Harding Dam in the West Pilbara Water Supply Scheme and Ophthalmia Dam at Newman.

The towns of Karratha, Dampier, Roebourne, Wickham, Point Samson and Cape Lambert are supplied from the West Pilbara Water Supply Scheme. There have been turbidity and quality problems at Harding Dam, hence, most water has been sourced from the Millstream calcrete aquifer. The safe yield for the calcrete at Millstream has been set at 10 million m^3/yr (4.9 million m^3 abstracted in 1997), in order to maintain and protect the sensitive spring ecosystem.

The Port Hedland town water supply is drawn from alluvial aquifers within the De Grey and Yule Rivers. In 1997, combined abstraction from the two borefields was 5.6 million m^3, with the safe yield estimated at 8.4 million m^3/yr. There are elevated levels of fluoride levels in groundwater from the De Grey borefield, which requires shandying and mixing of the two sources to produce a level of about 0.7 mg/L.

The mining towns of Tom Price and Newman have similar potable water requirements of about 2 million m^3/yr. The water supplies for the towns of Marble Bar, Nullagine, Onslow, Paraburdoo, Pannawonica and Wittenoom are generally from shallow alluvial aquifers. Annual abstractions from these borefields are generally less than 1 million m^3/yr.

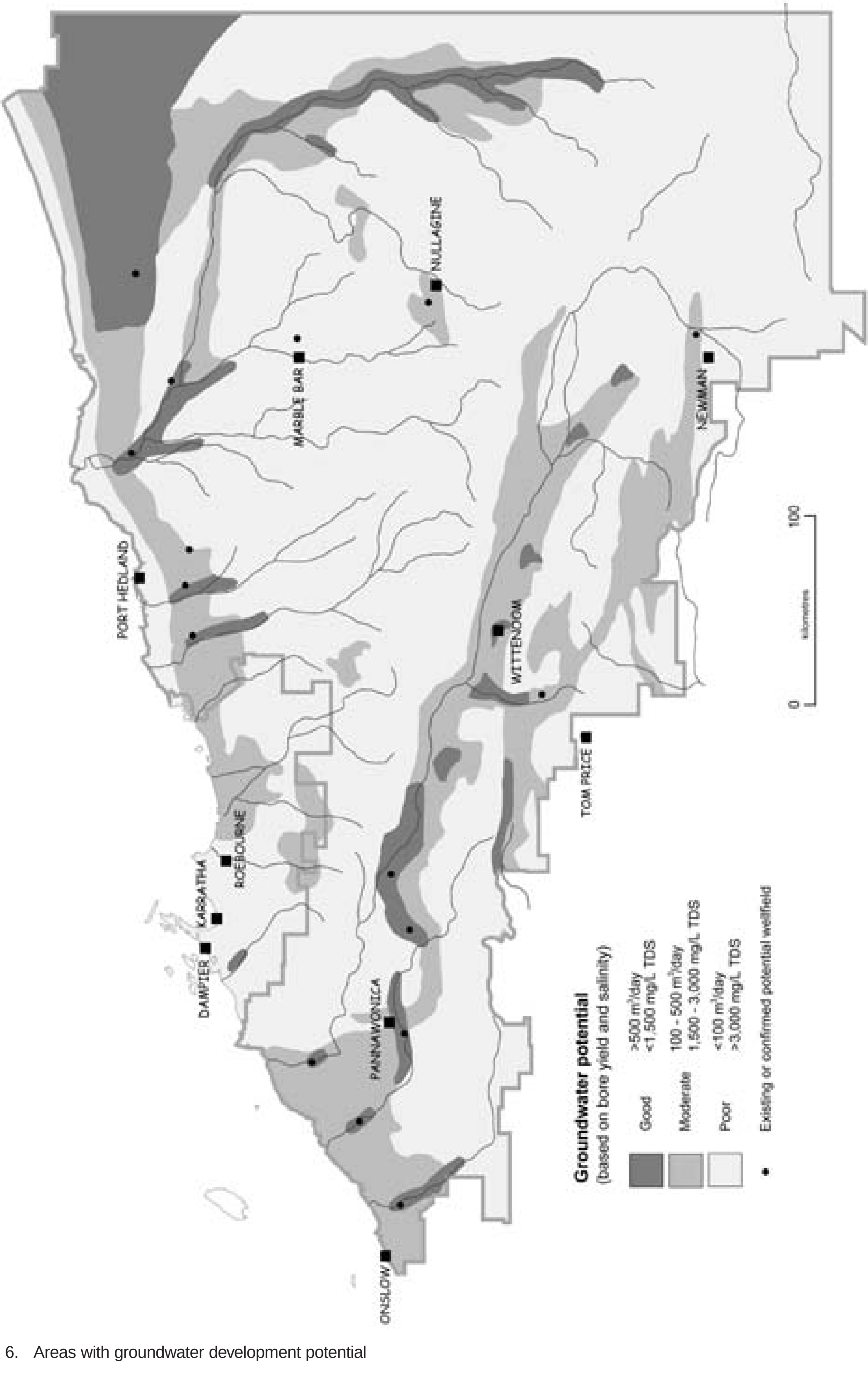

Figure 6. Areas with groundwater development potential

Mining industry

The mining industry is the major groundwater user in the Pilbara (Johnson and Wright 2001). In 1999, annual groundwater abstraction by the iron-ore industry was about 31 GL. Mining operations generally abstract about 2 GL/yr, which is used for mine dewatering, dust suppression, mineral processing and ore beneficiation. The BHP and HI operations at Yandicoogina abstract 5 GL/yr and 7 GL/yr respectively with the majority (96%) for mine dewatering and only a small portion (4%) for mineral processing and dust suppression. The surplus water from these dewatering activities is piped to a controlled discharge point located downstream of each operation.

Most borefields are established to provide potable and mining process water, with bores abstracting groundwater at the "safe-yield" to ensure long-term sustainability. Mine dewatering borefields are designed to lower the watertable in advance of mining to facilitate safe mining conditions. In order to achieve dewatering, pumping rates must exceed the groundwater throughflow resulting in localised storage depletion. In cases where dewatering exceeds the mine water demand, the discharge has to be responsibly disposed into local creeks. On completion of mining and cessation of dewatering, groundwater levels should recover to near pre-pumping levels.

Conclusions

The Pilbara region is semi-arid with a variable, unreliable rainfall and high evaporation rates. Hence, groundwater resources are the most readily obtainable and reliable source of water for the pastoral and mining industry. The pastoral industry is dependent on groundwater and surface water for watering of cattle and sheep.

The quality of groundwater is generally suitable for stock-watering purposes throughout the Pilbara. However, there are areas along the coast where brackish to saline groundwater occurs restricting development of pastoral water supplies. Domestic supplies on pastoral leases are usually met from the collection of rainwater, whilst town water supplies are positioned in alluvial and calcrete aquifers.

There are small supplies, less than 10 m^3/day, of variable salinity groundwater available throughout the region, but larger groundwater supplies are generally restricted to specific aquifer types, such as calcrete, thick alluvium and dolomitic formations. In addition, there are also large supplies of groundwater available from deeper sedimentary aquifers within the Carnarvon and Canning Basins.

The pastoral industry utilises a small percentage of groundwater held in storage, and there is considerable scope for further development of these groundwater resources. Due to the nature of the aquifers and their episodic recharge, they will however have to be carefully managed to ensure the quality and quantity of the groundwater resource is not compromised.

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Declared plants and animals

A. Longbottom

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 staff of the Department of Agriculture with offices located within the survey area at Karratha and Port Hedland.

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 control and containment. Specific categories for plants are as follows:

P1 Plants that should not be introduced.

P2 Plants that should be eradicated.

P3 Plant numbers or distribution or both should be reduced.

P4 Plants that should be prevented from spreading.

P5 Plants that should be treated only on public lands such as along roads or on reserves.

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

The number of declared plants in the survey area is limited. Those that are present have the potential to spread over large distances and cause problems with stock management and access to watering points.

All declared plants have been introduced by human activity mainly through escaped garden plants but also as plantings for shelter belts and stock feed especially along the coastal areas. They have been spread by wandering animals (native, domestic and feral), periodic flooding and vehicles.

Specific categories for animals are as follows:

A1 Animals that should not be introduced.

A2 Introduced animals that should be eradicated.

A3 Introduced animals that should not be kept.

A4 Animals that should only be introduced under conditions and restrictions.

A5 Animals that should be reduced in numbers and kept under restrictions.

A6 Animals that should only be kept under restrictions and conditions.

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

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

Declared plants

Calotropis (*Calotropis procera*) - P1, P2

This plant infests limited areas along the De Grey River system.

Ecology

Calotropis is a shrub or small tree growing up to four metres tall which originated from tropical Africa and Asia. The flowers are purple and white. The underside of the leaf is densely covered in white hairs. It is an escaped garden plant that has probably been transported as a contaminant of stock feed.

Significance and management

Calotropis reduces grazing and can be poisonous to stock and man. The milky sap can cause dermatitis. Dense thickets can be formed on alluvial flats along rivers, substantially reducing the grazing value of the country.

To control calotropis individual bushes may be pulled out, however, root suckering is likely to occur unless the top 20 cm of roots are removed. The recommended chemical treatment is to apply a mixture of Picloram® and Garlon®, such as Access® at 20 mL per litre of diesel in a knapsack sprayer. The chemical should be applied as a basal spray.

Chinee apple *(Ziziphus mauritiana)* - P1, P2

This plant has recently been declared and only one infestation is known to be present in the survey area.

Ecology

Chinee apple is a thorny spreading tree to 6 m high and 10 m in diameter, reproducing by seed. The stems are zigzag in form and produce either a thorn or leaf at each joint. The leaves are glossy green, covered with fine whitish to rusty colored hairs below and have toothed margins. It has small inconspicuous flowers and the fruit is pale yellow when mature. The fruit has succulent white flesh with a pleasant apple taste, surrounding a large stone. It has spreading deep roots.

Significance and management

This rapidly growing woody weed has the potential to form dense, thorny, impenetrable thickets which can reduce the carrying capacity, interfere with stock movement and limit access to water. Chinee apple can be controlled by using Garlon 600® mixed with diesel and either basal sprayed or applied to cut stumps.

Mesquite *(Prosopis spp.)* - P1 whole of state, P2 whole of state except Mardie station less 1 km buffer zone inside boundary, P4 Mardie station except for the 1 km buffer zone inside boundary

Mesquite infests extensive areas of Mardie station and is also found in coastal areas on Peedamulla and Yarraloola stations. Small infestations occur on Mundabullangana and Warambie stations and on the Roebourne Common.

Ecology

Mesquite develops as a densely branched shrub about one metre high and can also grow into a tree which can reach heights of 15 m or more. It grows well on a variety of soils including saline and highly alkaline areas, but makes the best growth on alluvial soils associated with watercourses. Seed production is variable and a proportion of hard seeds are produced that can remain dormant for many years. Seeds are transported through surface water movement as well as by animals and birds. Some varieties of mesquite can survive repeated cutting and defoliation for several years.

Significance and management

Mesquite trees were planted on many Pilbara stations in the 1920s for shade and ornamental purposes and also to provide nutritious pods for grazing. These plantings were initially spineless and showed little tendency to spread. However, within a few years most trees reverted to having spines and weedy tendencies.

Mesquite is an aggressive invader of rangeland. It forms dense thickets which shade out more useful forage plants, interfere with stock mustering and block access to watering places. When cattle eat large amounts of leaf and pods digestive problems frequently occur. Mesquite has sharp spines which injure animals and puncture vehicle tyres.

Four biological control insects have been released on mesquite in the Pilbara (mainly at Mardie station) to determine the potential for insects as an adjunct to other control methods. These consist of two seed borers (*Algarobius bottimeri* and *A. prosopis*), a leaf tying moth (*Evippe sp.*) and a sapsucker (*Prosopidopyslla flava*). The effect of these biological agents is yet to be assessed.

Physical removal of mesquite can be used as a control method, however, the preferred method is to basal spray using Garlon 600® at 20 mL per litre of diesel.

Spineless mesquite (Prosopis spp.) *was originally planted for shade and stock feed, however after several generations most trees reverted to spiny forms. Mesquite forms dense thickets competing with more useful forage plants, and has sharp spines up to 5 cm long. Biological control is currently being assessed.*

Parkinsonia *(Parkinsonia aculeata)* - P1, P2

Parkinsonia is present on the Robe River on Yarraloola and Mardie stations, on the Fortescue River from Millstream to Yalleen, on the Maitland River on Karratha station, on the Harding River on Mount Welcome station and the Roebourne Common. It is also found on the De Grey River from Warrawagine station through to the coast, and on Pardoo Creek on Pardoo station. There are also small infestations on Roy Hill and Panorama stations.

Ecology

Parkinsonia is a native of tropical America. It is a large, spiny shrub or small tree growing to 8 m that has bright yellow fragrant flowers. These are borne in loose bundles on long flower stalks. Later, large seed pods with marked constrictions between each seed develop. Many of the seeds are hard and will germinate some years later, in some cases after long immersion in water. The pods float and are spread by floods and surface water movement. Parkinsonia is suited to growing in moist conditions along river flats.

Significance and management

Parkinsonia can form dense thickets along watercourses. These become virtually impenetrable to stock. Grazing is limited by the sharp spines. Parkinsonia also competes with other vegetation, hampers mustering, restricts grazing and blocks access to water points at dams and along rivers.

Chemical control is the preferred method of control, using Garlon 600® at 20 mL per litre of diesel applied as a basal spray.

Parkinsonia (Parkinsonia aculeata) *is a native of tropical America. It is a large, spiny shrub or small tree growing to 8 m with bright yellow fragrant flowers. The hard seeds may lie dormant for many years. It occurs along some major river systems.*

Prickly pear *(Opuntia spp.)* - P1, P2

The name prickly pear is used to describe several similar species of the genus *Opuntia*, a member of the cactus family. All of these species are declared north of latitude 26˚S. Prickly pear was originally cultivated for its edible fruit and as an ornamental species.

Small infestations are found through out the survey area mainly around homesteads and rubbish tips and also along the Turner River.

Ecology

Prickly pear is a very drought resistant perennial plant. It reproduces from seeds and pieces of stem, which readily break off and can survive for long periods. The seeds of prickly pear are consumed and spread by native and domestic animals. Seeds germinate throughout the year and plants can mature in about two years.

Significance and management

Prickly pear has long, sharp spines that can injure livestock and prevent access to grazing. The plants also compete vigorously with more valuable pastures.

In the 1920s the moth *Cactoblastis* and the cochineal scale insect were introduced into Queensland as biological control agents. These were re-released in Western Australia in the late 1980s and have proved successful in keeping most infestations to a minimum level. Chemical control can be successful using Garlon 600® or Access® mixed with diesel at 20 mL per litre.

Declared animals - native species

Red kangaroo *(Macropus rufus)* and **Euro** *(Macropus robustus)* - A7

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

Significance

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 most impact on station management and pastoral production during droughts and studies (Wilson 1991a, b) confirm this. Kangaroos can adversely affect the regeneration of shrubs and perennial grasses (Gardiner 1986a, b; Wilson 1991b; Norbury and Norbury 1992, 1993; Norbury, Norbury and Hacker 1993), a fact which must be recognised when regeneration programs are planned. It is also important to recognise that in many arid rangeland areas such as the Pilbara, kangaroo numbers increased after European settlement as new watering points were created or habitats altered (Ealey 1967; Oliver 1986).

Status and management

Red kangaroos and euros are declared animals 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 Conservation and Land Management (McNamara and 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 are not endangered while at the same time preventing unacceptable damage to the rangelands. However, the major control on populations is seasonal conditions, rather than any Government strategy.

Dingo *(Canis familiaris dingo)* - A4, A5, A6

Dingoes occur throughout the survey area.

Significance

The impact of dingoes has been quite high in some areas of the Pilbara in the past and there is the potential for significant stock losses. This has been reduced somewhat with the reduction of sheep in the survey area although cattle losses still occur but mainly to calves either by direct attack or by mismothering due to pursuit of cattle by dingoes.

Status and management

Dingoes are classed as A4, A5 and A6, which means that introduction, keeping and control are subject to regulation. The main method of control is through trapping and poisoning. The Department of Agriculture coordinates an aerial baiting program on behalf of pastoralists using 1080 poison baits in spring, and contract doggers carry out ground control throughout the year.

In the past dingo (Canis familiaris dingo) *predation caused significant stock losses on pastoral properties carrying sheep. Dingoes also cause calf losses either by direct attack or by causing mismothering.*

Emu *(Dromaius novaehollandiae)* - A7

Emus are widely distributed throughout the survey area, but are found in higher densities along the coastal area.

Significance

Emus are not considered to be major forage competitors with livestock (Davies 1978). They are more of a nuisance with spreading weed seed (especially mesquite) and damage to fences.

Status and management

Emus are protected native birds, but are listed in category A7 so that control can be undertaken if they reach very high numbers which can occasionally occur after two or three good seasons.

Declared animals - introduced species

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

Wild dogs (feral domestic dogs and domestic dog x dingo crosses) occur throughout the survey area and especially in the vicinity of towns and settlements.

Significance

The impact of wild dogs is variable but can be quite high in some areas adjacent to towns or settlements. With many stations changing from sheep to cattle the potential for heavy losses has reduced significantly, however, losses of cattle (mainly calves) may occasionally be significant.

Status and management

Wild dogs, as with dingoes, are classed as A4, A5 and A6. The periodic 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*. Control by pastoralists and contract doggers is through trapping, shooting and poisoning including aerial poison baiting coordinated by the Department of Agriculture.

Feral goat *(Capra hircus)* - A2, A5, A6

Feral goats are limited to very small infestations on Peedamulla station in the west and have been reported on Weelarrana station in the east. There have been occasional incursions into neighboring stations from these populations but no general spread through the survey area.

Significance

The impact of these populations is insignificant due to the low numbers. The impact that feral goats could cause if numbers were to increase markedly could be significant with direct competition for grazing and increased stocking rates causing erosion and land degradation.

Status and management

Pastoralists and Department of Agriculture staff carry out control by mustering and aerial shooting as required.

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

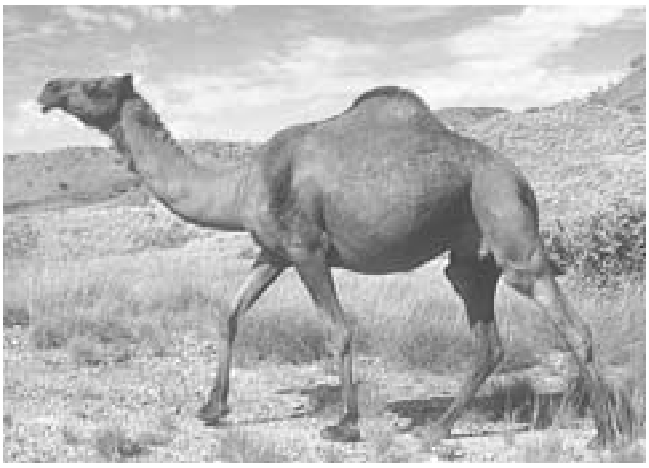
Camels occur in small numbers throughout much of the survey area. They are most common on pastoral properties and unallocated Crown land in the far east of the survey area.

Significance

Camels cause damage to fences and watering points and when in large numbers compete with stock for food. The only large numbers of camels likely to be encountered in the survey area are on pastoral leases that border the unallocated Crown land and on the unallocated Crown land itself to the east.

Status and management

Feral camels are declared animals although permission has been granted in a small area of Crown land, east of Weelarrana station, for the catching of camels. Control is carried out where numbers are large by aerial shooting operations organized by Department of Agriculture staff.



Camels (Camelus dromedarius) *occur in small numbers throughout the far east of the survey area and may cause damage to infrastructure or compete with livestock for food.*

Feral donkey *(Equus asinus)* - A4, A5, A6

Feral donkeys are found on most stations throughout the survey area. Their numbers vary from station to station with the highest numbers being in the lower east Pilbara.

Significance

Donkeys were used as pack and draught animals in the development of the Pilbara and Kimberley and late in the 19th century large donkey trains regularly carried goods from Carnarvon to the Kimberley. As the donkey was superseded by the motor vehicle many were released to roam freely and quickly reverted to the feral state.

Feral donkeys compete directly with domestic stock for forage and water. Where numbers are large trampling and heavy grazing can cause vegetation degradation and soil erosion. Donkeys may behave aggressively towards domestic stock, sometimes denying them access to water.

Status and management

Shooting is the most practical method of control, and programs are undertaken regularly by the Department of Agriculture and pastoralists.

Feral horse *(Equus caballus)* - A5

Low numbers of feral horses are found on nearly every station in the survey area.

Significance

Feral horses are direct competitors for food and water with domestic stock. The few remaining leases that use stock horses have problems retrieving lost working horses once they have joined up with feral populations.

Status and management

Shooting is the most effective method of control although a market does exist for some horses once they have been transported to South Australia.

Feral pig *(Sus scrofa)* - A4, A5, A6

Feral pigs are found on stations along the De Grey River from Warrawagine to the coast.

Significance

Feral pigs can cause extensive damage to pastures and also increase soil erosion. Should an exotic disease such as foot and mouth become established in the feral pig population of Australia, it would be extremely difficult and costly to eliminate. Effects on the meat export trade would be significant.

Status and management

Feral pigs are classified A4, A5 and A6, with regulations pertaining to their introduction keeping and control. Shooting and trapping are the best methods of control. No organized programs for pig control are undertaken within the survey area but pigs are shot opportunistically by pastoralist and officers of the Department Agriculture.

Fox *(Vulpes vulpes)* - A4, A5, A6

Foxes are found on many pastoral leases where wild dog control programs have reduced the number of dogs.

Significance

Foxes pose very little threat to the pastoral industry in the Pilbara. Occasional lamb losses have been reported in the past but there are now very few properties in the survey area running sheep. Foxes pose a threat to native fauna (Kinnear, Onus and Bromilow 1988) and may have caused the extinction of some species (Christensen 1980). Foxes could be an important carrier of rabies if the disease was introduced into Australia.

Status and management

The fox is a declared animal, however, no major coordinated control work is conducted. Some localised control is undertaken on individual pastoral leases, however, most control is achieved as a result of aerial baiting for dingoes and wild dogs.

Feral cat *(Felis catus)*

Feral cats are not declared animals but are common throughout the survey area.

Significance

Feral cats pose no economic threat to the pastoral industry. They do, however, have adverse effects on populations of native animals (Fitzgerald and Veitch 1985; Burrows and Christensen 1994).

Status and management

No management programs exist for feral cats that are established throughout pastoral and unoccupied parts of the rangelands. They appear destined to remain an unfortunate component of the Australian fauna. Pastoralists are known to control feral cats in an effort to reduce numbers. Desexing of station cats will minimise the impact of domestic cats turning feral.

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The Survey

Methodology (A.M.E. Van Vreeswyk[1])

Geomorphology (A.L. Payne[1])

Soils (P. Hennig[1])

Vegetation (A.M.E. Van Vreeswyk[1])

Site type ecology (A.M.E. Van Vreeswyk[1] and A.L. Payne[1])

Land systems (A.L. Payne[1] and K.A. Leighton[2])

Resource condition (A.M.E. Van Vreeswyk[1])

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[2] Geographic Services Branch, Department of Land Information, Western Australia

Methodology

A.M.E. Van Vreeswyk

The rangeland resource survey of the Pilbara area was jointly undertaken by the Department of Agriculture (DAWA) and the Department of Land Administration (DOLA), now the Department of Land Information (DLI). Rangeland surveys in Western Australia have been conducted since the 1950s when they were commenced by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). In 1969 the Pastoral Appraisement Board (now Pastoral Lands Board) commissioned the first regional survey (Wilcox and McKinnon 1972) to be conducted jointly by the Department of Lands and Surveys (now DLI) and the Western Australian Department of Agriculture. Since then a further nine surveys have been completed (Payne *et al*. 1979, Payne, Curry and Spencer 1987, Mitchell, McCarthy and Hacker 1988, Payne, Mitchell and Holman 1988, Payne and Tille 1992, Curry *et al.* 1994, Pringle, Van Vreeswyk and Gilligan 1994, Payne *et al.* 1998 and Cotching unpublished). The regional survey described here is the eleventh in the rangelands of Western Australia.

The land system approach to mapping different country types has been used in all of the previous regional rangeland surveys in Western Australia. Land systems were 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. Once identified, the assumption is made that similar land systems (patterns) represent similar types of country (landscapes). The land systems are then ground-truthed during field work.

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

The minimum sized piece of land which can be mapped at these scales is approximately one square kilometre in extent. Narrower pieces, for example 500 m wide, can be mapped provided they are at least 1.5 km long. This allows linear features such as rivers and ranges and long, narrow pieces of severely degraded and eroded land to be mapped.

Reconnaissance field work

Black and white aerial photographs at a scale of 1:50,000 and taken between 1993 and 1995 were used to identify land systems and facilitate navigation throughout the survey.

Topographic features and infrastructure such as roads, fences and watering points, were identified and marked on the aerial photographs. Members of the survey team then mapped provisional land system boundaries onto the aerial photos, using stereoscopes. To help define the land system boundaries many sources of information on the biophysical resources of the survey area were reviewed, including Beard's vegetation survey of the Pilbara (1975), the 1:250,000 geological map series produced by Geological Survey of Western Australia and the Atlas of Australian Soils (Northcote *et al.* 1968).

Over half of the land systems used in the survey had previously been described in adjoining survey areas, with about one third from the Ashburton River catchment survey (Payne, Mitchell and Holman 1988), and the remainder from the Roebourne Plains survey (Payne and Tille 1992), Gascoyne River catchment survey (Wilcox and McKinnon 1972), Ophthalmia dam survey (Payne and Mitchell 1992) and Broome coastal survey (Cotching unpublished). Country types which were not familiar to the survey team members were identified for more intensive sampling during the reconnaissance field work.

A botanical trip to collect and become familiar with the plant species was done in March/April 1995. This followed Cyclone Bobby which provided an opportunity to collect many annual plants, as well as perennial plants in flower. After the initial photo interpretation the photos were laid out and traverse routes were planned for reconnaissance trips. In 1995 the survey team undertook two trips each lasting two weeks. The first in August-September covered the southern part of the survey area and the second, in October-November, covered the northern part. Because of the large area to be covered in a relatively short time, the route mainly stayed on roads and major tracks, and the team moved through quickly, camping in a different place each night. As well as sampling new land systems, the work concentrated on developing techniques for the main field work. Detailed descriptions of the soil and vegetation were made at 108 inventory sites during the reconnaissance trips.

An assessor recorded the land system, land unit and site type at kilometre intervals along the traverse. This allowed descriptions of land systems to be built up, including the proportion of each land unit within a land system, and the variation of site types within each land unit. Severely degraded and eroded areas 40 ha or more in extent were mapped onto the aerial photographs and the location of country in 'near pristine' condition (potential 'reference' areas) was recorded.

Plant species which could not be identified were collected and their locations recorded. The specimens were identified by Andrew Mitchell, with many confirmed by botanists throughout Australia. A field herbarium of identified specimens was prepared. This field herbarium was updated throughout the survey. A list of all plant species recorded in the survey area, and their collection numbers, can be found in Appendix 1.

After the reconnaissance trips, during the summer of 1995-96, the survey team had an opportunity to refine the methodology and prepare tentative land system and site type descriptions, and to fully plan the main trips.

1,149 different plant species (of which 41 were priority species) were collected during the course of the survey.

Main field work

Between May 1996 and August 1997 eight trips lasting three weeks each were made to the survey area. A further two week trip was made in June 1999. Two survey teams worked simultaneously in the field. Each team comprised one or two rangeland advisers and a soil surveyor from the Department of Agriculture, and a navigator from the Department of Land Administration. The teams were supported by a technical assistant from DOLA. The staff involved in the fieldwork were:

Rangeland advisers	A.L. Payne, A.M.E. Van Vreeswyk, A.A. Mitchell
Navigators	K.A. Leighton, P.T. Godden, A.F. MacDonagh
Soil surveyor	P. Hennig
Technical assistant	R. Wetterings

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 two and four days was spent on each station, 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 it was surveying their station.

During field work the navigator checked and updated the position of infrastructure which had been transposed onto the aerial photos from existing 1:100,000 scale topographic maps, station plans and geological maps. Names of wells and bores were checked with the pastoralist, and new watering points, tracks and fences were plotted on the 1:100,000 topographic maps and their geographical position stored using a Global Positioning System (GPS) navigation unit. This ensured that the land resource information could be provided on an accurate base map.

Verification of land system boundaries and station infrastructure with a GPS unit and aerial photography during traversing.

Traverses

The navigator followed the predetermined traverse on the aerial photos, and in this way the land system boundaries could be verified and amended where necessary by the assessor. In addition to recording the land system, land unit and site type at kilometre intervals along the traverse, as was done on the reconnaissance trips, an assessment of range condition at each of these points was made, together with assessments of other factors, such as evidence of recent fire and of old burns, the level of ecological modification and the abundance of exotic species and increaser species. The range condition was recorded as a rating of the vegetation condition (see Table 1) and the extent and type of accelerated erosion

Table 1. Criteria for assessment of vegetation condition

Rating	Condition indicators
1	**Excellent or very good** For the land unit-vegetation type (site type), the site's cover and composition of shrubs, perennial herbs and grasses is near optimal, free of obvious reductions in palatable species or increases in unpalatable species, or the site type 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 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 a general loss of perennials or is increased by 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.

Table 2. Criteria for assessment of accelerated erosion

Estimate of area affected by erosion

Rating	Severity
0	No accelerated erosion present
1	Slight erosion (<10% of site affected)
2	Minor erosion (10-25% of site affected)
3	Moderate erosion (25-50% of site affected)
4	Severe erosion (50-75% of site affected)
5	Extreme erosion (75-100% of site affected)

Type of erosion present (dominant type recorded)

Rating	Erosion characteristics present
0	No erosion
A	Microterracing/sheeting
B	Scalding/capping
C	Pedestalling
D	Rilling/guttering
E	Guttering/gullying
F	Accelerated accretion of soil material

(see Table 2) 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 vegetation condition ratings are 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 having an understanding of the 'natural' range in such attributes as species composition, density and cover, and likely changes in these attributes that occur as a result of (unnatural) disturbance. If the site is judged to be in the 'natural' range it is rated as being in very good condition. If there have been induced changes in the 'natural' range, the site is rated as good, fair, poor or very poor, depending on the extent of the changes. Pastoralism is by far the most extensive land use in the survey area, and the changes seen are mostly due to the impact of grazing animals, including introduced stock, feral animals and native herbivores. However, changes due to other causes such as fire, mining, tourism and infrastructure are also commonly encountered.

If an assessment point occurred on an area undergoing mining or exploration activities, this was recorded, but the site was not assessed for range condition. If an assessment point fell within 100 m of a watering point, or on a major road or within homestead or shearing shed grounds the point was not assessed for range condition.

Areas which had been interpreted as being severely degraded and eroded on the aerial photographs were visited to verify that they were degraded, and to ensure that their extent was accurately mapped.

Three hundred traverse routes, with an average length of about 43 km, were completed in the survey area. These are shown in Figure 1. Some 12,827 traverse points, 12,445 of which had a range condition assessment, were recorded in the survey area. The geographical locations of the traverse points were stored using a GPS navigation unit.

Inventory sites

Inventory sites were pre-selected during traverse planning. They were selected to ensure that each major land unit within each land system was adequately sampled and could be described, and to help with interpreting the aerial photo patterns. Occasionally, when a different land unit/vegetation/soil association was encountered *en route*, additional sites were sampled.

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

At inventory sites detailed information on the landform, vegetation and soil was recorded. The attributes were recorded in code form on a standard record sheet based on those used by Curry *et al.* (1994) in the Murchison regional survey. The attributes recorded at inventory sites were:

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

Physical environment
- slope
- unit relief
- geology (according to 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
- vegetation condition rating (Table 1)
- type and intensity of accelerated erosion features (Table 3)
- extent and type of surface crusting
- evidence of fire.

Vegetation
- site type
- total foliar cover class of the tree and shrub strata (Table 4)
- dominant species in each stratum
- relative dominance (rank) of each stratum
- foliar cover class of the tree stratum, each shrub stratum and the hummock grass stratum
- basal cover class for perennial tussock grasses
- height class of tree stratum
- height class of tall shrub stratum
- list of perennial plant species
- list of annual plant species.

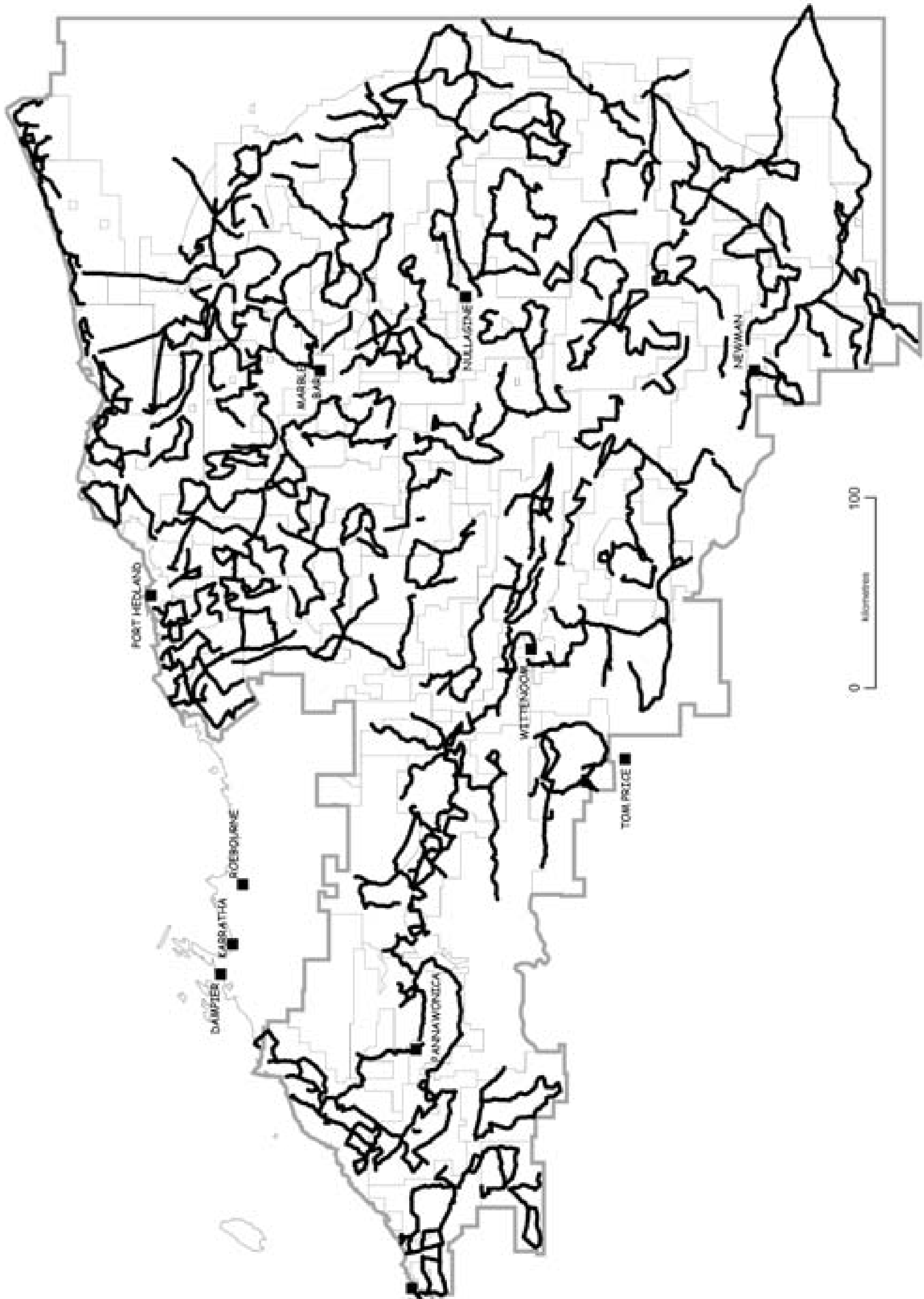


Figure 1. Traverse routes in the survey area

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 each soil horizon; horizon designation, depth, texture and texture group, moist colour (according to Munsell Soil Color Charts 1954), 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, electrical conductivity and field pH.

Notes and landscape sketches were also made on an *ad hoc* basis. At each site a standardised method was used to take photographs (slide and colour print) from the roof of the survey vehicle, with a board identifying the survey area and the site number placed approximately 10 m from the vehicle.

The assessors generally spent between 30 and 60 minutes at a site to complete this description. The geographical location of each site was stored on a GPS so it could be mapped at a later date.

During the fieldwork 763 inventory sites were sampled. Figure 2 shows their location throughout the survey area.

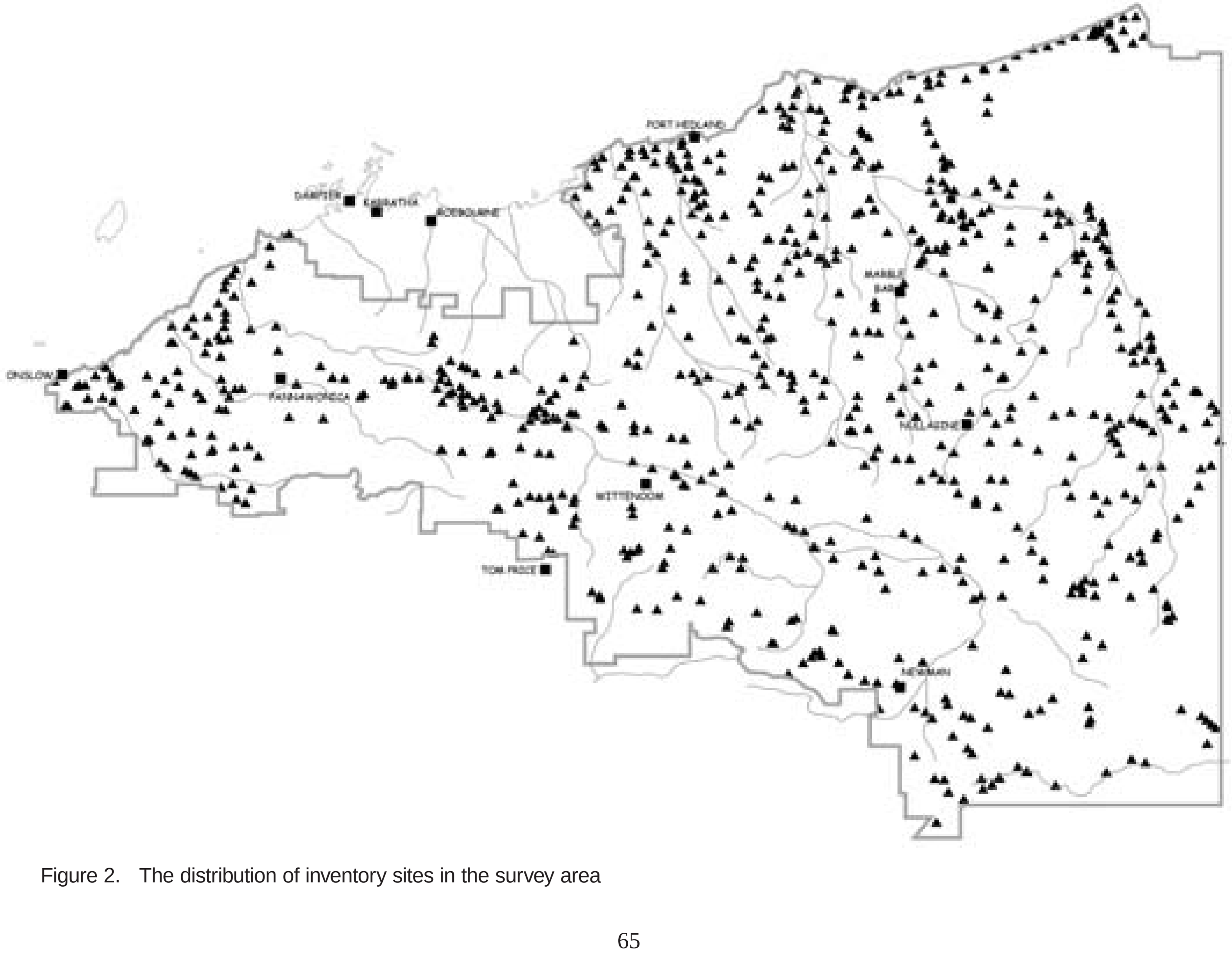


Figure 2. The distribution of inventory sites in the survey area

Table 3. Criteria for assessment of accelerated erosion at sites

Type – intensity combination	Rating
No accelerated erosion present	00
Slight erosion (<10% of site affected)	
Slight accumulation of wind-blown soil around plant bases and other obstacles and/or	11
Removal of finer soil particles evident but soil crust is largely intact and/or	12
Occasional rills (<300 mm deep evident) and/or	13
A few scalds present, usually <2 m in diameter	14
Minor erosion (10-25% of site affected)	
Accumulation of soil around plant bases with plant mounds noticeably enlarged and/or	21
Evidence of pedestalling but soil loss minor and plant bases not greatly elevated and/or	22
Breaking of surface crust with small erosion faces and some redistribution of soil and/or	23
Rilling evident but no gully development and/or	24
Scalding evident but scalds relatively small and discontinuous	25
Moderate erosion (25-50% of site affected)	
Wind piling around plant bases and other obstacles is common but no plants completely covered and/or	31
Pedestalling apparent with plant bases distinctly raised and with obvious soil loss and/or	32
Rilling common or gullying present on parts of site and/or	33
Surface sheeting with erosion faces (and/or microterracing) and active redistribution of soil and/or	34
Wind scalds common	35
Severe erosion (50-75% of site affected)	
Extreme hummocking around plants and other obstacles; some plants completely covered and/or	41
Severe pedestalling with plant bases greatly elevated and major soil loss and/or	42
Widespread rilling or major gullying and/or	43
Scalding extensive, smaller scalds have coalesced to form large, more or less continuous scalded areas and/or	44
Surface sheeting with extensive exposure of subsoil or parent material ; erosion faces (and/or microterracing) and active redistribution of soil and/or	45
Much of surface generally unstable with ripple mark formation	46
Extreme erosion (75-100% of site affected)	
General surface movement, total surface area bare with formation of shifting dunes and/or	51
Surface sheeting and/or scalding complete with exposure of subsoil or parent material and/or	52
Extensive gullying	53

Table 4. Foliar cover classes for tree and shrub strata (from Curry, Payne and 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

Condition sites

Condition site sampling was first implemented in the rangeland survey of the Murchison River catchment (Curry *et al.* 1994). It was designed as a quantitative approach to investigating various site attributes which could be used as key variables of grazing impact and to characterise the full pattern of condition states within major site types. It also enables the most powerful indicators of soil and vegetation status to be determined. These indicators would be of value in one-off assessments, such as for land and conservation status, and in evaluating ecosystem change (e.g. at monitoring sites). The indicators also provide a means of quantitatively calibrating subjective traverse assessments.

The survey team undertook intensive condition sampling on six important site types which would be encountered during the survey. The site types were selected to determine how sensitive they were to grazing impact. The site types were:

- alluvial plain tussock grass grassland (APTG)
- alluvial plain Roebourne Plains grassland (ARPG)
- basaltic upland tussock grassland (BUTG)
- grove mulga woodland/shrubland (GMUW)
- grove mulga grassy woodland/shrubland (GMGW)
- plain soft spinifex grassland (PSSG)

Recording species diversity within a mulga (Acacia aneura) grove.

The following attributes were recorded in code form at each site on a standard record sheet based on those used by Curry *et al.* (1994) in the Murchison regional survey:

General
- site number
- land system
- land unit
- pastoral station
- traverse number
- site technique(s)
- 1:250,000 mapsheet name
- aerial photograph year, run and number
- date
- paddock and quadrant
- area sampled
- name of the nearest watering point
- distance from the nearest watering point
- salinity of the nearest watering point.

Physical environment
- vegetation condition rating (Table 1)
- type and intensity of accelerated erosion features (Table 3)
- extent and type of surface crusting
- evidence of fire

Vegetation
- site type
- dominant species in each stratum
- relative dominance (rank) of each stratum
- total foliar cover class of the tree and shrub strata (Table 4)
- foliar cover class of the hummock grass stratum
- basal cover class of the perennial tussock grasses
- density of annuals
- transect area (m^2)
- quadrat frequency
- quadrat size
- number of points on soil transect
- condition of soil transect points
- month and year of last fire
- identification of annual plants
- growth form of each annual
- abundance of each annual
- identification of perennial plants
- growth form of perennials
- density of shrubs and trees
- frequency of perennial grasses
- indicator value of each perennial species (Table 5)
- level of recent grazing of each perennial species
- population structure of each perennial species
- vigour of each perennial species

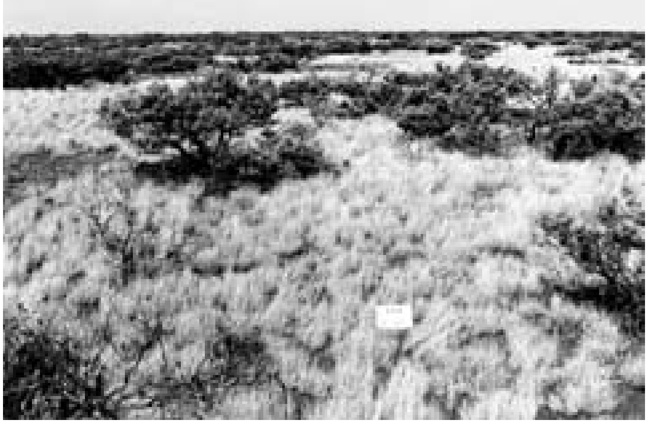
Table 5. Species indicator values

Decreaser
Highly palatable species whose cover and density decline under excessive grazing pressure.

Intermediate
Moderately palatable species which, under grazing, initially increase relative to desirable species or increase in absolute terms as they utilise niches vacated by (more palatable) decreasers. Intermediate species may dominate the stand. They decline under extreme grazing pressure, and are common in areas regenerating from severe degradation.

Increaser
Generally unpalatable species which increase in number and cover as decreaser species decline under excessive grazing. Also common in disturbed (e.g. fire) areas.

No indicator value
Species which are generally not grazed and hence not affected by grazing pressure except in extreme situations.



Plant species frequency and density were recorded at sites to assess the condition of different vegetation types.

Two sampling techniques were used to provide a density of each perennial plant species, depending on the type of vegetation being sampled. At mulga groves, perennial shrub species were counted within a measured area (usually along a 100 m by 2 m wide (200 m^2) transect) while the frequency of perennial grasses was assessed using fifty 0.5 m^2 quadrats. For grass communities the frequency of perennial grass and shrub species was assessed using fifty 0.5 m^2 quadrats.

Notes and landscape sketches were made on an *ad hoc* basis and colour print and slide photographs were taken at each site using the method standardised for inventory sites. The assessors generally spent between 40 and 60 minutes at each of the 131 sites to complete this description and measurement. The geographical location of each site was stored on a GPS navigation unit so it could be mapped at a later date. Figure 3 shows their location throughout the survey area.

Water point sampling

As a means of maximising the effectiveness of the survey team an agreement was made with the Water and Rivers Commission, Hydrology Division (now the Department of Environment) to gather information on all artificial water points located adjacent to traverse routes. The information recorded onto their proforma record sheets included: water point name, GPS coordinates and map sheet reference, well or bore, depth to water, field salinity and field pH. Also noted was whether the watering point was operational and its position within the landscape.

Data from 950 water points were returned to the agency and entered into their state-wide Water Information (WIN) database and either validated against existing records or added as new records. The data are available to pastoralists for their use but should be used as a guide only as pH, salinity and water depth can change with the seasons. Figure 2 in the Geology and hydogeology chapter shows the location of about 6,000 water points within the survey area.

Analysis of data

Traverse records

Traverse assessments, with their land unit and site type, were entered into a database. As the assessment points had been recorded using a GPS, the points could be referenced onto the land system resource maps. In this way the pastoral lease, paddock name and land system in which each point lay could be verified with the lease, paddock and land system identified during traversing and amended as 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 site 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 site types in the survey area. Land system area and condition statements for individual pastoral leases in the survey area have been published separately (Van Vreeswyk, Payne and Leighton 2004).

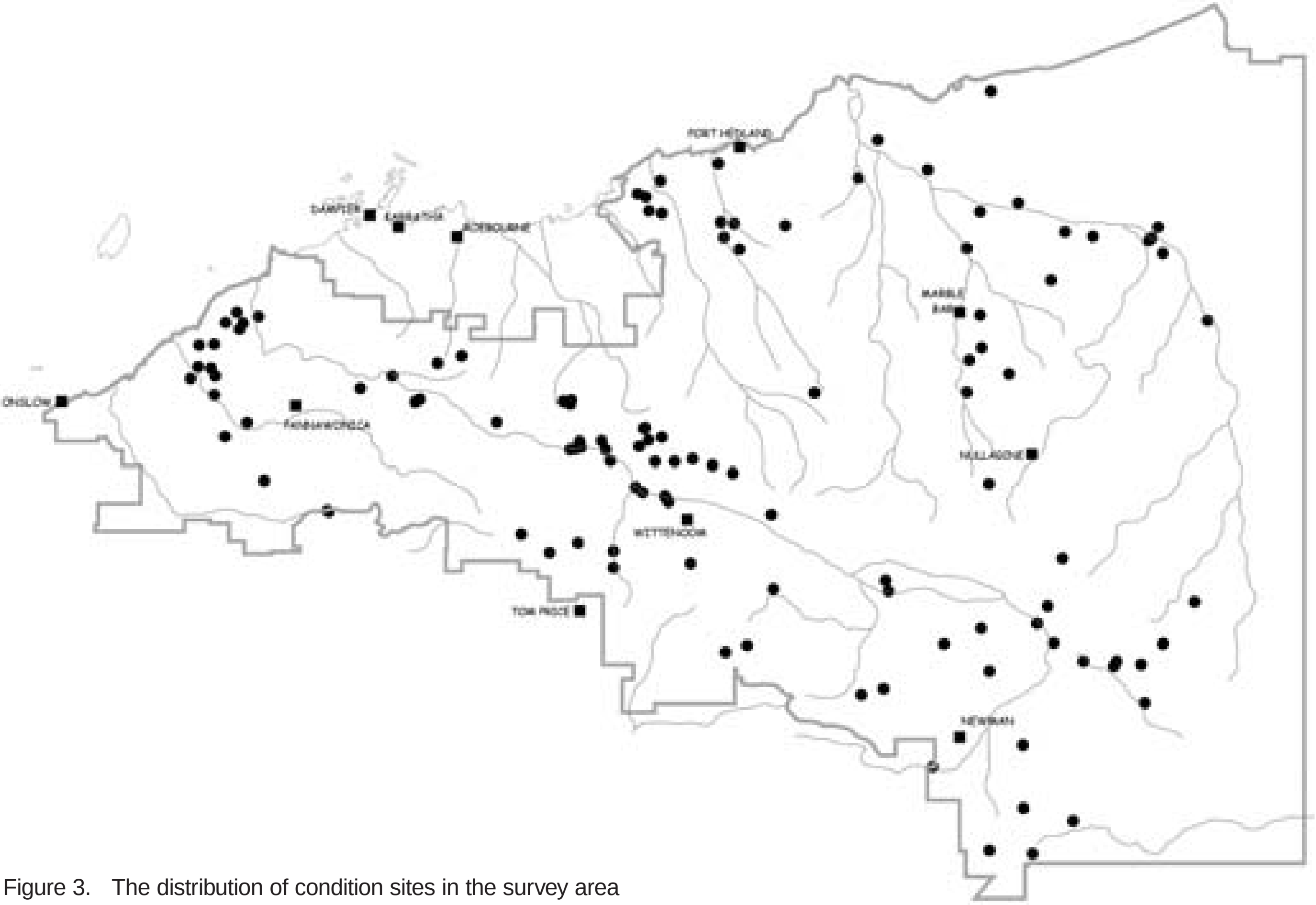


Figure 3. The distribution of condition sites in the survey area

Inventory site data

The inventory site data were sorted and analysed using computer software packages. The data were used to build detailed descriptions of land systems, land units, soil and vegetation. These are presented in the main chapters of this report. The data were then linked to the resource maps, allowing spatial interrogation.

Condition site data

The condition site data were sorted and analysed using computer software packages. The data were used to provide quantitative information on the impacts from grazing on six selected site types. The results of the condition site analysis can be found in the Site type ecology chapter.

Map production

The land systems were finalised using the knowledge gained during field work, and the land system boundaries were reinterpreted on the aerial photographs. The aerial photos were scanned and the land system boundaries on-screen digitised. Verification plots of the digitised boundaries were produced at 1:50,000 scale for checking against the original land system boundaries on the aerial photos.

Topographical and cultural information covering the survey area was loaded onto the computer system and updated from information collected during 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 larger scale. Special purpose maps can be produced displaying any of the data requested by the client as all information has been captured in a multi-layered and geographically referenced digital format. Not all of the data collected during the field work of this survey is presented in this report or on the accompanying map. More detailed information and maps are available on request from the Department of Agriculture.

In addition to the land system map accompanying this report, station plans at a scale of 1:100,000 have been produced for each of the pastoral leases within the survey area. These are available to leaseholders as full colour maps from the Department of Agriculture.

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Geomorphology

A.L. Payne

Introduction

The geomorphology of the survey area is briefly 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 briefly discussed in terms of Cenozoic alteration of the morphotectonic setting and the interactions between land use and landscape processes are considered.

The morphotectonic setting

In geological terms the survey area falls very largely within the Pilbara Craton with granite-greenstone terrane in its northern third and volcano-sedimentary successions (Hamersley Basin) in the remainder (Trendal 1990). Small southern and eastern parts of the survey area fall within the Bangemall, Bresnahan and Savory Proterozoic sedimentary basins. Minor parts of the area fall within the Carnarvon and Canning Phanerozic sedimentary basins.

Jutson (1950) considered that the physiography of the area resulted from the incomplete dissection of an ancient peneplain, part of the 'Great Plateaux of Western Australia'. North of the Fortescue River Jutson named this old land surface the 'Nullagine Plateau' but it is now commonly referred to as the 'Hamersley Surface' and is preserved as extensive plateaux and dissected plateaux with prominent erosion scarps.

Physiographically most of the survey area falls within the Pilbara Province of Jennings and Mabbutt (1986). Smaller areas in the north-east and south-east fall within the Sandland Province and a very small area in the far west falls within the Western Coastlands Province (Figure 1). Within the Pilbara Province the survey area occupies all or parts of the following component sections of the Province - the De Grey Lowlands, Fortescue Valley, Nullagine Hills, Chichester Range, Hamersley Plateau and very small parts of the Augustus Ranges and Rudall Tablelands. These sections and those sections occupied by the survey area in the Sandland and Western Coastlands Provinces are described in Table 1.

A major drainage divide (the Chichester Ranges) traverses the southern part of the survey area in a generally west north-west direction. South of the divide the Fortescue River passes through almost the full width of the survey area in a westerly direction to the Indian Ocean. The present valley of the Fortescue River contains the most prominent alluvial valley fill deposits in the State (Hocking and Cobain 1990) and constitutes the Fortescue Valley physiographic section. North of the drainage divide a number of substantial, more or less parallel rivers such as the Sherlock, Yule, Turner, Shaw and De Grey flow generally north north-westerly to the Indian Ocean (Figure 2). All rivers in the survey area are seasonally intermittent.

The regional geology of the northern half of the survey area is characterised by the best exposed and oldest granite-greenstone terrane in Australia (Griffin 1990), occurring in broad expanses of granitoid rocks interspersed with arcuate and linear belts of greenstone formations. Granitoid rocks constitute about 60% of the total and generally occupy anticlinal culminations and domes, up to 100 km across and separated by greenstones in synclinal structures. The granite-greenstone terrane formed between 3,500 and 2,800 million years ago as a result of probably four major phases of complex deformation and associated metamorphism (Griffin 1990).

The regional geology of southern parts of the survey area is characterised by sequences of volcano-sedimentary rocks of the Mt Bruce Supergroup which go to make up the

Table 1. Brief description of the physiographic regions in the survey area (Jennings and Mabbutt 1986)

Province	Sections
Pilbara	De Grey Lowlands – flood plains and deltaic plains; granitic and limestone lowlands; scattered ranges of metamorphic rocks in the north. Nullagine Hills – dissected flat topped hills of granites and metamorphic rocks with partial lateritic cappings; narrow estuarine plain and islands. Chichester Range – narrow range of dipping quartzite and sandstone. Fortescue Valley – mainly alluvial lowlands, possibly a graben. Hamersley Plateau – dissected bold plateaux and ranges of flat lying or moderately folded sandstone and quartzite. *Augustus Ranges – parallel ranges and dissected plateaux with intervening sandy lowlands. *Rudall Tablelands – dissected low sandstone tablelands.
Sandland	Eighty Mile Plain – coastal dunes and estuarine plains. Anketell Hills – low mesas, buttes and stony rises of lateritized sandstone and shale among E-W longitudinal dunes and sandy plains. Great Sandy Desert Dunefield – E-W longitudinal dunes and minor salt lakes. Stanley Hills and Dunes – isolated sandstone ridges among E-W longitudinal dunes and sandplains.
Western Coastlands	Carnarvon Dunefield – S-N longitudinal dunes. Onslow Plain – alluvial, deltaic and littoral plains; minor islands.

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

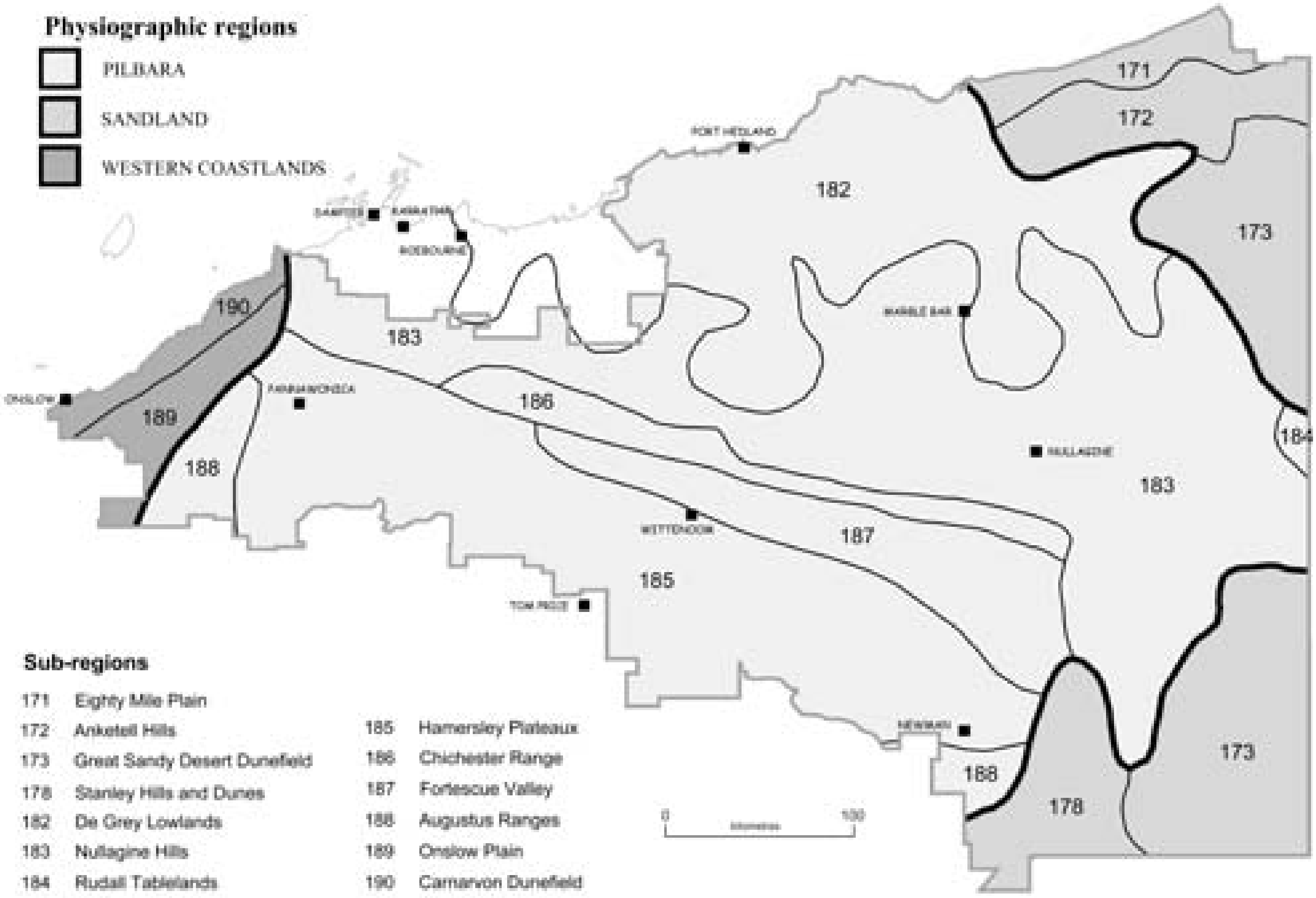


Figure 1. Physiographic regions of the Pilbara (after Jennings and Mabbutt 1986)

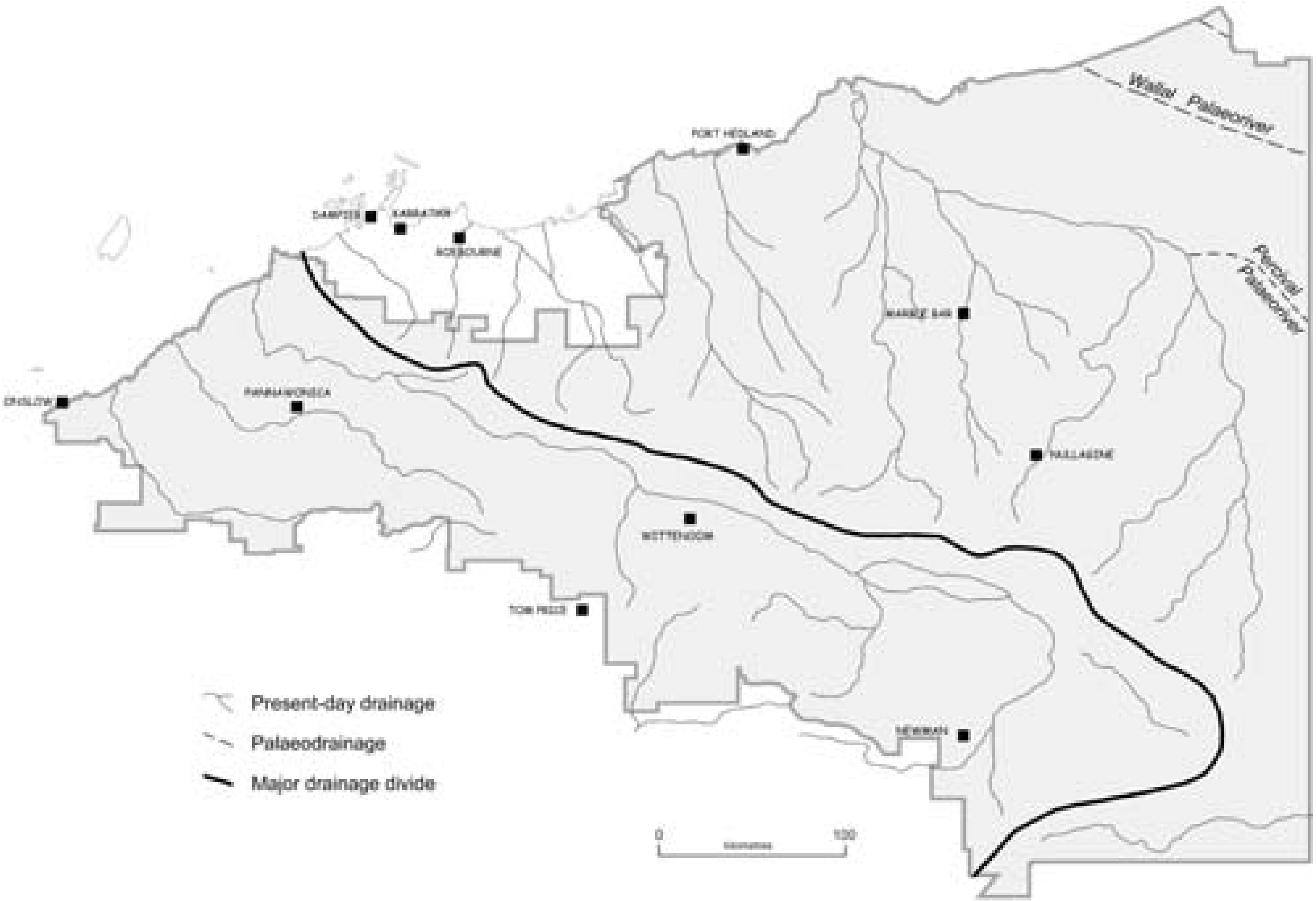


Figure 2. Pilbara drainage systems (after van de Graaff *et al.* 1977)

Hamersley Basin (Trendall 1990). This supergroup is the younger (2,760 to 1,700 million years old) of the two components of the Pilbara Craton and forms a relatively undisturbed cover over the older granite-greenstone terrane. Along the northern boundary of its main outcrop area the supergroup rests unconformably on granite-greenstone terrane while the southern boundary is a complex arcuate zone of tectonic disturbance. The Mt Bruce Supergroup consists mainly of mafic volcanic and volcaniclastic rocks plus subordinate acid volcanics, sandstone, greenstone, siltstone and carbonate. In parts it contains economically important banded iron formations.

Land surface types (groups of land systems)

Fourteen land surface types were defined within the survey area and grouped primarily on whether they represent erosional or depositional surfaces and secondly on genesis and soil and drainage features (Table 2). Colloquialisms are used to maintain brevity in description.

More than a third of the Pilbara consists of rugged ranges, hills and plateaux which are source zones for run-off to lower surfaces. Some of the most prominent are the ridges and plateaux of the Newman land system of the Ophthalmia and Hamersley Ranges. These are based on jaspilite, chert and shale, and relief above the surrounding plains is up to 450 m.

Table 2. Land surface types of the Pilbara survey area

Land surface type	Relief	Land system	Predominant surface geology	Characteristic landform(s)	Distribution
Predominantly erosional surfaces					
(i) Hills and ridges	Low to very high (30-450 m)	Augustus	Sedimentary rocks	Strike ridges, hills	South and west, rare
		Black	Dolerite	Ridges many kilometres long	Central, common
		Boolaloo	Granite	Tor fields, domes	Northern half, common
		Capricorn	Sandstone, greywacke	Strike ridges	Wide, common
		Charley	Dolerite, basalt	Hills, ridges	South-east, common
		Granitic	Granite, gneiss	Hills	Central and east, common
		Houndstooth	Shale	Low hills	West, common
		Marandoo	Basalt	Hills	South-central, common
		McKay	Sedimentary rocks	Hills	Wide, common
		Newman	Jaspilite	Ridges, plateaux	Southern half, very common
		Robertson	Sedimentary rock	Hills, ridges, plateaux	South-east, very common
		Rocklea	Basalt	Hills, plateaux	Wide, very common
		Ruth	Volcanics, sedimentary rocks	Low hills, ridges	North-west, uncommon
		Talga	Greenstone	Ridges, hills	North-central, common
(ii) Plateaux and breakaways	Very low to low (9-90 m)	Callawa	Sandstone	Low dissected hills, mesas	North-east, common
		Coongimah	Silcrete, sedimentary rocks	Plateaux, hills	East, common
		Kumina	Jaspilite, laterite	Low plateaux, uplands	Mainly west, uncommon
		Laterite	Laterite	Low mesas, gravelly plains	South-east, common
		Nanutarra	Conglomerate, sandstone	Mesas	West, common
		Oakover	Calcrete, limestone	Mesas, low plateaux	Mainly east, common
		Robe	Limonite	Mesas, mesa chains	Wide, common
		Table	Calcrete	Mesas, low plateaux	South-central, uncommon

Table 2. continued...

Land surface type	Relief	Land system	Predominant surface geology	Characteristic landform(s)	Distribution
Predominantly erosional surfaces (continued)					
(iii) Dissected plains	Very low (9-30 m)	Billygoat	Colluvium	Incised plains	East, common
		Egerton	Colluvium	Incised hardpan plains	Mainly south, common
		Platform	Colluvium	Incised slopes	Central, south & west, common
(iv) Stony plains and hills	Low (30-90 m)	Adrian	Silcrete	Stony rises, rounded hills	South-east, uncommon
		Bonney	Basalt	Undulating stony plains, hills	Mainly central, common
		Collier	Sedimentary rocks	Uplands, hills, ridges	South-east, uncommon
		Mosquito	Schist	Stony plains, ridges	Central east, common
		Nirran	Basalt, metabasalt	Undulating plains	South, uncommon
		Prairie	Granite	Hills, gritty surfaced plains	South-east, common
		Tanpool	Sandstone	Stony plains, low ridges	Far west, uncommon
(v) Stony plains and gritty surfaced plains	Very low (9-30 m)	Ford	Shale, colluvium	Gently undulating plains	South-east, rare
		Lochinvar	Granophyre, felsic & intermediate lava	Level stony plains with sand dunes	North-east, uncommon
		Macroy	Granite, colluvium	Gently undulating gritty surfaced plains	Central north, very common
		Stuart	Schist, gneiss colluvium, alluvium	Gently undulating quartzy plains	Far west, common
		Sylvania	Granite, colluvium	Gently undulating gritty surfaced	South-east, common
		Taylor	Shale, sedimentary rocks	Stony plains	Central north, uncommon
		Wona	Basalt, eluvium	Stony gilgai uplands	Central and west, common
Predominantly depositional surfaces					
(vi) Stony plains	Very low (9-30 m)	Boolgeeda	Colluvium	Gently sloping plains	Wide, very common
		Dollar	Colluvium, alluvium	Level plains	West, rare
		Elimunna	Alluvium, eluvium, basalt	Gently undulating plains	Central east & south, common
		Paraburdoo	Colluvium, alluvium	Stony gilgai plains	South-west and west, common
		Paterson	Sand, alluvium, colluvium, sandstone	Sandy plains, low hills	East, common
		Peedamulla	Gravel, alluvium	Level gravelly plains, low rises	Far west, common
		Pyramid	Alluvium, eluvium	Stony gilgai plains	North-west, uncommon
		Satirist	Alluvium, colluvium	Level plains with some gilgais, low rises	North & central west, uncommon
		White Springs	Eluvium, colluvium	Level stony gilgai plains	Central, uncommon

Table 2. continued...

Land surface type	Relief	Land system	Predominant surface geology	Characteristic landform(s)	Distribution
Predominantly depositional surfaces (continued)					
(vii) Hardpan wash plains	Extremely low to very low (<9-30 m)	Cadgie	Alluvium, sand	Hardpan plains with sandy banks	South-east, common
		Fan	Alluvium	Hardpan plains	Central south, common
		Jamindie	Alluvium	Stony hardpan plains, low rises	East, common
		Jurrawarrina	Alluvium	Hardpan plains, gilgai plains	Mainly central west, common
		Nooingnin	Alluvium	Hardpan plains, large groves	Mainly south-east, common
		Pindering	Alluvium	Stony or gravelly hardpan plains	Central south, common
		Spearhole	Alluvium	Gently undulating gravelly hardpan plains	South and south-east, common
		Three Rivers	Alluvium	Hardpan plains	Far south, rare
		Wannamunna	Alluvium	Hardpan plains, internal drainage flats	Central south, common
		Washplain	Alluvium	Hardpan plains with drainage tracts	South-east, common
		Zebra	Alluvium	Hardpan plains, gravelly banks	South-east, common
(viii) Sandy surfaced plains on old alluvium	Extremely low (<9 m)	Uaroo	Alluvium, colluvium, sand	Sandy surfaced plains	North and far west, very common
(ix) Plains on non-saline (occasionally saline) alluvium	Extremely low (<9 m)	Balfour	Alluvium, gravel, shale	Level plains (some saline)	South-east, common
		Brockman	Alluvium	Gilgaied alluvial plains	Central west and east, common
		Christmas	Alluvium	Stony alluvial plains	Central, rare
		Cowra	Alluvium, gravel	Gravelly alluvial plains	Central, common
		Cundelbar	Alluvium	Alluvial plains (saline)	South-east, rare
		Hooley	Alluvium	Gilgai clay plains	Central west, common
		Horseflat	Alluvium	Gilgai clay plains	North and west, common
		Kanjenjie	Alluvium	Gilgai clay plains	Central west, uncommon
		Marillana	Alluvium	Alluvial plains, unincised drainage tracts	Central, uncommon
		Narbung	Alluvium, sand	Alluvial plains, internal drainage foci	Central south, uncommon
		Pullgarah	Alluvium	Gilgai clay plains	North-east, common
		Sherlock	Alluvium	Stony alluvial plains	West, uncommon
		Talawana	Alluvium, sand	Alluvial plains (some saline), pans, swampy depressions	Far east, rare
		Turee	Alluvium	Stony gilgai clay plains	Central, common

Table 2. continued...

Land surface type	Relief	Land system	Predominant surface geology	Characteristic landform(s)	Distribution
Predominantly depositional surfaces (continued)					
(x) River flood plains	Extremely low (<9 m)	Cane	Alluvium	Flood plains, river channels	West, uncommon
		Coolibah	Alluvium, calcrete	Flood plains	Central, uncommon
		Fortescue	Alluvium	Flood plains, river channels	Mainly south-east, uncommon
		Jigalong	Alluvium, gravel	Flood plains	South-east, common
		Mallina	Alluvium	Flood plains, alluvial plains	Mainly north, common
		Paradise	Alluvium	Flood plains, alluvial plains	North, common
		River	Alluvium	River channels, banks, alluvial plains	Wide, common
		Urandy	Alluvium	Alluvial fans, flood plains	Mainly west, common
		Yamerina	Alluvium	Flood plains, deltas	Coastal, common
(xi) Calcreted drainage plains	Extremely low (<9 m)	Calcrete	Calcrete, alluvium	Calcrete platforms	Wide, common
		Lime	Calcrete, alluvium, sand	Calcrete plains, alluvial plains	North coastal, rare
		Warri	Calcrete, alluvium	Calcrete platforms	Mainly south, common
(xii) Salt lakes and marshes	Extremely low (<9 m)	Marsh	Alluvium, gypsum	Lake beds, saline flood plains	South central, common
		Weelarrana	Alluvium, sand	Lake beds, saline alluvial plains, sandy plains	South-east, rare
(xiii) Sandplains, gravelly sandplains and sand dunes	Very low (9-30 m)	Buckshot	Gravel, sand, laterite	Gravelly plains, Low rises	Mainly south-east, common
		Divide	Sand	Sandplain	Mainly south-east, common
		Giralia	Sand, minor alluvium	Linear dunes, sandy plains	Far west, rare
		Gregory	Sand	Linear dunes	North central, uncommon
		Little Sandy	Sand	Linear dunes, sandplains	Far east, very common
		Nita	Sand	Very gently undulating sandplains	North-east, very common
(xiv) Littoral plains and coastal dunes	Extremely low to very low (<9-30 m)	Anna	Estuarine alluvium	Littoral plains	North-east coast, common
		Cheerawarra	Sand, alluvium	Sandy plains, saline clay plains	Coastal, common
		Dune	Sand	Linear and reticulate dunes, sandplains	Far west coast, uncommon
		Eighty Mile	Sand	Coastal dunes, beach foredunes	North east coast, common
		Littoral	Estuarine alluvium	Bare mud flats, saline littoral plains	Coastal, common
		Mannerie	Alluvium	Alluvial plains (some saline)	North-east coastal, uncommon
		Onslow	Sand, alluvium	Gently undulating sandplains, littoral plains	Far west coast, common
		Roebuck	Estuarine alluvium	Saline littoral plains, bare mud flats	North-east coast, rare

(i) Hills and ridges

This erosional surface type is the largest in the survey area occupying about one third of the area. It occurs as widespread prominent hill tracts, rugged ranges and plateaux. Common rock types are greenstones, basalt, banded ironstone, sandstone, shale, quartzite, dolomite and minor felsic volcanics. Land systems of the surface type are:

Augustus: Rugged ranges and hills of sandstone, shale and other sedimentary rocks with skeletal soils, relief up to 350 m.

Black: Conspicuous linear ridges (dykes) of dolerite or basalt with black unvegetated rock piles and tor heaps along summits and on upper slopes, relief up to 90 m.

Boolaloo: Granite hills, domes, tor fields and gritty surfaced sandy plains, relief up to 50 m.

Capricorn: Prominent strike ridges and ranges (relief up to 180 m) of sandstone and other sedimentary rocks with steep slopes and skeletal soils.

Charley: Dolerite hills and ridges with relief up to 50 m, a minor system found only in the south-east, differs from most other hill systems in the vegetation it supports.

Granitic: Hill tracts of granitic rocks with pockets of shallow gritty surfaced acidic soils, relief up to 100 m.

Houndstooth: Low hills and plains on shale, drainage floors with braided channels, relief usually less than 30 m.

Marandoo: Large hills and ranges (relief up to 300 m) on basalt. It is restricted to south central parts of the survey area. Similar to Rocklea land system but differs in the vegetation that it supports.

McKay: Hills, ridges, plateaux remnants and minor breakaways of sedimentary and meta sedimentary rocks, relief up to 100 m.

Newman: Rugged high mountains, ridges and plateaux with near vertical escarpments of jaspilite, chert and shale, the second largest system in the survey area and prominent in southern parts (e.g. Ophthalmia Range, Hamersley Range), relief up to 450 m.

Robertson: Hills, ridges and plateaux mainly of sandstone in the east of the area and extending into the sandplain and dune terrain of the Little Sandy and Great Sandy Deserts, relief up to 80 m.

Rocklea: Rough hill and mountain tracts predominantly of basalt, the largest land system in the survey area and widespread throughout, relief up to 110 m.

Ruth: Low hills and ridges (relief up to 90 m) on intermediate and basic volcanic rocks and minor sedimentary rocks, only in north central parts of the survey.

Talga: Hill and ridge tracts of mafic and ultramafic rocks (greenstones), other metamorphics and chert, relief up to 100 m.

(ii) Plateaux and breakaways

This land surface type occupies about 4.5% of the survey area. Despite relatively low relief (9-90 m), it is distinctive in the landscape for its flat-topped plateaux, mesas and buttes of indurated duricrust material and steep breakaway faces. These surfaces are associated with sedimentary rocks or metamorphics and duricrusts are ferricrete, silcrete or calcrete.

Callawa: Highly dissected plateaux remnants, mesas, buttes and low rounded rises on sandstone and conglomerate, frequently lateritized, relief up to 60 m.

Coongimah: Uplands, plateaux and breakaways of silcrete, relief up to 80 m.

Kumina: Ferricrete duricrust plains, uplands and plateaux remnants, relief up to 15 m.

Laterite: Lateritic mesas with breakaway faces and gravelly plains, relief up to 20 m.

Nanutarra: Low mesas, plateaux and hills of sandstone, siltstone and minor conglomerate, relief up to 40 m.

Oakover: Prominent plateaux, mesas and buttes of calcrete with lower plains with highly calcareous soils, similar to Table system, differing mainly in the vegetation it supports, relief up to 60 m.

Robe: Conspicuous chains of limonite mesas and buttes with steep breakaway faces, source of iron ore as pisolitic limonite, relief up to 50 m.

Table: Plateaux remnants, mesas, buttes, breakaways and lower plains (relief up to 60 m) of calcrete, similar to Oakover system, differing mainly in the vegetation it supports. A minor system restricted to a few locations in south central parts of survey area.

(iii) Dissected plains

This land surface is characterised by distinctive patterns of very closely spaced or closely spaced dendritic drainage lines incised into plains of partly consolidated or consolidated ferruginised colluvium and alluvium. Relief is very low or low (9-30 m). This surface type occupies about 2% of the survey area and the land systems comprising it are:

Billygoat: Highly dissected plains and slopes on ironstone gravels and colluvium and broad lower drainage floors, relief up to 20 m.

Egerton: Highly dissected hardpan plains, slopes and narrow drainage floors, relief up to 20 m.

Platform: Narrow, raised plains and highly dissected slopes on partly consolidated colluvium below the footslopes of hill systems such as Newman, relief mostly up to about 30 m but occasionally considerably greater.

(iv) Stony plains and hills

These are erosional surfaces of gently undulating plains, pediments and rises characterised by mantles of lag and colluvium and low hills, ridges and associated footslopes. Quartz is widespread as a mantle component. Ironstone, basalt, sandstone, shale, decomposing granite and silcrete are commonly dominant as mantles depending on underlying geology. Relief is mostly low (30-90 m). This surface type occupies about 2.5% of the survey area and component land systems are:

Adrian: Level stony plains and low silcrete hills, shallow acidic soils, relief up to 40 m.

Bonney: Gently undulating stony plains, rises and low hills of basalt, tributary drainage patterns and alkaline soils, relief up to 30 m.

Collier: Undulating stony uplands and plains with low hills and ridges of sedimentary rocks, relief up to 50 m. A minor system only found in the far south-east of the survey area.

Mosquito: Gently undulating stony plains and prominent ridges and hills (relief up to 100 m) of schist and other metamorphic rocks, largely restricted to a large single area to the east of Nullagine.

Nirran: Gently undulating to undulating stony plains and low hills of basalt and metabasalt and narrow drainage floors, occurs only as a small area in the south. Similar to Bonney system, differing mainly in the vegetation it supports.

Prairie: Gently undulating to undulating stony plains, granite hills and tributary drainage floors, narrow dolerite dykes give prominent patterns on stony plains, relief up to 50 m.

Tanpool: Stony plains and low ridges of sandstone and other sedimentary rocks, relief up to 40 m. A small system restricted to the west of the survey area.

(v) Stony plains and gritty surfaced plains

These surfaces are level to gently undulating plains and pediments of very low relief (9-30 m) with surface mantles of pebbles, cobbles and quartz grit. Quartz is the dominant mantle component in granite domains, elsewhere basalt, ironstone and shale are dominant or occur as mixtures. This surface type occupies 9.7% of the survey area and component land systems are:

Ford: Gently undulating shaly plains with isolated low hills and tributary drainage floors, relief up to 20 m. A very small system found only in the south-east of the survey area.

Lochinvar: Level stony plains on granophyre and lava with a few low hills and longitudinal sand dunes, relief up to 30 m.

Macroy: Level to gently undulating stony and gritty surfaced plains with occasional granite tor fields and domes and closely to moderately spaced dendritic tributary drainage floors, relief up to 25 m. The fourth largest land system (7.2% of the survey area) widespread in the north and centre.

Stuart: Gently undulating stony plains with quartz surface mantles and broad tributary drainage tracts, relief up to 25 m.

Sylvania: Level or gently undulating gritty surfaced plains and low rises on granite and tributary drainage floors, relief up to 20 m.

Taylor: Level stony plains and isolated low hills of shale and other sedimentary rocks, tributary drainage floors, relief up to 20 m.

Wona: Level to gently undulating upland basaltic plains with gilgai microrelief and clay soils, relief up to 30 m.

(vi) Stony plains

These surfaces have very low relief (9-30 m) and abundant surface mantles as for **(v)** but differ in that they are based predominantly on alluvium and colluvium rather than colluvium and parent rock. Land systems in this surface type have higher proportions of depositional units such as lower plains, alluvial plains and drainage floors than land systems in **(v)**. This surface occupies about 6.3% of the survey area and component land systems are:

Boolgeeda: Stony lower slopes, level stony plains and narrow sub-parallel drainage floors, relief up to 20 m. A common system in shallow valleys below hill systems such as Newman and Rocklea.

Dollar: Level stony plains and alluvial plains with small discrete drainage foci and drainage floors, relief up to 10 m. A minor system found only in the far west of the survey area.

Elimunna: Level to gently undulating stony plains, gilgai plains and drainage tracts derived from basalt, relief up to 15 m.

Paraburdoo: Level to gently undulating basalt derived stony plains, gilgai plains with clay soils and broad tributary and through going drainage tracts with braided channels, relief up to 25 m.

Paterson: Level to gently undulating stony and sandy surfaced plains, broad drainage floors with tributary channels and isolated prominent low hills or buttes of sandstone or conglomerate with relief up to 60 m, relief of plains generally less than 20 m.

Peedamulla: Level to gently undulating gravelly plains and broad, usually unchannelled drainage tracts, relief up to 15 m, found only in the west of the survey area.

Pyramid: Level stony plains with surfaces with or without gilgai microrelief and clay soils, relief up to 10 m. An uncommon system found only in the mid north of the survey area.

Satirist: Level stony plains, low rises, clay plains with gilgai microrelief and drainage tracts with few channels, relief up to 10 m.

White Springs: Level stony plains derived from basalt and with gilgai microrelief, minor dissected stony sloping margins, relief up to 10 m.

(vii) Alluvial plains subject to intermittent sheet flow, with shallow neutral to acid soils on hardpan ('hardpan wash plains')

These level to very gently undulating plains which occupy about 5% of the survey area, are commonly found between erosional surfaces and river flood plains **(x)** mostly (but not exclusively) in south western parts of the survey area. Relief is mostly extremely low (<9 m) but there are occasionally low rises and isolated hills with up to 30 m relief. The plains frequently have mantles of ironstone grit and pebbles. They are subject to sheet water flow after rainfall and vegetation is often densely clumped in arcuate bands (groves and sandy banks) with the long axes of the bands at right angles to the direction of sheet flow. The land systems of this surface type are:

Cadgie: Level to very gently inclined wash plains with sandy and loamy soils over hardpan and sandy banks, relief up to 5 m.

Fan: Level to very gently inclined alluvial plains with loamy soils over hardpan, minor sandy banks and plains with clay soils, vegetation in prominent bands (groves) on alluvial plains, relief less than 10 m.

Jamindie: Level to gently undulating hardpan wash plains with mantles of ironstone grit and pebbles, minor stony plains, low rises and occasional low ridges with relief up to 30 m.

Jurrawarrina: Level alluvial plains with loamy soils over hardpan, broad alluvial tracts receiving more concentrated sheet and channelled through flow and with deeper more clayey soils.

Nooingnin: Level hardpan wash plains characterised by parallel bands of very large (up to 5 km long by 40 m wide) groves of dense vegetation with much wider and sparsely vegetated intergrove areas with variable density mantles of ironstone pebbles and shallow loamy soils over hardpan; minor sandy banks and plains receiving more concentrated through flow.

Pindering: Level to gently undulating hardpan wash plains with surface mantles of ironstone pebbles and gravel, some patterns of small groves and minor tracts receiving more concentrated through flow; relief up to 10 m.

Spearhole: Level to gently undulating hardpan wash plains with abundant to very abundant surface mantles of ironstone pebbles and prominent grove patterns of vegetation, widely spaced tributary drainage channels, low rises and dissected slopes with relief up to 35 m.

Three Rivers: Level hardpan wash plains with variable density mantles of gravel and pebbles, shallow loamy soils over hardpan; broad, usually unchannelled tracts receiving more concentrated through flow and minor sandy banks, relief up to 5 m. A minor system found only in the far south of the survey area.

Wannamunna: Level alluvial plains with prominent grove patterns of vegetation and shallow loamy soils over hardpan and broad internal drainage plains with deeper more clayey soils, relief up to 5 m. The system is found in south central parts of the survey area as broad flats within the Hamersley Ranges (Newman land system).

Washplain: Level wash plains and tracts receiving more concentrated through flow with prominent grove patterns of vegetation, loamy and clayey soils of variable depth over hardpan, relief less than 10 m.

Zebra: Level wash plains characterised by parallel bands of very large (up to 3.5 km long) sandy banks with much wider inter-bank areas; banks and inter-bank areas have abundant mantles of ironstone gravels, relief up to 5 m.

(viii) Sandy surfaced plains on old alluvium

These plains have deeper coarser soils than **(vii)** and are not associated with hardpan but may overlie calcrete. They are level depositional plains covering broad areas in far western and northern parts of the survey area. They are based on old alluvial and minor colluvial deposits which have been variously reworked by fluvial and eolian processes.

Soils are sands or loamy sands at the surface without mantles or with sparse mantles of waterworn pebbles of quartz and other rocks. Soil depth is variable but commonly deep (>1 m). Soils may be full depth sands or become more loamy or clayey with depth and occasionally overlie calcrete or rock such as granite. This surface type occupies just over 4% of the survey area and is comprised of a single land system.

Uaroo: Broad, level sandy surfaced plains, minor pebbly plains and tracts receiving sheet flow, relief mostly less than 10 m.

(ix) Alluvial plains mostly with non-saline clay soils

These level plains are found in depositional areas, as broad plains and distributary fans with texture contrast and clay soils with gilgai microrelief. The land systems of this surface type (which occupies almost 4% of the survey area) are:

Balfour: Level shale, gravel and clay plains (some saline).

Brockman: Level alluvial plains with clay soils and gilgai microrelief.

Christmas: Level alluvial plains and distributary fans with abundant mantles of ironstone pebbles and cobbles and patches with gilgai microrelief.

Cowra: Level plains on non-saline and weakly saline alluvium, abundant surface mantles of ironstone gravel and pebbles, fringing the Marsh land system in central parts of the survey area.

Cundelbar: Level plains on saline alluvium, gravelly plains with abundant mantles of ironstone gravel and minor sandy banks. A small system confined to the far south-east of the survey area.

Hooley: Broad alluvial plains with clay soils and a mosaic of stony non-gilgaied and less stony gilgaied surfaces.

Horseflat: Extensive level plains with clay soils and gilgai microrelief, also stony plains and very gently inclined slopes marginal to major rivers, both with non-gilgaied clay soils.

Kanjenjie: Stony plains with clay soils and gilgai microrelief, similar to Hooley and Horseflat land systems, differing mainly in the vegetation it supports.

Marillana: Level gravelly plains with drainage foci and broad, unchannelled drainage tracts.

Narbung: Level alluvial plains with prominent internal drainage foci and minor sandy banks and sand sheets.

Pullgarah: Level plains with clay soils and gilgaied and non-gilgaied surfaces.

Sherlock: Level stony plains with clay soils and occasionally with gilgai microrelief.

Talawana: Level alluvial plains, drainage tracts and claypans (some saline) with non-gilgaied clay soils.

Turee: Stony alluvial plains, fans and distributary drainage tracts with clay soils and gilgaied and non-gilgaied microrelief.

(x) River flood plains

These level depositional surfaces are more or less active flood plains associated with the major rivers of the area. They receive run-on from adjacent higher surfaces and are subject to fairly regular over-bank flooding from major river channels. Soils are both non-saline and saline (predominantly non-saline) duplex (texture contrast) types and clays. These surfaces occupy about 7.5% of the survey area and the component land systems are:

Cane: Flood plains, stony alluvial plains and river channels; non-saline and weakly saline clayey soils.

Coolibah: Flood plains and minor channels with weakly gilgaied clay soils, differs from other flood plain systems mainly in the vegetation it supports.

Fortescue: Flood plains, alluvial plains and river channels, non-saline clay and duplex soils.

Jigalong: Alluvial plains, more active flood plains, gravelly plains, plains with gilgai microrelief and channels; duplex soils (sometimes saline) and clays.

Mallina: Sandy surfaced alluvial plains with occasional claypans, minor stony plains and sandplains.

Paradise: Flood plains with duplex soils (sometimes weakly saline) and clays.

River: Narrow floodplains and major channels.

Urandy: Alluvial plains with or without stony mantles and river channels.

Yamerina: Flood plains, deltaic deposits and river channels, duplex (sometimes saline) soils and clays.

(xi) Calcreted drainage plains

These level, extremely low relief (<9 m) calcrete surfaces occur within valley fill sediments in broad paleovalleys and existing trunk drainage systems. They are undissected, the bodies forming mounds on valley floors, separated by alluvial channels. The land systems of this land surface type (which occupies about 1% of the survey area) are:

Calcrete: Calcrete platforms, plains and narrow drainage tracts, shallow alkaline loamy soils.

Lime: Calcareous plains partly overlain by eolian sand sheets; shallow, generally unchannelled, drainage floors.

Warri: Calcrete platforms, drainage tracts and inter-platform areas occasionally with saline alluvium, minor hardpan wash plains on outer margins of system. Similar to Calcrete land system but differing mainly in the vegetation it supports.

(xii) Salt lakes and marshes

Level salt lakes, saline marshes and their fringing tributary plains are the lowest surfaces in the survey area and have resulted from the infill of paleodrainage systems or the blocking and infill of present day drainage systems. They hold water for several months after large rainfall events. This surface type occupies only about 0.5% of the survey area and component land systems are:

Marsh: Lake beds and flood plains on saline alluvium. The system only occurs along the Fortescue River in the south-east central part of the survey area and is the most prominent alluvial valley fill in Western Australia.

Weelarrana: Salt lakes with fringing plains on saline alluvium and eolian sandy banks and islands; only occurs in the far south-east of the survey area.

(xiii) Sandplains, gravelly sandplains and sand dunes

Sandplains with prominent linear dunes, cover large areas in eastern and north-eastern parts of the survey area (parts of the Little Sandy and Great Sandy Deserts) and also occur as much smaller areas in the far west. The dunes are composed of largely unconsolidated deep red-brown quartz sand. They are mostly linear (occasionally reticulate) and generally trend east-west or south-east to north-west. Sandplains with no dunes or occasional small linear dunes occur scattered throughout south-eastern parts of the survey area.

The component land systems of this surface type (which occupies about 18% of the survey area) are:

Buckshot: Level to gently undulating gravelly sandplains, occasional linear dunes with relief up to 15 m, minor gently undulating gravelly plains and rises with mantles of ironstone or lateritic gravel.

Divide: Level to gently undulating sandplains and occasional small dunes.

Giralia: Linear dunes and broad sandy plains, a very small system found only in the far west of the survey area.

Gregory: Linear red dunes and associated swales and narrow sandplains.

Little Sandy: Extensive sandplains and dune fields with large linear (occasionally reticulate) dunes of red sand extending for many kilometres. The third largest (7.3%) system in the survey area; occurring only in the far east.

Nita: Level, red sandplains and occasional dunes. The fifth largest land system (6.2%) in the survey area; occurring only in the north-east.

(xiv) Littoral plains and coastal dunes

These extremely low to very low relief (<9-30 m) surfaces occur around the whole coastal fringe of the survey area. They consist of extensive level supratidal plains, tidal mudflats and mangrove fringes with saline soils and locally consolidated to unconsolidated calcareous coastal ridges and dunes. This surface type occupies about 2% of the survey area and the component land systems are:

Anna: Level coastal plains on saline and calcareous littoral and alluvial deposits.

Cheerawarra: Gently undulating sandplains, level sandy surfaced coastal plains and plains with saline clay soils.

Dune: Linear and reticulate dunes, narrow swales and sandplains, minor swamps, depressions and claypans.

Eighty Mile: Beaches, unconsolidated fore dunes and hind dunes (relief up to 15 m) with narrow sandy swales, narrow limestone ridges and minor inter-dunal corridors with saline clay soils.

Littoral: Bare coastal mudflats subject to occasional tidal inundation, minor samphire flats, sandy plains and islands, mangrove outer margins, coastal dunes and beaches.

Mannerie: Level seepage areas and minor plains on saline alluvium, only found in north-eastern coastal areas of the survey.

Onslow: Gently undulating sandplains, level plains with saline clay soils and minor coastal dunes, relief up to 20 m.

Roebuck: Level coastal plains on saline estuarine and littoral deposits, bare tidal mudflats and seaward outer margins with mangroves. A very small system only found in the north-east coastal parts of the survey area.

The evolution of landforms in the Cenozoic

Today's diverse land surfaces described above have evolved by processes of weathering, erosion and deposition during the Cenozoic (Beckman 1983 in Wyrwoll 1988) on the previous landforms of the Pilbara Craton and the various sedimentary basins associated with the survey area.

During the early to mid Tertiary Western Australia had a moist, temperate to tropical climate (McGowran 1979) which was conducive to deep weathering and the formation of laterites or 'Walther profiles' (Walther 1915) and silcretes over large areas. Twidale, Horwitz and Campbell (1985) suggested that the earliest of the Hamersley surfaces (their 'upland surface', stripped in the Eocene) contained pockets of pisolitic iron that could be remnant of pre-Eocene laterite surfaces. In the survey area dissected lateritic surfaces (the Robe pisolite, Robe land system) occur as sinuous lines along paleodrainages which drained much of the Hamersley Basin. The system is probably based on detrital fluvial deposits and residual deposits and was formed by percolation of iron-rich groundwater in the fluvial system (Hocking 1990).

Early perceptions (Jutson 1950, Woolnough 1927) were of a lateritic surface of almost continental extent (the 'Old Plateau') which has subsequently been back stripped to produce the 'New Plateau' surface. This Old Plateau/New Plateau model has been used to interpret landform evolution in the Wiluna-Meekatharra area (Mabbutt 1961, 1963) to the south of the present survey area. More recent perceptions of geomorphological processes, based on technological advances such as remote sensing and sediment dating, suggest that the early model is an oversimplification (Wasson 1982, Ollier *et al*. 1988). However, the fundamental concept of etchplanation operating by retreat at breakaway faces reducing the extent of *in situ* deeply weathered rock and exposing fresh rock is still relevant.

Explanations for the different genesis of the landforms seen today depend largely on the theory of ferricrete formation which in itself is a contentious issue. One opinion is that ferricretes and silcretes form in areas of high relief as a result of *in situ* vertical mobilisation of iron and silica and its precipitation near the surface (e.g. Churchward 1977). Others such as Ollier *et al*. (1988), Ollier (1991) suggest that duricrusts developed by lateral transport of silica and iron in groundwaters and cementation in areas of low relief and that the duricrust attains positive relief by subsequent inversion. Ollier *et al.* (1988) view the extensive occurrences of hardpan (the Wiluna Hardpan of Bettenay and Churchward 1974) on lower slopes and sheet wash plains as incipient duricrust.

Duricrusts in the survey area are ferricretes and silcretes on sedimentary and metamorphic rocks (rarely granitic rocks) and as the hardpan of alluvial wash plains and calcrete on limestone or in broad paleovalleys and existing trunk drainage systems.

Following the tropical climates which resulted in extensive deep weathering (Wyrwoll and Glover 1988) and the formation of laterites during the Early and Mid-Tertiary came the onset of a much more arid and fluctuating climate. Bowler (1976) suggests that the onset of aridity occurred in the Pliocene. Cockbain and Hocking (1990) suggest that the Miocene and Pliocene was a transitional period during which aridity spread from the centre of Australia. By the end of the Pliocene much of Western Australia was arid and hardpans (see Litchfield and Mabbutt 1962), calcrete duricrusts and groundwater calcretes began to form in parts of this survey area and elsewhere in Western Australia.

Generally more arid climates extended into the Quaternary but with numerous fluctuations between cooler and drier periods and warmer and wetter periods associated with glacial maxima and minima. During this period the extensive longitudinal dune systems of the Great Sandy and Little Sandy Deserts (parts of which fall within this survey area) formed as did the coastal dunes in the far west of the area. These dunes are currently stabilised; the last period of significant activity being during the last glacial maximum between 13,000-25,000 years ago with a peak of aridity about 15,000-18,000 years ago (Bowler 1976).

Within the survey area the geomorphological expressions of the arid climates which set in during the late Tertiary and particularly the Quaternary are most strikingly manifest as dune fields in the west and east. Climate changes during this period have impacted on the effectiveness of weathering, erosional and depositional processes in particular causing variations to stream hydrology and sediment supply controlling rate of alluvial deposition along rivers such as the Fortescue and De Grey. It is likely that rates of denudation on the Pilbara block in the late Cenozioc have been similar to the very slow rates reported for the Yilgarn block (van de Graaff 1981, Wyrwoll 1988). Landscapes have obviously been modified by etchplanation, scarp retreat, differential erosion and local fluvial and eolian process but, in general, the effect of drier climates has been to preserve, rather than substantially modify landscapes. Nonetheless indications are that the evolution of present landscapes has been complex involving repeated cycles of denudation, transportation and deposition proceeding at rates controlled by climate variability and which are continuing today. Such models of genesis (Ollier *et al*. 1988, Ollier 1991) involve multiple plantation surfaces and repeated inversions of relief.

Erosional landforms and processes

Five erosional land surface types collectively occur over about 52% of the survey area (see Table 2).

(i) The most elevated and prominent landforms are ranges and dissected plateaux on banded ironstone, other sedimentary rocks and volcanics, extensive hill tracts on relatively unaltered basalts, and strike ridges and hills on greenstones and chert. Examples on banded ironstone are the Ophthalmia Ranges and Hamersley Ranges (Newman land system) in the south-central area and include Mt Meharry (1,249 m) and Mt Bruce (1,235 m) the former being the highest peak in Western Australia. Examples on basalt are parts of the Chichester Ranges (Rocklea land system) and hills to the north of Nullagine (Rocklea land system). Examples on greenstones are the tracts of parallel ridges and hills (Talga land system) south, south-east and north of Marble Bar.

Other prominent landforms are low domes, tor fields and corestone masses of fresh granite (e.g. Boolaloo and Granitic land systems) which are common in the northern half of the survey area. These resistant batholith masses have been exposed after more or less complete stripping of the adjacent weathered mantle. The shape and orientation of domes and rock clusters are influenced by jointing and the direction of structural belts. Dome surfaces are often partly covered with exfoliation plates, produced by 'onion skin' weathering, and joint blocks.

(ii) Other striking erosional landforms are breakaway escarpments, plateaux remnants, mesas and buttes which may be up to 50 m above the surrounding plains. Breakaways represent regional erosion fronts in which highly weathered saprolite, capped by a duricrust of ferricrete, silcrete or calcrete is eroded by lateral retreat. Calcrete breakaways are common on limestone (Oakover land system) in the east of the area. Lateritic breakaways, associated mesas and gravelly plains occur on sedimentary rocks and greenstones in many parts of the survey area (Robe and Laterite land systems) but are rare on granitic terrain.

(iii,iv,v) Other erosional landforms with less relief characterise much of the survey area. They include minor hill tracts, dissected plains, undulating stony plains and pediments and gritty surfaced plains. The most extensive and widespread are gently undulating gritty surfaced plains based on granite and gneiss (e.g. the Macroy and Sylvania land systems). These and other stony plains, based on shale and sedimentary rocks, receive water from adjacent hill tracts and from their own extensive catchments and shed water onto depositional surfaces further downslope.

As well as hills and ranges, other predominantly erosional surfaces are gently undulating plains with gritty or stony surfaces such as these of the extensive Macroy land system. Such plains are regional transfer zones receiving water from adjacent ranges and shedding the majority of it onto lower plains and into major rivers.

Depositional landforms and processes

Nine depositional land surface types collectively occur over about 48% of the survey area (see Table 2).

(vi) Level, to gently undulating stony plains of colluvium, eluvium, gravel and alluvium constitute predominantly depositional surfaces over about 6.3% of the survey area. Surface mantles are of common to abundant pebbles predominantly of basalt and/or ironstone. Soils are frequently clays with weakly gilgaied microrelief (e.g. Elimunna, Paraburdoo and Pyramid land systems). Drainage features are internal or as widely spread to sparse tributary drainage floors of alluvium with or without channels. Minor run-off from these surfaces passes to other plains further downslope.

(vii) Almost level plains with semi-consolidated to consolidated alluvial sediments ('hardpan') are extensive in south-western parts of the survey area as they are elsewhere in other semi-arid parts of Western Australia (Litchfield and Mabbutt 1962). In the Wiluna area to the south-east of the present survey area, Bettenay and Churchward (1974) formalised the name Wiluna Hardpan for a highly indurated form of these sediments. Hardpan is likely to have formed during alternating periods of flooding and desiccation and the transport of iron and silicates, derived from weathering upslope, in groundwater to the zone of precipitation. The time of commencement of its formation (late Pliocene to Pleistocene) is probably broadly contemporaneous with groundwater calcretes. Ollier *et al*. (1988) view hardpan as incipient duricrust, attaining its relief by subsequent landscape inversion.

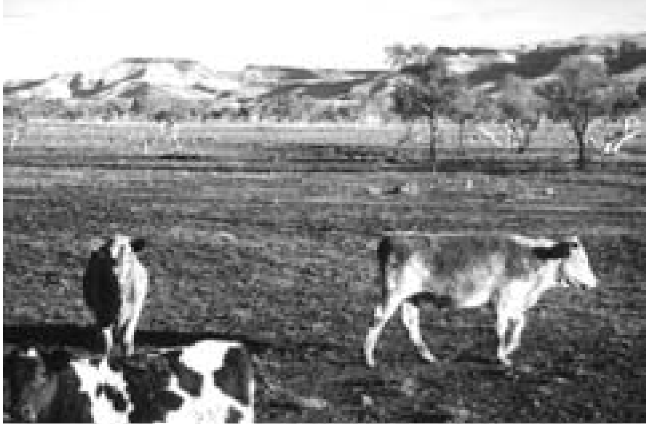
These hardpan plains which have very shallow non-saline loamy soils overlying the hardpan are subject to intermittent, broad sheet flow. Some drainage corridors receive more concentrated through flow than the surrounding plains and have occasional channels and creeklines.

Many of these plains show characteristic patterns of vegetation banding with relatively large areas with very scattered vegetation ('intergroves') alternating with smaller arcuate areas of dense vegetation ('groves'). The patterning is associated with gently inclined surfaces receiving overland sheet flow and is further controlled (Mabbutt and Fanning 1987) by soil type and differential rates of water infiltration on soils of variable depth over hardpan.

(viii) Sandy surfaced plains on old alluvium occur as a single land system (Uaroo) in northern and far western parts. They are subject to some sheet flow but because of their very sandy nature much of this is absorbed. Infrequent broad, shallow, usually unchannelled, drainage tracts with somewhat heavier textured soils may contribute minor through flow to surfaces further downslope. For further description see (viii) previously.

(ix) Level plains with non-saline (and occasionally saline) alluvium occur widely throughout the survey area. They differ from (vii) in that soils are heavier textured, deeper and do not overlie hardpan. They occur downslope from hill and gently undulating stony plain catchments from which they receive overland and channelled flow and are marginally upslope from flood plains (x) associated with the major rivers of the area. Surfaces frequently have gilgai microrelief and mantles vary from nil to abundant pebbles and gravels of ironstone, basalt and other rocks. Many of the plains have numerous small drainage foci and swampy depressions representing sump areas of lowest relative relief which are characterised by heavier soils than on adjacent areas. Infrequent shallow drainage corridors, with or without minor channels, contribute some through flow to downslope surfaces such as flood plains (x) or salt lakes (xii).

(x) Active flood plains are associated with the major rivers of the survey area. They vary from narrow plains and minor levees (less than 500 m wide) flanking major channels in narrow valleys passing through extensive hill tracts such as in the lower reaches of the Fortescue River and upper reaches of the Nullagine River, to much broader plains and deltaic deposits towards the mouths of such rivers as the De Grey and the Yule. They are subject to fairly regular overbank and channelled flooding and run-on from adjacent higher surfaces. The plains contain various sedimentary sequences including bedload deposits from prior streams and old levees including occasional 'mega' levees presumably from past massive flood events. Fluvial processes are active on these surfaces and some parts (such as the scalded plains of the Paradise land system) have been reworked by recent eolian processes.



River flood plains occupy about 7.5% of the survey area. These level depositional surfaces with deep mostly non-saline soils support grass pastures which are favoured by cattle.

(xi) Calcreted valley fill deposits are common in palaeodrainage and present day drainage lines and represent valley floors whose alluvium has been replaced by carbonate. According to Hocking and Cockbain (1990) the formation of these groundwater calcretes requires conditions of low, irregular rainfall, high evaporation, little surface drainage or run off, and a shallow water table with sluggish groundwater movement. Such conditions commenced in the Pliocene and there is evidence that calcretes are still forming in recent alluvium.

In the survey area the calcrete bodies are generally undissected and form mounds (elevated only to a few metres) separated by alluvial floors and locally masked by superficial eolian sand deposits.

(xii) Salt lakes and saline marshes are uncommon in the survey area occurring as playas in old paleodrainage systems (Weelarrana land system) or as more recent alluvial infills along the Fortescue River valley (Marsh land system). The salt lakes of the Weelarrana system contain terrestrial sediments including saline and gypseous lacustrine and fluviatile clays and wind blown quartz sand. The lakes fill with water from surrounding country after heavy rain.

Lake beds and marshes (Marsh land system) of Quaternary saline and gypseous alluvium form an extensive drainage sump area caused by blockage of the Fortescue River by the Goodiadarrie Hills about mid-way along its length. Only after exceptional rainfall does water upstream from the Goodiadarrie Hills flow on to the lower reaches of the river.

One of the lowest landscape surfaces in the Pilbara is the unique Marsh land system. This is an extensive area of saline and gypseous alluvial infill along the Fortescue River valley caused by blockage of the river by the Goodiadarrie Hills.

(xiii) Sandplains and associated dunes are extensive and widely distributed (particularly in eastern parts) in the survey area (Buckshot, Divide, Giralia, Gregory, Little Sandy and Nita land systems). They can occur as surfaces overlying granite, sandstone, laterite, hardpan and calcrete and are essentially transported in nature by fluvial and eolian processes rather than sedentary. Eolian deposits as very large longitudinal dunes of unconsolidated red quartz sand are prominent features of landscapes in the east.

(xiv) During the Quaternary, fluviatile and eolian processes on littoral and estuarine substrates of clay, silt, sand and shelly deposits resulted in distinctive land forms developing along the coastal fringes of the survey area. Some of these coastal landforms and their vegetation are described by Craig (1983).

Present day broad coastal flats have developed on saline littoral deposits now supratidal as a result of sea level falls. Narrow beaches and mangrove fringes at the coast are backed by unconsolidated to locally consolidated fore dunes, beach ridges and hind dune of calcareous sands and calcarenite.

The digital elevation model (Figure 3) broadly shows the arrangement of erosional and depositional landforms of the Pilbara. The depositional surfaces of the Fortescue River valley, between the Hamersley and Chichester Ranges, and the wide coastal plains are clearly delineated. The coarseness of the resolution of the computer generated model means that some linear features such as the dunefields in the far north-east and south-east cannot be well depicted.

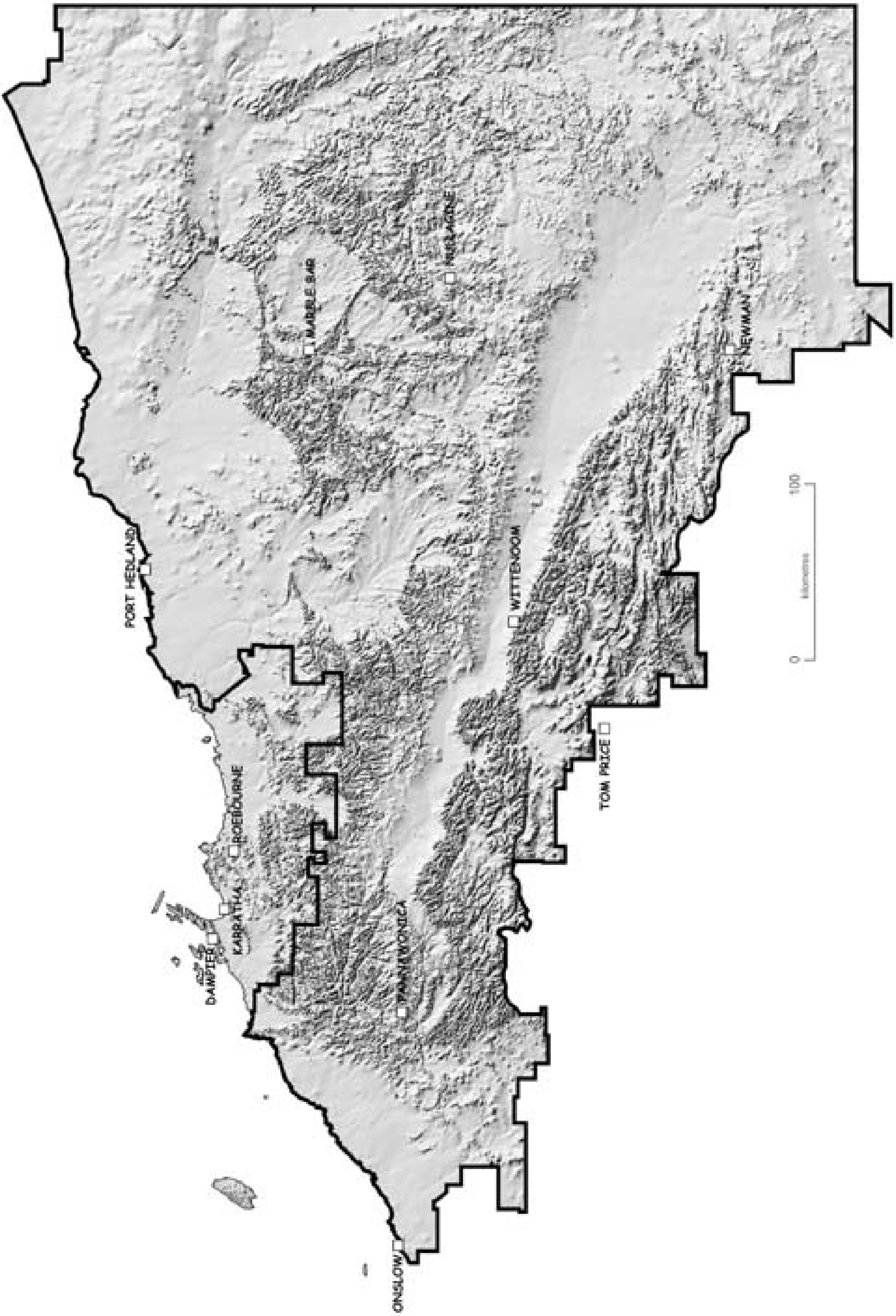


Figure 3. Digital elevation model of the Pilbara (after Geoscience Australia GEODATA 9 second DEM version 2)

In summary, the present landforms in the survey area comprise about 52% erosional surfaces and 48% depositional surfaces. They consist of extensive hill and plateaux tracts on sedimentary, igneous and metamorphic rocks (33%) above lower pediments and sheetwash plains draining into major river systems and their associated alluvial plains. Sandplains and dune fields are common particularly in the east and far west. Distinctive landforms of coastal plains and beach dunes flank the coastal strip. Over large areas relief is subdued but elsewhere is low to high (30-300 m) and occasionally very high (>300 m) with rugged topography (e.g. the Chichester Plateau and Ophthalmia Range). The Karijini National Park includes strongly defined, dissected plateaux of the Hamersley Ranges on which structural and lithological controls have developed a spectacular terrain. Drainage is very largely organised and integrated with seasonally intermittent rivers flowing north-westerly to the Indian Ocean. Landform patterns are best appreciated in terms of a morphotectonic setting of greenstone belts surrounded by extensive granitoid expanses and peripheral sedimentary basins that have undergone deep weathering and stripping in the Mid to Late Cenozoic and have been largely preserved with the onset of aridity in the late Cenozoic, with some modification by erosion and deposition.

Land use impacts on landscape processes

There has been little research on the impacts of land use on landscape processes in Western Australian rangelands. However, this and similar surveys (e.g. Wilcox and McKinnon 1972, Payne, Curry and Spencer 1987, Payne, Mitchell and Holman 1988) document those lands on which natural erosion processes have been accelerated by inappropriate land uses. The survey of the Gascoyne River catchment (Wilcox and McKinnon 1972) was undertaken largely because of off-site effects, i.e. severe flooding in Carnarvon which was suggested as occurring because of excess run-off from a degraded catchment.

Hills, plateaux, breakaways and footslopes

Very shallow soils, abundant surface mantles of stones and the frequently sloping nature of these surfaces mean that water infiltration rates are low and levels of run-off are high. Accelerated erosion is rare. However, on some lower footslopes where soils are deeper, the removal of the stony mantle along tracks or grid lines can result in accelerated erosion in the form of rills, gutters or shallow gullies.

Footslopes on soft weathered material immediately below breakaway duricrusts occupy relatively very small areas in this survey. Although, in geological terms, they represent some of the most active erosion fronts in the area they are not as prone to accelerated erosion as similar sites in other survey areas in southern shrublands (e.g. Payne *et al*. 1998). Reasons for this may be surface mantles of stone and moderate cover of spinifex hummocks which are not preferred by grazing animals.

Dissected plains

These surfaces (Billygoat, Egerton and Platform land systems) are characterised by very closely spaced highly dendritic drainage patterns. In geological terms they are active erosion faces but are not prone to accelerated erosion. They frequently have abundant surface mantles of ironstone gravel.

Pediments

Pediments below ranges and hill tracts are usually level to gently undulating, have a surface cover of pebbles and stones, vegetation cover of spinifex varying from 5 to 50% or more and poor infiltration characteristics. They are generally not susceptible to erosion even when plant cover is reduced (or entirely lost by fire) largely as a result of the protection afforded by the stony mantle.

Drainage floors and alluvial tracts occupy only a small proportion of the total of this terrain but are locally and collectively extensive. They often have inherently fragile texture contrast (duplex) soils, sparse or no stony surface covers and support soft spinifex or tussock grasses which are favoured by grazing animals. They are moderately susceptible to degradation and accelerated erosion.

Many Pilbara landscapes have dense stony surface mantles of ironstone, quartz, shale or other rocks providing protection from erosion. However, disturbance of mantles may lead to soil erosion. This site is an upland plain derived from basalt on the Wona land system, and shows track erosion on a long gentle slope.

Sheetwash (hardpan) plains

The extensive, level to gently inclined, hardpan alluvial plains in the south-east of the area support scattered tall shrublands of mulga with low shrubs and/or spinifex understoreys and are subject to intermittent sheet flow. Plant cover is only very locally subject to significant reduction by overgrazing but can occasionally be totally lost for short periods of time due to fire. Cryptogamic crusting is well developed and widespread on these plains and confers stability to soil surfaces. Surface mantles vary from none to abundant gravels, predominantly of ironstone. These conditions render the plains fairly immune to soil erosion except in some localised more concentrated through-flow drainage tracts where vegetation is lost or where there is no surface mantle and surface crusts have been excessively broken due to trampling or other disturbance.

Surface hydrology processes are extremely important in maintaining the ecological integrity of these systems. Any disturbance that restricts, diverts or concentrates surface sheet flows will effect (often adversely) vegetation communities.

For example, these plains are susceptible to water starvation caused by inappropriately located or constructed tracks and roads. In such cases vegetation may decline down slope of the impedance to flow and expose the soil to wind erosion. Tracks should allow for the regular and frequent passage of water down slope so as to reduce the risk of water build-up and high energy discharge where it breaks through the track. Similarly spoon drains should be used to disperse water moving along tracks so as to minimise track erosion and down slope water starvation. Construction of tracks in the same direction as sheet flow should be avoided as this can cause water starvation problems and track erosion which may spread laterally by microterracing away from the track.

Many of these plains support obvious fertile patches in the form of more or less distinct groves or arcuate bands of vegetation which are denser than that surrounding. The groves receive and retain sheet flow from up slope intergrove areas and are areas of high biological activity including being favoured feeding and resting places for domestic stock and native animals. Although generally stable, groves can be degraded by excessive grazing or by alterations to surface water flows. In extreme cases shrubs and trees die, water is no longer retained, nutrients are lost and the grove structure collapses.

Overland sheet flow processes on this near level hardpan plain of the Jurrawarinna land system have been disrupted and channelised. The result has been water starvation, death of mulga shrubs and soil erosion.

Plains with non-saline (and occasionally saline) alluvium

These surfaces occupy about 4% of the survey area and support tussock grasslands and shrublands which are moderately to highly preferred by grazing animals. They are usually level, often have clay soils with gilgai microrelief and surface mantles vary from nil to abundant gravels and pebbles. Because of flat topography, heavy textured soils, moderately dense surface cover of vegetation (when in good condition) and surface mantles (where present) most of these surfaces are inherently resistant to erosion. However, more saline parts and broad drainage tracts with duplex soils, no surface mantles and which support preferentially grazed low shrublands of saltbush and bluebush are moderately susceptible to degradation and erosion.

River flood plains

These level flood plains support tussock grasslands, soft spinifex grasslands and halophytic shrublands which are highly preferred by grazing animals. Soils are saline and non-saline cracking and non-cracking clays and sandy surfaced duplex types usually with no or little surface mantle. The plains receive fairly regular overbank flooding from river channels and those parts with duplex soils and where vegetative cover is lost are highly susceptible to erosion.

Many of the floodplains support dense shrub and grass vegetation and there is no accelerated erosion. Here the evidence of erosion is limited to the movement and deposition of silt and fine sand, the deposition of clay veneers in sink zones and obvious trails and accumulations of litter. When in good condition water and nutrients are conserved and cycled within the system (the ‘fertile patch’ concept, Tongway 1994). In these alluvial systems the individual plant mounds and small drainage foci are the fertile sites where water infiltration rates, nutrient accumulations and biological activities are at their maximum.

Where vegetative cover is depleted by preferential grazing or other disturbances, erosion is accelerated and natural cycling processes dislocated. Erosion is evident as surface sheeting, microterracing, scalding, scouring, guttering and wind hummocking. Loss of shrubs and perennial grasses results in the breakdown and eventual dispersion of plant mounds and the loss of the system’s ability to trap and utilise water and nutrients.

It seems likely from anecdotal evidence that river frontages in the survey area were much more widely degraded and eroded in the early and mid 1900s than they are now. Saltbush shrublands and native grasslands were severely depleted by preferential overgrazing during these times resulting in extensive areas of eroded country. There are still large areas of severely degraded lands within this surface type but many formerly degraded parts are now stabilised by increases in soft spinifex and the widespread establishment of the introduced, grazing resistant, buffel grass. Better stock management practices and good seasons over the last decade have assisted the recovery.

Sandplains and dunefields

The use of fire as a grazing management tool in spinifex hummock grasslands on sandplains (and other landforms) in the area is fairly common. Occasionally accelerated wind erosion occurs on sandplains and dune crests after burning but vegetative cover re-establishes rapidly after rain and stabilises these sites. Dune flanks and crests are susceptible to erosion from other forms of disturbance such as tracks and, wherever possible, tracks and roads should not be constructed on such sites.

Coastal plains and dunes

Coastal sand dunes (e.g. as on the Onslow and Eighty Mile land systems) and sandy plains (e.g. Cheerawarra land system) are subject to strong sea breezes and are highly susceptible to wind erosion if vegetative cover is lost. Some areas of longstanding bare coastal dune blowouts occur within the survey area but most dunes are currently stabilised by dense stands of soft spinifex and/or buffel grass. However, overgrazing, fire, disturbance by vehicles, etc. can remove vegetation and initiate erosion which is likely to continue at least until the next seasonal rains. The use of fire as a grazing management tool in these areas is problematic.

In summary, the Pilbara survey area has a number of natural characteristics which help protect landscapes from the impacts of inappropriate land use practices. Examples of these characteristics are the high proportion of rugged hills and ranges which are inherently resistant to all but the most extreme forms of disturbance, widespread stony surface mantles which afford protection to soil surfaces, widespread relatively dense stands of predominantly spinifex hummock grass vegetation which is largely unaffected by grazing, cryptogamic soil crusts on some landforms and the nearly level nature of much of the terrain.

Fire is a natural feature of the Pilbara environment but alterations to fire regimes caused by man's recent activities are inappropriate in some circumstances and have adverse consequences for fire sensitive plant species such as mulga (Fortech 1999).

The areas in which the landscape is most susceptible to inappropriate land use are drainage floors, alluvial plains and flood plains subject to flooding and through flow and with duplex soils; sand dunes and sandy plains in coastal areas; hardpan washplains where hydrological processes are disrupted, 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 increased run-off velocities, 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

Soil summary

More than a third of the Pilbara consists of rugged, hills, ranges and plateaux occurring mostly in central and southern parts. The central and central east area consists of extensive gently undulating granitic plains, tor fields, drainage tracts and occasional low greenstone hill tracts. In the far north-east and south-east, hills and mesas give way to broad sandplains and eolian dune fields. In the west, low ranges give way towards the coast to gently sloping peneplains, level sandy plains and alluvial plains. The whole length of the Pilbara coastal strip includes bare mudflats, coastal dunes, sandy plains and broad deltaic deposits associated with the mouths of major rivers.

Soils on the ranges are predominately stony (Soil Group 203). Most of the soil types within these ranges and hills have significant to dominant proportions of stone throughout the soil profile and often have a very stony mantle and prominent rock outcrop. Other minor soils include red shallow loams (522) with some red shallow sands (423). Calcareous shallow loams (521) are mostly common on hills based on basalt, and shallow red/brown non-cracking clays (622) occur as isolated pockets of soil within the hill systems and within hill valleys. Soils become deeper downslope from the ranges. In these areas the dominant soils are stony surfaced red loamy earths (544) with some areas of deep red/brown non-cracking clay (622). The lowest landscape units have self-mulching cracking clays (602) with areas of deep red/brown non-cracking clays (622) or red deep loamy duplexes (506).

Soils of the granitic terrain and within the immediate vicinity of granite hills and outcrops are mostly red shallow sands (423). The hills give way to broad gently sloping plains with red sandy earths (463), red deep sands (445) and red loamy earths (544).

Hills and mesas on the eastern margins of the survey have stony soils (203) and calcrete dominated areas primarily have calcareous shallow loams (521). The stony plains below the hill systems have red loamy earths (544) and give way further downslope to deep red/brown non-cracking clays (622). Further to the east the desert areas have mostly red deep sands (445) and red sandy earths (463) with areas of stony soils (203) on isolated hills.

The hinterland of the Onslow plain receives overland water flow from adjacent hills systems with stony soils (203). The stony lower plains have red loamy earths (544) which give way to sandplains of red deep sand (445) and red sandy earths (463).

The major rivers of the Onslow plain have alluvial plains and floodplains of mostly red deep sandy duplexes (405) with some red deep loamy duplexes (506) and red/brown non-cracking clays (622). Further north, the alluvial plains of the major rivers have self-mulching cracking clays (602), red/brown non-cracking clays (622) and some red deep loamy duplex (506) soils. On river deltas and alluvial plains near the coast, the soils are deep red/brown non-cracking clays (622) and deep duplex types (405 and 506) with some self-mulching cracking clays (602). The mostly sandy dry rivers and associated levees have river bed soils (705).

The coastal fringe of the area has tidal soils (104) with beach zones of calcareous deep sands (442). Adjacent to many tidal areas are soils of red deep sandy duplexes (405), saline red/brown non-cracking clays (622) and red deep sand (445). The northern coastal margin has inland plains of grey deep loamy duplexes (509) and minor areas of grey non-cracking clays (621).

Previous surveys

The soils of the survey area have previously been described and mapped at a scale of 1:2,000,000 by Bettenay, Churchward and McArthur (1967) as part of The Atlas of Australian Soils, providing a general overview of distribution.

Teakle (1936) and Bettenay and Churchward (1974) described the red-brown siliceous hardpan occurring in the southern margins of the region. Payne and Mitchell (1992) conducted a survey of landforms, soils and vegetation on two pastoral leases in the south-east of the survey area.

In the Land systems chapter of this report, the land unit descriptions detail the distribution of soil types within land systems.

Field sampling methods

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

Soils were sampled via shallow soil pits and a 50 mm diameter graduated soil auger, to retrieve soil to a depth of 1 m or to the level of the impermeable layer of underlying rock or hardpan. Samples were laid out to determine different soil layers.

Soil textures were determined for the fine earth fraction (<2 mm) after sieving out coarse fragments. The sieved fraction was moistened and the behaviour of the kneaded soil recorded.

Field textures provided an indication of the proportions of sand, silt and clay and determined the thickness of soil layers. Soil textures ranged from sand (<5% clay) to heavy clay (>50% clay).

Textures were determined down the profile to separate the major soil layers into A, B, C or D horizons where, the 'A' horizon is the topsoil, the 'B' horizon is the subsoil, the 'C' horizon is weathered rock and the 'D' horizon mostly represents a subsoil hardpan.

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 bonding, was determined by compressing a 20 mm undisturbed soil unit, while examination of the appearance of an undisturbed soil mass determined fabric. Soil structure, related to soil fabric, was 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 the material retrieved via the soil auger or from geological maps. Soil pH was measured in the field 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.

Over 720 soil profiles were described during the survey and classified into 21 Soil Groups.

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.

Tongway (1994) describes cryptogams as microbiotic assemblages of mosses, fungi, lichen and liverworts forming thin surface crusts covering many soil surfaces. These surface crusts stabilise the soil and protect the soil from rainfall impact and overland water flow. The crusting is generally coloured black during the dry months, rapidly greening after rain. Cryptogam crusts are easily broken by the trampling of livestock but will re-establish easily if left undisturbed, providing the topsoil has not been severely altered. A loss of cryptogam crusting may lead to the erosion of fine soil particles in the first instance and possible larger scale erosion in time.

The soils were classified using the Australian Soil Classification (Isbell 1996), in which the soil depth classes are:

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

Soil Groups

Twenty-one Soil Groups (Schoknecht 2002) were identified in the survey area and are summarised in Table 1. 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% of a land system are listed as major soils. Soils occupying 10-25% of a land system are listed as minor soils.

Soil Group 104 - Tidal soils

These soils occur as intertidal and supratidal soil types. Intertidal soils are inundated regularly and supratidal soils are inundated infrequently. Soils are deep (>100 cm) sandy clay loams or silty light to medium clays overlying silty medium clays. These soils have a saline water table at shallow depths (<60 cm), and are mostly bare or support minimal amounts of salt tolerant mangrove or samphire vegetation on the margins of the adjacent higher land units. Soils are red to dark brown, strongly alkaline and highly saline.

Supratidal soils on tidal plains often occur adjacent to calcareous deep sands (Soil Group 442) or deep red sands (Soil Group 445) on wind deposited sand banks or sand dunes.

Tidal soils summary

Australian Soil Classification	Argillaceous, Intertidal or Epicalcareous, Supratidal Hydrosols
Soil textures	Sandy clay loam to light/medium clay overlying silty medium clay
Land systems	Major soil within the Littoral land system. Minor soil within the Cheerawarra and Roebuck land systems
Land units	Tidal flat, saline plain
Soil colour	Red (10R 4/6) to dark brown (10YR 3/3) or dark greyish brown (10YR 4/2)
Soil depth	Deep (>100 cm)
Pedality/Fabric/ Structure	Apedal, earthy and massive or weakly pedal
Soil surface condition	Soft
Topsoil slaking	Partial to complete
Subsoil slaking	Nil to partial
Topsoil/subsoil dispersion	Nil to partial
Topsoil pH range	Alkaline (7.9-9.5)
Subsoil pH range	Alkaline (8.2-9.5)
Topsoil EC range	Highly saline (>1000 mS/m)
Subsoil EC range	Highly saline (400-3000 mS/m)
Wind/water erosion hazard	Low
Inundation/ flooding risk	Very high

Table 1. Soil Groups in the survey area

Soil Group (code)	Description	Landscape location
Tidal soils (104)	Highly saline sands and mud on the coast	Tidal flats
Calcareous stony soils (202)	Soils which are coarse gravelly, stony or rocky throughout and calcareous	Low rises, hills, footslopes, and calcrete platforms
Stony soils (203)	Soils which are coarse gravelly, stony or rocky throughout and not calcareous (excluding ironstone gravel soils)	Hills, ridges, slopes, low rises, plateaux , tor fields and breakaways
Shallow gravel soils (304)	Shallow sands or loams overlying gravels	Low rises, plateaux, breakaways and lateritic stony plains
Red deep sandy duplex soils (405)	Red deep sandy surfaced soils overlying heavy textured subsoils	Lateritic plains, loamy plains, alluvial plains and drainage zones
Red shallow sandy duplex soils (406)	Red shallow sandy surfaced soils overlying heavy textured subsoils	Low rises, footslopes and stony plains
Red shallow sands (423)	Red shallow red sands with 3 sub-groups overlying granite, basalt or calcrete	Hills, ridges, tor fields, footslopes, gritty surfaced plains and stony plains
Calcareous deep sands (442)	Calcareous sands over 1 m deep	Beaches and sand dunes
Red deep sands (445)	Red sands over 1 m deep	Sand sheets, sand dunes, sand banks and river levees
Red sandy earths (463)	Red soils with a sandy surface grading to loam or clay by 80 cm	Lateritic plains, loamy plains, sand sheets, sand banks, alluvial plains, and drainage zones
Red deep loamy duplex soils (506)	Red deep loamy surfaced soils overlying heavy textured subsoils	Alluvial plains, floodplains, gilgaied groves, drainage zones and saline plains
Grey deep loamy duplex soils (509)*	Grey loamy surfaced soils overlying heavy textured subsoils	Alluvial plains, drainage foci and swamps
Calcareous shallow loams (521)	Shallow calcareous loam mostly overlying calcrete or rock	Calcrete platforms and stony plains
Red shallow loams (522)	Shallow red loam overlying rock or other cemented layers	Low rises, footslopes and stony plains
Red-brown hardpan shallow loams (523)	Shallow red loamy surfaced soils overlying red-brown hardpan or other subsoil cemented layers	Hardpan plains, stony hardpan plains and lateritic stony plains
Calcareous loamy earths (542)	Calcareous deep loams often grading to heavier textures	Saline plains and loamy plains
Red loamy earths (544)	Deep red loamy surfaced soils often grading to heavier textures	Lateritic stony plains, loamy plains, stony plains, alluvial plains, groves, floodplains and drainage zones
Self-mulching cracking clays (602)	Deep clay soils predominantly red/brown exhibiting soil surface cracks when dry	Drainage foci, swamps, gilgai plains and saline plains
Grey non-cracking clays (621)	Deep clay soils predominantly coloured grey at the surface	Alluvial plains
Red/brown non-cracking clays (622)	Red clays (may be variable depth)	Stony plains, alluvial plains, claypans, swamps, floodplains, gilgai plains, groves and saline plains
River bed soils (705)*	Very coarse sands with variable amounts of river stones and rocks	Major drainage channels and river levees

* Descriptions of Soil Groups 509 and 705 will be detailed in the next edition of Soil Groups of Western Australia. The current edition of Soil Groups of Western Australia (Resource Management Technical Report 246) is available, free of charge from the Natural Resource Assessment Group, Department of Agriculture, 3 Baron-Hay Court, South Perth 6151.

Soil Group 202 - Calcareous stony soils

These soils are stony, very shallow (<25 cm) uniform textured loamy sands to sandy loams overlying weathered dolerite, shale or limestone. Calcareous stony soils occur as a minor component of only a few land systems. They are dark reddish brown in colour, calcareous throughout, non-saline with an alkaline soil reaction trend. This Soil Group shares many features of the stony Soil Group (203) in the abundant stone content on the soil surface and throughout the soil profile. Calcareous soft segregations often occur within the soil profile as the soils are derived from weathered mixed metamorphic or limestone rock types.

Calcareous stony soils summary

Australian Soil Classification	Paralithic or Lithic, Leptic Rudosols
Soil textures	Loamy sand to sandy loam
Land systems	Minor soil within the Capricorn, McKay and Rocklea land systems
Land units	Low rise, ridge
Soil colour	Dark reddish brown (2.5YR 3/4 to 5YR 3/4)
Soil depth	Very shallow (<25 cm)
Pedality/Fabric/ Structure	Apedal, earthy and massive
Soil surface condition	Firm with an abundant (>50%) stony mantle and common (10-50%) cryptogam crusting
Substrate	Weathering shale, dolerite, siliceous limestone and mixed metamorphic rock
Topsoil/subsoil pH range	Alkaline
Topsoil EC range	Non-saline (13-20 mS/m)
Subsoil EC range	Non-saline (8-17 mS/m)
Wind/water erosion hazard	Nil
Inundation/ flooding risk	Nil

Soil Group 203 - Stony soils

The majority of stony soils occur within the extensive areas of hills, ranges and upper stony plains and are very shallow to shallow (<25-50 cm) and skeletal or poorly developed. The soils vary depending on the nature of the parent rock. The parent material is mostly basalt, granite or sedimentary rocks such as sandstone and shale and, less frequently, metamorphic rocks.

The soils formed on basalt, shale or metamorphic rocks tend to have texture ranges from fine sandy loam to loam or clay loam. Soil colour is dark reddish brown to dark red and soil reaction is generally acidic to neutral. Some soils are alkaline and may contain calcium carbonate derived from weathered rock.

Soils developed on granite rocks tend to have lighter textures ranging from loamy coarse sand to sandy loam. Soil colour is mostly dark red and soil reaction is acidic to weakly acidic.

A heavy stony mantle mostly protects the stony soils. Stone or rock may comprise 20-80% of the soil profile. Outcropping rock is a feature of this soil group and some soils may contain ironstone gravel.

Stony soils summary

Australian Soil Classification	Lithic and Paralithic, Leptic Rudosols and minor Red Ferrosols and Kandosols
Soil textures	Fine sandy loam to loam, or occasionally clay loam in areas dominated by basalt, ironstone and shale. Loamy coarse sand to sandy loams in areas dominated by granite or sandstone
Land systems	Major soil within the Adrian, Augustus, Black, Boolaloo, Bonney, Callawa, Capricorn, Granitic, Houndstooth, Jamindie, Laterite, Marandoo, McKay, Mosquito, Nanutarra, Newman, Prairie, Robe, Robertson, Rocklea, Ruth, Talga, Tanpool and Taylor land systems. Minor soil within the Billygoat, Collier, Coongimah, Elimunna, Peedamulla, Platform and Sylvania land systems
Land units	Breakaway, footslope, hill, hillcrest, hillslope, low rise, plateau, ridge, scree face and stony plain
Soil colour	Dark reddish brown (2.5YR 2.5/3) to dark red (2.5YR 3/6)
Soil depth	Mostly very shallow (<25 cm) to shallow (25-50 cm)
Pedality/Fabric/ Structure	Apedal, earthy and massive to weakly structured
Soil surface condition	Mostly rock outcrop (10->50%) or abundant stony mantle (>50%). Infrequent (<10%) cryptogam crusting in absence of a stony mantle
Substrate	Basalt, banded ironstone, dolerite, granite, ironstone, sandstone, sedimentary rock, shale, silcrete, unconsolidated or metamorphic rock
Topsoil slaking	Variable
Subsoil slaking	Partial to complete
Topsoil/subsoil dispersion	Nil to partial
Topsoil/subsoil pH range	Mostly neutral (6.0-7.5) with ranges from 5.1 to 9.0 dependent on parent rock
Topsoil EC range	Non-saline (1-25 mS/m)
Subsoil EC range	Non-saline (1-20 mS/m)
Wind/water erosion hazard	Low (due to stony mantle and rock outcrop)
Inundation/ flooding risk	Nil

Soil Group 304 - Shallow gravel soils

The abundant high gravel content (>50%) in the lower soil profile is a dominant feature of this Soil Group. The gravel content in the upper soil is minimal (<10%) with increased gravel size and abundance with depth. The soil surface is mostly a fine to medium veneer of black or dark ironstone gravel and soil textures are loamy throughout. Thin to medium (10-30 cm) topsoils have textures of fine sandy loam to loam or sandy clay loam overlying medium to thick (30-50 cm) subsoils of loam to clay loam with abundant gravel. Soil depth rarely exceeds 60 cm and the soils overlie densely packed gravels. Soil colour is dark reddish brown to red and the soils are non-calcareous and non-saline.

These soils occur within land systems featuring laterite or ferruginous duricrusts derived from deeply weathered metamorphic rock or cemented alluvium. In some instances gravel soils occur within shallow sand sheets of sandplain land systems. Here the soil surfaces are stone free and gravels in the upper soil are few to common. Soil colour may vary from reddish-brown to reddish-yellow. These soils have abundant ironstone concentrations in the lower subsoil and often overlie gravel and duricrust.

Shallow gravel soils summary

Australian Soil Classification	Leptic Rudosols, Duric Leptic Rudosols, Ferric Clastic Rudosols, Orthic Tenosols and minor Red Kandosols
Soil textures	Weakly grading or uniform profiles of coarse sandy loam, fine sandy loam, loam or occasionally sandy clay loam with common to abundant (10->50%) ironstone gravels throughout the soil, increasing in abundance and size with depth
Land systems	Major soil within the Billygoat, Laterite, Peedamulla and Robe land systems. Minor soil within the Buckshot, Divide and Little Sandy land systems
Land units	Lateritic plain, low rise, plateau, stony hardpan plain, stony plain and occasional sand sheet
Soil colour	Dark red (2.5YR 3/6) to red (10R 4/6) or reddish-yellow (7.5YR 6/6)
Soil depth	Mostly shallow (25-50 cm), occasionally very shallow (<25 cm) or moderately deep (<60 cm)
Pedality/Fabric/ Structure	Apedal, earthy and massive
Soil surface condition	Common to abundant (20->50%) medium to coarse (2-20 mm) ironstone gravel mantle. (Sand sheet stone free with a loose surface)
Substrate	Ironstone gravel or ferruginous duricrust with minor red-brown hardpan or unconsolidated rock
Topsoil/subsoil slaking	Complete
Topsoil/subsoil dispersion	Nil
Topsoil pH range	Mostly acid to neutral (5.1-7.3)
Subsoil pH range	Mostly acid to neutral (5.1-7.7)
Topsoil EC range	Non-saline (1-7 mS/m)
Subsoil EC range	Non-saline (1-11 mS/m)
Wind erosion hazard	Low (due to stony mantle), sand sheet low to moderate
Water erosion hazard	Low (due to stony mantle)
Inundation/ flooding risk	Nil

Soil Group 405 - Red deep sandy duplex soils

These soils have medium (10-30 cm) topsoils of loamy sands to sandy loams overlying medium to thick (30-60 cm) subsoils of clay loams or light to medium clay. The soils are mostly deep (>100 cm). Occasional more shallow (80-100 cm) soils may overlie granite or hardpan. Soil surfaces have common (10-50%) mantles of stone or common to abundant (10->50%) cryptogam crusts. Soil colour is dark reddish brown to dark red and the soils are generally non-calcareous with a neutral to alkaline soil reaction trend. The soils contain few if any coarse fragments. Where occurring on calcrete platforms or within coastal alluvial plains these soils are alkaline and may have calcareous subsoils. Coastal alluvial plains often have highly saline subsoils.

Red deep sandy duplex soils summary

Australian Soil Classification	Red Chromosols, and occasional Red Kandosols, Red Dermosols or Red Sodosols
Soil textures	Loamy sand to sandy loam topsoils over loamy clay or light to medium clay subsoils
Land systems	Major soil within the Anna, Cowra, Cundelbar, Fortescue, Jigalong, Lime, Mallina, Narbung, Paradise, Washplain and Yamerina land systems. Minor soil within the Balfour, Black, Macroy, Prairie, Sherlock and Weelarrana land systems
Land units	Alluvial plain, calcrete plain, drainage zone, ironstone plain, loamy plain, saline plain and stony plain
Soil colour	Topsoils of dark reddish brown (2.5YR 3/4) to dark red (2.5YR 3/6). Subsoils of dark red (2.5YR 3/6) to reddish brown (2.5YR 4/4)
Soil depth	Mostly deep (>100 cm), occasionally moderately deep (>80 cm)
Pedality/Fabric/ Structure	Apedal topsoils and mostly pedal subsoils (textures heavier than clay loam). Earthy or sandy topsoils and pedal subsoils (textures heavier than clay loam). Moderate to strongly structured subsoils
Soil surface condition	Common to abundant (10->50%) stony mantles or common to abundant (10->50%) cryptogam crusting where stony mantle is absent
Substrate	Infrequently granite or hardsetting subsoil pan
Topsoil/subsoil slaking	Partial to complete
Topsoil dispersion	Nil to partial
Subsoil dispersion	Partial to complete
Topsoil pH range	Neutral to alkaline (6.2-8.6)
Subsoil pH range	Weakly to strongly alkaline (7.8-9.7)
Topsoil EC range	Non-saline (1-20 mS/m), moderately saline within saline plains (up to 50 mS/m)
Subsoil EC range	Non-saline (20-230 mS/m), highly saline within saline plains (up to 450 mS/m)
Wind erosion hazard	Low to moderate dependant on stony mantle
Water erosion hazard	Moderate to high dependant on stony mantle and slope
Inundation/ flooding risk	Moderate to high on alluvial plains, saline plains and drainage tracts, otherwise low

Soil Group 406 - Red shallow sandy duplex soils

Red shallow sandy duplex soils have thin to medium (10-20 cm) topsoils of loamy sand to sandy loam overlying medium (10-30 cm) subsoils of sandy clay loam to light clay. Many of these soils have substrates of weathering granite, and less commonly, sandstone, hardpan, calcrete or basalt. The soil profiles contain very few to few coarse fragments, the nature of which is dependent on geology. Soil colour is primarily dark reddish brown to red. Soils reaction is dependent on the location of the landscape unit. Shallow duplex soils occurring on hillslopes or hillcrests trend to weakly acidic or neutral soil reaction. Soils occurring within drainage tracts, alluvial plains or stony plains generally have a neutral soil reaction. Soils occurring within saline plains, calcrete or areas dominated by basalt have alkaline soil reaction trends. Stony mantles are often coarse mixed ironstone and quartz or fine ironstone gravels.

Red shallow sandy duplex soils summary

Australian Soil Classification	Red Chromosols, and minor Red Dermosols and Red Kandosols
Soil textures	Loamy sand to sandy loam topsoils over sandy clay loam to light clay subsoils
Land systems	Major soil within the Cowra, Jurrawarrina, Macroy, Marandoo, Talawana, Tanpool, Taylor, Pindering and Urandy land systems. Minor soil within the Billygoat, Callawa, Ford, Houndstooth, McKay, Platform, Prairie, Sylvania, Rocklea and Urandy land systems
Land units	Alluvial plain, drainage zone, footslope, hillcrest, hillslope, lateritic plain, loamy plain, saline plain and stony plain
Soil colour	Dark reddish brown (2.5YR 3/4) to dark red (2.5YR 3/6)
Soil depth	Shallow (25-50 cm)
Pedality/Fabric/ Structure	Apedal, earthy and massive
Soil surface condition	Common (10-50%) stony mantle with firm to hardsetting surfaces. Cryptogam crusting common (10-50%) where stony mantle is absent
Substrate	Dominantly decomposing granite, occasionally sandstone, red-brown hardpan, calcrete, basalt or ironstone
Topsoil/subsoil slaking	Partial to complete
Topsoil/subsoil dispersion	Nil to partial
Topsoil pH range	Mostly neutral (6.0-7.0) ranging to alkaline (8.0) on basalt areas
Subsoil pH range	Mostly neutral to weakly alkaline (7.0-8.0)
Topsoil EC range	Non-saline (1-25 mS/m)
Subsoil EC range	Non-saline (1-10 mS/m), highly saline within saline plain land units (to 660 mS/m)
Wind erosion hazard	Low (due to stony mantle)
Water erosion hazard	Low (due to stony mantle) to moderate or high (in absence of a stony mantle and dependant on slope)
Inundation/ flooding risk	Low (low to moderately high within drainage tracts)

Soil Group 423 - Red shallow sands

Soil sub-group - Red shallow sands on granite

These soils are uniform textured coarse sands or medium textured sands overlying weathered granite, sandstone or red-brown hardpan at shallow (25-50 cm) depth. Some soils occur over substrates such as conglomerate or quartz and are incorporated into this group. The soils are red to dark red in colour and non-calcareous with a weakly acidic to neutral soil reaction trend. The soils are mostly found within or adjacent to the parent rock resulting in gritty sands. The lower subsoil mostly overlies partially weathered granite rock and coarse fragments of quartz and granite are common throughout the profile. These soils often have a common to abundant (10->50%) stony mantle. Slightly saline soils may infrequently occur at the base of occasional large granite domes or outcrops. Domes and tors of bare rock are included in this soil group.

Red shallow sand on granite soils summary

Australian Soil Classification	Paralithic Leptic Rudosols, Orthic Tenosols, and minor Colluvic Clastic Rudosols, Stratic Rudosols, and Lithic Leptic Rudosols
Soil textures	Sand to clayey coarse sand or sandy loam
Land systems	Major soil within the Boolaloo, Granitic, Laterite, Lochinvar, Macroy, Prairie, Sylvania and Taylor land systems. Minor soil within the Giralia, Nita, River and Uaroo land systems
Land units	Stony plain, gritty plain and tor field. Less commonly on the alluvial plain, drainage zone, footslope, hill and loamy plain land units
Soil colour	Dark reddish brown (2.5YR 3/4) to dark red (2.5YR 3/6)
Soil depth	Mostly very shallow (<25 cm) to shallow (25-50 cm)
Pedality/Fabric/ Structure	Apedal or sandy (occasionally intergrading to earthy). Single grain to massive
Soil surface condition	Common (10-50%) cryptogam crusting or coarse loose sand developed from adjacent bare rock. Infrequent to common (1-50%) stony mantle or rock outcropping
Substrate	Dominantly granite, occasionally sandstone or red-brown hardpan
Topsoil/subsoil slaking	Partial to complete
Topsoil/subsoil dispersion	Nil to partial
Topsoil pH range	Mostly neutral (6.0-7.0) with ranges from 5.1 to 7.8.
Subsoil pH range	Mostly neutral (6.5-8.0) with ranges from 5.1 to 8.8
Topsoil EC range	Non-saline (1-15 mS/m)
Subsoil EC range	Non-saline (1-20 mS/m)
Wind erosion hazard	Low (due to stony mantle and rock outcrop)
Water erosion hazard	Low (due to stony mantle and rock outcrop) to moderate (dependant on slope)
Inundation risk	Low
Flooding risk	Low (on some low-lying plains), otherwise nil

Soil sub-group - Red shallow sands on basalt

These soils are uniform textured fine clayey sands to sandy loams overlying basalt, shale or metamorphic rock at very shallow to shallow depth (<50 cm). The soils are red to dark reddish brown to yellowish red in colour and mostly non-saline. Some of these soils are calcareous and occasionally saline, depending on the geological composition and weathering status of the parent material. Soil reaction is alkaline.

The soils within hill and low rise land units often feature high stone or rock contents throughout the profile and often occur with red shallow loams (522) and shallow red/brown non-cracking clays (622).

Red shallow sand on basalt soils summary

Australian Soil Classification	Red Kandosol, Paralithic Leptic Rudosol, Arenic Orthic Tenosol and Paralithic Supracalcic Calcarosols
Soil textures	Clayey fine sand to fine sandy loam with common to abundant (10->50%) coarse fragments of basalt, chert, shale or mixed metamorphics
Land systems	Major soil within the Robertson land system. Minor soil within the Collier, Newman and Rocklea land systems
Land units	Hill, hillslope, low rise, narrow drainage zone, plateau, ridge and stony plain
Soil colour	Dark reddish brown (2.5YR 3/3) to yellowish red (5YR 4/6)
Soil depth	Very shallow (<25 cm) to shallow (25-50 cm)
Pedality/Fabric/ Structure	Apedal, earthy and massive
Soil surface condition	Mostly abundant (>50%) mixed basalt, shale, ironstone or metamorphic rock mantle. Some areas support minor stone mantles with common (10-50%) cryptogam crusting. Soil surface generally firm
Substrate	Basalt or occasionally shale, chert or metamorphic rock
Topsoil/subsoil slaking	Partial to complete
Topsoil/subsoil dispersion	Nil to partial
Topsoil/subsoil pH range	Mostly alkaline (7.8-9.2)
Topsoil EC range	Non-saline (1-20 mS/m)
Subsoil EC range	Non-saline (1-30 mS/m)
Wind/water erosion hazard	Low (due to stony mantle)
Inundation risk	Nil (low to moderate in drainage zones)
Flooding risk	Nil (low in drainage zones)

Soil sub-group - Red shallow sands on calcrete

These soils are very shallow to shallow (<25-50 cm) uniform textured clayey sands to fine sandy loams overlying calcrete or coastal limestone. They are red to dark red in colour, calcareous throughout, non-saline and have a highly alkaline soil reaction trend. Calcrete fragments may be common within the soil profile and the calcrete or limestone surface mantle is often common to abundant (10->50%). Within some land units the soils are derived from weathered metamorphic parent rock producing calcareous substrates. On the coastal margins, wind derived sand accumulations occur on limestone ridges. These sands are mostly free of stone and soil colour may be red to brownish.

Red shallow sand on calcrete soils summary

Australian Soil Classification	Petrocalcic and Rendic Supracalcic Calcarosols, Hypocalcic Calcarosols and Petrocalcic Leptic Rudosols
Soil textures	Uniform profiles of fine sandy loam or clayey sands grading to sandy loams overlying calcrete or coastal limestone
Land systems	Major soil within the Calcrete and Warri land systems. Minor soil of the Capricorn, Eighty Mile, Giralia and Littoral land systems
Land units	Calcrete platform, calcrete plain, stony plain and ridge
Soil colour	Dark red (2.5YR 3/6) to weak red (2.5YR 4/2)
Soil depth	Very shallow (<25 cm) to shallow (25-50 cm)
Pedality/Fabric/ Structure	Apedal, sandy and single grain
Soil surface condition	Common to abundant (10->50%), coarse (20-60 mm), calcrete fragments with minor outcrops. Coarse fragments very few (<2%) on coastal limestone soils. Common (10-50%) cryptogam crusting
Substrate	Calcrete and coastal limestone
Topsoil/subsoil slaking	Complete
Topsoil/subsoil dispersion	Nil
Topsoil pH range	Alkaline (8.0-9.1)
Subsoil pH range	Alkaline (9.1-9.2)
Topsoil EC range	Non-saline (1-13 mS/m)
Subsoil EC range	Non-saline (7-11 mS/m)
Wind/water erosion hazard	Low (due to stony mantle)
Inundation/ flooding risk	Nil

Soil Group 442 - Calcareous deep sands

This Soil Group comprises of deep white, grey and brown calcareous sands of the coastal margins of the survey area. The sands tend to be white to light grey on the beach and foredune zones, trending to yellowish brown to strong brown away from the beaches. Medium to thick (30-60 cm) topsoils of fine sand overlie thick (>60 cm) subsoils of loamy sand. In some areas the beach and foredunes are coloured greyish to yellowish brown.

The soils are exclusive to the beach, sand sheet, sand bank, dune and inter-dune swale land units. Soils within two kilometres of the beach have sandy textures with a high component of sea-shell grit and are highly calcareous. Away from the coast, the soils show a marginal increase in texture and a reduced amount of shelly coarse fragments. Within some tidal margins calcareous deep sands co-exist amongst deep red/brown non-cracking clays (622).

Calcareous deep sand soils summary

Australian Soil Classification	Shelly, Arenic or Hypersalic Rudosol or occasional Orthic Tenosol
Soil textures	Sand to clayey fine or loamy fine sand. Occasional deep sand over clay (mangrove tidal margins only)
Land systems	Major soil within the Eighty Mile land system. Minor soil within the Littoral and Onslow land systems
Land units	Beach, inter-dune swale, sand bank, sand dune, sand sheet and tidal margins
Soil colour	White or light grey (10YR 7/1) to yellowish brown (10YR 5/2) to strong brown (7.5YR 4/6)
Soil depth	Deep (>100 cm)
Pedality/Fabric/ Structure	Apedal, sandy and single grain (occasionally intergrading to massive inland from the coast)
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	Partial to complete
Topsoil/subsoil dispersion	Nil
Topsoil pH range	Alkaline (>8.9)
Subsoil pH range	Alkaline (>8.2)
Topsoil EC range	Non-saline (1-25 mS/m)
Subsoil EC range	Non-saline (1-17 mS/m), highly saline (>500 mS/m) for mangrove clays
Wind erosion hazard	High
Water erosion hazard	Low (beach and dune land units high)
Inundation risk	Low (tidal flat land unit high)
Flooding risk	Low

Soil Group 445 - Red deep sands

The majority of the red deep sands occur on sandplains, sand sheets and sand banks. These soils are deep and have thin to medium (10-30 cm) topsoil textures of loamy sand overlying thick (>60 cm) subsoils of clayey sand or sandy loam. The soils are dark red to red in colour and have an acidic soil reaction trend. The profiles are mostly free of coarse fragments and the soil surfaces are soft to firm with light cryptogam crusting.

These soils may occur adjacent to, and amongst red sandy earths (Soil Group 463). There may be some inter-grading of these Soil Groups. In many instances the red deep sands and the red sandy earths share similar types of topsoils. Red sandy earths differ in being more clayey with depth.

The red deep sands of the sand dunes are mostly very deep fine sands with no significant clay component. The soils exhibit a loose consistence and contain no coarse fragments. These soils share similar colours to the sandplain soils and generally show a slightly more acidic soil reaction trend.

Some red deep sands may also contain gravels in the lower profile where they are associated with lateritic plains and some duricrusts.

Red deep sand soils summary

Australian Soil Classification	Arenic Rudosols and Arenic Orthic Tenosols with occasional Red Kandosols
Soil textures	Sand to loamy fine sand on dunes. Loamy sand to clayey sand or sandy loam, on sand sheets or sand banks. Sand to clayey sand overlying sandy loam in drainage zones
Land systems	Major soil within the Buckshot, Cadgie, Divide, Dune, Giralia, Gregory, Lime, Little Sandy, Nita and Onslow land systems. Minor soil within the Boolaloo, Three Rivers, Weelarrana and Zebra land systems
Land units	Drainage zone, dune, levee, sand bank and sand sheet
Soil colour	Dark red (2.5YR 3/6, 10R 3/6) rarely to yellowish red (5YR 4/6)
Soil depth	Deep (>100 cm)
Pedality/Fabric/ Structure	Apedal or sandy, single grain occasionally grading to earthy
Soil surface condition	Loose sand on sand dunes. Soft to firm surfaces with infrequent (<10%) cryptogam crusts on sand sheets and sand banks. Firm with light stony mantles or infrequent (<10%) crusting on drainage zone areas
Topsoil/subsoil slaking	Variable (nil to complete)
Topsoil/subsoil dispersion	Nil
Topsoil pH range	Dunes acidic (4.4-6.0), alkaline adjacent to the coast (9.2). Sand sheets and sand banks acidic (5.5-6.5) with some neutral soils (7.0-8.0)
Subsoil pH range	Dunes acidic (4.8-6.5), alkaline adjacent to the coast (9.5). Sand sheets and sand banks acidic to neutral (6.0-7.5) with some neutral soils (7.5 to 8.0)
Topsoil EC range	Non-saline (1-15 mS/m), partially saline adjacent to coast (to 40 mS/m)
Subsoil EC range	Non-saline (1-15 mS/m)
Wind erosion hazard	Moderate to high for sand dunes. Low to moderate for sand sheets and sand banks. Moderate for drainage zones
Water erosion hazard	Low for dunes, sand sheets and banks, moderate for drainage zones
Inundation/ flooding risk	Nil for dunes, sand sheets and banks, low for drainage zones

Soil Group 463 - Red sandy earths

These soils exhibit thin to medium (10-30 cm) topsoils of clayey sand to sandy loam graduating to medium to thick (30-60 cm) subsoils of sandy clay loam or clay loam. Deep versions of this soil are over 1 m deep with moderately deep to shallow versions (80-100 cm) overlying ironstone, quartz or decomposing granite. These soils usually contain very few coarse fragments, are non-saline and show a weakly acidic to neutral soil reaction trend. Soil colour is dark reddish brown to red. Inter-grades of red sandy earths and red deep sands (Soil Group 445) occur within some land units.

Deep versions of this soil mostly occur within the sand sheets and loamy plain land units. More shallow forms of red sandy earths occur adjacent to some drainage areas or within some stony plains. In zones associated with duricrusts or lateritic areas soils will often contain coarse fragments of rock or gravel at a shallow to moderate depth (50-80 cm).

Red sandy earth soils summary

Australian Soil Classification	Red Kandosols and minor Orthic Tenosols and Red Chromosols
Soil textures	Loamy coarse sand to sandy loam overlying sandy loam, sandy clay loam or occasionally clay
Land systems	Major soil within the Cheerawarra, Cundelbar, Giralia, Little Sandy, Macroy, Mallina, Onslow, Uaroo and Zebra land systems. Minor soil within the Paterson land system
Land units	Moderately deep soils within stony plain, gritty surfaced plain and lateritic plain land units. Deep soils within alluvial plain, drainage zone, levee, loamy plain, sand bank and sand sheet land units
Soil colour	Dark reddish brown (2.5YR 3/3) to red (10R 4/6)
Soil depth	Mostly shallow to moderately deep (25 80 cm) to deep (>100 cm)
Pedality/Fabric/ Structure	Apedal to sandy or earthy (with intergrades). Single grain to massive
Soil surface condition	Soft to firm. Minor areas of infrequent (<10%) cryptogam crusting or infrequent to common (1-50%) stony mantle
Substrate	Occasionally decomposing granite, ironstone or quartz
Topsoil slaking	Complete to partial
Subsoil slaking	Complete
Topsoil dispersion	Nil to partial
Subsoil dispersion	Partial
Topsoil pH range	Mostly neutral (6.0-6.5) with ranges from 5.5 to 8.5
Subsoil pH range	Mostly neutral (6.0-7.0) with ranges to 8.5
Topsoil EC range	Non- saline (1-6 mS/m)
Subsoil EC range	Non-saline (1-12 mS/m)
Wind erosion hazard	Low
Water erosion hazard	Low or low to moderate (dependant on slope)
Inundation risk	Low (low to moderate on stony or loamy plains)
Flooding risk	Low (on some low-lying stony or loamy plains), otherwise nil

Soil Group 506 - Red deep loamy duplex soils

These deep (>100 cm) soils have thin to medium (10-30 cm) topsoils of loams or light sandy clay loams overlying thick (>60 cm) subsoils of clay loams or light to medium clay. Soil surfaces have mostly infrequent to common (10-50%) mantles of stone or common to abundant (10->50%) cryptogam crusts in the absence of stony mantles. Soil colour is dark reddish brown to dark red and coarse fragments throughout the profile are very few. Soil reaction is mostly neutral in the topsoil with alkaline to occasionally strongly alkaline subsoils. Some subsoils are calcareous.

Red deep loamy duplex soils summary

Australian Soil Classification	Red Chromosols, with minor Red Kandosols, Red Dermosols and Red Kandosols
Soil textures	Topsoils of loam (fine sandy) to loam (rarely light clay loam) overlying subsoils of light to medium clay
Land systems	Major soil within the Christmas, Marillana, Turee, Washplain and Yamerina land systems. Minor soil within the Balfour, Cane, Jigalong, Paradise, Stuart, Talawana and Tanpool land systems
Land units	Alluvial plain, drainage zone, flood plain, gilgai grove, gilgai stony plain, loamy plain, saline plain and stony plain
Soil colour	Dusky red (10R 3/3) to dark red (2.5YR 3/6) to dark reddish brown (2.5YR 3/4) and reddish brown (5YR 4/4)
Soil depth	Deep (>100 cm).
Pedality/Fabric/ Structure	Earthy or weakly pedal topsoils and mostly moderately to strongly pedal subsoils. Massive topsoils and moderately to strongly structured subsoils
Soil surface condition	Infrequent to common (1-50%) stony mantles, otherwise stone free with abundant (>50%) cryptogam crusting
Topsoil slaking	Complete to partial
Subsoil slaking	Complete
Topsoil/subsoil dispersion	Nil to partial
Topsoil pH range	Neutral to alkaline (6.5-7.5) for Chromosols, Kandosols and Dermosols. Alkaline (8.5-9.0) for Sodosols
Subsoil pH range	Neutral to alkaline (7.0-8.5) for Kandosols and Dermosols. Alkaline (8.5-9.0) for Sodosols and some Chromosols
Topsoil EC range	Low (1-15 mS/m) for Chromosols, Kandosols and Dermosols. Moderate to high (50-100 mS/m) for Sodosols
Subsoil EC range	Low for Chromosols, Kandosols and Dermosols (1-120 mS/m). High (120->400mS/m) for Sodosols
Wind erosion hazard	Low (due to stony mantle or cryptogam crusting)
Water erosion hazard	Low to moderate for units with a stony mantle, otherwise high (especially in drainage zones)
Inundation risk	Moderate within drainage zones, otherwise low
Flooding risk	Moderate to high within drainage zones, otherwise low

Soil Group 509 - Grey deep loamy duplex soils

These soils are mainly restricted to the coastal plains in the far north of the survey area. They are characterised by medium (10-30 cm) loamy topsoils overlying thick (30-60 cm) subsoils of light to heavy clay. Soil colour is black to dark grey in the topsoil and light grey in the subsoil. The soils are deep, highly calcareous and show highly alkaline soil reaction trends. Coarse fragments throughout the soil profile are few. The soil surfaces are mostly stone free with abundant (>50%) cryptogam cover.

Grey deep loamy duplex soils summary

Australian Soil Classification	Grey Kandosols and Grey Dermosols
Soil textures	Loam overlying light to heavy clay
Land systems	Major soil within the Anna and Mannerie land systems. Minor soil within the Eighty Mile land system
Land units	Alluvial plain and drainage depressions
Soil colour	Very dark grey (10YR 3/1, 5Y 3/1) to black (10YR 3/1) or grey (5YR 3/1) topsoils and grey (10YR 6/2) to light grey (5Y 7/1, 5YR 7/1) subsoils
Soil depth	Deep (>100 cm)
Pedality/Fabric/ Structure	Apedal topsoils overlying pedal subsoils. Earthy topsoils overlying rough or smooth ped subsoils. Massive topsoils overlying moderate to strong structured subsoils
Soil surface condition	Common to abundant cryptogam crusting (10->50%), infrequently with light (<10%) stony mantles of limestone
Substrate	Occasionally limestone
Topsoil slaking	Nil to partial
Subsoil slaking	Partial to complete
Topsoil dispersion	Nil to partial
Subsoil dispersion	Nil
Topsoil pH range	Alkaline (7.7-9.0)
Subsoil pH range	Alkaline (8.8-9.5)
Topsoil EC range	Non-saline (1-40 mS/m)
Subsoil EC range	Non-saline (5-50 mS/m)
Wind erosion hazard	Low (with good vegetative cover), otherwise moderate to high
Water erosion hazard	Low
Inundation/ flooding risk	Moderate to high

Soil Group 521 - Calcareous shallow loams

Calcareous shallow loams are shallow (25-50 cm) uniform textured, fine sandy loams to sandy clay loams or clay loams overlying calcrete, weathered basalt or occasionally dolerite. Soil colour varies from dark reddish brown to brown or yellowish red. The soils are highly alkaline and calcareous throughout. Mostly the soils have an abundant stony mantle with stones through much of the profile. Some soil surfaces tend to be soft to firm with infrequent to common (<50%) cryptogam crusts in the absence of abundant stony mantles.

Calcareous shallow loam soils summary

Australian Soil Classification	Calcic, Hypocalcic, Lithocalcic and Supracalcic Calcarosols
Soil textures	Fine sandy loam to sandy loam or clay loam
Land systems	Major soil within the Calcrete, Oakover, Rocklea, Table, Talga, Warri and White Springs land systems. Minor soil within the Charley, Kanjenjie, Paterson and Stuart land systems
Land units	Calcrete platform, calcrete plain, drainage zone, footslope, loamy plain, low rise and stony plain
Soil colour	Dark reddish brown (2.5YR 3/4) to brown (7.5YR 3/4), strong brown (10YR 5/4) and yellowish red (5YR 4/6)
Soil depth	Shallow (25-50 cm)
Pedality/Fabric/ Structure	Apedal, earthy and massive
Soil surface condition	Mostly common (10-50%) stony mantles of calcrete or weathered basalt with infrequent to common (1-50%) cryptogam crusting
Substrate	Calcrete, weathered basalt or dolerite
Topsoil/subsoil slaking	Partial to complete
Topsoil/subsoil dispersion	Nil to partial
Topsoil pH range	Alkaline (occasionally neutral) with ranges from 7.6 to 9.5
Subsoil pH range	Alkaline with ranges from 8.7 to 9.5
Topsoil EC range	Low (1-20 mS/m)
Subsoil EC range	Low (1-120 mS/m, mostly under 50 mS/m)
Wind erosion hazard	Low (due to stony mantle)
Water erosion hazard	Low (due to stony mantle) to moderate (dependant on slope)
Inundation/ flooding risk	Low to moderate on some low-lying plains, otherwise nil

Soil Group 522 - Red shallow loams

These soils are shallow loams often overlying weathered rock. The thin (1-10 cm) topsoils range from sandy loam to clay loam and overlie thin to medium (10-30 cm) subsoils of sandy clay loam or clay loam. Some soils have uniform textures throughout the soil profile. The main type of underlying rock is basalt, shale or schist and less commonly the soils may overlie hardpan or gravel. Many soils have acid to neutral soil reaction trends. Soils occurring on or with dolerite, some shales and basalts tend to be alkaline. The alkaline soils tend to contain carbonates either partly or completely through the soil profile. Soil properties can be variable depending on parent material. The soils are mostly dark reddish brown in colour and non-saline.

Shallow loams on basalt or shale occur on the hillslope, lower footslope, low rise and stony plain land units. Shallow loams on gravel occur on the lateritic plain, lower footslope and stony plain land units. Shallow loams occur on a wide variety of other units, although generally are not dominant.

Red shallow loam soils summary

Australian Soil Classification	Red Kandosols with minor Leptic Rudosols
Soil textures	Sandy loam to clay loam throughout or overlying sandy clay loam to clay loam
Land systems	Major soil within the Billygoat, Callawa, Charley, Collier, Coongimah, Cundelbar, Egerton, Ford, Marandoo, Mosquito, Nanutarra, Newman, Paraburdoo, Pindering, Platform, Rocklea, Ruth, Table and Talga land systems. Minor soil within the Adrian, Augustus, Balfour, Black, Boolgeeda, Calcrete, Capricorn, Macroy, McKay, Nirran, Oakover, Peedamulla, Robe, Robertson, Satirist, Stuart, Turee and Zebra land systems
Land units	Hillcrest, hill slope, laterite plain, low rise, lower footslope, narrow drainage zone, saline plain, stony plain, scree slope and ridge
Soil colour	Dark reddish brown (2.5YR 3/4) to dark red (2.5YR 3/6), occasionally yellowish red (5YR 4/6)
Soil depth	Very shallow (<25 cm) to shallow (25-50 cm)
Pedality/Fabric/ Structure	Apedal, earthy and massive
Soil surface condition	Common to abundant (10->50%) stony mantle or common to abundant (10->50%) cryptogam crusting where stony mantle is absent
Substrate	Basalt, schist, shale, banded ironstone, ironstone gravel or occasionally granite
Topsoil/subsoil slaking	Nil to complete
Topsoil/subsoil dispersion	Nil to partial
Topsoil pH range	Weakly acidic to neutral (5.8-7.5) with some alkaline shale and basalt soils (7.8-8.6)
Subsoil pH range	Mostly neutral to alkaline (6.5-9.0)
Topsoil EC range	High for some shale dominated soils (150->400 mS/m), otherwise low (1-25 mS/m)
Subsoil EC range	High for some shale dominated soils 130-220 mS/m), otherwise low (1-38 mS/m)
Wind erosion hazard	Low (due to stony mantle or cryptogam crusting)
Water erosion hazard	Low (due to stony mantle) to moderate (dependant on slope)
Inundation risk	Moderate on some low-lying plains, otherwise low
Flooding risk	Moderate on some low-lying plains, otherwise low or nil

Soil Group 523 - Red-brown hardpan shallow loams

Red-brown hardpan shallow loams are shallow (25-50 cm) sandy loams to clay loams overlying red-brown hardpan. The soils are mostly uniform in texture, but occasionally have thin to medium (10-30 cm) lighter textured topsoils overlying more clayey, medium to thick (30-60 cm) subsoils. The soils are dark reddish brown in colour, non-calcareous, non-saline and have acidic to neutral soil reaction trends. Soil surfaces are hardsetting with an infrequent to common crytpogam crust and occasional light stony mantles of fine ironstone or mixed ironstone and quartz. The red-brown hardpan is often an almost continuous layer below the subsoil and occurs in the south-east of the survey area.

Red-brown hardpan shallow loam soils summary

Australian Soil Classification	Duric Red Kandosol
Soil textures	Either uniform or slight gradational sandy loams to clay loam
Land systems	Major soil within the Cadgie, Jamindie, Nooingnin, Spearhole, Three Rivers, Wannamunna and Zebra land systems. Minor soil within the Billygoat, Jurrawarrina, Prairie and Turee land systems
Land units	Hardpan plain, inter bank and stony plain
Soil colour	Dark reddish brown (2.5YR 3/4) to dark red (2.5YR 3/6)
Soil depth	Shallow (25-50 cm, occasionally to 60 cm)
Pedality/Fabric/ Structure	Apedal, earthy and massive
Soil surface condition	Hardsetting with infrequent to common (1-50%) cryptogam crusting or a light mantle of fine ironstone or quartz
Substrate	Red-brown siliceous hardpan
Topsoil/subsoil slaking	Complete
Topsoil/subsoil dispersion	Nil to partial
Topsoil pH range	Weakly acidic to neutral (5.6-7.2)
Subsoil pH range	Weakly acidic to neutral (6.0-7.8)
Topsoil EC range	Non-saline (1-13 mS/m)
Subsoil EC range	Non-saline (1-29 mS/m)
Wind erosion hazard	Low
Water erosion hazard	Moderate (dependant on slope, stone mantle and cryptogam cover)
Inundation/ flooding risk	Moderate on low-lying plains

Soil Group 542 - Calcareous loamy earth

This group is comprised of grey calcareous loamy earths and red calcareous loamy earths.

Grey calcareous loamy earths have topsoils of thin to medium (10-30 cm) silty loams or clay loams overlying thick (30-80 cm) subsoils of silty clay loam to light and medium clay. Soil colour is dark grey to black or reddish grey overlying light grey subsoils. These soils often have saline subsoils and are calcareous throughout with strongly alkaline soil reaction trends. Soil surfaces are hardsetting with common to abundant (10->50%) cryptogam crusts. The grey calcareous loamy earths occur with grey deep loamy duplex (509) and grey non-cracking clay (621) soils on the northern coastal plains.

Red calcareous loamy earth soils occur inland as isolated pockets of soil. The soils mostly occur as small components of larger, more dominant soil phases within the stony plain, calcrete plain, alluvial plain and gilgai/clay plain land units. Soil textures are thin to medium (10-30 cm) sandy loams to loams overlying thick (30-80 cm) clay loams or light to medium clay. Soil colour is primarily dark reddish brown. These soils are calcareous throughout, generally non-saline and have alkaline soil reaction trends. Within gilgai and clay plains the soils tend so have slightly saline subsoils. Soil surfaces are firm to hardsetting and have either light stony mantles or common to abundant cryptogam crusts.

Calcareous loamy earth soils summary

Australian Soil Classification	Calcic Pedal, Supracalcic, Hypercalcic and Lithocalcic Calcarosols, or Grey and Red Kandosols or Dermosols
Soil textures	Sandy loams to loams and silty loams overlying clay loams or light to medium clay
Land systems	Grey calcareous loamy earths are a major soil type within the Anna and Mannerie land systems, and a minor soil within the Eighty Mile land system. Red calcareous loamy earths are a major soil type of the Bonney and Calcrete land systems, and a minor soil within the Charley, Cheerawarra, Collier, Kanjenjie, Oakover, Roebuck and Satirist land systems
Land units	Alluvial plain, drainage zone, flood plain, saline plain, sandy bank, stony gilgai plain and stony plain
Soil colour	Grey (10YR 5/1) to black (10YR 2/1) or light grey (10YR 7/2). Dark reddish brown (2.5YR 3/4) to dark red (2.5YR 3/6)
Soil depth	Deep (>100 cm)
Pedality/Fabric/ Structure	Moderate to strongly pedal with smooth or rough peds for grey soils. Red soils have apedal earthy topsoils with massive to moderately structured pedal subsoils
Soil surface condition	Mostly stone free with common to abundant cryptogam (10->50%) crusting for grey soils. Common (10-50%) stony mantles of calcrete or basalt for red soils
Substrate	Calcrete or occasionally weathering basalt on red soils
Topsoil slaking	Nil to complete
Subsoil slaking	Partial to complete
Topsoil/subsoil dispersion	Nil to partial
Topsoil pH range	Alkaline (8.7-9.6)
Subsoil pH range	Alkaline (8.8-9.8)
Topsoil EC range	Non-saline to moderately saline (10-90 mS/m) for grey soils. Non-saline (1-21 mS/m) for red soils
Subsoil EC range	Non-saline to highly saline (35-520 mS/m) for grey soils). Non saline (1-35 mS/m) for red soils and highly saline (>350 mS/m) for clay plain soils
Wind erosion hazard	Low to moderate for cryptogam crusted grey soils, and low (due to stony mantle) for red soils
Water erosion hazard	Low (due to stony mantle or cryptogam crusting) or low to moderate (dependant on slope)
Inundation/ flooding risk	Moderate to high on lower plains, otherwise low

Soil Group 544 - Red loamy earths

Red loamy earths soils exhibit thin to medium (10-30 cm) loam to clay loam topsoils overlying thick (30-60 cm) clay loam to light clay subsoils. The soils are deep but occasionally have substrates of red-brown hardpan, granite or banded ironstone at moderate depth (80-100 cm). The soils are dark reddish brown in colour, non-calcareous, non-saline with neutral to slightly alkaline soil reaction trends. The soils have either common to abundant (10->50%) cryptogam crusts or common to abundant (10->50%) stony mantles. Many soils occurring on footslopes, hillslopes, stony plains and laterite plains, are deep with common to abundant (10->50%) stones or gravels through all or most of the soil profile. Red loamy earth soils occurring in broad drainage zones, groves or open plains tend to be stone free apart from occasional surface mantles.

Red loamy earth soils summary

Australian Soil Classification	Red Kandosols and minor Red Dermosols
Soil textures	Sandy loam to clay loam topsoils over clay loam to light clay subsoils
Land systems	Major soil within the Bonney, Boolgeeda, Cane, Dollar, Fan, Jurrawarrina, Kumina, Lochinvar, Nirran, Paradise, Platform, Pullgarah, River, Spearhole, Urandy, Yamerina and Zebra land systems. Minor soil within the Balfour, Brockman, Buckshot, Cowra, Cundelbar, Hooley, Marandoo, Newman, Nooingnin, Paterson, Peedamulla, Robe, Satirist, Stuart, Wannamunna, Washplain and Wona land systems
Land units	Alluvial plain, drainage zone, flood plain, footslope, grove, hill slope, laterite plain, low rise, ridge, saline plain, stony plain and some sand sheets
Soil colour	Dark reddish brown (2.5YR 3/4) to dark red (2.5YR 3/6)
Soil depth	Deep (>100 cm)
Pedality/Fabric/ Structure	Apedal topsoils with occasional pedal subsoils. Earthy topsoils with earthy or pedal subsoils. Massive topsoils and massive or moderate to strongly pedal subsoils
Soil surface condition	Common to abundant (10->50%) stony mantles, otherwise common to abundant (10->50%) cryptogam crusting
Substrate	Occasionally ironstone gravel, red-brown hardpan, banded ironstone or granite

Topsoil slaking	Nil to complete
Subsoil slaking	Partial to complete
Topsoil/subsoil dispersion	Nil to partial
Topsoil pH range	Mostly neutral (6.0-7.0) with ranges from 5.8 to 8.8
Subsoil pH range	Mostly neutral to slightly alkaline (6.7-8.2) with ranges from 6.5 to 9.0
Topsoil EC range	Mostly non-saline (1-20 mS/m). Moderately saline on some stony, saline or alluvial plains (20-70 mS/m)
Subsoil EC range	Mostly non-saline (1-50 mS/m). Highly saline on some stony, saline or alluvial plains (50-370 mS/m)
Wind erosion hazard	Low
Water erosion hazard	Low (due to stony mantle) to moderate (dependent on slope)
Inundation/ flooding risk	Moderate on some low-lying plains, otherwise low or nil

Soil Group 602 - Self-mulching cracking clays

Self-mulching cracking clay soils are deep (>100cm) with thin to medium (10-30 cm) light, silty or medium clay topsoils. Occasionally the topsoils may include a thin (1-10 cm) layer of clay loam. The thick to very thick (>60 cm) subsoils have textures of medium to heavy clay or, less frequently, light clay. The uppermost layers of these soils exhibit 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. Surface mantles of fine ironstone pebbles are common to abundant. The soil surfaces are generally non-saline with deep sub soils being partially saline. On upland areas large boulders of basalt occur on the soil surface and throughout the soil profile. Cracking clay soils often occur with or adjacent to, deep red/brown non-cracking clay soils (Soil Group 622) and are susceptible to gullying where found on undulating plains.

Self-mulching cracking clay soils summary

Australian Soil Classification	Crusty, Epipedal and Massive Vertosols, Red Self-mulching Vertosols and Red Kandosols
Soil textures	Silty clay loam to light or medium clay topsoils overlying light to heavy clay subsoils
Land systems	Major soil within the Balfour, Brockman, Cane, Christmas, Elimunna, Hooley, Horseflat, Kanjenjie, Pullgarah, Pyramid, Sherlock and Wona land systems. Minor soil within the Cane, Fortescue, Jurrawarrina, Marillana, Paraburdoo, Satirist, Turee, Wannamunna, Warri, White Springs and Yamerina land systems
Land units	Calcareous stony plain, drainage zone, floodplain, saline plain, alluvial plain, swamp, gilgai plain, gilgai mosaic plain
Soil colour	Dark reddish brown (2.5YR 3/4) to red (10R 4/6) or dark red (10R 3/6)
Soil depth	Deep (>100 cm)
Pedality/Fabric/ Structure	Apedal earthy and massive, or moderately to strongly pedal topsoils overlying strongly pedal subsoils
Soil surface condition	Cracking or self-mulching (crumbly) topsoils with infrequent to common (1-50%) stony mantles of quartz, calcrete, ironstone or basalt. Common to abundant (10->50%) cryptogam crusting where stony mantle is absent
Substrate	Infrequently calcrete or basalt
Topsoil/subsoil slaking	Partial to complete
Topsoil/subsoil dispersion	Variable (nil to complete)
Topsoil pH range	Alkaline (7.5-9.5)
Subsoil pH range	Alkaline (8.0-9.9)
Topsoil EC range	Non-saline (1-31 mS/m), infrequently low to moderately saline (50-80 mS/m)
Subsoil EC range	Non-saline (1-64 mS/m), infrequently highly saline (80-400 mS/m). Highly saline for saline plains (>850 mS/m)
Wind erosion hazard	Low
Water erosion hazard	Moderate to high for drainage zones otherwise, low
Inundation/ flooding risk	Moderate to high for drainage plains, otherwise low to moderate

Soil Group 621 - Grey non-cracking clays

These soils are mainly restricted to the coastal plains in the far north of the survey area and generally occur with or adjacent to, grey deep loamy duplex soils (509) and calcareous loamy earths (542). Grey clays are characterised by thin to medium (10-30 cm) topsoils of light clay or silty light to medium clay overlying thick to very thick (>60 cm) subsoils of light to heavy clay. The soils are mostly deep (>100 cm), yet moderate depth (<80 cm) versions overlying calcrete or limestone may occur. Soil colour is dark grey and dark greyish brown to light grey. These soils are calcareous throughout out and have an alkaline soil reaction trend. Soil surfaces are generally stone free with common to abundant cryptogam crusting.

Grey non-cracking clay soils summary

Australian Soil Classification	Grey Kandosol
Soil textures	Light clay to silty light clay or medium clay over light to heavy clay
Land systems	Minor soil within the Anna and Roebuck land systems
Land units	Alluvial plain and drainage zone
Soil colour	Dark grey (10YR 4/1) and dark greyish brown (10YR 4/2) to light grey (10YR 7/2)
Soil depth	Mostly deep (>100 cm) or occasionally moderate (>80 cm)
Pedality/Fabric/ Structure	Apedal, earthy, massive topsoils and weak to moderately pedal subsoils with smooth peds

Soil surface condition	Stone free with abundant (>50%) cryptogam crusting
Substrate	Occasionally calcrete or limestone
Topsoil slaking	Nil to partial
Subsoil slaking	Complete
Topsoil dispersion	Nil to partial
Subsoil dispersion	Partial
Topsoil pH range	Alkaline (8.8-9.6)
Subsoil pH range	Alkaline (8.9-9.3)
Topsoil EC range	Non-saline to moderately saline (1-53 mS/m)
Subsoil EC range	Non-saline (9-32 mS/m)
Wind erosion hazard	Moderate if vegetation lost, otherwise low
Water erosion hazard	Low
Inundation/ flooding risk	Moderate to high

Soil Group 622 - Red/brown non-cracking clays

Shallow (<50 cm) red/brown non-cracking clays have thin clay loam or light clay topsoils overlying subsoils of light clay or are uniformly clay throughout. These soils occur on stony plains, calcrete platforms, narrow drainage zones, hills, footslopes and low rises. Some of these soils overlie basalt, shale, schist or calcrete and may be locally saline dependent on the weathering status of the parent rock. The soils are generally alkaline with slightly calcareous subsoils. Soil colour is dark reddish brown to red or dark yellowish brown. Within areas of significant relief these soils have stony mantles and some rock outcrop. Shallow clay soils are generally non-saline. Red shallow loams (522) often occur adjacent to the clay soils.

Deep red/brown non-cracking clays occur on open broad or flat land units of alluvial plains, claypans, major drainage zones, gilgai plains, saline plains and swamps with. These soils are mostly deep (>100 cm) with thin to medium (10-30 cm) topsoil textures of mainly clay loam to light or medium clay. The thick subsoils (30-80 cm) have light to heavy clay textures. The subsoils are mostly well structured and overlain by massive topsoils. Some of the red/brown clays occurring within gilgai plains intergrade with the self-mulching cracking clays (602). Deep clays associated with cracking clays in upland areas, such as the Wona land system contain abundant basalt rocks on the soil surface and throughout the soil profile.

Soil colours range from dark reddish brown to yellowish brown. Soil salinity is variable and is dependent on land unit location, however many deep clays tend to have weakly saline subsoils. Deep saline clays do occur within some alluvial plain, gilgai plain, stony plain and drainage zone land units within the Cheerawarra, Hooley, Horseflat and Peedamulla land systems.

Red/brown non-cracking clay soils summary

Australian Soil Classification	Red Dermosols, Red Kandosols, Hypocalcic and Calcic Calcarosols
Soil textures	Clay loam to light or medium clay topsoils over light to heavy clay subsoils
Land systems	Major soil within the Balfour, Brockman, Cane, Cheerawarra, Christmas, Coolibah, Elimunna, Fortescue, Hooley, Horseflat, Houndstooth, Jigalong, Marillana, Marsh, Onslow, Paraburdoo, Pullgarah, Pyramid, River, Sherlock, Stuart, Weelarrana, White Springs and Wona land systems. Minor soil within the Bonney, Collier, Jurrawarrina, Kanjenjie, Laterite, Mosquito, Oakover, Paradise, Peedamulla, Roebuck, Satirist, Tanpool and Warri land systems
Land units	Alluvial plain, calcareous stony plain, calcrete platform, claypan, drainage zone, hill, hill footslope, gilgaied grove, gilgai plain, gilgaied low rise, mosaic plain, saline plain, stony plain and swamp
Soil colour	Dark reddish brown (2.5YR 3/4) to red (2.5YR 4/8) or dark yellowish brown (10YR 3/6)
Soil depth	Deep (>100 cm), shallow (<50 cm) within hill areas
Pedality/Fabric/ Structure	Shallow clays are mostly apedal and massive. Deep clays have apedal, earthy, massive topsoils and mostly moderately to strongly pedal subsoils, or mostly massive topsoils and structured subsoils
Soil surface condition	Mostly common to abundant (10->50%) stony mantle or common (10-50%) cryptogam crusting where stony mantle is absent
Substrate	Basalt, calcrete, shale, ironstone or gravel underlying shallow soils
Topsoil slaking	Partial to complete
Subsoil slaking	Mostly complete
Topsoil dispersion	Nil to partial
Subsoil dispersion	Nil to complete
Topsoil pH range	Mostly neutral to alkaline (7.0-9.5)
Subsoil pH range	Mostly alkaline (7.5-9.5)
Topsoil EC range	Moderately to highly saline (40-280 mS/m) on some alluvial, stony or drainage plains, otherwise non-saline (1-15 mS/m)
Subsoil EC range	Non-saline to highly saline (40-280 mS/m) on some alluvial, stony or drainage plains, otherwise non-saline (1-40 mS/m)
Wind erosion hazard	Low (high for soils with saline soft puffy surfaces)
Water erosion hazard	Moderate to high on alluvial plains, gently sloping gilgai plains, sloping stony plains and some footslopes, otherwise low to moderate dependent on slope
Inundation/ flooding risk	High on low-lying areas such as alluvial plains and drainage zones, otherwise low

Soil Group 705 - River bed soils

Most of the soils within this group are either poorly developed or occur as a minor component in relation to the complete survey area. The poorly developed soils are juvenile or recent alluvial deposits associated with active drainage channels, levees, or flood plains of major and minor creek or river systems. These soils exhibit sediment layers of coarse loose sand, clayey sand, silty sand and silty clay.

Layers containing water-worn rocks, boulders and pebbles often occur through the profile. Soil depth is mostly variable and dependent on the location within the landscape catena. Where soil depth is less than one metre the soil is often underlain by rock, calcrete or occasionally red-brown hardpan. These soils may also occur in drainage foci or other low-lying areas receiving major run-on.

The juvenile soils are mostly weakly acidic to neutral (pH 6.0-7.5) and non-saline although saline juvenile soils may occur as localised areas within or adjacent to some drainage foci and the coast. Soil colour varies from dark red (2.5YR 3/6) to strong brown (5YR 5/6).

Soil and land attributes and land capability

Land units within land systems have unique properties such as soil type and slope, which influence the type and intensity of use that can be applied to the unit. These properties are rated to assist in determining land capability. Land capability is the ability of the land to support a particular land use, without permanent damage (Wells and King 1989). It is determined by considering a combination of the land unit attributes and the land use under consideration.

Four risk factors can be considered to be the main limiting factors relating to the use of land for pastoralism and other purposes. These are the susceptibility of the particular land unit to:

- wind erosion
- water erosion
- flooding
- inundation.

Many other attributes can be applied to soil types and land units such as water repellence of the topsoil, soil permeability or available water storage. These other attributes may also need to be assessed for the consideration of any other intended land uses.

Susceptibility to selected risk factors

Risk classes of the susceptibility of land units to wind erosion, water erosion, flooding and inundation are presented in Tables 2, 3, 4 and 5. The risk classes listed in these tables were adapted from those developed for land capability by Overheu *et.al.* (1993).

Susceptibility ignores land use and land management factors. Inherent properties of the land unit such as slope, topsoil texture, surface mantle (including rock outcrop) and condition of the soil surface are considered.

Wind erosion risk (Wi)

Wind erosion risk is defined as the susceptibility of a parcel of land to erosion caused by wind. Wind erosion is a process in which soil is detached and transported by wind. Table 2 shows wind erosion risk classes.

Table 2. Classes of wind erosion risk

Risk class	Likely situation
High	Soils with loose or soft surfaces and light to medium topsoil textures exhibiting low moisture retention*. Soils with <25% stony mantles or cryptogamic crusts. Highly saline soils with soft or puffy surfaces.
Moderate	Soils with firm surfaces and light to medium topsoil textures exhibiting moderate moisture retention. Soils with 25-50% stony mantles or cryptogamic crusts. Soils with common gravel or coarse rock fragments in the topsoil.
Low	Soils with hardsetting surfaces and heavy topsoil textures exhibiting moderate or high moisture retention. Soils with 50-90% stony mantles or cryptogamic crusts.Soils with abundant gravel or coarse rock fragments in the topsoil.
Nil	Soils with seasonal, semi-permanent or permanent waterlogging for >3 months a year.

*Low moisture retention suggests the topsoil will remain moist for less than one week after rain. Moderate moisture retention suggests the topsoil will remain moist for one to three weeks after rain. High moisture retention suggests the topsoil will remain moist for more than three weeks after rain.

Water erosion risk (Wa)

Water erosion risk is defined as the susceptibility of a parcel of land to erosion caused by water. Water erosion is a process in which soil is detached from the land and transported by the action of rainfall, run-off or seepage. Sheet, gully and rill erosion are the most common. Table 3 shows water erosion risk classes.

Table 3. Classes of water erosion risk

Risk class	Likely situation
High	Land surfaces without protective surface mantles or cryptogamic crusts that are subject to high flood risk. Sloping land surfaces with light or medium textured topsoils with minimal (<25%) surface mantles or cryptogamic crusts.
Moderate	Land surfaces without protective stony mantles or cryptogamic crusts that are subject to moderate flood risk. Sloping land surfaces with some soil protection afforded by moderate (25-50%) surface mantles orcryptogamic crusts.
Low	Land surfaces without protective stony mantles or cryptogamic crusts that are subject to low flood risk. Level or sloping land surfaces with soil protection afforded by abundant (50-90%) stony mantles or cryptogamic crusts. Level plains with deep sand soils.
Nil	Surfaces not subject to any flood risk. Land surfaces protected by very abundant (>90%) surface mantles, cryptogamic crusts or rock outcrop. Surfaces in sink or accumulation zones (e.g. lakes, playas and claypans).

Flooding risk (Fl)

Flooding is the temporary covering of land by water from overflowing creeks or rivers and run-off from adjacent slopes or plains. The water erosion risk is directly proportional to the intensity and velocity of overland flow. Table 4 shows flooding risk classes.

Table 4. Classes of flooding risk

Risk class	Likely situation
High	Land surfaces covered in water due to sheet flow or catchment overflow at a frequency of at least once per year.
Moderate	Land surfaces covered in water due to sheet flow or catchment drainage overflow at a frequency of one in two years, to one in five years.
Low	Land surfaces covered in water due to sheet flow at a frequency of one in five years to one in twenty (or more) years.
Nil	No flooding frequency.

Inundation risk (In)

Inundation is the temporary covering of land by water from overflowing creeks or rivers and run-off from adjacent slopes or plains, which involves very little movement, or ponding of water over the land surface. This in turn relates to the drainage qualities of the land surface and the soil type. Table 5 shows inundation risk classes.

Table 5. Classes of inundation risk

Risk class	Likely situation
High	Water is removed very slowly in relation to supply; soils are inundated for longer than several weeks with seasonal, semi-permanent or permanent waterlogging for over three months a year.
Moderate	Water is removed only slowly in relation to supply. Soils are inundated for up to 12 hours or may be waterlogged for more than one day to several weeks.
Low	Water is removed readily in relation to supply; soils are inundated for up to 3 hours or waterlogged for up to one day.
Nil	Water is removed rapidly in relation to supply; soils are never inundated or waterlogged.

Summary

Table 6 summarises the risk factors for the main land types/units, soil types and site types within the survey area. The site types are listed in abbreviated code form. The site types are described in detail in the Site type ecology chapter.

Table 6. Risk assessment summary for land types/units, soil types and site types

Land types/units	Main soil types	Dominant site type(s)*	Wi	Risk factors** Wa	Fl	In
Ranges, hills and low rises						
Hills, ridges and slopes	Stony soil (203)	HSPG	L	L	N	N
	Red shallow loam (522)	HSPG	L	L	N	N
Low rises	Red shallow sandy duplex (406)	HSPG	L	L-M	N	N
	Red shallow loam (522)	HSPG	L	L	N	N
	Calcareous shallow loam (521)	HSPG	L	L	N	N
	Shallow gravel (304)	HSPG	L	L	N	N
	Red shallow sand (423)	PAGS, HSPG	L	L	N	N
	Stony soil (203)	HSPG, SAES	L	L	N	N
Plateaux and breakaways	Stony soil (203)	HSPG	L	L	N	N
	Shallow gravel (304)	PHSG	L	L	N	N
Tor fields and rock outcrop	Stony soil (203)	HSPG	L	L	N	N
	Red shallow sand (423)	HSPG	L	L	N	N
Upper and lower footslopes, scree slopes and alluvial fans	Red shallow loam (522)	HSPG	L	L	N	N
	Stony soil (203)	HSPG	L	L	N	N
	Calcareous shallow loam (521)	HSPG	L-M	L	N	N
Plains; calcrete, lateritic, stony and loamy						
Calcrete plains and stony calcrete plains	Calcareous shallow loam (521)	CASG, CACS	L	L	L	L
Calcrete platforms	Calcareous shallow loam (521)	CASG, CACS	L	L	L	L
Hardpan plains and stony hardpan plains	Red-brown hardpan shallow loam (523)	HPMS, PSMS	L	L	L	L
Lateritic stony plains	Red-brown hardpan shallow loam (523)	HPMS, PSMS	L	L	N	N
	Red loamy earth (544)	PSSG	L	L	N	N
Lateritic plains	Red loamy earth (544)	PSSG, PMSS	L	L	L	N
	Red sandy earth (463)	PSSG	L	L	L	N
	Red deep sandy duplex (405)	PHSG, PMSS	L	L-M	L	N
	Shallow gravel (304)	PSSG, LHAS	L	L	L	N
Gritty-surfaced plains	Red shallow sand (423)	PSSG, PHSG	L	L	L	N
Loamy plains	Red loamy earth (544)	PSSG, PHSG	L	L-M	L-M	L
	Red sandy earth (463)	PSSG, PHSG	L	L	L	N
	Red deep sandy duplex (405)	PHSG, PSSG	L	L-M	L	N
Stony plains	Red shallow loams (522)	PHSG, PSSG	L	L	L-M	L-M
	Red loamy earth (544)	PMSS, PHSG	L	L	L	L
	Red/brown non-cracking clay (622)	PHSG	L	L	L	L
	Calcareous shallow loam (521)	PHSG, CASG	L	L	L	L
	Red shallow sand (423)	PHSG, PSSG	L	L	L	L
	Red shallow sandy duplex (406)	PHSG, PMSS	L	L-M	L	L

Table 6. continued...

Land types/units	Main soil types	Dominant site type(s)*	Risk factors**			
			Wi	Wa	Fl	In
Sandplains and dunes						
Sand sheets	Red deep sand (445)	SSSG, SHSG	L-H	L	N	N
	Red sandy earth (463)	SSSG, SHSG	L	L	N	N
Sand dunes	Red deep sand (423)	SSSG, SHSG	M-H	L	N	N
	Calcareous deep sand (445)	PSSG, CDSG	M-H	L	N	N
Sand banks	Red deep sand (423)	SSSG, SHSG	L-M	L	N	N
	Red sandy earth (463)	SSSG, SHSG	L	L	N	N
Sand sheets with ironstone gravel	Red deep sand (445)	PHSG, SAES	L	L	N	N
	Red sandy earth (463)	PHSG, SAES	L	L	N	N
Alluvial plains and drainage zones						
Alluvial and stony alluvial plains	Red deep sandy duplex (405)	AHSG, ASSG	L	M-H	M-H	M-H
	Red loamy earth (544)	ASSG, AHSG	L	L-M	L-M	L
	Red/brown non-cracking clay (622)	ASSG	L-H	L-H	L-H	L-H
	Red sandy earth (463)	ASSG, PSSG	L	L	L	L
	Red deep loamy duplex (506)	AHSG, ASSG	L-M	L-H	L-H	L-H
	Grey non-cracking clay (621)	APBG	L-M	L	M-H	M-H
	Grey deep loamy duplex (509)	APBG	L	L	M-H	M-H
Drainage foci	Self-mulching cracking clay (602)	GMGW	L	L	L	L
	Grey deep loamy duplex (509)	DMES	L	L	L-M	L-M
	Red loamy earth (544)	GMUW	L	L	L-M	L-M
Claypans	Red/brown non-cracking clay (622)	APTG	L	L	M-H	M-H
Swamps	Red/brown non-cracking clay (622)	DEGW	L	L	M-H	M-H
	Self-mulching cracking clay (602)	DEGW	L	L	L-M	L-M
	Grey deep loamy duplex (509)	DMES	L	L	M-H	M-H
Floodplains	Red/brown non-cracking clay (622)	DEGW, APTG	L	M-H	L-M	L-M
	Red loamy earth (544)	APBG, APTG	L	M	L-M	L-M
	Red deep loamy duplex (506)	PCGS	L	M	L-M	L-H
Gilgai and stony gilgai plains	Self-mulching cracking clay (602)	ARPG, APTG	L	L-M	L	L
	Red/brown non-cracking clay (622)	APTG	L	L-M	L-M	L-M
Gilgai/clay mosaic plains	Red/brown non-cracking clay (622)	PHSG, AHSG	L	L	L	L
Groves	Red loamy earth (544)	DAHW, GMGW	L	L	L	L
Groves with gilgai	Red/brown non-cracking clay (622)	GMGW	L	L	L	L
	Red deep loamy duplex (506)	GMGW	L	L	L	L
Major drainage channels	River bed soil (705)	DEGW	L	H	L-M	L-M
Minor drainage channels	Red loamy earth (544)	DAGW, DEGW	L	L-M	L-M	L-M
	Red sandy earth (463)	DEGW, APTG	L	M-H	L-M	L-M

Table 6. continued...

Land types/units	Main soil types	Dominant site type(s)*	Risk factors**			
			Wi	Wa	Fl	In
Drainage zones	Red loamy earth (544)	DEGW, DAHW	L	L-M	L-M	L-M
	Red sandy earth (463)	DEGW, ASSG	L	L	L	L
	Red deep sandy duplex (405)	ASSG, DEGW	L-M	M-H	L-H	L-H
	Red/brown non-cracking clay (622)	APTG, DAHW	L-M	L	L-M	L-M
	River bed soil (705)	DAHW, DEGW	L	H	L-M	L-M
River bank levees	Red deep sand (423)	APBG, DAHW	L	M-H	M-H	L-M
	River bed soil (705)	AETG, DEGW	L	H	L-M	L-M
Saline and stony saline plains	Red/brown non-cracking clay (622)	PSPS	L-M	L	L-M	L-M
	Calcareous loamy earth (542)	APTG	L	L	M-H	M-H
	Red deep loamy duplex (506)	PSPS, ASSG	L-M	L-M	L-M	L-H
	Self-mulching cracking clay (602)	PMGS	L-M	L-H	L	L
Coastal zones						
Beaches and dunes	Calcareous deep sand (445)	CDSG	H	L	L-H	L-H
Tidal flats	Tidal soils (104)	PSPS	L	L	L-H	L-H

*Dominant site type codes: see Site type ecology chapter

**Risk factors:

Wi - Wind erosion risk
Wa - Water erosion risk
Fl - Flooding risk
In - Inundation risk

where N - Nil; L - Low; M - Moderate; H - High.

Soil erosion in the survey area

Accelerated soil erosion is localised and restricted to a small number of susceptible land surfaces and soil types. Some form of soil erosion was recorded on 6.5% of the traverse assessments in the survey area (see Resource condition chapter). Of those assessments, 5.3% indicated slight, minor or moderate erosion (up to 50% of the surface affected). About 1.2% of assessments showed severe or extreme erosion (>50% of the surface affected). The most common form of erosion was sheeting, scalding and rilling by water.

The land units most affected by erosion are those associated with broad drainage zones. Areas of erosion, large enough to be mapped, occurred in the south eastern Pilbara within the alluvial plains or floodplains of the Brockman, Coolibah, Jurrawarrina, Jigalong and Turee land systems. Areas of alluvial drainage tracts within the Christmas land system were also eroded. In the western and north eastern areas of the Pilbara erosion was noted on the alluvial plains and floodplains of the Horseflat, Cane, Paradise and Yamerina land systems. At the coast, some parts of the Littoral and Eighty Mile land systems showed erosion mainly in the form of blow-out sand dunes. Near the coast, some soil erosion was found on the Cheerawarra land system.

Stony soils (203), calcareous stony soils (202), calcareous shallow loams (521) and most red shallow loams (522) are generally not prone to soil erosion due to the high amounts of gravel or rock within the soil profile or the protective stony mantle on the surface. Some red shallow sands (423) and some shallow gravel soils (304) also may have stony mantles protecting the soil surface from wind and water erosion.

Shallow gravel soils (304) and some red shallow sands (423) may be prone to water erosion when occurring in undulating areas of the landscape.

Calcareous deep sands (442) occurring adjacent to the coastal areas are prone to wind erosion and are most at risk after vegetation depletion.

Red deep sands (445) and red sandy earths (463) mostly occur as sandplains, sand sheets, sand dunes or loamy plains. These soils are generally stable but may be subject to wind erosion if vegetation is depleted.

Duplex soils with little or no stone cover are most sensitive to water and wind erosion. Significant vegetation loss may lead to the breakdown of the crusted surfaces, exposing the soils to erosion. The duplex soils with sandy surfaces (405 and 406) are more prone to erosion that the loamy surfaced duplex types (506), due to the softer nature of the topsoil. These areas often support desirable forage for grazing animals and as such may have been subject to unrealistic grazing pressures in the past, resulting in degraded soils. Generally duplex soils with abundant stony mantles are less prone to erosion provided the mantle remains intact.

Camel tracks mark the exposed subsoil on a previously highly productive saltbush plain. Such sites have texture contrast (duplex) soils with surface layers which readily erode to expose clayey subsoil, if vegetative cover is lost.

Red/brown shallow hardpan loams (523) occurring on hardpan plains tend to show some erosion features. These soils often support sparse vegetation cover and are subject to overland sheet water flow.

Red loamy earths (544) show minimal minor erosion where there is some gradual slope to the landscape. Within depressions or sink zones these soils are stable.

Red/brown non-cracking clay soils (622) within broad drainage tracts, alluvial or large open plains may be subject to erosion after significant vegetation loss. Self-mulching cracking clay soils (602) tend to loose soil structure after major, long-term vegetation depletion.

Tidal soils (104) are not prone to erosion.

River bed soils (705) are restricted to river and stream channels and are inherently unstable.

Many soil surfaces are protected from erosion by inherent soil characteristics such as stone mantles, well-developed cryptogam crusts, hardsetting surfaces or high infiltration rates.

Some soils are protected by landscape attributes such as very gentle slopes resulting in low energy water flows. Many soils are protected by dense vegetation cover particular on loamy plains and sandplains. Disturbance to any of these factors is likely to result in accelerated erosion. In particular, the loss of vegetative cover renders soil surfaces more prone to the effects of wind and water. Soils that support vegetation types that are highly preferred by grazing animals are at risk of eroding unless control of grazing is adequate to prevent loss of vegetation.

Rangeland regeneration

Management of areas with soil erosion needs to be part of a process that includes whole property or catchment management. Areas with minimal erosion may recover in time by manipulating grazing intensity (downwards), through fencing and water availability. Areas with moderate to severe degradation and/or erosion will require more intensive regeneration methods and recovery may take many years.

Soils are most vulnerable to erosion under continuous grazing, and where total grazing pressure from livestock, feral animals and native animals is high. Removal of grazing pressure on a regular basis during seedling establishment will often provide sufficient spelling to encourage plant growth.

Sandy duplex soils (405 and 406) are highly susceptible to erosion after initial soil surface crust decline. Below the topsoil, the clayey subsoil is less fertile and usually more saline. If exposed through erosion, the subsoil may become scalded and sealed, with greatly reduced water infiltration rates and increased surface salinity. This creates a harsh environment for seedling establishment and survival. Similarly, the topsoils of loamy duplexes (506), loamy earths (542 and 544) and clayey soils (602, 621 and 622) have lighter textures than the subsoils and similar scalding can occur as a result of erosion after significant vegetation loss.

Soils with partial topsoil loss will most likely remain viable for seedling establishment providing there is no grazing pressure. Spelling from grazing on a regular basis is the most cost-effective method to regenerate such areas.

Highly saline soils often have very soft puffy soil surfaces with a very thin fragile crust. Immediately under the surface crust, salt grains derived from the subsoil via capillary action may be visible. It is not recommended to cultivate these soils with earth moving machinery, as the soils will be exposed to more erosive forces.

Regeneration of degraded land may require cultivation using heavy earth moving machinery and seeding or planting suitable native or introduced plant species.

Some soils with completely eroded topsoils may have saline subsoils with hard, scalded and sealed surfaces. These soils tend to be salt free on the surface, but are often saline within a depth of 10-20 cm. To encourage plant establishment on these soils, the prime principle is to reduce the high salinity just below the soil surface.

The use of earth moving equipment to create large water holding ponds will often reduce the surface salinity as the water carries some of the salts to the lower soil profile. However, ponding banks cannot be placed in areas of moderate or intense overland water flow, as breaches of the banks can occur and possibly create further erosion. The construction of ponding banks and ponds is a high cost option for regeneration.

Fencing and shutting off artificial waters to exclude, as much as possible, all grazing animals are the first requirements towards re-establishing vegetation. Suitable niches for seed and adequate soil moisture for plant establishment and growth are the most important factors for successful regeneration. Recovery may require the use of expensive techniques involving earth works and reseeding/planting of native species, and treatment may need to be repeated over several years.

For more details on methods of regenerating degraded rangelands see Ward (1990), Williams and Shepherd (1991), Payne and Tille (1992), Scholz (1995) and Addison (1997).

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Vegetation

A.M.E. Van Vreeswyk

This chapter describes aspects of the vegetation in the survey area. The first section provides a review of previous work undertaken by Beard (1975), then the findings from the current survey are presented. A summary listing of major plant families and genera provides the taxonomic context for subsequent description of the vegetation, first according to plant forms and second according to vegetation formations. Regional vegetation patterns across the survey area are then considered. Flora conservation is the final topic addressed.

This chapter focuses on describing the plants and the communities they comprise. The Site type ecology chapter looks in more detail at plant community ecology including aspects of land use impacts and conservation. Site types at plant community/landform/soil type scale are described.

Regional overview

Biogeographic regions

The majority of the survey area (79%) lies in the Pilbara Biogeographic Region as classified in the Interim Biogeographic Regionalisation of Australia (Thackway and Cresswell 1995) and its sub-regions Fortescue, Hamersley, Chichester and Roebourne (see Figure 1). In the north-east small parts of the survey area fall into the Dampierland Region (Pindanland sub-region) and the Great Sandy Desert Region (McLarty and McKay sub-regions). In the south-east small parts fall into the Little Sandy Desert Region (Trainor sub-region) and the Gascoyne Region (Augustus sub-region). In the far west a very small portion on the coast falls into the Carnarvon Region (Cape Range sub-region).

The Pilbara Biogeographic Region corresponds with the Fortescue Botanical District of the Eremaean Province (Beard 1990).

Vegetation formations

Beard has mapped the major structural vegetation formations within Western Australia at 1:1,000,000. The survey area falls on the Pilbara map sheet (Beard 1975). Figure 2 shows a generalisation of the vegetation formations mapped within the survey area.

Pilbara Biogeographic Region

In the main central area of the Pilbara Biogeographic Region (Chichester sub-region) the predominant vegetation formations are tree and shrub steppe (hummock grassland) communities with *Eucalyptus* trees, *Acacia* shrubs and *Triodia pungens* and *T. wiseana* hummock grasses. Mulga (*Acacia aneura*) communities occur in valleys and short bunch grasslands occur on alluvial plains. Soils are primarily hard alkaline red soils on plains and pediments, and shallow and skeletal soils on the ranges. To the north of the Fortescue valley shrub steppe with kanji bush (*Acacia inaequilatera*) on granite plains, and tree steppe with snappy gum (*Eucalyptus leucophloia*) on ranges are the dominant vegetation formations. Around Warrawagine homestead where the Nullagine and Oakover Rivers converge into the De Grey River there is a large area of short bunch grassland.

In the Roebourne sub-region along the coast the river deltas support a mosaic unit of bunch grasslands mixed with

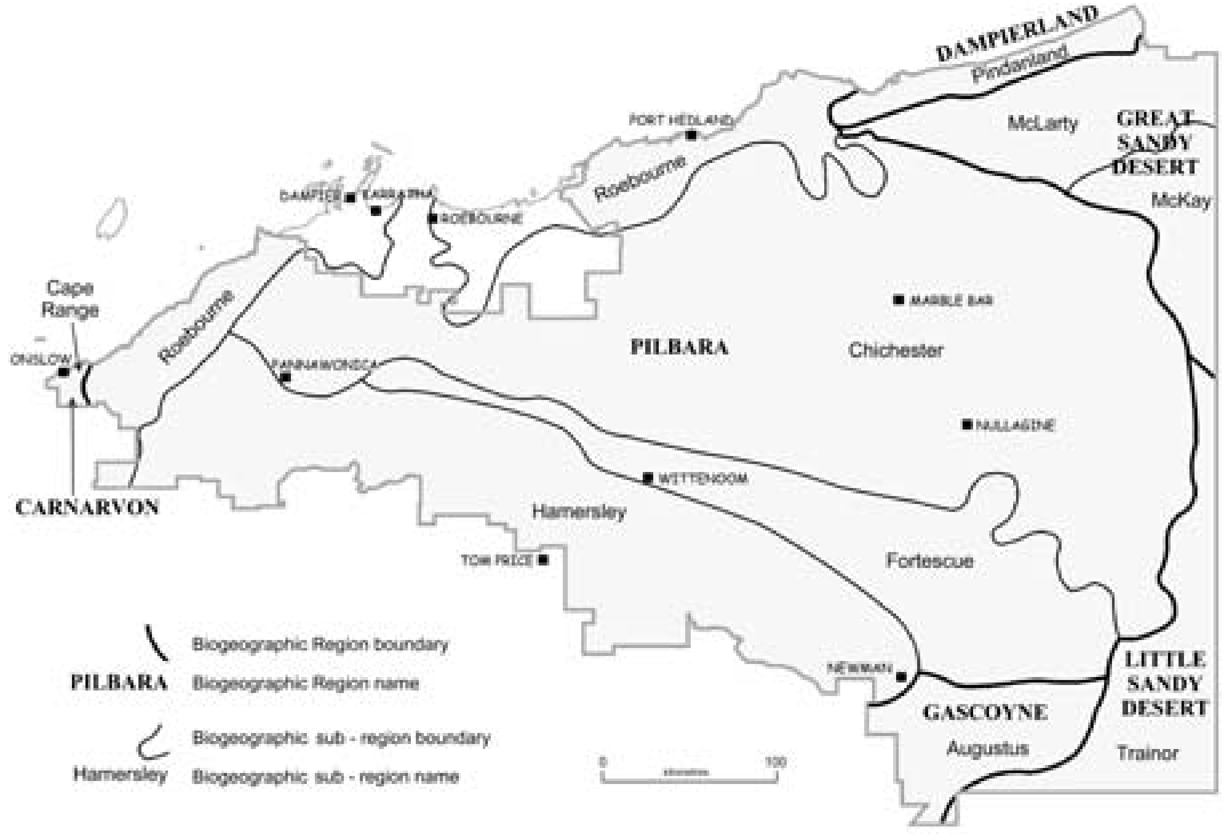

Figure 1. Biogeographic Regions and sub-regions in the survey area (after Thackway and Cresswell 1995)

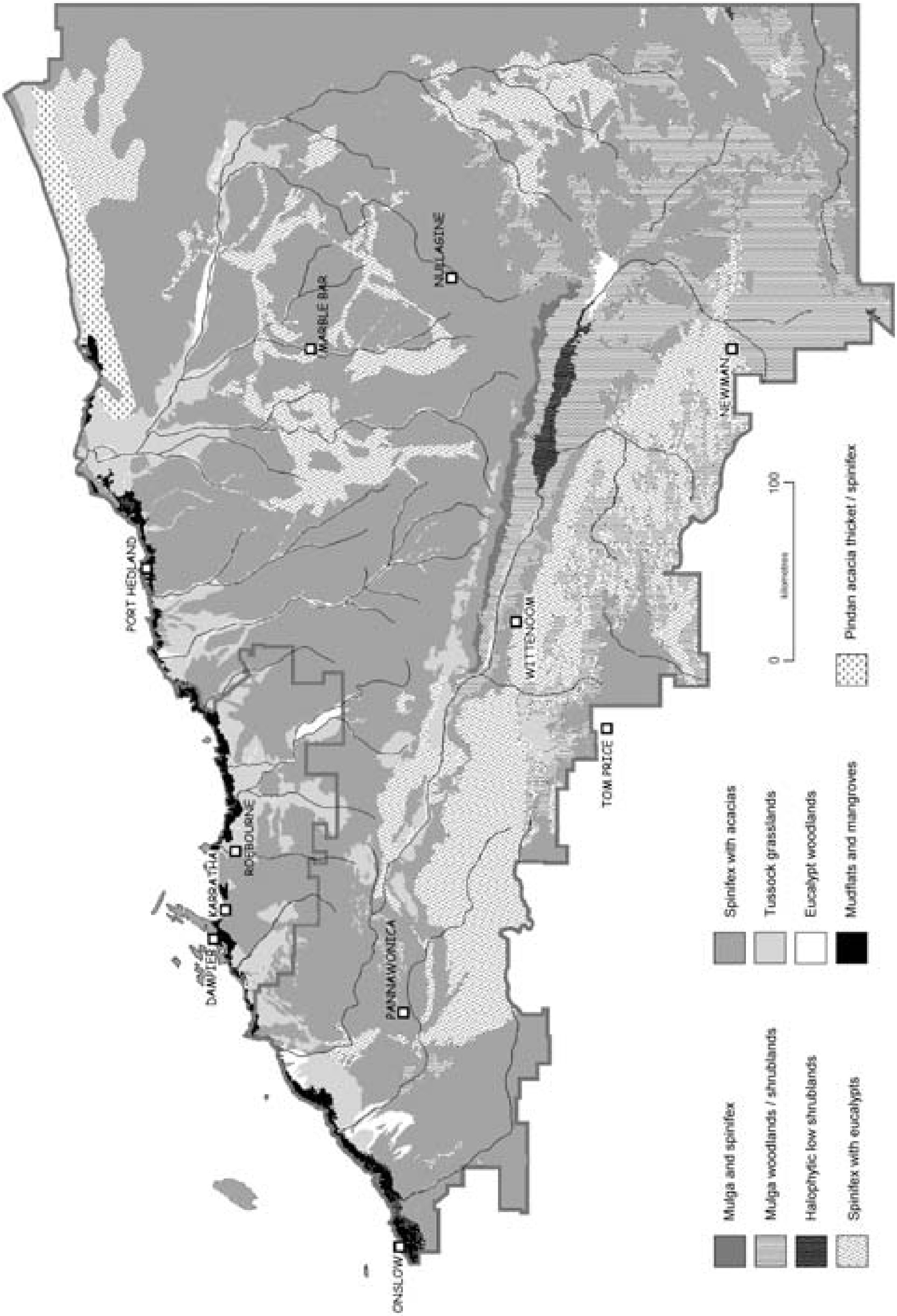

Figure 2. Generalised vegetation formations within the survey area (modified from Beard 1975)

spinifex. Along much of the coastline there are bare tidal mud flats and areas of mangrove. Along the major rivers there are sclerophyll woodlands, mostly with coolibah *(Eucalyptus victrix)* and river red gum *(E. camaldulensis)*. Between the Fortescue and Robe Rivers on the coast there is a mosaic of shrub savanna (with snakewood - *Acacia xiphophylla*) and shrub steppe (with kanji bush).

The Fortescue sub-region is characterised by patches of short bunch grassland along the north side of the Fortescue River, mulga in groves and patches in the main valley and a large salt marsh (Fortescue Marsh) which supports unwooded succulent steppe (halophytic low shrublands) with saltbush, bluebush and samphire. To the east of the Roy Hill homestead there is an area of coolibah trees over bunch grassland.

In the rugged Hamersley sub-region on the south side of the Fortescue Valley tree steppe with snappy gum is predominant. Mulga low woodland occurs in valleys. In the south-west corner, around Cane River homestead, there is sparse shrub steppe with snakewood on drainage lines and around Red Hill homestead there is shrub steppe with snakewood.

Carnarvon Biogeographic Region

The very small part of the survey area within the Carnarvon Biogeographic Region in the south-west around Onslow is predominantly tidal mud flats and unwooded succulent steppe.

Gascoyne Biogeographic Region

The part of the survey area in the Gascoyne Biogeographic Region (Augustus sub-region), in the south-east between Weelaranna station and Jigalong, is predominantly mulga low woodland and mulga in groves.

Little Sandy Biogeographic Region

The south-eastern side of the survey area in the Little Sandy Biogeographic Region is dominated by shrub steppe with scattered shrubs and buck spinifex (*Triodia basedowii*). To the east of Robertson Range there are areas of mulga low woodland and patches of tree steppe with desert oak (*Allocasuarina decaisneana*).

Great Sandy Biogeographic Region

The north-east part of the survey area in the Great Sandy Biogeographic Region is predominantly shrub steppe on sandplain and between sand dunes in the south and tree steppe with desert walnut (*Owenia reticulata*) on sandplain to the north. Sandstone mesas have grass steppe (with no trees or shrubs) between scattered shrub steppe with *Acacia pachyacra.*

Dampierland Biogeographic Region

The small part of the survey area within the Dampierland Biogeographic Region is dominated by pindan; a three tiered community with trees, shrubs and spinifex. Short bunch grassland occurs along the coast.

Taxonomic summary

The plant taxonomy adopted in this survey is based on the Census of Western Australian Plants (Chapman, Gioia and Wilson, in prep.) but also adopts changes on the advice of the Western Australian Herbarium. Scientific names are used, colloquial names of common species are listed in the appendices.

Based on field collections, 1,137 species of vascular plants were identified representing 348 genera in 98 families (see Appendix 1). These consisted of 775 perennial species and 362 annual species.

A large number of species belong to a small group of families and genera that characterise the flora in the area surveyed (Table 1).

Table 1. Major families and dominant genera in the survey area

Family	No. of species	Dominant genera
Amaranthaceae	42	*Ptilotus*
Asteraceae	71	*Pluchea, Pterocaulon, Streptoglossa*
Caesalpiniaceae	28	*Senna*
Chenopodiaceae	68	*Atriplex, Dysphania, Halosarcia, Maireana, Sclerolaena*
Convolvulaceae	30	*Bonamia, Evolvulus, Ipomoea, Polymeria*
Cyperaceae	32	*Cyperus, Fimbristylis*
Goodeniaceae	30	*Goodenia, Scaevola*
Malvaceae	69	*Abutilon, Hibiscus, Sida*
Mimosaceae	76	*Acacia*
Myoporaceae	33	*Eremophila*
Myrtaceae	36	*Corymbia, Eucalyptus, Melaleuca*
Papilionaceae	105	*Cullen, Indigofera, Rhynchosia, Tephrosia, Swainsona*
Poaceae	158	*Aristida, Astrebla, Cenchrus, Chrysopogon, Enneapogon, Eragrostis, Eriachne, Themeda, Triodia*

The Poaceae contains the largest number of species (158), which occur in many different landscapes across the area. Many of the families in the survey area are widely spread throughout Australia. However, at species level many have Eremaean (arid zone) distributions. Some of the species which occur in the northern parts of the survey have distribution more typical of the sub-tropical Kimberley region.

Plant forms

The major plant forms observed were trees, mallees, tall shrubs (>2 m), mid shrubs (1-2 m), low shrubs (<1 m), perennial hummock grasses, perennial tussock grasses, annual herbs, annual grasses, mistletoes, creepers, sedges (and allies), ferns and soil cryptogams. They are very briefly described below.

Trees

Eucalyptus, Corymbia (formerly *Eucalyptus*) and *Acacia* are the dominant trees in the survey area. The eucalypts and corymbias generally have glabrous, laminar leaves with oil glands. The most commonly occurring species are *Corymbia hamersleyana, Eucalyptus camaldulensis, E. gamophylla, E. leucophloia* and *E. victrix.* The most common tree acacias in the survey area are *Acacia catenulata, A. citrinoviridis, A. coriacea* and *A. pruinocarpa. Acacia aneura* may occur as a tree in the survey area in drainage tracts and groves but more commonly occurs as a tall shrub. *Hakea lorea* subsp. *suberea* is a common tree in the survey area. Other trees which occur occasionally include *Atalaya hemiglauca, Eremophila longifolia, Dolichandrone heterophylla, Melaleuca argentea* and *Owenia reticulata.*

Allocasuarina decaisneana *(desert oak) may grow to a height of 15 metres and is one of the few tree species to grow amongst spinifex on the sandplains and swales of the desert region.*

Mallees

Mallees are not common in the survey area. They are usually found as open multi-stemmed plants rarely exceeding 6 m in height. The mallees recorded in the survey area are *Eucalyptus kingsmillii, E. gamophylla, E. odontocarpa, E. socialis* and *E. trivalvis.*

Tall shrubs

Acacias dominate the tall shrubs (>2 m) throughout the survey area, with *Acacia ancistrocarpa, A. aneura, A. inaequilatera, A. tetragonophylla* and *A. victoriae* being the most common. Other commonly occurring acacias include *A. farnesiana, A. tumida* var. *pilbarensis, A. trachycarpa* and *A. xiphophylla.* Acacias are typically phyllodinous and sclerophyllous. Other common tall shrubs include *Grevillea wickhamii* and *G. pyramidalis.*

Mid shrubs

This group of shrubs between 1 and 2 m in height is often represented by species of *Acacia, Eremophila* and *Senna* (formerly *Cassia*). Common acacias include *Acacia bivenosa, A. pyrifolia* and *A. sclerosperma,* common eremophilas include *Eremophila forrestii* and *E. latrobei* and common sennas include *Senna glutinosa* and its sub-species *S. glutinosa subsp.* x *luerssenii* and *S. glutinosa subsp. pruinosa.*

Other common mid shrubs include *Carissa lanceolata, Gossypium australe* and *Rhagodia eremaea.*

Low shrubs

Low shrubs (<1 m) are a common growth form which occur in many landscapes throughout the survey area. A large group of these shrubs are characterised by leaves exhibiting varying degrees of sclerophylly. These are often found in tall acacia shrublands and in hummock grassland communities. These species are commonly from the *Goodenia, Ptilotus, Senna, Sida* and *Solanum* genera. *Evolvulus alsinoides, Indigofera monophylla* and *Mollugo molluginis* are also very common.

Some acacia species occur as sclerophyllous low shrubs, particularly where they occur on hills or on sandplains in association with spinifex grasslands. *Acacia stellaticeps* is a commonly occurring low shrub.

Succulent low shrub species are much less common in the survey area. They are generally represented by genera of the Chenopodiaceae, including the semi-succulent *Atriplex. Atriplex bunburyana, Enchylaena tomentosa, Halosarcia spp., Maireana planifolia, M. villosa, Sclerolaena densiflora* and *S. deserticola* are common low succulent shrubs. Succulent low shrubs occur on saline alluvial soils but some also occur with sclerophyllous species on non-saline soils.

Annual herbs

The survey was conducted in good seasonal conditions, with the reconnaissance trip conducted following a major cyclonic event, and at times there was prolific ephemeral growth. Many annual herbs were from the *Ptilotus* genus, with species including *P. aervoides, P. exaltatus, P. helipteroides* and *P. gomphrenoides,* and the related *Gomphrena canescens.* Other common annual herbs include *Cleome viscosa, Dysphania rhadinostachya, Euphorbia australis, Pterocaulon sphacelatum, Senna notabilis* and *Trichodesma zeylanicum.* The introduced species *Malvastrum americanum* and the pancontinental species *Salsola tragus* were also common.

Perennial hummock grasses

Hummock grasses are a uniquely Australian form of grass in which rigid, pungent, involute leaves form a dense hummock. In some species the hummocks grow outwards and senesce in the middle to leave a ring or band of outward growing living material. Hummock grasses occur extensively in the survey area on landscapes ranging from rugged hills to sandplains to saline alluvial plains. Twenty-one species of hummock grasses were recorded in the survey area. All but one, the coastal species *Spinifex longifolius* are from the *Triodia* genus. The most common species are *Triodia lanigera, T. longiceps, T. pungens* and *T. wiseana.*

Perennial tussock grasses

Tussock grasses vary from dense, well developed plants such as *Eriachne benthamii* to open forms such as

Chrysopogon fallax. The most commonly occurring tussock grass species in the survey area is the introduced *Cenchrus ciliaris*. Other common tussock grasses are *Aristida holathera* var. *holathera, A. latifolia, Astrebla pectinata, Chrysopogon fallax, Eragrostis eriopoda, E. xerophila, Eriachne benthamii, E. obtusa, Eulalia aurea, Paraneurachne muelleri* and *Themeda triandra.*

Annual grasses

As with annual herbs, annual grasses were abundant during the survey following the wet summer of 1995. The most common annual grass species in the survey area, as in many regions of the Western Australian rangelands, is *Aristida contorta,* an open, narrow-stemmed grass with conspicuous three-awned seeds. Other common annual grass species were from the genera *Brachyachne, Enneapogon, Eriachne, Iseilema* and *Sporobolus.*

Sedges

Species of the sedge genera *Bulbostylis, Cyperus* and *Fimbristylis* occur in the survey area. The most common species were from the *Fimbristylis* genus. The large sedge *C. vaginatus* was encountered around permanent pools in rivers.

Creepers

Numerous creepers occur in the survey area. The most common species is *Rhynchosia minima* which occurs on many different soil types but is a characteristic plant on cracking clay soils. Species from the genera *Boerhavia* and *Ipomoea* were also common while species from *Desmodium* and *Vigna* were less common.

Mistletoes

Mistletoes are epiphytic parasites commonly found growing on the branches of acacia, eucalypt and sheoak species. Their foliage is very variable and often resembles that of their host. Five species of mistletoe from the *Amyema* and *Lysiana* genera were recorded in the survey area but these were not common.

Ferns

Three species of the genus *Cheilanthes* were recorded: *Cheilanthes austrotenuifolia*, a nearly glabrous, delicate plant found in a variety of habitats, *C. lasiophylla*, a prostrate tomentose plant usually found in rock crevices and *C. sieberi*, a plant with densely clustered fronds found in a number of habitats including mulga woodland. Three species of *Marsilea* were recorded in wet areas: *Marsilea drummondii, M. exarata* and *M. hirsuta.*

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. They also provide forage for microscopic herbivores, hence contributing both directly and indirectly to biological activity at the soil surface. Cryptogams were not collected in this survey.

Vegetation formations and their floristic components

Vegetation formations described below have been developed from inventory site data in which strata were ranked. The vegetation formations are defined as:

Woodlands	dominant stratum is trees (plants with a single stem at a height of 1.3 m above ground level)
Tall shrublands	dominant stratum is shrubs over 2 m tall
Mid shrublands	dominant stratum is shrubs 1 to 2 m tall
Low shrublands	dominant stratum is shrubs less than 1 m tall
Hummock grasslands	dominant stratum is hummock grasses
Tussock grasslands	dominant stratum is tussock grasses

Mallees (multi-stemmed eucalypts) were treated as trees. Mallee woodlands were not sampled and rarely occur in the survey area. Isolated to scattered mallees sometimes occur in hummock grasslands.

This is a simplification of traditional methods of describing vegetation (e.g. Specht 1970; Beard and Webb 1974; Muir 1977 and Wilcox and Fox 1995). Muir's formations are referred to within each broad formation described below. Some aggregation has taken place. For instance, a small number of tree and tall shrub dominated sites classified according to Muir as low forest and thicket have been described under woodlands and tall shrublands respectively.

Vegetation was described at 763 inventory sites in the survey area. Twenty-nine of these had co-dominant strata and nine sites had no distinct strata. The dominant strata at the remaining 725 sites is shown in Table 2.

Table 2. The floristic variability of dominant strata

Dominant stratum	No. of sites	No. of dominant species
Tree	39	10
Tall shrub	60	17
Mid shrub	29	13
Low shrub	73	42
Hummock grass	424	16
Tussock grass	100	24
Total	725	122

Hummock grass provided the most common dominant stratum at inventory sites, followed by tussock grass, low shrubs, tall shrubs, trees and mid shrubs respectively.

Hummock grasslands were the most commonly sampled vegetation formation and showed the least floristic variability in the dominant strata (Table 2). With far fewer sites there were many more dominant species recorded in low shrublands.

Woodlands

The woodland sites generally have a canopy height between 4 and 12 m, or up to 20 m for *Melaleuca argentea* woodlands. Most have canopy cover between 10 and 30% and are thus 'Open Low Woodland A' and 'Low Woodland A' according to Muir (1977). Several 'Low Forest A' (canopy cover >30%) of *M. argentea* or *Acacia aneura* were recorded.

While ten dominant tree species were recorded, almost half of the 39 woodland sites were dominated by *A. aneura. Eucalyptus victrix* was dominant at seven sites, *M. argentea* at four sites, and *E. camaldulensis* at three sites.

Most of the woodland sites occurred on drainage zones including unchannelled drainage tracts, channels and swamps, and also in groves. The woodlands which fringe major river pools were often dominated by *E. camaldulensis* or *M. argentea. Acacia aneura* was the dominant tree at most grove sites and *A. catenulata* was occasionally dominant at grove sites. Sites on drainage tracts were dominated most often by *A. aneura* or by eucalypts. The five woodland swamp sites were all dominated by *E. camaldulensis* or *E. victrix*. Four or more of the woodland sites occurred in River, Coolibah and Wannamunna land systems which are systems which receive fairly regular overbank flooding or run-on from adjacent systems.

Most of the woodland sites occurred on the three central-southern map sheets Mount Bruce, Roy Hill and Newman which are associated with the mulga washplain zone, however the other sites occurred across the survey area.

Most (71%) of the woodland sites were in good condition, with 21% in fair condition and 8% in poor condition.

Woodlands in the Pilbara are mostly confined to well watered drainage tracts and floodplains. They include narrow riparian zones (as shown here) flanking major river channels with large trees including Eucalyptus camaldulensis *(red river gum),* E. victrix *(coolibah) and* Melaleuca *species (paperbark).*

Tall shrublands

The tall shrublands in the survey are very variable in many characteristics. For example their projected foliar cover (PFC) ranged from <2.5 to >50%, although most were 10 to 30%. Their height varied from 2 to 8 m. According to Muir (1977), these sites are 'Open Scrub' (where PFC is <10%), 'Scrub' (where PFC is 10 to 30%) or 'Thicket' (where PFC is >30%). Thickets occurred in drainage tracts and foci and groves which are areas receiving more concentrated run-on. The open scrub and scrub occurred on a range of land units but mostly on plains.

Tall shrublands occur on a variety of land systems and land units across the survey area. Acacias dominate the overwhelming majority of tall shrublands in the survey area, with *A. aneura* dominating almost half of these. Seventeen dominant tall shrub species were recorded, 13 of these were acacias. *Acacia aneura* and *A. catenulata* are the dominant species in groves, *A. aneura* is the dominant species on hardpan plains, *A. xiphophylla* is most commonly the dominant species on saline or gilgaied plains and a variety of acacia species dominate drainage zones but most commonly *A. aneura* and *A. citrinoviridis.*

Acacia aneura is the most common dominant species in tall shrublands in the south-east of the survey area, *A. xiphophylla* occurs as the dominant species in the south-west, and *Melaleuca alsophila* is the dominant species in the north coastal part of the survey area. *Prosopis juliflora* was the dominant species of a tall shrubland in an area of the Fortescue River delta where this introduced declared species has formed infestations in areas that were originally saltbush shrublands.

Most (68%) of the tall shrubland sites were in good condition, with 21% in fair condition and 11% in poor condition.

Mid shrublands

Most mid shrublands sampled had a PFC between 5 and 30%, making them 'Open Low Scrub A or B' (where PFC is <10%) or 'Low Scrub A or B' (where PFC is 10 to 30%) according to the Muir (1977) classification system. Most mid shrublands in the survey area are 1.5 to 2 m tall rather than 1 to 1.5 m so fall into the 'A' groupings.

Mid shrublands are the least common plant communities in the survey area. Thirteen species of dominant mid shrubs were recorded at the 29 mid shrubland sites, seven of these were acacias. These acacia species typically occur as tall shrubs and were stunted in these mid shrublands environments. Twenty sites were dominated by acacias, of which 10 were dominated by *Acacia xiphophylla.* These occurred in the south-western part of the survey area. Five mid shrubland sites were dominated by sennas and two by eremophilas. These occurred in the south-east part of the survey area. The two mid shrubland sites which occurred in the north coastal part of the survey area were dominated by *Melaleuca lasiandra* and *Acacia ampliceps*, which are both species characteristic of this area.

Mid shrublands occur on a variety of land systems and land units across the survey area. The mid shrublands dominated by *A. xiphophylla* generally occur on alluvial plains which are often stony and may be gilgaied.

About half (54%) of the mid shrubland sites were in good condition, 25% were in fair condition and 21% were in poor condition.

Low shrublands

The low shrubland sites sampled are classified as 'Dwarf Scrub C or D' (with PFC 10 to 30%) or 'Open Dwarf Scrub A or B' (with PFC 2 to 10%) according to the Muir (1977) vegetation classification system. Low shrublands in the survey area are most commonly 0.5 to 1 m in height so fall into the 'C' grouping rather than the 'D' grouping (with height <0.5 m).

Low shrublands were the most common non-grassland vegetation communities and occur on a variety of land systems and land units across the survey area although they most commonly occur on plains. They have highly variable dominant species. Forty-two dominant species were recorded at the 73 low shrubland sites. These included 13 species of *Eremophila* on 22 sites, four *Senna* species at nine sites, four *Maireana* species at six sites and four *Ptilotus* species at five sites.

Most (70%) of the low shrubland sites were in good condition, with about 15% in fair condition and 15% in poor condition.

Two main groups of low shrublands can be recognised in the survey area: halophytic low shrublands and non-halophytic low shrublands.

Halophytic low shrublands

Nineteen of the 73 low shrubland sites sampled are classified as halophytic shrublands. Halophytic low shrublands generally occur on saline alluvial plains and floodplains. They occur across the survey area but are most common in coastal areas and in the south-east.

Halophytic low shrublands are dominated by species of the Chenopodiaceae family. Five sites were dominated by *Atriplex bunburyana,* eight sites by *Halosarcia* species and five sites by *Maireana* species. In some instances, particularly in historically overgrazed communities, non-succulent low shrubs such as *Senna* spp. and *Ptilotus obovatus* may replace chenopod species as dominants. Two halophytic low shrubland sites were dominated by *Senna* species.

Halophytic low shrublands are more susceptible to degradation through grazing as they are preferentially grazed and occur on land units that are sensitive to erosion. The halophytic shrublands sampled were in poorer condition than the non-halophytic low shrublands with 53% in good condition, 26% in fair condition and 21% in poor condition.

Non-halophytic low shrublands

Fifty-four of the low shrubland sites are classified as non-halophytic shrublands. They occur on many land units throughout the survey area but are most common on stony and gritty-surfaced plains in the south-east of the survey area.

The non-halophytic low shrubland sites are dominated by a variety of species with 35 dominant species recorded at the 54 sites. However, over half of the sites are dominated by *Eremophila* species (13 species at 21 sites) or *Senna* species (three species at ten sites). *Acacia*, *Ptilotus* and *Corchorus* species each dominated five sites. Unlike halophytic low shrublands, there are often subordinate overstorey strata, often typified by *Acacia* species.

Common dominant species that were recorded at three or more sites are *Acacia stellaticeps, Corchorus sidoides, Cullen martinii, Eremophila exilifolia, E. pensilis* and *Senna artemisioides* subsp. *helmsii*.

The dwarf acacia species *A. stellaticeps* was dominant at four sites. These sites occurred in coastal areas in the central north of the survey area. This species is a component of the coastal soft spinifex grasslands in this area, however in some areas when the fire history favours it, it becomes much more dense and in extreme cases can exclude spinifex.

Some non-halophytic low shrublands are associated with post fire successions in hummock grasslands. Many of the seral species are from the Malvaceae family. These communities are characteristically highly variable in terms of the dominant species. Some of the more common dominant species include *Corchorus walcottii, Indigofera monophylla* and *Senna notabilis*. The seral communities may persist for up to three years before spinifex resumes its dominance.

Most (76%) of the non-halophytic low shrubland sites were in good condition, with 11% in fair condition and 13% in poor condition.

Hummock grasslands

The hummock grassland sites most commonly have a PFC between 10 to 60% and are thus 'Hummock Grass' (where PFC is 10 to 30%) and 'Mid-Dense Hummock Grass' (where PFC is 30 to 70%) according to Muir (1977). Some 'Open Hummock Grass' with PFC <10% was sampled but in most cases these were communities of young spinifex which had been subjected to recent fire. Hummock grasslands are susceptible to fires from lightning strikes and prescribed burning. A range of herbaceous plants often emerges with rains in recently burnt areas but are usually succeeded by spinifex.

Sixteen dominant species were recorded at the 424 hummock grassland sites, although 70% of the sites were dominated by three species: *Triodia pungens* (179 sites), *T. wiseana* (87 sites) and *T. lanigera* (36 sites). About one third of the sites had tree and shrub layers with a PFC of scattered or greater (PFC >10%).

The hummock grassland sites occurred on a range of land units throughout the survey area, ranging from hill slopes to stony plains, sandsheets and drainage lines.

Most (88%) of the hummock grassland sites were in good condition, with 6% in fair condition and 6% in poor condition.

Hummock grasslands are extensive throughout the Pilbara on plains and hills. Mature stands of Triodia pungens *(soft spinifex), frequently support scattered shrubs, but after fire, the community becomes considerably more diverse for a few years.*

Tussock grasslands

The tussock grassland sites may have a basal cover of over 10% but most commonly are between 1 and 10%. The tussock grasslands are mostly <0.5 m in height. The canopy cover of grasses was not measured at sites, however it is estimated that most tussock grasslands would be classified as 'Open Low Grass' (where PFC is 10 to 30%) and 'Low Grass' (where PFC is 30 to 70%) according to Muir (1977). *Themeda triandra* (kangaroo grass) grasslands are >0.5 m tall and would be classified as 'Open Tall Grass' (where PFC is 10 to 30%) and 'Tall Grass' (where PFC is 30 to 70%).

Twenty-four dominant species were recorded at the 100 tussock grassland sites. Species which were dominant at three or more sites are *Cenchrus ciliaris* (31 sites), *Eragrostis xerophila* (20 sites), *Chrysopogon fallax* (12 sites), *Eriachne benthamii* (11 sites) and *Aristida holathera* subsp. *holathera, Astrebla pectinata* and *Themeda triandra* (3 sites each). About one quarter of the sites had tree and shrub layers with a density of scattered or greater (PFC >10%).

The tussock grassland sites occurred mostly on alluvial plains, gilgaied plains and drainage tracts.

Most (75%) of the tussock grassland sites were in good condition, with 17% in fair condition and 8% in poor condition. Tussock grasslands are generally more susceptible to grazing as their component species are palatable and preferentially grazed, particularly when they are green.

Regional distribution of plant communities

There is noticeable geographic variation in the dominant strata at the sampling sites across the survey area (Table 3). Hummock grasslands are the most common vegetation formation on all 1:250,000 scale map sheets except Robertson in the south-east where low shrublands are most common, and Mandora in the north where tussock grasslands are most common. Hummock grasslands are relatively more common on the Port Hedland, Yarrie, Marble Bar and Nullagine map sheets in the central Pilbara and to the east. Hummock grasslands are also very common on the Wyloo map sheet.

Woodlands are considerably more common on the Mount Bruce, Roy Hill and Newman map sheets in the southern central area where mulga groves are more common than elsewhere. Snakewood shrublands, which are often mid height shrublands, occur in the south-west areas. Tussock grasslands are less common towards the south, with none sampled on the Onslow, Wyloo and Robertson map sheets and only 7% of the sites sampled on the Newman sheet being tussock grasslands.

Triodia pungens was the most commonly recorded species in the northern, central and south-western parts of the survey area, where it was recorded over 50% more often then the next most commonly recorded species: *Hakea lorea* subsp. *suberea*, *Cenchrus ciliaris* and *Acacia inaequilatera.* In the south-east part of the survey *Acacia aneura, Senna artemisioides* subsp. *helmsii, Solanum lasiophyllum* and the annual grass *Aristida contorta* were the most commonly recorded species. In the far north-east of the survey area, on the Mandora map sheet, *C. ciliaris* was the most commonly recorded species.

Triodia pungens was the most commonly recorded spinifex species on all map sheets except the Mandora map sheet where *Triodia epactia* was most commonly recorded.

Acacia aneura is the predominant species in rangelands to the south of the survey area, and was the most commonly recorded acacia species on the Balfour Downs, Mt Bruce, Newman, Robertson and Roy Hill map sheets where it was often the dominant species in woodlands or tall shrublands. Where mulga was recorded in the north and west it was most commonly a component of hummock grassland communities. Mulga is susceptible to fire and its range is restricted by the frequency and intensity of fire which increases in spinifex dominated areas. It may occur in 'fire refuge' areas on spinifex covered ranges.

Table 3. The proportion (%) of the plant form of the dominant strata recorded at 725 inventory sites on the 1:250,000 map sheets

Map sheet	Tree	Tall shrub	Mid shrub	Low shrub	Hummock grass	Tussock grass	No. of sites
Balfour Downs	5	16	8	24	36	11	63
Mandora	0	14	9	0	36	41	22
Marble Bar	0	3	2	10	74	11	70
Mount Bruce	30	18	0	0	39	13	46
Newman/Collier	14	21	14	17	27	7	29
Nullagine	1	0	3	4	79	13	71
Onslow	7	0	20	13	60	0	15
Port Hedland/Bedout Island	1	2	2	5	71	19	116
Pyramid	3	15	4	5	56	17	66
Robertson	6	14	0	47	33	0	36
Roebourne	0	4	0	12	60	24	25
Roy Hill	17	17	0	10	48	8	48
Wyloo	0	0	0	12	88	0	17
Yarraloola/Dampier	3	7	12	5	52	21	61
Yarrie	2	2	0	5	83	8	40
Average	5	8	4	10	59	14	

Acacia xiphophylla occurs almost exclusively in the south-west and central-west parts of the survey area. It is often the dominant species in mid and tall shrublands and is occasionally a component of tussock grasslands.

Acacia inaequilatera was the most commonly recorded acacia in the survey area. It was the most commonly recorded acacia on the Marble Bar, Nullagine, Port Hedland, Roebourne and Yarrie map sheets in the central-east and north of the survey area. *Acacia bivenosa* was the most commonly recorded acacia on the Yarraloola and Wyloo map sheets in the south-west of the survey area. *Acacia ancistrocarpa* was the most commonly recorded acacia on the Pyramid map sheet in the central-west part of the survey area These acacias are most commonly a component of hummock grasslands.

Acacia ampliceps was the most commonly recorded acacia on the Mandora map sheet. It is generally associated with tall shrublands and tussock grasslands on coastal drainage zones and alluvial plains.

These patterns of vegetation distribution are consistent with the regional overview of Beard (1975), reflecting a change from the spinifex dominance of the Fortescue Botanical District across much of the survey area to the mulga woodlands with associated low shrublands of the Ashburton Botanical District in the south-east and the coastal tussock grasslands of the Northern Botanical Province in the far north-east. These regional patterns reflect both climate and biophysical environmental factors.

Spectacular *Melaleuca argentea* woodlands up to 20 m tall and which can be very dense were recorded fringing major river pools in the survey area including Skull Springs on the Davis River on Wandanya station in the east, Hancock Gorge and Fortescue Falls in Karijini National Park, and on the Robe River on Yarraloola station in the south-west.

The Fortescue Marsh (Marsh land system) is a unique area where lake beds and saline peripheral floodplains form a termination basin for the upper reaches of the Fortescue River. The area is subject to regular inundation and supports low halophytic shrublands, often dominated by *Halosarcia* spp. and *Sporobolus virginicus* grasslands with *Muehlenbeckia florulenta* and *Muellerolimon salicornaceum* shrubs. There are also extensive areas with no perennial vegetation.

Flora conservation

Flora conservation involves maintaining biological diversity at a variety of scales, from the genetic diversity within single populations to continental and global species richness. In this section, the conservation of plant species and communities in terms of threats, and the threatened species and ecological communities that occur in the survey area are discussed.

Threats to native flora

Pastoralism

Pastoralism has extensively modified native rangeland plant communities in Western Australia. Where grazing has been excessive, species palatable to domestic stock, feral animals and kangaroos have been substantially reduced or removed. Replacement by suites of less palatable species well adapted to establishing in vacated niches rarely equals the species richness, density or cover of the previous vegetation community (Payne *et al.* 1998). The level of grazing modification is dependant on the location of developed water points and fences and the spatial arrangements of preferred and less preferred vegetation communities (and their sensitivity to grazing) within a paddock or management unit. Cridland and Stafford Smith (1993) have shown that grazing impacts are disproportionately severe in proximity to stock water points. This effect is particularly evident in large paddocks (>50 km^2) where stock are constrained by the need to drink regularly in hot weather and thus cannot readily access all of a paddock. Plant communities with predominantly palatable plants, such as tussock grasslands and chenopod shrublands, are preferentially grazed. The palatable plants may be killed by grazing when ephemeral feed is scarce in poor seasons. Communities with predominantly unpalatable plants, such as hard spinifex hummock grasslands, are largely unattractive to stock.

Plant communities in the Pilbara overall have been considerably less affected by pastoralism than other rangeland regions of Western Australia (see the Resource condition chapter). Of the 12,445 traverse points where range condition was assessed, 77% indicated good resource condition, 11% indicated fair condition and 12% indicated poor condition. The average condition for all previously surveyed areas in the Western Australian rangelands is 39% good, 34% fair and 27% poor (Payne *et al.* 1998). A large proportion of the Pilbara supports spinifex grasslands which are largely unaltered by grazing. Also significant areas are not used for pastoralism because they are inaccessible to stock. However, some minor plant communities within the survey area have been considerably affected by pastoralism. Tussock grasslands and chenopod shrublands have been most severely modified, partly as a result of preferential grazing and also because they often have fragile soils which are inherently susceptible to erosion.

At a species level, there are no plants known to have become extinct in the survey area since pastoralism commenced. However, the distribution of some highly palatable species such as the tussock grasses *Astrebla pectinata* and *Chrysopogon fallax* and the chenopod shrub *Atriplex bunburyana* have been reduced.

Much of the original native vegetation in coastal areas of the Pilbara is believed to have been tussock grasslands, however, some areas supported halophytic shrublands. Remnant patches of *Atriplex bunburyana* (silver saltbush) shrublands remain, notably on Boodarie and Yarraloola stations. The saltbush shrublands are subject to preferential grazing. The Roebourne-Port Hedland Land Conservation District Committee was concerned that if appropriate and timely measures were not implemented silver saltbush may become locally extinct. In December 2000 the group obtained funding from the Gordon Reid Foundation to construct an exclosure fence to provide long-term protection to approximately 15 ha of saltbush shrublands on Boodarie station. The fence which will prevent grazing by stock, feral animals and kangaroos was completed in October 2001. A concomitant reduction of total grazing pressure within the surrounding Mundeena paddock together with increased saltbush recruitment, will over time allow the reintroduction of this species into its former range on Boodarie station and surrounding areas. A site survey conducted in July 2002 indicated that the total number of saltbush plants identified within the exclosure site increased nearly two-fold over that recorded in May 2001. Several adult plants appeared to have set seed in the preceding season resulting in the successful germination of a number of saltbush seedlings. This was a positive trend when compared with observations made in August 2000 which showed that the remnant populations of saltbush were predominantly comprised of adult plants.

Introduced species

Forty-four introduced species were recorded during the survey (see Table 4). Introduced species were recorded as infrequent, common or abundant at traverse ratings. Of the 12,445 traverse ratings where range condition was assessed, 14% recorded introduced species. Cenchrus grasses were recorded at 12% of the ratings; they were infrequent at 2%, common at 4% and abundant at 6%. *Aerva javanica* was recorded at 1.5% of the ratings and *Malvastrum americanum* was recorded at 0.4% of the ratings. Other introduced species recorded at traverse ratings were *Indigofera oblongifolia* (<0.1%), *Prosopis* spp. (0.2%) and *Argemone ochroleuca* subsp. *ochroleuca* (<0.1%).

- *Cenchrus* grasses

The introduced grasses, *Cenchrus ciliaris* (buffel grass) and to a lesser extent *C. setigerus* (Birdwood grass) have become widely established in parts of the survey area, particularly the coastal plains and the floodplains of major rivers. It is estimated that the approximate area of communities dominated by *Cenchrus* grasses in the combined Pilbara and

Table 4. Introduced species recorded in the survey area

Taxon	Common name	Growth form	Collection number[1]	No. of inventory sites
Acetosa vesicaria	ruby dock	Annual herb		4
Aerva javanica	kapok bush	Low shrub		45
Agave americana	century plant	Tall shrub	PRP1803	-
Argemone ochroleuca subsp. ochroleuca	Mexican poppy	Annual herb	PRP1695	-
Asphodelus fistulosus	onion weed	Annual herb	PRP1312	-
Bidens bipinnata	black jack	Annual herb	PRP154	12
Cenchrus ciliaris	buffel grass	Tussock grass	PRP757	217
Cenchrus echinatus	Mossman River grass	Annual grass	PRP1654	-
Cenchrus setigerus	Birdwood grass	Tussock grass		28
Chenopodium murale	nettle-leaf goosefoot	Annual herb	PRP1271	-
Chloris virgata	feathertop Rhodes grass	Annual grass	PRP145	10
Citrullus colocynthis	colocynth	Creeper	PRP923	-
Citrullus lanatus	pie or bitter melon	Creeper	PRP1685	-
Crotalaria juncea	sunnhemp	Annual herb	PRP744	-
Cynodon dactylon	couch	Tussock grass		1
Cyperus rotundus	nut grass	Perennial sedge		1
Datura leichhardtii	thornapple	Annual herb	PRP715	1
Digitaria sanguinalis	crab grass	Annual grass	AAM3591	-
Echinochloa colona	awnless barnyard grass	Annual grass	PRP18	-
Gossypium hirsutum	upland cotton	Mid shrub	PRP1532	-
Indigofera oblongifolia	-	Low shrub	AAM3566	-
Leucaena leucocephala	leucaena	Tree/tall shrub	PRP1531	-
Malvastrum americanum	spiked Malvastrum	Annual herb	PRP699	70
Melochia pyramidata	-	Perennial herb	PRP1936	-
Merremia dissecta	-	Creeper	PRP1900	-
Opuntia stricta	common prickly pear	Tall shrub	PRP1841	-
Parkinsonia aculeata	parkinsonia	Tree		-
Passiflora foetida var. *hispida*	stinking passion flower	Creeper	PRP948	-
Persicaria lapathifolia	-	Perennial herb	PRP944	-
Phoenix dactylifera	date palm	Tree		1
Phyla nodiflora var. *nodiflora*	lippia or fogfruit	Annual herb	PRP1772	1
Polypogon monspeliensis	annual beardgrass	Annual grass	PRP554	-
Prosopis glandulosa x *velutina*	mesquite	Tall shrub	PRP1686	2
Prosopis juliflora	mesquite	Tall shrub		5
Pseudognaphalium luteoalbum	jersey cudweed	Annual herb	PRP780	-
Ricinus communis	castor oil plant	Tall shrub	PRP843	-
Senna occidentalis	coffee senna	Mid to low shrub	PRP1809	-
Setaria verticillata	whorled pigeon grass	Annual grass	PRP1123	2
Sigesbeckia orientalis	Indian weed	Annual herb	PRP1504	-
Sisymbrium orientale	Indian hedge mustard	Annual herb	PRP1270	-
Solanum nigrum	black berry nightshade	Annual herb	PRP1946	1
Sonchus asper	rough sowthistle	Annual herb	PRP1947	1
Sonchus oleraceus	common sowthistle	Annual herb	PRP1519	2
Stylosanthes hamata	Caribbean stylo	Annual herb		-

[1] Collection number: Rangeland survey specimen collecting number

Roebourne Plains survey areas is 3,434 km^2 or 1.8% of the total area. A distribution map is presented in the Resource condition chapter.

These plants were introduced from arid parts of India and Africa. It is believed buffel grass was introduced in the Yule River delta in the early 1900s. Buffel and Birdwood grass were spread by pastoralists across the survey area to enhance pastoral production. They are strong competitors and are now naturalised in many Pilbara habitats.

In coastal areas buffel grass grasslands are a major component of the Anna and Eighty-Mile land systems and also occur on the Cheerawarra, Dune and Onslow systems. Buffel grass has colonised many disturbed and previously eroded sites and some soft spinifex (*Triodia pungens*) sand dunes on the coast where it forms dense stands that exclude most other plants. It is thought to be allelopathic, in that it has the ability to produce chemicals from its roots that inhibit the establishment and survival of other plants (Cheam 1984).

Buffel grass grasslands are a major plant community on the Yamerina land system in the deltas of the De Grey, Turner and Yule Rivers and on the River land system along the major rivers and creeks. Buffel grass is common on drainage floors and smaller creek lines of many other land systems.

Buffel grass may have replaced or displaced *Chrysopogon fallax* (ribbon grass) and/or *Atriplex bunburyana* (silver saltbush) on some alluvial plains. Much of the original vegetation probably disappeared due to overgrazing before the introduction of buffel grass which has now colonised and stabilised many erosion-prone soils.

The buffel grass invasion, its replacement of native species and adverse effects on biodiversity, especially in National Parks and wilderness areas, is of major concern in relation to flora and consequently ecosystem conservation. A difficult paradox exists in its classification as both a valuable pasture plant and a significant environmental weed.

- Serious weeds

Mesquite (*Prosopis* spp.) is an aggressive invader of rangelands in northern Australia, forming dense thorny thickets which shade out native species hence reducing biodiversity. It is one of twenty weeds of national significance (Thorp and Lynch 2000). Mesquite is most prolific on alluvial soils associated with watercourses. The largest single infestation in Australia is in the Pilbara at the mouth of the Fortescue River on Mardie station (Osmond 2003). This infestation, which originated from trees planted in the 1930s, now covers 150,000 ha (30,000 ha of which is dense) and is still expanding rapidly (van Klinken and Campbell 2001). Mesquite is also found in coastal areas of the Pilbara on Peedamulla, Yarraloola, Mundabullangana and Warambie stations and on the Roebourne Common (see the Declared plants and animals chapter).

The Pilbara Mesquite Management Committee Inc. was established in April 2000 with representation from pastoral, community, mining, local, state and commonwealth agencies. The group obtained funding in February 2002 from the National Heritage Trust (National Weeds Program) to develop and implement a strategic plan for mesquite management in the Pilbara. Essential elements of the strategy will be the use of fire, biological control, mechanical and chemical techniques, the management of seed dispersal and long term monitoring of control work. It is anticipated that a sustainable management strategy can be developed and implemented to restrict the further spread of mesquite in the Pilbara within four years.

Parkinsonia (*Parkinsonia aculeata*) is another weed of national significance (Thorp and Lynch 2000) that occurs in the Pilbara. It competes with native vegetation and can form dense thickets along watercourses. It occurs on rivers throughout the survey area, including the De Grey, Fortescue and Robe Rivers and Pardoo Creek (see the Declared plants and animals chapter).

The De Grey River Parkinsonia Group provide a contract for chemical control of parkinsonia along this river system. The Department of Conservation and Land Management (CALM) has instigated a successful control program for parkinsonia on the Fortescue River in the Millstream-Chichester National Park using community volunteers.

Feral herbivores

In rangelands to the south of the Pilbara feral goats pose the greatest threat to flora conservation of all feral herbivores (Payne *et al.* 1998). In the Pilbara feral goats are restricted to the far south-west and far south-east and their impact on vegetation is insignificant due to the low numbers (see the Declared plants and animals chapter).

Feral donkeys, feral horses and camels are the most significant feral herbivores in the survey area. Donkeys are found throughout the area with the highest numbers being in the south-east. Feral horses and camels occur in small numbers throughout much of the survey area. Camels are most common in the far east of the survey area. Shooting is the most practical method of control for these animals and control programs are undertaken regularly by pastoralists, other land managers such as Aboriginal communities and CALM, and the Department of Agriculture.

Kangaroos

Kangaroo numbers are unnaturally high in pastoral country due to the provision of permanent water at artificial watering points (Oliver 1986, Norbury 1992). This results in additional grazing pressure on native plants. As with feral herbivores, kangaroo grazing is largely uncontrolled because of the ineffectiveness of conventional stock fences. Kangaroos have been shown to retard regeneration programs in areas from which stock have been excluded to encourage recovery (Gardiner 1986a,b, Norbury and Norbury 1991). Kangaroo control in the survey area involves commercial shooters.

Mining activity

Mining activity generally has profound but very localised impacts on natural habitats (Pringle *et al.* 1990). Of the 12,827 traverse points over the survey area, only 42 (0.3%) recorded obvious mining impacts. Major threats from mining activity are land clearing and impacts of mining infrastructure. Areas in which populations of rare or priority flora exist may be cleared. Priority species such as *Eriachne tenuiculmis* are found in ironstone ranges (primarily the Newman and Robe land systems) which attract a disproportionately high level of mining activity. The Priority species *Acacia aphanoclada* and *Atriplex spinulosa* were only recorded on the Mosquito land system. This land system has a restricted occurrence east of Nullagine and attracts a high level of mining activity because it is based on schist and other metamorphic rocks with high mineral prospectivity. Impacts of mining infrastructure include the changes to hydrological regimes associated with infrastructure corridors (e.g. railways and their drainage shadows) and impacts on riparian vegetation of aquifer draw-downs associated with mine dewatering and extraction of water for domestic and production purposes.

This report and the accompanying map highlight areas where these populations may occur, but considerably more detailed survey is required to assess possible impacts of proposed mining activity on flora conservation. The biological surveys conducted by environmental consultants on behalf of mining companies aim to identify these populations.

Threatened species

The Department of Conservation and Land Management maintains a Declared Rare and Priority Flora List (Atkins 2003) under provisions of the Wildlife Conservation Act. Ninety-five species that occur in the survey area are on the Declared Rare and Priority Flora List, with two of these being Declared Rare Flora (Table 5). Almost a third of the species are not known to occur on lands set aside for nature conservation purposes.

Table 5. Declared Rare and Priority Flora listings for the survey area (source Atkins 2003)

Taxon	Priority code[2]	Collection number[1]	No. of inventory sites
Lepidium catapycnon	R		-
Thryptomene wittweri	R		-
Abutilon uncinatum	1	PRP719, PRP1632	-
Acacia aphanoclada	1	PRP399, PRP956	1
Acacia cyperophylla var. *omearana*	1	PRP1460, PRP1872	-
Asteraceae Genus sp. Hamersley Range hilltops (S. van Leeuwen 4345)	1		-
Atriplex spinulosa	1	PRP958, PRP1304	-
Barbula ehrenbergii	1		-
Calotis squamigera	1		-
Eragrostis sp. Mt Robinson (S. van Leeuwen 4109)	1		-
Eremophila pilosa ms	1	PRP1274	1
Eremophila spongiocarpa ms	1	PRP575, PRP1331	4
Eucalyptus sp. Marandoo (M.E. Trudgen 10362) [aff. *coolibah* var. *rhodoclada*] PN	1		-
Fimbristylis sp. Shay Gap (K.R. Newbey 10293) PN	1	PRP1403	-
Goodenia lyrata	1	PRP1349	-
Goodenia omearana ms	1	PRP727, PRP1436	-
Goodenia pallida	1		-
Gunniopsis sp. Fortescue (M.E. Trudgen 11019) PN	1		-
Josephinia sp. Marandoo (M.E. Trudgen 1554) PN	1	PRP1412	1
Lepidium amelum	1	PRP1408, PRP1613	-
Mimulus clementii	1		-
Myriocephalus scalpellus	1		-
Ptilotus appendiculatus var. *minor*	1		-
Ptilotus tetrandrus	1		-
Sida sp. Pilbara (S. van Leeuwen 4377)	1	PRP1058	-
Stackhousia clementii	1		-
Swainsona sp. Millstream (A.A. Mitchell PRP 798) PN	1	PRP706, PRP798	-
Terminalia supranitifolia	1		-
Acacia daweana	2		-
Acacia effuse	2		-
Dampiera atriplicina	2		-
Dicladanthera glabra	2	PRP1093	-
Euphorbia clementii	2		-
Euphorbia drummondii subsp. Pilbara (B.G. Thomson 3503) PN	2		-
Gomphrena cucullata	2		-
Gomphrena pusilla	2		-
Gonocarpus ephemerus	2	PRP1931	-
Indigofera ixocarpa ms	2		-
Ischaemum albovillosum	2	PRP25, PRP229, PRP266, PRP1338	7
Olearia fluvialis	2		-
Olearia mucronata	2		-
Paspalidium retiglume	2		-
Pilbara trudgenii ms	2		-
Scaevola sp. Hamersley Range basalts (S. van Leeuwen 3675)	2		-
Sida sp. Barlee Range (S. van Leeuwen 1642) PN	2	PRP1057	1
Spartothamnella puberula	2		-

Table 5. continued…

Taxon	Priority code[2]	Collection number[1]	No. of inventory sites
Abutilon trudgenii ms	3	PRP1322	6
Acacia glaucocaesia	3	PRP925, PRP1874	-
Astrebla lappacea	3	PRP191, PRP1049, PRP1132	3
Bulbine pendula ms	3	PRP707	-
Bulbostylis burbidgeae	3	PRP1323, PRP1929	10
Calotis latiuscula	3	PRP692, PRP1063, PRP1135	-
Comesperma pallidum	3		-
Corchorus interstans ms	3		-
Cynanchum sp. Hamersley (M.E. Trudgen 2302) PN	3		-
Dampiera anonyma ms	3		-
Dampiera metallorum ms	3		-
Daviesia arthropoda	3		-
Eragrostis crateriformis	3		-
Eremophila caespitosa ms	3	PRP653, PRP1018	-
Eremophila magnifica subsp. *velutina* ms	3		-
Eriachne tenuiculmis	3	PRP1054, PRP1487, PRP1499	8
Euryomyrtus patrickiae	3		-
Fimbristylis sieberiana	3		-
Frankenia glomerata	3		-
Fuirena incrassate	3		-
Glycine falcata	3	PRP734, PRP1064	9
Goodenia modesta	3		-
Goodenia nuda	3	PRP697, PRP705, PRP749, PRP782	-
Goodenia pascua	3	PRP719B, PRP1050B	16
Gymnanthera cunninghamii	3	PRP853, PRP1909	-
Hibiscus brachysiphonius	3	PRP189, PRP801, PRP1610	-
Indigofera gilesii subsp. *gilesii*	3		-
Mimulus repens	3		-
Owenia acidula	3		-
Phyllanthus aridus	3	PRP1762	-
Plantago sp. Hamersley (M.E. Trudgen 11207) PN	3	PRP81, PRP678	-
Polymeria sp. Hamersley (M.E. Trudgen 11353) PN	3		-
Rhynchosia bungarensis	3	PRP826, PRP1095, PRP1494, PRP1694?	-
Rostellularia adscendens subsp. *adscendens* var. *latifolia*	3		-
Sauropus arenosus	3		-
Sida sp. Marandoo (M.E. Trudgen 10976) PN	3		-
Sida sp. Wittenoom (W.R. Barker 1962) PN	3	PRP209, PRP1656, PRP1740	9
Solanum oligandrum	3		-
Tephrosia sp. Cathedral Gorge (F.H. Mollemans 2420) PN	3	PRP1415	1
Themeda sp. Hamersley Station (M.E. Trudgen 11431) PN	3	PRP199	-
Themeda sp. Mt Barricade (M.E. Trudgen 2471) PN	3		-
Triodia sp. Mt. Ella (M.E. Trudgen 12739) PN	3		-
Triumfetta leptacantha	3		-
Acacia balsamea	4	PRP1251, PRP1383, PRP1434, PRP1738	2
Comesperma viscidulum	4		-
Eremophila magnifica subsp. *magnifica* ms	4	PRP1099	-
Eremophila youngii subsp. *lepidota* ms	4	PRP550	-
Goodenia stellata	4	PRP670, PRP1076	2
Livistona alfredii	4	PRP1480	-

[1] Collection number: Rangeland survey specimen collecting number

[2] Priority codes:

R Declared Rare Flora (DRF)
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

Forty-one of the Declared Rare and Priority species which occur in the Pilbara survey area were collected during the survey. Sixteen of these were recorded at 58 inventory sites and 17 condition sites. Tussock grasslands support significantly higher numbers of Priority species than other vegetation formations. Of the inventory sites where priority species were recorded 23% were tussock grasslands whereas 14% of all sites sampled where there was a dominant strata were tussock grasslands. In contrast 43% of the sites where Priority species were recorded were hummock grasslands whereas 59% of all sites sampled were hummock grasslands. Woodland and shrubland sites had similar proportions of sites with Priority species and sites overall.

Six sites had more than one Priority species; five were on gilgaied alluvial plains and one was on a basaltic upland plain with stony gilgaied soil. The sites were all tussock grasslands; three were *Astrebla* spp. (Mitchell grass) sites, two were *Themeda triandra* (kangaroo grass) sites and one was an *Eragrostis xerophila* (Roebourne Plains grass) site.

Two Priority 1 species, *Acacia aphanoclada* and *Atriplex spinulosa*, were only recorded on the Mosquito land system. Mosquito is a unique land system of stony plains and prominent ridges on schist and other metamorphic rocks. It has a restricted occurrence east of Nullagine. Much of the system supports hummock grasslands, however, the stony saline plains (about 25% of the system) support *Triodia longiceps* (knitting needle spinifex) hummock grasslands with scattered low chenopod shrubs such as *Maireana melanocoma* and the Priority species *Atriplex spinulosa*. The chenopod shrubs are preferentially grazed and can be removed if grazing management is inappropriate. This system is also subject to a high level of mining activity.

Four Priority species were recorded from nine sites on the Wona land system; *Glycine falcata* (Priority 3), *Goodenia pascua* (Priority 3), *Ischaemum albovillosum* (Priority 2) and *Tephrosia* sp. Cathedral Gorge (Priority 3). Wona is a system of basalt upland gilgai plains supporting tussock grasslands and minor hard spinifex grasslands. The tussock grasslands are highly preferred by livestock and kangaroos and can degrade to annual grasslands/herbfields if stocking is uncontrolled.

Swainsona *sp. Millstream (A.A. Mitchell PRP 798) is a Priority 1 species and has only been recorded growing in two locations in the Pilbara. Priority 1 plants are species with few poorly known populations on threatened lands. Many plant samples were identified by, and now reside with, the Western Australian Herbarium.*

Threatened Ecological Communities

The Department of Conservation and Land Management maintains a list of Threatened Ecological Communities endorsed by the Minister for Environment. A Threatened Ecological Community is a community which is subject to processes that threaten to destroy or significantly modify it across much of its range, and which is found to fit into one of the following categories: 'presumed totally destroyed', 'critically endangered', 'endangered' or 'vulnerable'. Two Threatened Ecological Communities occur in the survey area: the grassland plains of the Pilbara region dominated by *Themeda* sp. 'Hamersley Station' (M.E. Trudgen 11431) on red calcareous clays and the Ethel Gorge/Ophthalmia Basin aquifer stygobiont community. The former community is a vegetation community that occurs on Brockman land system on Hamersley station. It is categorised as vulnerable.

As a result of this survey, CALM has added the plant assemblages of the Mosquito land system (hummock grasslands with chenopods on stony saline plains) and the Wona land system (tussock grasslands on gilgai plains) to the list of Priority Ecological Communities under Category 3. These are defined as 'poorly known ecological communities which are made up of large, and/or widespread occurrences, that may or may not be represented in the conservation reserve system, but are under threat of modification across much of their range from processes such as grazing by domestic and/or feral stock, and inappropriate fire regimes'. Further investigation is required to fully describe these communities in terms of species assemblages and to clarify the extent of their distribution, in order to determine whether or not they meet the criteria for listing as Threatened Ecological Communities.

Themeda triandra *(kangaroo grass) tussock grasslands occur only in a few areas and, where they occur on the Brockman land system on Hamersley Station, have been listed as a Threatened Ecological Community.*

Conclusion

The vegetation of the Pilbara area is essentially Eremaean with much of the area covered by spinifex hummock grasslands. Spinifex is a uniquely Australian plant form adapted to infertile soils, arid climate and fire. There is a change to mulga shrublands and woodlands towards the south of the survey area, and to pindan vegetation (acacia shrublands with scattered trees and a grass layer) towards the north.

It appears that European activities including pastoralism, mining, tourism and the introduction of exotic plants, have modified the Pilbara vegetation, but not as substantially as other rangeland regions of Western Australia. The relatively low overall impact of pastoralism is due to the large areas of vegetation of moderate to very low pastoral value, i.e. the spinifex hummock grasslands. Tussock grasslands and chenopod shrublands have been most extensively and substantially altered, both in appearance and with respect to ecosystem function. These formations support vegetation preferred by and accessible to stock, feral animals and kangaroos. The vegetation of the survey area may generally be considered to be in good condition (see the Resource condition chapter of this report).

Plant communities on two land systems identified and mapped in the survey area are particularly threatened. The Mosquito land system east of Nullagine supports hummock grasslands which include chenopod shrubs that are preferentially grazed, supports two Priority species including a chenopod shrub, and is subject to high levels of mining activity. The Wona land system on the basaltic uplands supports tussock grasslands which are subject to preferential grazing, and supports a number of Priority flora species.

Land managers have a major contribution to make to regional conservation through the integration of nature conservation and primary production objectives. Pastoralists have a major role to play in the control of grazing animals as improved stock control and management will make substantial progress towards ecological sustainability in the region.

The management of threatened species and communities which occur on pastoral leases, particularly those that are not known to occur on lands set aside for nature conservation, is an important issue which requires the cooperation of pastoralists, miners, Land Conservation Districts Committees and CALM.

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Site type ecology

A.M.E. Van Vreeswyk and A.L. Payne

Site types 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 site types. Site types are described in terms of combinations of landforms, soil types and plant communities. They most closely resemble the 'ecological site' of the Society for Range Management (1991) and the 'site type' of Tinley (1991). In previous rangeland surveys in Western Australia, site types have been termed 'pasture lands' (Payne, Mitchell and Holman 1988), 'pasture types' (Payne, Curry and Spencer 1987), 'vegetation types' (Curry *et al.* 1994), 'site types' (Pringle, Van Vreeswyk and Gilligan 1994) and 'habitat types' (Payne *et al.* 1998). 'Site type' was chosen as it most accurately fits the ecological classification below.

The classification of site types (see Table 1) in this chapter has partly developed from previous rangeland surveys and is augmented with new site types recognised during this survey.

For ease of description ecologically similar site types have been aggregated into broader site type groups. Site types, within a particular site type group, have generally similar positions in the landscape as well as similar vegetation and soils.

Site types are described according to their particular combination of land surface, dominant plant species, and vegetation formation and given an appropriate four letter code (e.g. hill spinifex grassland - HSPG).

Within the broader site type groups the site types are described in terms of:

- general information (physical environment, distribution patterns, general ecology);
- vegetation physiognomy and composition (by stratum);
- patterns of variation (including the impact of grazing and fire);
- nature conservation status;
- gradational associations; and
- land system representation (a site type is defined as being a major site type on a land system if it occurs on 30% or more of the land system, as common where it occurs on 20-29% of the land system, and as minor where it occurs on <20% of the land system).

Terminology used in describing site type composition

The following definitions have been used:

Tree	A plant over 2 m high with a single trunk to at least 1.3 m, including single trunk eucalypts
Mallee	A multi-trunked 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 or herbaceous plant less than 1 m in height
Perennial grass	A grass species usually persisting for at least two years
Annual	A short-lived plant usually persisting for less than two years
Other plant forms	Plants such as creepers and sedges

Dominant species are those which were recorded as dominant in a stratum at a quarter or more of sampling sites. Common species are those subordinate species recorded at a quarter or more sampling sites or where traverse notes indicated that they were common in the particular site type.

Taxonomic conventions

The plant taxonomy adopted in this survey is based on the Census of Western Australian Plants (Chapman, Gioia and Wilson, in prep.) but also adopts changes on the advice of the Western Australian Herbarium.

Species conservation status has been assigned according to the Declared Rare and Priority Flora List for Western Australia (Atkins 2003).

DRF Declared Rare Flora - Extant taxa

Taxa which have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction, or otherwise in need of special protection, and have been gazetted as such.

P1 Priority One - Poorly known taxa

Taxa which are known from one or a few (generally <5) populations which are under threat either due to small population size, or being on lands under immediate threat, e.g. road verges, urban areas, farmland, active mineral leases, etc. or the plants are under threat, e.g. from disease, grazing by feral animals, etc. 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.

P2 Priority Two - Poorly known taxa

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.

P3 Priority Three - Poorly known taxa

Taxa which are known from several 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 need of further survey.

P4	**Priority Four - Rare taxa** 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 to 10 years.

Assessment of grazing impacts

Grazing impacts are considered in recognition of their widespread impact on site types.

The site type classification used in this chapter reduces natural variation into a manageable number of ecological types, which facilitates the assessment of range 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. They have been termed ‘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 are 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 also common in disturbed (e.g. burnt) areas. They have been termed ‘woody weeds’ (in the case of shrubs) or ‘undesirables’.
No indicator value	The abundance of these species is not primarily related to grazing history. They usually only decrease in number after natural disturbances such as hail damage or fire. These species are 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 may play in maintaining soil stability and ecosystem function.

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 the survey team members and their ability to recognise and explain signs of impact.

This chapter in context

This chapter focuses on site type and plant community description and ecology. At a broader scale, landscape characteristics are covered in the Geomorphology and Land system chapters. Summaries of visual traverse assessments of vegetation and soil condition are presented in the Resource condition chapter.

Description of site types within their broader site type groups

Forty-four major site types split into eleven site type groups (Table 1) are described in some detail.

A. HILL HUMMOCK GRASSLAND SITE TYPES

The site types in this site type group are based on hummock grasses (spinifexes) and occur on nearly all hills, ridges and ranges in the Pilbara. Soils are stony skeletal sands, loams and clays with dense surface mantles of pebbbles and cobbles and frequent rock outcrop. The site types contrast markedly with shrubland site types which dominate hills and ranges in adjacent survey areas to the south of the Pilbara. Climatic, rather than edaphic, factors most likely explain the regional difference. A notable exception to hummock grass dominance on hills within the survey area is the minor mulga grassy shrubland site type which is unique to basaltic hills of the Marandoo land system in the far south.

This widespread site type group is floristically rich with a number of threatened species (e.g. *Lepidium catapycnon* - DRF, *Acacia aphanoclada* - P1, *Indigofera ixocarpa* ms - P2 and *Eremophila magnifica* subsp. *velutina* ms - P3) and has high conservation value. Coincidently it has relatively low pastoral value and stock preference and is little impacted by grazing. It is frequently impacted by burning as part of natural perturbations and/or planned or unplanned human actions. Mining activities can have heavy impact albeit relatively localised.

Nearly all hilly land systems in the Pilbara support hard spinifex site types (HSPG, HESG) occasionally with scattered eucalypts such as Eucalyptus leucophloia (snappy gum). Spinifex species include Triodia wiseana (limestone spinifex), T. lanigera (common hard spinifex) and T. brizoides (echidna spinifex). The nature of the vegetation and poor accessibility means these site types are of little or no use for pastoralism but they provide important habitat for native fauna.

Table 1. Site type groups and their component site types

A	**Hill hummock grassland site types**	
1.	HSPG	Hill spinifex grassland
2.	HESG	Hill eucalypt spinifex grassland
B	**Hill sclerophyll shrubland site types**	
3.	HMGS	Hill mulga grassy shrubland
C	**Upland plain tussock grassland site types**	
4.	BUTG	Basaltic upland tussock grassland
D	**Plain hummock grassland site types**	
5.	PHSG	Plain hard spinifex grassland
6.	PSSG	Plain soft spinifex grassland
7.	PMSS	Plain mulga spinifex shrubland/grassland
8.	CASG	Calcrete spinifex grassland
9.	SSCG	Stony plain spinifex grassland with chenopod shrubs
E	**Stony plain and low rise sclerophyll shrubland site types**	
10.	SAES	Stony plain acacia-eremophila-cassia shrubland
11.	PAGS	Plain acacia cassia grassy shrubland
12.	PMGS	Plain mosaic grassy shrubland
13.	CACS	Calcrete acacia cassia shrubland
F	**Sheet flood hardpan plain sclerophyll shrubland or woodland site types**	
14.	HPMS	Hardpan plain mulga shrubland
15.	LHAS	Lateritic hardpan plain acacia shrubland
16.	PSMS	Plain sparse mulga shrubland
17.	GMGW	Grove mulga grassy woodland/shrubland
18.	GMUW	Grove mulga woodland/shrubland
19.	PMCS	Plain mulga shrubland with chenopod low shrubs
G	**Sandplain and dune grassland site types**	
20.	SHSG	Sandplain hard spinifex grassland
21.	SSSG	Sandplain soft spinifex grassland
22.	CDSG	Coastal dune soft spinifex grassland
23.	CDBG	Coastal dune buffel grass grassland
24.	SBAS	Sandy bank acacia spinifex shrubland
H	**Alluvial plain hummock grassland (and occasionally grassy shrubland) site types**	
25.	AHSG	Alluvial plain hard spinifex grassland
26.	ASSG	Alluvial plain soft spinifex grassland
27.	ASHS	Alluvial plain snakewood hummock grass shrubland
I	**Alluvial plain tussock grassland (and occasionally grassy shrubland) site types**	
28.	APTG	Alluvial plain tussock grassland (includes 7 sub-types)
29.	ARPG	Alluvial plain Roebourne Plains grass grassland
30.	APBG	Alluvial plain buffel grass grassland
31.	AEBG	Alluvial plain buffel grass grassland with eucalypt overstorey
32.	PMOG	Plain mosaic grassland
33.	SPSG	Saline plain sporobolus grassland
34.	SSTS	Stony alluvial plain snakewood grassy shrubland
J	**Alluvial plain halophytic shrubland site types**	
35.	PSCS	Plain snakewood shrubland with chenopod low shrubs
36.	PXHS	Plain mixed halophyte shrubland
37.	PSPS	Plain samphire shrubland
38.	PCGS	Plain chenopod grassy shrubland
K	**Drainage shrubland and woodland site types**	
39.	DAHW	Drainage acacia hummock grass shrubland/woodland
40.	DESG	Drainage spinifex grassland with eucalypt overstorey
41.	DEGW	Drainage eucalypt and acacia grassy woodland/shrubland
42.	DEAW	Drainage eucalypt and acacia woodland/shrubland
43.	DMES	Drainage melaleuca shrubland
44.	GMEW	Gallery (riverbank and channel) melaleuca eucalypt woodland

1. Hill spinifex grassland (HSPG)

Sampling

84 inventory sites, 563 traverse points

General information

HSPG occurs on hillslopes, hillcrests, footslopes, plateaux, ridges and low rises throughout the survey area. Slopes may be up to 50% with relief up to about 450 m. Soils are shallow and commonly stony, with abundant to very abundant (>50%) stony mantles and some rock outcrop. Substrates include basalt, sandstone, granitic and metamorphic rocks.

Physiognomy and composition

HSPG hummock grassland of *Triodia* species, with isolated to scattered trees and shrubs (PFC varies between 0-20%). The dominant hummock grass species varies but is often *Triodia pungens* or T. wiseana. The hummock grass layer generally has 10-40% PFC but this ranges from 0-50% and is related to time since the last fire.

298 perennial species were recorded at the 84 inventory sites, at the survey average of 16 species per site. 106 annual species were recorded, with an average of 5 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – eucalypts occasionally recorded as a stratum Common – *Corymbia hamersleyana, Eucalyptus leucophloia*
Tall shrubs:	Dominant – variable; often *Acacia inaequilatera* Common – *Acacia orthocarpa, Grevillea wickhamii, Hakea lorea* subsp. *suberea*
Mid shrubs:	Dominant – variable; acacias or sennas Common – *Acacia bivenosa, A. inaequilatera, Senna glutinosa, S. glutinosa* subsp. x *luerssenii, S. glutinosa* subsp. *pruinosa*
Low shrubs:	Dominant – very variable Common – *Abutilon lepidum, Corchorus* spp., *Goodenia stobbsiana, Indigofera monophylla, Mollugo molluginis, Ptilotus calostachyus, Senna artemisioides* subsp. *oligophylla, Tribulus platypterus, Tribulus suberosus*
Perennial grasses:	Dominant – variable; often *Triodia pungens* or *T. wiseana* Common – *Cymbopogon ambiguus, Eriachne mucronata T. brizoides, T. lanigera, T. plurinervata*

Common annuals include *Aristida contorta, Cleome viscosa, Dysphania rhadinostachya, Enneapogon caerulescens, Eriachne pulchella, Euphorbia australis, Gomphrena cunninghamii, Ptilotus auriculifolius, P. exaltatus, Salsola tragus, Trachymene oleracea* and *Trichodesma zeylanicum.*

Patterns of grazing impact

Traverse condition summary (563 assessments):

Vegetation - good 100%.
Soil erosion - nil 100%.

HSPG is largely unaffected by grazing. It has very low pastoral potential. The hummock grasses and most of the shrubs are unattractive to stock, and it often occurs on areas which are poorly accessible to stock.

Nature conservation

HSPG provides habitat for small to large sized mammals and reptiles and birds and it supports a number of threatened flora. The following threatened flora were recorded on HSPG: *Acacia aphanoclada* (P1), *Bulbostylis burbidgeae* (P3), *Sida* sp. Barlee Range PN (P2) and *Sida* sp. Wittenoom PN (P3). *Acacia aphanoclada* and *Sida* sp. Barlee Range were exclusive to this site type.

HSPG is represented in conservation reserves within the survey area. It was recorded in the Karijini National Park and the Meentheena pastoral lease (a lease acquired by the Department of Conservation and Land Management for conservation purposes). It also occurs extensively on unallocated Crown land within the survey area.

Gradational associations

HSPG grades into *Plain hard spinifex grassland* (PHSG) or *Plain soft spinifex grassland* (PSSG) on gently sloping footslopes and lower plains.

Land systems

HSPG is the dominant site type on Black, Boolaloo, Callawa, Capricorn, Granitic, Houndstooth, McKay, Mosquito, Nanutarra, Robe, Robertson, Rocklea, Ruth and Talga land systems. It is a major site type on Adrian, Coongimah and Newman land systems and a minor site type on another 27 systems.

2. Hill eucalypt spinifex grassland (HESG)

Sampling

14 inventory sites, 164 traverse points

General information

HESG occurs on hillslopes, footslopes and low rises throughout the survey area. Slopes may be up to 25% with relief up to 120 m. Soils are generally shallow and stony, with common to abundant (10-90%) stony mantles and some rock outcrop. The substrate is often ironstone.

Physiognomy and composition

HESG is a hummock grassland of *Triodia* species with an overstorey of isolated to scattered (up to 15% PFC) eucalypts, and isolated to scattered (up to 20% PFC) shrubs. The dominant hummock grass species is variable and includes *Triodia angusta, T. biflora, T. brizoides, T. concinna, T. plurinervata, T. pungens* and *T. wiseana*. The dominant eucalypt species is most commonly *Eucalyptus leucophloia* and the tree layer is 2-8 m tall. The hummock grass layer generally has 20-50% PFC but this ranges from 0-60% and is related to time since the last fire.

116 perennial species were recorded at the 14 inventory sites, with an average of 20 species per site, 4 above the survey average. 29 annual species were recorded, with an average of 3 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – commonly *Eucalyptus leucophloia*, occasionally *Corymbia hamersleyana* Common – *Acacia pruinocarpa, C. hamersleyana*
Tall shrubs:	Dominant – acacias or *Grevillea wickhamii* Common – *Acacia adoxa, A. maitlandii, A. tetragonophylla, Grevillea wickhamii, Hakea lorea* subsp. *suberea*
Mid shrubs:	Dominant – acacias or sennas Common – *Acacia atkinsiana, Acacia bivenosa, A. monticola, Senna glutinosa, Senna glutinosa* subsp. x *luerssenii, Senna glutinosa* subsp. *pruinosa*
Low shrubs:	Dominant – very variable Common – *Acacia hilliana, Goodenia stobbsiana, Indigofera monophylla, Ptilotus calostachyus, P. obovatus, P. rotundifolius, Senna artemisioides* subsp. *oligophylla, Solanum lasiophyllum*
Perennial grasses:	Dominant – *Triodia* spp. Common – *Themeda triandra, Triodia brizoides, T. pungens, T. wiseana*

Common annuals are *Aristida contorta, Dysphania* spp., *Ptilotus aervoides, P. calostachyus, P. exaltatus* and *P. helipteroides.*

Patterns of grazing impact

Traverse condition summary (164 assessments):

Vegetation - good 100%.
Soil erosion - nil 100%.

HESG is largely unaffected by grazing. It supports few species which are attractive to livestock and much of it is poorly accessible. It has very low pastoral potential, although pastoral productivity is somewhat increased for a few years after burning.

Nature conservation

HESG provides habitat in terms of food and shelter for a wide range of invertebrate and vertebrate fauna and supports threatened flora.

HESG is represented in conservation reserves within the survey area. It was recorded in the Karijini and Millstream-Chichester National Parks. It also occurs extensively on unallocated Crown land within the survey area.

Gradational associations

HESG grades into *Plain hard spinifex grassland* (PHSG) and *Plain soft spinifex grassland* (PSSG) from uplands to lower plains. HESG occurs on similar landforms as *Hill spinifex grassland* (HSPG) but not as frequently. It is associated most commonly with hills on ironstone.

Land systems

HESG is the dominant site type on Newman land system and a major site type on Platform land system.

B. HILL SCLEROPHYLL SHRUBLAND SITE TYPES

This site type group is made up of one site type which is unique to the basaltic hills and plains of the Marandoo land system in the far south of the survey area. Soils are shallow with many large basalt pebbles and cobbles.

Vegetation is a mulga shrubland over a tussock grass layer of the genera *Chrysopogon* or *Themeda*. The site type can be impacted by excessive grazing where the palatable dominant perennial grasses are removed.

3. Hill mulga grassy shrubland (HMGS)

Sampling

4 inventory sites, 23 traverse points

General information

HGMS occurs on hillslopes and plains of the Marandoo land system. Slopes may be up to 25% with relief up to 250 m. Soils are shallow loams and loamy earths and have abundant to very abundant (>50%) mantles of basalt large pebbles and cobbles (2-20 cm).

Physiognomy and composition

HGMS occurs as a very scattered to scattered (5-20% PFC) mulga tall shrubland with low and mid shrub layers and a perennial tussock grass understorey. The shrubs are scattered to moderately close (10-30% PFC). The dominant perennial tussock grass is ribbon grass (*Chrysopogon fallax*) or kangaroo grass (*Themeda triandra*) and the grass layer has a basal cover of <0.5-3%.

61 perennial species were recorded at the 4 inventory sites, with an average of 21 species per site, 5 above the survey average. 20 annual species were recorded, with an average of 8 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – not usually present as a recognisable stratum Common – *Acacia pruinocarpa*
Tall shrubs:	Dominant – *Acacia aneura* Common – none
Mid shrubs:	Dominant – variable Common – *Eremophila fraseri, E. latrobei, Senna glutinosa* subsp. x *luerssenii*

Low shrubs:	Dominant – variable; often sennas Common – *Abutilon lepidum, Eremophila forrestii, Evolvulus alsinoides, Ptilotus rotundifolius, Senna artemisioides* subsp. *helmsii, Senna artemisioides* subsp. *oligophylla, Sida echinocarpa, Solanum horridum, S. lasiophyllum*
Perennial grasses:	Dominant – *Chrysopogon fallax* or *Themeda triandra* Common – *Chrysopogon fallax, Cymbopogon ambiguus, Themeda triandra*

Common annuals include *Aristida contorta, Enneapogon caerulescens, Gomphrena canescens, Ptilotus exaltatus, Salsola tragus* and *Trichodesma zeylanicum*.

Patterns of grazing impact

Traverse condition summary (23 assessments):

Vegetation - good 39%; fair 39%; poor 22%.
Soil erosion - nil 100%.

The palatable dominant perennial grasses can be removed by excessive grazing. These may be replaced by less palatable species or leave bare ground. The stony mantle protects the site type from erosion.

Nature conservation

HGMS is likely to have a high conservation value as it is restricted to the Marandoo land system.

HGMS was not recorded in conservation reserves within the survey area but was recorded on unallocated Crown land.

Gradational associations

HGMS grades into *Hardpan plain mulga shrubland* (HPMS) downslope.

Land systems

HGMS is the dominant site type on Marandoo land system. It occurs on no other land systems.

C. UPLAND PLAIN TUSSOCK GRASSLAND SITE TYPES

One distinctive site type makes up this group which is almost exclusive to basalt dominated upland or tableland terrain associated with the Chichester and other ranges. Soils are formed *in situ* and are clays that crack deeply seasonally with gilgai microrelief and many basalt cobbles and stones on the surface.

Vegetation is usually dominated by tussock grasses of the genera *Astrebla, Chrysopogon, Eragrostis* and *Aristida*. There may be occasional patches of *Acacia xiphophylla* (snakewood) shrubs but usually no tall or mid shrubs. The ground layer includes numerous perennial legume creepers and diverse annuals in season. The rare *Ischaemum albovillosum* (tableland white grass) occurs on this site type. The site type is preferred by grazing animals, both domestic and native, and is frequently heavily impacted.

Basaltic uplands of the Wona land system support a unique grassland site type (BUTG). Soils are very stony cracking clays supporting the perennial grasses Astrebla pectinata *(barley Mitchell grass),* A. elymoides *(weeping Mitchell grass),* Eragrostis xerophila *(Roebourne Plains grass),* Aristida latifolia *(feathertop threeawn) and* Eriachne species *(wiregrass). This vegetation is highly preferred by livestock and kangaroos, and can be degraded to annual grasslands or herbfields if grazing is uncontrolled. Some priority species including* Ischaemum albovillosum *(tableland white grass) occur solely within this site type which is represented in the Chichester Range National Park.*

4. Basaltic upland tussock grassland (BUTG)

Sampling

5 inventory sites, 17 condition sites, 131 traverse points

General information

BUTG occurs on basaltic upland gilgaied stony plains and some lower stony plains. Soils are deep cracking clays with many to very abundant mantles (>20%) of basalt pebbles and cobbles (usually 2-20 cm) but also larger stones and boulders. Slopes are up to 3%, but commonly much less.

Physiognomy and composition

BUTG is a tussock grassland with isolated (<2.5% PFC) low shrubs and very occasionally isolated taller shrubs such as snakewood (*Acacia xiphophylla*). It is dominated by the Mitchell grasses *Astrebla elymoides* and *A. pectinata* or (rarely) by *Ischaemum albovillosum*. Basal cover of the perennial grasses rarely exceeds 5%. Perennial creepers *Desmodium campylocaulon, Glycine falcata, Rhynchosia minima* and *Vigna* sp. are common on BUTG. Annual grasses and herbs are very common in season.

22 perennial species were recorded at the 5 inventory sites, with an average of 8 species per site, considerably lower than the survey average of 16. 34 annual species were recorded, with an average of 12 species per site.

The following perennial species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – not present as a recognisable stratum Common – *Acacia xiphophylla*
Mid shrubs:	Dominant – not present as a recognisable stratum Common – *Senna artemisioides* subsp. x *sturtii*
Low shrubs:	Dominant – occasionally present as a recognisable stratum; *Senna hamersleyensis* or *Sida fibulifera* Common – *Neptunia dimorphantha, Senna symonii, Sida fibulifera*
Perennial grasses:	Dominant – *Astrebla elymoides, A. pectinata* or *Ischaemum albovillosum* Common – *Aristida latifolia, Chrysopogon fallax, Eragrostis xerophila, Eriachne obtusa*
Other plant forms:	Common – *Cajanus marmoratus, Desmodium campylocaulon, Glycine falcata, Rhynchosia minima, Vigna* sp. (creepers)

Common annuals include *Brachyachne convergens, Calocephalus* spp., *Flaveria australasica, Heliotropium* spp., *Iseilema vaginiflorum, Ptilotus carinatus, P. exaltatus, P. gomphrenoides* and *Streptoglossa bubakii*.

Patterns of grazing impact

Traverse condition summary (131 assessments):

Vegetation - good 22%; fair 31%; poor 47%.
Soil erosion - nil 100%.

BUTG is preferentially grazed by domestic stock and kangaroos. Overgrazing will remove the dominance of palatable perennial grasses, often leaving a tussock grassland dominated by *Aristida latifolia*, or an annual community of herbs and grasses. BUTG is not susceptible to erosion as the clay topsoil and stone mantles make it inherently stable. However, if stone mantles are removed, such as along tracks on long slopes, erosion can occur.

Nature conservation

BUTG provides a unique habitat with large pebbles and cobbles and wide seasonal cracks in the soil for small mammals and invertebrates. The following threatened flora were recorded on BUTG: *Goodenia pascua* (P3), *Ischaemum albovillosum* (P2) and *Tephrosia* sp. Cathedral Gorge (F.H. Mollemans 2420) PN (P3). *Ischaemum albovillosum* and *Tephrosia* sp. Cathedral Gorge were exclusive to this site type.

BUTG is fairly well represented in conservation reserves within the survey area; 11 of the 131 traverse assessments were recorded on conservation reserves. BUTG was recorded in the Millstream-Chichester National Park. It was not recorded on unallocated Crown land. BUTG is a unique site type that supports threatened flora and is preferentially grazed.

Table 2. Summary of attributes for BUTG variation recorded from condition (C) sites

Vegetation attributes	Observations on natural variation and grazing impact
Spatial distinction of margin/edges to the type of site	Usually sharply bounded and ‘benched’ upper topographic site type (C229), with tight stony/less stony soil patch pattern (usually at too fine a scale to be distinguishable on aerial photography or satellite imagery).
Patchy microtopograhy of very stony and less stony soil patches	Dominance or density of *Eriachne obtusa* was mainly on stony patches (C50) while *Astrebla pectinata* was mainly on less stony patches (C57).
Perennial grass species dominance	Ubiquitously, except where degraded with perennial grass associations lost and replaced by annual herbfields.
Perennial grass species richness	1-6 species per site, from *Astrebla pectinata, Astrebla elymoides, Aristida latifolia, Chrysopogon fallax, Ischaemum albovillosum, Eragrostis xerophila, Eriachne obtusa.* Sites with only one or two species present and at high abundance (frequency) may be natural variation and not necessarily adversely impacted by prior usage.
Perennial grass frequency	*Astrebla pectinata* up to 95% (C52), *Aristida latifolia* up to 90% (C74).
Perennial grasses grazed preferentially with decreaser response	*Astrebla pectinata* (C51, C58). *Astrebla pectinata* as a remnant to increasing *Aristida latifolia* (C228). *Eragrostis xerophila* (C223).
Perennial grasses with intermediate grazing response	*Aristida latifolia* evidently increased on some sites (C57), sometimes heavily grazed by kangaroos (C228) and recorded as a remnant in a mixed annual herbfield (C223).
Presence of perennial shrubs and creepers	Varied, some sites none, on others isolated to scattered cover with low species richness and beyond their valuable presence little indication of any indicator value. Species include *Cajanus marmoratus, Desmodium campylocaulon, Neptunia dimorphantha, Rhyncosia minima, Sida fibulifera, Vigna* sp.
Shrubs probably increasers	*Glycine falcata, Sida fibulifera* (C49).
Presence of Priority Species of perennial grass	*Ischaemum albovillosum* appears to be a fairly short-lived or weak perennial. It was found on 31% of sites, sometimes co-dominant with *Aristida latifolia* (C59, C73).
Perennial vegetation replacement by an annual herbfield	All perennial grasses had been eliminated from some sites (C48). Annual herbfields develop dominated by *Iseilema vaginiflorum* and *Streptoglossa bubakii*.

As a result of this survey, CALM has added BUTG on the Wona land system to the list of Priority Ecological Communities under Category 3 (iii). This site type should be considered for further reservation.

Gradational associations

BUTG is a distinctive community occurring in elevated parts of the landscape specifically on cracking clay soils and thus has clear and sharp boundaries with other site types such as *Hill spinifex grassland* (HSPG).

Land systems

BUTG is the most extensive site type on the Wona land system. It also occurs as a minor site type on Rocklea, White Springs and Bonney land systems.

D. PLAIN HUMMOCK GRASSLAND SITE TYPES

Site types in this group are widely distributed throughout the survey area. The sites are mostly near level to gently sloping erosional surfaces as pedeplains or exposed valley fill deposits (in the case of calcretes) below ranges and hill tracts and upslope from depositional surfaces such as hardpan wash plains and alluvial plains associated with the major rivers of the area. They are essentially transfer zones receiving water from adjacent uplands and shedding water to plains downslope. The vegetation is dominated by *Triodia* species hummock grasses with variable shrub layers dominated by sclerophyllous and/or Eremaean genera including *Acacia*, *Senna*, *Eremophila* and *Ptilotus*.

Hummock grassland (spinifex) site types are the most widespread and common in the Pilbara and occur on many different landforms and soil types. This sandy plain supports Triodia plurinervata *(pincushion spinifex) (PHSG) which is of little use for pastoralism but provides habitat for a variety of small ground dwelling fauna.*

5. Plain hard spinifex grassland (PHSG)

Sampling

103 inventory sites, 2,790 traverse points

General information

PHSG occurs extensively on plains throughout the survey area, including stony plains, loamy plains, gravelly plains and gritty-surfaced plains. PHSG also occurs on footslopes and low rises. Slopes range from level to 6%, and relief is up to 15 m, although mostly 6 m or less. Soils are most commonly loams, calcareous loams, sandy earths, loamy earths and clays. They are generally shallow with variable cover of pebbles which are mostly 2-60 mm in size.

PHSG is the most common site type in the survey area, being recorded at 23% of the traverse points.

Physiognomy and composition

PHSG is hummock grassland of *Triodia* species, with isolated to scattered (<2.5-20% PFC) trees and shrubs. The dominant hummock grass species varies but is often *Triodia wiseana* (limestone spinifex). The grass layer may have up to 60% PFC (but most commonly 10-50%) depending on time since the last fire. For a short period after fire where the hummock grass PFC is <5%, the low shrub stratum may be dominant.

303 perennial species were recorded at the 103 inventory sites, at the survey average of 16 species per site. 163 annual species were recorded with an average of 6 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – occasionally recorded as a stratum; commonly *Corymbia hamersleyana* or *Eucalyptus leucophloia* Common – *Corymbia hamersleyana, Hakea lorea* subsp. *suberea*
Tall shrubs:	Dominant – variable; most commonly acacias; often *Acacia inaequilatera* Common – *A. ancistrocarpa, A. inaequilatera, A. victoriae, Grevillea wickhamii*
Mid shrubs:	Dominant – variable; most commonly acacias and occasionally sennas Common – *Acacia ancistrocarpa, A. bivenosa, A. inaequilatera, Senna, glutinosa, Senna glutinosa* subsp. x *luerssenii, S. glutinosa* subsp. *pruinosa*
Low shrubs:	Dominant – very variable Common – *Acacia stellaticeps, Corchorus* spp., *Goodenia stobbsiana, Indigofera monophylla, Mollugo molluginis, Ptilotus astrolasius, P. calostachyus, Senna artemisioides* subsp. *helmsii, Senna artemisioides* subsp. *oligophylla, Senna symonii, Sida echinocarpa, Solanum lasiophyllum*
Perennial grasses:	Dominant – variable; often *Triodia wiseana* Common – *Cenchrus ciliaris, Paraneurachne muelleri, Triodia lanigera, T. longiceps, T. plurinervata, T. pungens, T. wiseana*
Other plant forms:	Common – *Rhynchosia minima* (creeper)

Common annuals include *Aristida contorta, Cleome viscosa, Dysphania rhadinostachya, Enneapogon caerulescens, Eriachne pulchella, Euphorbia australis, Goodenia* spp., *Ptilotus aervoides, P. exaltatus, Senna notabilis, Sporobolus australasicus* and *Yakirra australiensis*.

Patterns of grazing impact

Traverse condition summary (2,790 assessments):

Vegetation	-	good 98%; fair 2%.
Soil erosion	-	nil 100%.

The spinifexes and most of the shrubs on PHSG are unattractive to grazing animals and the site type is largely unaffected by grazing. Pastoral potential is very low. Ground cover and plant species composition is influenced far more by burning history and seasonal conditions post burning than by grazing. Soils associated with PHSG are usually stable.

Nature conservation

This extensive site type includes many plants ubiquitous to the Pilbara, however, it also contains species of particular conservation value. The following threatened flora were recorded on PHSG: *Abutilon trudgenii* ms (P3), *Acacia balsamea* (P4), *Bulbostylis burbidgeae* (P3) and *Sida* sp. Wittenoom PN (P3). It also provides habitat for various vertebrates and invertebrates.

PHSG is well represented in conservation reserves within the survey area. It was recorded on the Karijini and Millstream-Chichester National Parks, Cane River Nature Reserve and the Meentheena pastoral lease. It occurs extensively on unallocated Crown land.

Gradational associations

PHSG grades into *Hill spinifex grassland* (HSPG) on footslopes below hills. It also grades laterally into *Plain soft spinifex grassland* (PSSG) where plains receive more water and into *Sandplain hard spinifex grassland* (SHSG) or *Sandplain soft spinifex grassland* (SSSG) on plains with deep sands.

Land systems

PHSG is the most extensive site type on the following land systems Adrian, Billygoat, Boolgeeda, Coongimah, Egerton, Giralia, Kumina, Lochinvar, Nirran, Paraburdoo, Paterson, Peedamulla, Platform, Pyramid, Satirist, Spearhole, Stuart, Tanpool, Uaroo and White Springs. It is the co-dominant site type with *Plain soft spinifex grassland* (PSSG) on the Macroy and Taylor systems and with *Plain snakewood shrubland with chenopod low shrubs* (PSCS) on the Sherlock system. It is a major site type on Buckshot land system and occurs as a minor site type on another 30 land systems.

6. Plain soft spinifex grassland (PSSG)

Sampling

66 inventory sites, 21 condition sites, 1,799 traverse points

General information

PSSG occurs extensively on stony plains, loamy plains and gritty-surfaced plains throughout the survey area. PSSG also occurs on gently sloping footslopes. Soils are generally shallow and may have gravelly or pebbly surface mantles of variable density. They are most commonly sands, sandy earths and loamy earths. Slopes range from level to 7% but are mostly <3%, and relief is up to 15 m, but most commonly less than 6 m. PSSG is the second most common site type in the survey area, being recorded at 15% of the traverse points.

Physiognomy and composition

PSSG is a hummock grassland of resinous *Triodia* species, with isolated to moderately close (<2.5-25% PFC) trees and shrubs. The shrubs may form prominent strata and are commonly acacias. The dominant grass is mostly *Triodia pungens* (soft spinifex), but is occasionally *T. epactia*. The grass layer may have 0-60% PFC (commonly 10-40%) partly depending on time elapsed (or the cumulative rainfall) since the last fire. For a year or two after fire when grass cover is very low the site type may take the form of a low or mid height shrubland with or without a seasonal herb understorey.

278 perennial species were recorded at the 66 inventory sites, with an average of 15 species per site, slightly below the survey average. 127 annual species were recorded, with an average of 6 species per site.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – occasionally recorded as a stratum; often *Corymbia hamersleyana* or *Eucalyptus leucophloia* Common – *Acacia pruinocarpa, Corymbia hamersleyana, Grevillea wickhamii, Hakea lorea* subsp. *suberea*
Tall shrubs:	Dominant – variable; most commonly acacias Common – *Acacia ancistrocarpa, A. atkinsiana, A. inaequilatera, Grevillea pyramidalis, Hakea lorea* subsp. *suberea*
Mid shrubs:	Dominant – variable; most commonly acacias, occasionally sennas Common – *Acacia ancistrocarpa, A. bivenosa, A. inaequilatera, Senna glutinosa, Senna glutinosa* subsp. x *luerssenii*
Low shrubs:	Dominant – very variable; often acacias, corchorus or sennas Common – *Acacia stellaticeps, Bonamia rosea, Corchorus sidoides, C. walcottii, Euphorbia australis, Indigofera monophylla, Mollugo molluginis, Ptilotus australasicus, P. calostachyus, Senna artemisioides* subsp. *oligophylla, Solanum lasiophyllum, Tephrosia uniovulata*
Perennial grasses:	Dominant – *Triodia pungens* or *T. epactia* Common – *Aristida holathera* var. *holathera, A. latifolia, Cenchrus ciliaris, Chrysopogon fallax, Eragrostis eriopoda, Paraneurachne muelleri*

Common annuals include *Aristida contorta, Cleome viscosa, Dysphania rhadinostachya, Eriachne aristidea, E. pulchella, Fimbristylis* sp., *Ptilotus exaltatus, Senna notabilis, Sporobolus australasicus, Trichodesma zeylanicum* and *Yakirra australiensis*.

Patterns of burning and grazing impact

Traverse condition summary (1,799 assessments):

Vegetation - good 93%; fair 6%; poor 1%.
Soil erosion - nil 98%; minor 2%.

PSSG is susceptible to wind erosion after burning but this is not usually a major problem as stability is quickly restored by post-fire regrowth unless grazing pressure is excessive.

Soil surfaces supporting PSSG were usually recorded as having no crypogamic crusting or only as minor areas (up to 5%).

PSSG sites with young soft spinifex are moderately attractive to livestock but mature stands are unattractive and of little use for pastoralism.

Generally PSSG is resilient under grazing but it can become degraded when small patches are burnt and stock congregate heavily on these preventing the spinifex and other palatable plants from establishing. This can result in bare patches or changes in species composition towards unpalatable plants. Suijdendorp (1981) suggests that shrub invasions can occur after a winter burn. The unpalatable low shrub *Acacia stellaticeps* (poverty bush) may thrive and establish thick stands at the expense of the spinifex. A stable, less productive disclimax is reached. Winter burning may promote prolific growth of other unpalatable plants such as *Senna notabilis* (cockroach bush) or *Corchorus* species.

About 33% of the condition sites had evidently been burnt within the previous 3 years. The high frequency of fires means that the presence or absence of particular plants or suites of plants may be more closely related to season of burning and post-fire stages rather than to grazing pressure. Suijdendorp (1967, 1981) suggests that summer burning coupled with deferred grazing for a few months after rain will facilitate the establishment of seral species (some of which are palatable to livestock) in competition with spinifex and delay its resumption of dominance. While in several cases the season of the fire was unknown, there was little conclusive evidence from the site vegetation record to distinguish summer-burnt from winter-burnt sites, in terms of their cover or frequency of spinifex seedlings, other perennial grasses, other perennials or annuals. All of these characteristics were subject to high variation between sites, so a larger number of sites observed over more years would be needed to examine the possible qualitative and quantitative differences stressed by Suijendorp (1981).

In some cases, presumably following good seasons and where conditions were suitable, the germination and regrowth of soft spinifex seedlings into hummock grass cover was rapid - achieving frequency measurements of up to 94% (C90) within a year of fire.

Table 3. Summary of vegetation attributes for variation recorded from recently burnt (<3 years) PSSG condition sites

Vegetation attributes	Observations on natural variation and grazing impact
Frequency of soft spinifex grasses	26% to100%, mean 71%.
Projected Foliar Cover of soft spinifex grasses	2% to 57%, mean 30%.
Other perennial grass species richness	0-4 species; mean 1.5.
Woody and herbaceous perennial species richness	0-21 species; mean 9.
Palatable (desirable) woody and herbaceous perennial species richness	0-7 species; mean 2.0.
Main palatable (desirable) woody and herbaceous perennial species frequency	*Boerhavia gardneri* to 8% *Bonamia alatissima* to 12% *Bonamia erecta* to 6% *Bonamia media* to 20% *Bonamia pannosa* to 32% *Bonamia rosea* to 32% *Cajanus marmoratus* to 6% *Cullen pogonocarpum* to 8% *Evolvulus alsinoides* to 36% *Goodenia microptera* to 26% *Ptilotus astrolasius* to 76% *Ptilotus axillaris* to 4% *Rhyncosia minima* to 2% *Sida pilbarensis* to 34% *Sida virgata* to 6% *Tephrosia stipuligera* to 2% *Tephrosia uniovulata* to 36% *Tribulus hirsutus* to 10% *Solanum diversifolium* to 26%
Annuals species richness	0-11 species; mean 2.

Nature conservation

This common site type is habitat for a range of fauna dependent on spinifex for food or shelter.

The following threatened flora were recorded on PSSG: *Abutilon trudgenii* ms (P3), *Bulbostylis burbidgeae* (P3), *Eremophila pilosa* ms (P1) and *Sida* sp. Wittenoom PN (P3). *Eremophila pilosa* was exclusive to this site type.

PSSG is well represented in conservation reserves within the survey area. It was recorded in the Karijini and Millstream-Chichester National Parks, Cane River Nature Reserve and the Meentheena pastoral lease. It occurs extensively on unallocated Crown land.

Gradational associations

PSSG grades into *Hill spinifex grassland* (HSPG) upslope. It also grades laterally into other spinifex site types such as *Alluvial plain soft spinifex grassland* (ASSG) on alluvial plains and drainage floors and *Sandplain hard/soft spinifex grassland* site types (SHSG, SSSG) on plains with deep sands. It has sharp boundaries with spinifex sites based on substrate changes over short distances, e.g. *Calcrete hard spinifex grassland* (CASG).

Land systems

PSSG is the most extensive site type on Bonney, Dollar, Mallina and Urandy land systems. It is the co-dominant site type with *Plain hard spinifex grassland* (PHSG) on Macroy and Taylor land systems and with *Stony acacia-eremophila shrubland* (SAES) on Sylvania land system. It occurs on another 37 land systems as a minor site type.

7. Plain mulga spinifex shrubland/grassland (PMSS)

Sampling

16 inventory sites, 406 traverse points

General information

PMSS occurs in the southern half of the survey area on stony plains, loamy plains, gravelly plains and hardpan plains with slopes up to 5% but commonly less than 1%. Relief is up to 5 m, but mostly less than 2 m. Soils are loamy and sandy earths frequently overlying siliceous hardpan or parent rock at shallow depth. They have surface mantles ranging from very few (<2%) to abundant (50-90%) pebbles. Rock outcrop is uncommon.

Physiognomy and composition

PMSS occurs as either a moderately close to close (20-50% PFC) *Acacia aneura* (mulga) shrubland with a prominent if patchy ground layer of spinifex, or a hummock grassland with a scattered (10-20% PFC) overstorey of mulga and other shrubs. The spinifex species may be soft (*Triodia pungens*) or hard (*T. wiseana, T. lanigera*) types.

138 perennial species were recorded at the 16 inventory sites, with an average of 21 species per site, 5 above the survey average. 75 annual species were recorded, with an average of 8 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – not present as a recognisable stratum Common – *Acacia aneura, A. pruinocarpa, Corymbia hamersleyana*
Tall shrubs:	Dominant – *Acacia aneura* Common – *Acacia inaequilatera, Hakea lorea* subsp. *suberea*
Mid shrubs:	Dominant – variable; acacias, eremophilas or sennas Common – *Acacia ancistrocarpa, Acacia bivenosa, Eremophila forrestii, E. latrobei, Rhagodia eremaea, Senna artemisioides* subsp. *helmsii, Senna artemisioides* subsp. x *sturtii, S. glutinosa* subsp. *luerssenii*
Low shrubs:	Dominant – variable; mostly commonly eremophilas Common – *Eremophila forrestii, Hibiscus burtonii, Maireana planifolia, M. villosa, Ptilotus obovatus, Solanum lasiophyllum, Tribulus platypterus*
Perennial grasses:	Dominant – variable but often *Triodia pungens* Common – *Chrysopogon fallax*

Common annuals include *Aristida contorta, Dysphania rhadinostachya, Enneapogon caerulescens, E. cylindricus, Gomphrena canescens, Lepidium* sp., *Ptilotus exaltatus, P. gardneri, P. polystachyus Senna notabilis* and *Trichodesma zeylanicum*.

Patterns of grazing impact

Traverse condition summary (406 assessments):

Vegetation - good 91%; fair 8%; poor 1%.
Soil erosion - nil 100%.

PMSS is largely unaffected by grazing as most species are not palatable to livestock. However, sparse palatable low shrubs and mid shrubs such as *Ptilotus obovatus* and *Eremophila latrobei* are occasionally removed by overgrazing. Soils are inherently stable.

Nature conservation

PMSS is a unique site type in which one of the dominant species, mulga, is not resistant to fire, and the other, spinifex, is fire dependent. This site type may eventually be lost as the fire regimes of increased burns encourage spinifex and suppress mulga.

PMSS is well represented in conservation reserves within the survey area. It was recorded in the Karijini National Park. It occurs on unallocated Crown land.

Gradational associations

PMSS grades into *Plain hard spinifex grassland* (PHSG) and *Plain soft spinifex grassland* (PSSG) when soils become sandier and deeper.

Land systems

PMSS is the most extensive site type on Pindering land system. It is a major site type on Billygoat and Boolgeeda land systems and occurs as a minor site type on 16 other systems.

In the south eastern parts of the Pilbara, Acacia aneura (mulga) grows in association with Triodia spp. (spinifex) hummock grasses. The balance between shrubs, grass and fire in this site type (PMSS) is delicate. Mulga is fire sensitive and too frequent burning can jeopardise its persistence.

8. Calcrete spinifex grassland (CASG)

Sampling

27 inventory sites, 335 traverse points

General information

CASG is a common site type occurring on calcrete platforms and plains based on calcrete and on footslopes and plateaux of hill systems based on calcrete and limestone. Slopes on the platforms and plains are usually less than 7% with relief up to 10 m. Slopes on the hill systems are gently inclined to very steep (3-100%) with up to 60 m relief. Soils are calcareous shallow loams with few to very abundant (2->90%) calcrete fragments on the surface. Outcropping of calcrete or limestone parent material is common.

Physiognomy and composition

CASG is a hummock grassland of *Triodia* species, with isolated to scattered (up to 20% PFC) shrubs which may form a prominent strata and occasional trees. The dominant spinifex is commonly *Triodia wiseana* (limestone spinifex), and occasionally *T. plurinervata* or *T. pungens*, and the dominant shrubs are *Acacia* and *Senna* species. The PFC of the spinifex varies between 0-60% depending on time since burning but is commonly 10-40%.

176 perennial species were recorded at the 27 inventory sites, with an average of 17 species per site, slightly above the survey average. However, 94 of these species occurred only at single sites. 71 annual species were recorded, with an average of 7 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – occasionally present as a recognisable stratum; *Corymbia hamersleyana, Eucalyptus leucophloia* Common – *Corymbia hamersleyana, Eucalyptus leucophloia*
Tall shrubs:	Dominant – occasionally present as a recognisable stratum; acacias Common – *Acacia ancistrocarpa, A. inaequilatera, A. pyrifolia, Hakea lorea* subsp. *suberea, Grevillea wickhamii*
Mid shrubs:	Dominant – variable; often acacias, occasionally sennas Common – *Acacia bivenosa, A. ligulata, A. victoriae, Senna glutinosa, Senna glutinosa* subsp. x *luerssenii*
Low shrubs:	Dominant – variable; often acacias, occasionally sennas Common – *A. bivenosa, Corchorus sidoides, Evolvulus alsinoides, Heliotropium ovalifolium, Hibiscus sturtii, Indigofera monophylla, Ptilotus calostachyus, P. obovatus, Sida fibulifera, Senna artemisioides* subsp. *helmsii, Senna artemisioides* subsp. *oligophylla, Solanum lasiophyllum*
Perennial grasses:	Dominant – usually *Triodia wiseana*, occasionally *T. plurinervata, T. pungens* Common – *Cenchrus ciliaris, Paraneurachne muelleri, Triodia pungens*

Common annuals include *Aristida contorta, Cleome viscosa, Dichanthium sericeum* subsp. *sericeum, Dysphania rhadinostachya, Enneapogon caerulescens, Euphorbia australis, Ptilotus exaltatus, P. gardneri, Salsola tragus, Sclerolaena deserticola, Senna notabilis, Sporobolus australasicus, Streptoglossa decurrens and Trichodesma zeylanicum.*

Patterns of grazing impact

Traverse condition summary (335 assessments):

Vegetation - good 98%; fair 2%.
Soil erosion - nil 100%.

Most plants in CASG are unpalatable to livestock and it is largely unaltered by grazing. Soils are generally stable.

Nature conservation

The threatened flora species *Abutilon trudgenii* ms (P3) was recorded on CASG.

CASG is represented, but rather poorly, on conservation reserves within the survey area. It was recorded on the Karijini and Millstream-Chichester National Parks. It occurs on unallocated Crown land.

Gradational associations

CASG usually has distinct boundaries with other site types due to substrate changes over short distances (e.g. calcrete to alluvium or colluvium). CASG grades into *Plain hard spinifex grassland* (PHSG) as the influence of calcrete diminishes.

Land systems

CASG is the most extensive site type on Calcrete and Oakover land systems. It is a major site type on Lime and Table land systems and a minor component on another 17 land systems.

9. Stony plain spinifex grassland with chenopod shrubs (SSCG)

Sampling

4 inventory sites, 67 traverse points

General information

SSCG is an uncommon site type found only near Nullagine in the east of the survey area. It occurs on saline stony plains with up to 5% slope. Soils are sandy duplexes and clays with abundant to very abundant (>50%) surface mantles of quartz or mixed pebbles (2-60 mm). The plains may have minor (<10%) outcrop of schist and other metamorphic rocks.

Physiognomy and composition

SSCG occurs as a hummock grassland with isolated to scattered (<2-20% PFC) shrubs and trees. The dominant spinifex is *Triodia longiceps* (knitting needle spinifex) but other species also occur. Common tall and mid shrubs are *Acacia* and *Melaleuca* species with sparse low shrubs of weakly halophytic *Maireana* and *Sclerolaena* species.

39 perennial species were recorded at the 4 inventory sites, with an average of 14 species per site, 2 below the survey average. 13 annual species were recorded, with an average of 5 species per site.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – not present as a recognisable stratum Common – *Corymbia hamersleyana, Eucalyptus leucophloia, E. socialis*
Tall shrubs:	Dominant – acacias when present Common – *Acacia acradenia, A. arrecta, A. inaequilatera, A. wanyu*
Mid shrubs:	Dominant – variable Common – *Acacia bivenosa, Melaleuca eleuterostachya, Senna glutinosa* subsp. x *luerssenii*
Low shrubs:	Dominant – *Maireana melanocoma* Common – *Corchorus parviflorus, Evolvulus alsinoides, Goodenia stobbsiana, Heliotropium ovalifolium, Hibiscus burtonii, H. coatesii, H. sturtii, Maireana georgei, M. tomentosa, M. triptera, Sclerolaena diacantha, S. uniflora, Tribulus platypterus*
Perennial grasses:	Dominant – *Triodia longiceps* Common – *Triodia brizoides, T. pungens, T. wiseana*

Common annuals include *Aristida contorta, Atriplex codonocarpa, Lepidium pholidogynum, Ptilotus exaltatus, Salsola tragus, Sclerolaena densiflora* and *Trianthema triquetra.*

Patterns of grazing impact

Traverse condition summary (67 assessments):

Vegetation	-	good 87%; fair 9%; poor 4%.
Soil erosion	-	nil 96%; moderate 3%; severe 1%.

SSCG includes sparse palatable chenopod shrubs which can be removed by excessive grazing pressure. However, total ground cover is little changed by grazing as the spinifexes, which provide by far the bulk of the cover, are unpalatable. Generally, SSCG is not susceptible to erosion but localised areas of serious erosion occur. The saline soils may be susceptible to secondary salinisation if vegetative cover is removed.

Nature conservation

SSCG is uncommon and unusual in terms of plant species composition. It is locally impacted by grazing and mining disturbance and is largely confined to one land system, Mosquito. The SSCG on Mosquito land system supports the priority species *Atriplex spinulosa*. The adjacent site type *Hill spinifex grassland* (HSPG) on hills of the Mosquito land system support the priority species *Acacia aphanoclada*. As a result of this survey, CALM has added SSCG of the Mosquito land system to the list of Priority Ecological Communities under Category 3 (iii).

SSCG was not recorded on conservation reserves within the survey area. Two of the 67 traverse assessments were recorded on unallocated Crown land. This site type should be considered for reservation.

Gradational associations

SSCG grades into *Plain hard spinifex grassland* (PHSG) when soils become less saline.

Land systems

SSCG is a common site type on Mosquito land system and a very minor site type on Taylor land system.

E. STONY PLAIN AND LOW RISE SCLEROPHYLL SHRUBLAND SITE TYPES

The site types in this site type group occur mostly in the south and south-east of the survey area. They are common in granite-dominated upland terrain, occurring on etchplains and pediments below hills and further downslope onto alluvial plains with substantial stony mantles. They also occur on lower footslopes, stony plains and alluvial plains below hill tracts based on shale and basalt. Calcrete surfaces in the south often support the CACS site type of this site type group.

The vegetation in this group is generally dominated by sclerophyllous and/or Eremaean genera including *Acacia, Senna, Eremophila* and *Ptilotus*, usually occurring as very scattered to scattered tall shrubland with easily recognisable, though sparse understoreys and occasional trees.

10. Stony plain acacia-eremophila-cassia shrubland (SAES)

Sampling

11 inventory sites, 187 traverse points

General information

SAES is common in the southern half of the survey area mainly on stony plains and low rises, but also on stony hardpan plains, gravelly plains and occasionally hill slopes. Slopes vary from level to gently inclined (<1-10%), occasionally steeper on hills, and relief is up to about 20 m. SAES invariably has a surface mantle of common to very abundant (10->90%) pebbles of mixed lithology. Soils are stony, shallow (<60 cm) loams and clays. SAES is a typically Eremaean site type and to the south of this survey area is the most widespread erosional plains site type in the Murchison and north-eastern Goldfields (Curry *et al*. 1994, Pringle, Van Vreeswyk and Gilligan 1994).

Physiognomy and composition

SAES generally occurs as a very scattered to scattered (5-20% PFC) cassia and eremophila low or mid height shrubland, with prominent tall acacia shrubs. The dominant low shrub species varies, while trees and perennial grasses are not usually conspicuous.

87 perennial species were recorded at the 11 inventory sites, with an average of 15 species per site, slightly below the survey average. 34 annual species were recorded, with an average of 3 species per site.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – stratum occasionally recorded; *Acacia pruinocarpa* Common – none
Tall shrubs:	Dominant – acacias Common – *Acacia aneura, A. tetragonophylla, A. victoriae, A. wanyu*
Mid shrubs:	Dominant – eremophilas or sennas Common – *Eremophila exilifolia, E. fraseri, E. latrobei, Rhagodia eremaea, Senna glutinosa* subsp. x *luerssenii, Sida calyxhymenia*
Low shrubs:	Dominant – very variable (9 species recorded as dominant at sites) Common – *Eremophila cuneata, Maireana georgei, M. tomentosa M. triptera, Ptilotus obovatus, P. roei, P. schwartzii, Senna artemisioides* subsp. *helmsii, S. artemisioides* subsp. *oligophylla, S. artemisioides* subsp. x *sturtii, S. stricta, Solanum lasiophyllum*
Perennial grasses:	Dominant – not present as a recognisable stratum Common – *Eragrostis eriopoda, Triodia lanigera, T. wiseana*

Common annuals include *Aristida contorta, Enneapogon caerulescens, Eriachne pulchella, Goodenia prostrata, Ptilotus aervoides, P. helipteroides, Sclerolaena cuneata* and *S. densiflora*.

Patterns of grazing impact

Traverse condition summary (187 assessments):

Vegetation - good 37%; fair 36%; poor 27%.
Soil erosion - nil 96%; minor 2%; moderate 1%; severe 1%.

Patterns of grazing impact on this site type have been studied in more detail in other rangeland areas of Western Australia such as the north-eastern Goldfields (Pringle, Van Vreeswyk and Gilligan 1994). Care should be taken when assessing grazing impacts as natural variation can be as influential as management on botanical composition. However, grazing is likely to reduce the number of sensitive palatable shrubs. These include *Eremophila latrobei, Maireana* spp. and *Sida calyxhymenia* although they may have different resiliences under grazing. Increaser species do not seem to be a feature of this site type. SAES is not generally susceptible to erosion as the soil surface is protected by a stone mantle.

Nature conservation

SAES rarely supports priority species for conservation and consists mostly of plants with wide environmental affinities. It is poorly represented in nature reserves in the Pilbara but is widespread south of the Pilbara in the Eremaean Zone and is represented in the Wanjarri Nature Reserve in the north-eastern Goldfields (Pringle, Van Vreeswyk and Gilligan 1994).

Gradational associations

SAES grades downslope into *Hardpan plain mulga shrubland* (HPMS) as the mulga cover increases and stone mantles become sparser. It may grade laterally into *Plain acacia cassia grassy shrubland* (PACS) as soils become more sandy.

Land systems

SAES is the most extensive site type on Balfour, Elimunna, Ford, Laterite and Prairie land systems. It is co-dominant with *Plain soft spinifex grassland* (PSSG) on Sylvania land system. It is a minor component of four other systems; Cundelbar, Jigalong, Spearhole and Washplain.

11. Plain acacia cassia grassy shrubland (PAGS)

Sampling

11 inventory sites, 133 traverse points

General information

PAGS occurs in the south-east of the survey area on gritty-surfaced plains, stony plains and low rises. It occurs mostly in granitic terrain but also on dolerite, sedimentary rocks and colluvium. Slopes are up to 5% and relief up to 12 m. PAGS sites have sandy or gritty surfaces, or stone mantles varying in density from common to very abundant (10->90%). Soils are shallow sands and loams.

Physiognomy and composition

PAGS occurs as a very scattered (2.5-20% PFC) mixed shrubland with low, mid and tall shrub strata of *Acacia, Senna*, and *Eremophila* species. Most commonly the low shrub stratum is dominant but occasionally the mid shrub stratum is dominant. There is a characteristic understorey of *Aristida contorta* and *Enneapogon* spp. annual grasses or the perennial grass *Aristida holathera* var. *holathera.* Many of the shrubs in PAGS are common to *Stony plain acacia-eremophila-cassia shrubland* (SAES) but it differs from SAES in that the soils are sandier and support more perennial and annual grasses.

121 perennial species were recorded at the 11 inventory sites, with an average of 21 species per site, 5 above the survey average. 37 annual species were recorded, with an average of 6 species per site.

The following species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – acacias Common – *Acacia aneura, A. tetragonophylla, A. victoriae, Hakea lorea* subsp. *suberea*
Mid shrubs:	Dominant – eremophilas or sennas Common – *Eremophila fraseri, E. latrobei, Rhagodia eremaea, Senna artemisioides* subsp. *helmsii, S. glutinosa* subsp. x *luerssenii*
Low shrubs:	Dominant – eremophilas or sennas Common – *Enchylaena tomentosa, Eremophila forrestii E. margarethae, E. pensilis, Evolvulus alsinoides, Indigofera monophylla, Maireana planifolia, M. villosa, Ptilotus obovatus, Senna artemisioides* subsp. *helmsii, S. artemisioides* subsp. *oligophylla, Sida echinocarpa, S. fibulifera, Solanum lasiophyllum Tephrosia supina*
Perennial grasses:	Dominant – variable Common – *Aristida holathera* var. *holathera, Chrysopogon fallax, Eragrostis eriopoda, Monachather paradoxa*

Common annuals include *Aristida contorta, Cleome viscosa, Enneapogon caerulescens, E. cylindricus, E. polyphyllus, Eriachne aristidea, Euphorbia australis, Gomphrena canescens* and *Sclerolaena deserticola*.

Patterns of grazing impact

Traverse condition summary (133 assessments):

Vegetation	-	good 37%; fair 47%; poor 16%.
Soil erosion	-	nil 89%; minor 9%; moderate 2%.

Many of the plants in PAGS are unpalatable but the site type does include some shrubs and grasses which are preferred by grazing animals. Uncontrolled grazing is likely to reduce the palatable species such as *Eremophila latrobei, Maireana planifolia, Ptilotus obovatus* and *Monachather paradoxa*. PAGS generally has low susceptibility to erosion as many surfaces are protected by gravelly and stony mantles.

Nature conservation

PAGS consists mostly of species found widely in other site types, however, it contains some threatened species. The following threatened flora were recorded on PAGS: *Acacia balsamea* (P4), *Eriachne tenuiculmis* (P3), *Goodenia pascua* (P3) and *Josephinia* sp. Marandoo (M Trudgen 1554) PN (P1). *Josephinia* sp. Marandoo was exclusive to this site type.

PAGS was not recorded on conservation reserves within the survey area. It is very poorly represented on unallocated Crown land; 3 of the 133 traverse assessments were recorded on unallocated Crown land.

Gradational associations

PAGS grades into *Stony plain acacia-eremophila-cassia shrubland* (SAES) as soils become shallower and more stony.

Land systems

PAGS is the co-dominant site type with *Plain snakewood shrubland with chenopod low shrubs* (PSCS) on Narbung land system. It is a major site type on Charley land system and a common site type on Sylvania land system.

12. Plain mosaic grassy shrubland (PMGS)

Sampling

4 inventory sites, 67 traverse points

General information

This fairly uncommon site type occurs on alluvial plains and stony plains which often have alternate patches with and without gilgaied microrelief. Gilgai and non-gilgai surfaces occur as tight mosaics with each component covering about 10 to 100 m. Generally, but not always, the non-gilgaied surfaces occupy a higher proportion of the plains than the gilgaied surfaces. Slopes on the plains are up to 2%. Stony mantles vary between few to very abundant (2->90%) pebbles of mixed lithology. Soils are cracking clays in gilgai areas and sands, loams and duplexes in non-gilgai areas.

Physiognomy and composition

PMGS occurs as a variable density low shrubland of *Senna* and *Eremophila* species with a prominent but patchy ground layer of perennial grasses such as *Chrysopogon fallax* (ribbon grass) and *Eragrostis xerophila* (Roebourne Plains grass). The grasses tend to be much denser in the gilgaied areas rather than the non-gilgaied. There may also be a very scattered to scattered (2.5-20% PFC) tall shrub or tree layer of mulga or other acacias.

41 perennial species were recorded at the 4 inventory sites, with an average of 14 species per site, 2 below the survey average. 20 annual species were recorded, with an average of 7 species per site.

The following species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – not present as a recognisable stratum Common – *Acacia tetragonophylla*
Mid shrubs:	Dominant – not present as a recognisable stratum Common – *Eremophila forrestii, Senna glutinosa* subsp. x *luerssenii*
Low shrubs:	Dominant – eremophilas or *Senna artemisioides* subsp. *helmsii* Common – *Eremophila cuneifolia, E. lanceolata, E. pantonii, Maireana planifolia, Sclerolaena deserticola, Senna artemisioides* subsp. *helmsii, S. artemisioides* subsp. *oligophylla, S. hamersleyensis, Solanum lasiophyllum*
Perennial grasses:	Dominant – *Chrysopogon fallax, Eragrostis xerophila* Common – *Chrysopogon fallax, Eragrostis xerophila*

Common annuals include *Aristida contorta, Eriachne pulchella, Lepidium* spp., *Ptilotus* spp., and *Sclerolaena cuneata*.

Patterns of grazing impact

Traverse condition summary (67 assessments):

Vegetation - good 24%; fair 24%; poor 52%.
Soil erosion - nil 84%; minor 12%; moderate 4%.

A portion of the low shrubs on this site type are attractive to livestock as are the perennial grasses in the weakly gilgaied stony areas. They can be readily reduced or removed by excessive grazing pressure. The traverse data indicates that the vegetation is considerably degraded. Generally PMGS is resistant to erosion but some localised areas are eroded.

Nature conservation

PMGS was not recorded on conservation reserves or on unallocated Crown land within the survey area.

Gradational associations

PMGS grades laterally into *Hardpan plain mulga shrubland* (HPMS) and *Plain sparse mulga shrubland* (PSMS) when the soils become less clayey and the hardpan substrate more developed.

Land systems

PMGS is the most extensive site type on Turee land system. It is common on Fortescue land system and a minor component of Cowra, Jigalong, Marandoo and Washplain land systems.

13. Calcrete acacia cassia shrubland (CACS)

Sampling

4 inventory sites, 15 traverse points

General information

CACS occurs only in the far south and south-east of the survey area on calcrete platforms and calcrete plains. These usually have common to many surface mantles (10-50%) of calcrete fragments about 2-6 cm in size. Slopes are up to 2% and the relief of the calcrete platforms is generally 1-3 m. Soils are shallow calcareous sands and loams over calcrete.

Physiognomy and composition

CACS occurs as scattered to moderately close (10-25% PFC) tall acacia shrubland, dominated by *Acacia tetragonophylla* or *A. aneura*, with mid and low shrub layers and occasional trees. The low shrub layer is often dominated by *Ptilotus obovatus* or *Senna* species. Perennial grasses are uncommon but annual grasses such as *Aristida contorta* and *Enneapogon caerulescens* may form a dense ground layer.

43 perennial species were recorded at the 4 inventory sites, with an average of 17 species per site, slightly above the survey average. 34 annual species were recorded, with an average of 11 species per site.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – occasionally present as a recognisable stratum; variable including *Acacia pruinocarpa, Eucalyptus socialis, Grevillea striata* Common – *Acacia pruinocarpa, Hakea lorea* subsp. *suberea*
Tall shrubs:	Dominant – *Acacia aneura, A. tetragonophylla* Common – *Acacia aneura, A. tetragonophylla, Grevillea* spp.
Mid shrubs:	Dominant – sennas Common – *Eremophila forrestii, Rhagodia eremaea, Senna artemisioides* subsp. *filifolia, S. artemisioides* subsp. *helmsii*
Low shrubs:	Dominant – eremophilas, sennas or *Ptilotus obovatus* Common – *Eremophila forrestii, Ptilotus obovatus, Senna artemisioides* subsp. x *artemisioides, S. artemisioides* subsp. *filifolia, S. artemisioides* subsp. *helmsii, S. artemisioides* subsp. *oligophylla, Ptilotus obovatus, Sida fibulifera, Solanum lasiophyllum*
Perennial grasses:	Dominant – not present as a recognisable stratum Common – *Triodia pungens*

Common annuals include *Aristida contorta, Enneapogon caerulescens, Ptilotus exaltatus, P. helmsii, Rhodanthe sterilescens, Salsola tragus* and *Sclerolaena deserticola*.

Patterns of grazing impact

Traverse condition summary (15 assessments):

Vegetation - good 20%; fair 47%; poor 33%.
Soil erosion - nil 100%.

This site type is attractive to stock and kangaroos. Palatable shrubs, such as *Ptilotus obovatus*, are likely to decline under excessive grazing. In overgrazed situations unpalatable sennas such as *Senna artemisioides* subsp. *helmsii* and *S. artemisioides* subsp. *filifolia* may act as increasers. The soils of CACS are generally not prone to erosion due to the stony surface mantles.

Nature conservation

CACS is a preferentially grazed site type of minor extent in this survey area. The build up of annual grasses can pose a threat of fire in a site type whose perennial shrubs are not well adapted to it.

CACS was not recorded on conservation reserves within the survey area. It is very poorly represented on unallocated Crown land; 1 of the 15 traverse assessments was recorded on unallocated Crown land.

Gradational associations

CACS often has sharp boundaries with other site types such as *Hardpan plain mulga shrubland* (HPMS) as substrates change from calcrete to hardpan or alluvium over short distances. It grades laterally into *Calcrete hard spinifex grassland* (CASG). On calcrete sites in central, northern and eastern parts of Pilbara it is completely replaced by CASG probably as a result of the higher incidence of summer rainfall which favours spinifex rather than shrubs.

Land systems

CACS is the most extensive site type on Table and Warri land systems. It is a minor component of Coolibah and Paraburdoo land systems.

Calcrete surfaces occur widely in the Pilbara as low platforms and plains along paleodrainages, drainage lines and as more elevated and dissected duricrust remnants. They most commonly support the hard spinifex site type CASG but in the south-east support acacia shrublands (CACS) as shown here. The common tall shrubs are mostly Acacia aneura *(mulga) or* Acacia tetragonophylla *(curara). Very common low shrubs are* Ptilotus obovatus *(cotton bush) and* Senna *species. Annual grasses such as* Aristida contorta *(windgrass) and* Enneapogon caerulescens *(limestone grass) indicate good seasonal conditions.*

F. SHEET FLOOD HARDPAN PLAIN SCLEROPHYLL SHRUBLAND OR WOODLAND SITE TYPES

These site types are common throughout the arid shrublands of Western Australia, extending from the inland southern Pilbara in the north to Yalgoo in the south-west and Menzies in the south-east. They are associated with the occurrence of red-brown hardpan (Teakle 1936). Mulga (*Acacia aneura*) dominates these site types.

The site types occur on broad, nearly level alluvial plains subject to intermittent sheet flooding. Water and nutrients are concentrated during sheet flows by obstructions such as plants and debris across slopes to form a mosaic of fertile patches and poorer, runoff zones (Hacker 1979, Tongway 1994). These fertile patches occur at different scales from mulga groves to individual shrubs. Disruption of sheet flow can cause water starvation and consequent shrub deaths.

Soils are generally shallow (<60 cm deep) red clay loams over hardpan, except in groves where soil depth is commonly >1 m. While clays in the upper soil profiles are sometimes dispersive, they are protected from sheet-flow erosion by cryptogamic crusts, very low slopes and substantial density of overstorey plants.

The main grazing impacts on these site types are the loss of palatable understorey shrubs and the disturbance of the surface crust. Curry *et al.* (1994) compared the data from 30 reference sites with the data from grazed sites in the Murchison River catchment and found that the sites in the undeveloped areas showed significantly greater perennial shrub density and species richness, which was related primarily to differences in palatable species and was reflected in higher diversity.

14. Hardpan plain mulga shrubland (HPMS)

Sampling

5 inventory sites, 317 traverse points

General information

HPMS is one of the most widely distributed site types in the arid zone of Western Australia (Wilcox and McKinnon 1972, Payne, Mitchell and Holman 1988, Curry *et al.* 1994, Pringle, Van Vreeswyk and Gilligan 1994, Payne *et al.* 1998). It occurs extensively on broad plains overlying hardpan between erosional uplands and salt lake or river systems. Soils are generally shallow (<60 cm) loams over a ferruginous-siliceous hardpan and have well-developed cryptogamic crusts. Surface mantles are absent to abundant (0-90%) pebbles or fine ferruginous gravel. In this survey area HPMS is restricted to south-central and south-eastern parts. After major rainfall events these plains, which rarely attain a slope of 1%, are subject to low energy sheet flows.

Physiognomy and composition

HPMS is usually a very scattered to scattered (2.5-20% PFC) tall shrubland of mulga with well developed mid and low shrub layers. Occasionally the low shrub layer is dominant.

55 perennial species were recorded at the 5 inventory sites, with an average of 19 species per site, 3 above the survey average. 16 annual species were recorded, with an average of 4 species per site.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – not usually present as a recognisable stratum Common – *Acacia pruinocarpa, Hakea lorea* subsp. *suberea*
Tall shrubs:	Dominant – *Acacia aneura* Common – *Acacia tetragonophylla*
Mid shrubs:	Dominant – *Acacia aneura* or *Senna glutinosa* subsp. x *luerssenii* Common – *Acacia wanyu, Eremophila fraseri, E. latrobei, Psydrax latifolia, Rhagodia eremaea, Sida calyxhymenia*
Low shrubs:	Dominant – often eremophilas Common – *Eremophila forrestii, E. margarethae, Hibiscus burtonii, Maireana tomentosa, M. villosa, Ptilotus obovatus, P. roei, P. schwartzii, Senna artemisioides* subsp. *helmsii, S. artemisioides* subsp. x *sturtii, Solanum lasiophyllum*
Perennial grasses:	Dominant – rare as a recognisable stratum Common – *Eriachne obtusa, Monachather paradoxa*

Common annuals include *Aristida contorta, Enneapogon caerulescens, E. cylindricus, E. polyphyllus, Eriachne pulchella, Ptilotus gardneri* and *P. helipteroides*

Patterns of grazing impact

Traverse condition summary (317 assessments):

Vegetation - good 32%; fair 28%; poor 40%.
Soil erosion - nil 92%; minor 4%; moderate 2%; severe 2%.

The grazing ecology of HPMS was investigated in some detail in the Murchison River catchment (Curry *et al.* 1994) and north-eastern Goldfields (Pringle, Van Vreeswyk and Gilligan 1994) rangeland surveys. Grazing reduces the density and number of palatable understorey shrubs. Hacker (1979, 1984a, b) noted that palatable low shrubs were often removed first and more easily from open areas rather than from under existing clumps of overstorey species. The overstorey itself is rarely adversely affected except in exceptionally degraded situations where soil sealing retards water infiltration or where overland sheet water flows have been severely disrupted.

In this survey area HPMS has been substantially impacted by grazing with considerable loss of palatable species from the low shrub layer. HPMS is often protected from soil erosion by gentle slopes, stony surface mantles and well developed cryptogammic crusts. However, serious erosion can occur in localised areas where soils are without mantles, where cryptogamic crusts have been lost by disturbance or where overland flows have been concentrated.

Nature conservation

The low shrub stratum of HPMS has been modified by grazing and some localised areas are severely degraded and eroded. However, it appears that ecological processes continue to operate on degraded areas other than those that are severely degraded and eroded. This is due to low slopes, the diffuse nature of overland flow and the natural predominance of unpalatable species.

HPMS is represented, but poorly, in the Karijini National Park. Of the 317 traverse assessments, 2 were recorded on Karijini National Park and 12 were recorded on unallocated Crown land.

Gradational associations

HPMS grades upslope into *Stony acacia-eremophila-cassia shrubland* (SAES) as soils become shallower and more stony. It changes abruptly into *Grove mulga woodland/shrubland* (GMUW) where the mulga becomes much larger and denser as a result of much deeper soils with more favourable moisture and nutrient status in the groves.

Land systems

HPMS is the most extensive site type on Nooingnin, Three Rivers and Washplain land systems and is co-dominant with *Plain sparse mulga shrubland* (PSMS) on Fan land system. It is a major site type on Cadgie land system and common on Jamindie and Zebra systems. HPMS is a minor component of 12 other systems.

15. Lateritic hardpan plain acacia shrubland (LHAS)

Sampling

4 inventory sites, 39 traverse points

General information

LHAS occurs on plains on hardpan with ironstone gravel or pebbles. Slopes are up to 1%. Soils are generally shallow (<60 cm) loams over a ferruginous-siliceous hardpan with surface mantles of common to many (10-50%) ironstone fine to medium gravel (2-20 mm) or large pebbles (20-60 mm).

Physiognomy and composition

LHAS is an isolated to scattered (<2.5-15% PFC) tall acacia shrubland with well developed mid and low shrub layers. The dominant acacia is most commonly *Acacia aneura* (mulga).

38 perennial species were recorded at the 4 inventory sites, with an average of 12 species per site, 4 below the survey average. 22 annual species were recorded, with an average of 8 species per site.

The following species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – most commonly *Acacia aneura*, occasionally other acacias Common – *Acacia synchronicia, Hakea lorea* subsp. *suberea*

Mid shrubs:	Dominant – *Acacia aneura, A. wanyu* Common – *Acacia wanyu, Senna glutinosa* subsp. x *luerssenii*
Low shrubs:	Dominant – eremophilas Common – *Eremophila exilifolia, E. lanceolata, E. pensilis, Maireana planifolia, M. villosa, Ptilotus schwartzii, Senna artemisioides* subsp. *helmsii, Senna artemisioides* subsp. x *sturtii, Senna stricta*
Perennial grasses:	Dominant – not present as a recognisable stratum Common – *Aristida holathera* var. *holathera, Triodia pungens*

Common annuals include *Aristida contorta, Calandrinia* sp., *Enneapogon caerulescens, Eragrostis pergracilis, Eriachne pulchella, Ptilotus exaltatus* and *P. helipteroides*.

Patterns of grazing impact

Traverse condition summary (39 assessments):

Vegetation - good 23%; fair 44%; poor 33%.
Soil erosion - nil 95%; minor 5%.

As with HPMS grazing reduces the density and number of palatable understorey shrubs in this site type. LHAS is often protected from soil erosion by gentle slopes and gravelly surface mantles.

Nature conservation

LHAS was not recorded on conservation reserves or on unallocated Crown land within the survey area.

Gradational associations

LHAS is very similar to *Hardpan plain mulga shrubland* (HPMS) apart from its ironstone gravel mantles and sparser shrubs. LHAS grades upslope into *Stony acacia-eremophila-cassia shrubland* (SAES) as soils become shallower and more stony.

Land systems

LHAS is common on Washplain and Zebra land systems and is a minor component of Elimunna and Jigalong land systems.

16. Plain sparse mulga shrubland (PSMS)

Sampling

3 inventory sites, 154 traverse points

General information

PSMS is a common site type mostly occurring in the southern half of the survey area on wash plains on hardpan, stony plains and low rises. Slopes are generally less than 1% but may be up to 5% on low rises. Soils are shallow loams which may be over a ferruginous-siliceous hardpan. They frequently have stony or gravelly surface mantles.

Physiognomy and composition

PSMS usually occurs as a very scattered (2.5-10% PFC) tall mulga shrubland with very sparse mid or low shrubs of *Acacia, Eremophila* and *Ptilotus* species which rarely form defined strata. Occasionally the low shrubs are dominant as a very scattered to scattered (5-20% PFC) low shrubland with isolated to very scattered (<2.5-5% PFC) tall and/or mid shrubs. PSMS is similar in botanical composition to *Hardpan plain mulga shrubland* (HPMS) but shrubs are generally sparser and PSMS occurs on soils other than shallow hardpan loams and may overlie parent rock at shallow depth.

39 perennial species were recorded at the 3 inventory sites, at the survey average of 16 species per site. 14 annual species were recorded, with an average of 6 species per site.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – not present as a stratum Common – *Acacia catenulata, A. pruinocarpa*
Tall shrubs:	Dominant – *A. aneura* Common – *A. tetragonophylla, Acacia* sp. *Weelarrana, Hakea lorea* subsp. *suberea*
Mid shrubs:	Dominant – very variable; acacias or eremophilas Common – *Acacia aneura, A. marramamba, Eremophila fraseri, E. latrobei, Rhagodia eremaea, Senna glutinosa* subsp. x *luerssenii, Sida calyxhymenia*
Low shrubs:	Dominant – eremophilas or *Ptilotus obovatus* Common – *Eremophila caespitosa, E. glutinosa, E. lanceolata, Hibiscus sturtii, Maireana convexa, M. georgei, M. villosa, Ptilotus obovatus, P. schwartzii, Senna artemisioides* subsp. *helmsii, Solanum lasiophyllum*
Perennial grasses:	Dominant – not present as a stratum Common – *Chrysopogon fallax, Eriachne mucronata*
Other plant forms:	Common – *Fimbristylis dichotoma* (sedge)

Common annuals include *Abutilon cunninghamii, Aristida contorta, Enneapogon cylindricus, Eragrostis pergracilis, Eriachne pulchella, Euphorbia australis, E. boophthona, Goodenia microptera* and *G. prostrata*.

Patterns of grazing impact

Traverse condition summary (154 assessments):

Vegetation - good 26%; fair 24%; poor 50%.
Soil erosion - nil 84%; minor 9%; moderate 4%; severe 3%.

PSMS supports very sparse palatable species which are easily removed by grazing. Soils are moderately resistant to erosion but become susceptible if surface crusts are broken by grazing animals or other disturbances. The traverse data shows that palatable plants have been considerably reduced by grazing. However, mostly it appears that ecological processes continue to operate as the bulk of plants are unpalatable and not impacted. The overstorey itself is rarely adversely affected except in exceptionally degraded situations where there is severe erosion. Most mulga deaths are more likely attributable to fire and the synergy of age and disturbances such as drought.

Nature conservation

PSMS contains plant species common to many other site types and appears not to have particularly high conservation value.

PSMS is represented in the Karijini National Park. Nine traverse assessments were recorded on unallocated Crown land.

Gradational associations

PSMS grades laterally into *Hardpan plain mulga shrubland* (HPMS) when the hardpan substrate becomes more developed and upslope into types like *Stony acacia-eremophila-cassia shrubland* (SAES) as soils become more stony.

Land systems

PSMS is the most extensive site type on Charley, Collier, Jamindie and Wannamunna land systems. It is common on Christmas, Elimunna, Fan and Ford land systems and is a minor component of 7 other systems.

17. Grove mulga grassy woodland/shrubland (GMGW)

Sampling

12 inventory sites, 8 condition sites, 110 traverse points

General information

This site type generally occurs as arcuate clumps (groves) of considerably denser mulga shrubs and trees than areas around them, and are generally arranged with their long axes along the contour as a series of bands of vegetation on gently inclined wash plains. They also occur as more diffuse foci on drainage tracts. They have distinct and abrupt boundaries with sparser intergrove communities. Soils are loamy earths, clays and cracking clays. Surface mantles vary from none to many (0-50%) pebbles (2-6 mm) mostly of ironstone. Surfaces are frequently gilgaied.

Groves represent fertile patches in the landscape in that they disproportionately accumulate litter, water and nutrients compared to intergrove areas and have much deeper soils with high water storage capacity.

Physiognomy and composition

GMGW occurs as a moderately close to closed (20->50% PFC) acacia woodland with a tussock grass ground layer. The dominant acacia is commonly *Acacia aneura* (mulga) but may occasionally be *A. catenulata*. There may be a mid and/or tall shrub layer. There is generally a low shrub layer except in very dense groves. The perennial grass layer, which is dominated by *Chrysopogon fallax* (ribbon grass) or *Themeda triandra* (kangaroo grass), has a basal cover of 0.5-5%, but is often patchy.

91 perennial species were recorded at the 12 inventory sites, with and average of 17 species per site, slightly above the survey average. 105 annual species were recorded, with an average of 17 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – commonly *Acacia aneura*, occasionally *A. catenulata* Common – *Acacia aneura, A. catenulata*
Tall shrubs:	Dominant – *Acacia aneura* Common – *Hakea lorea* subsp. *suberea*
Mid shrubs:	Dominant – acacias or eremophilas Common – *Eremophila forrestii, E. latrobei, Psydrax latifolia, P. suaveolens, Rhagodia eremaea*
Low shrubs:	Dominant – variable; usually eremophilas or maireanas Common – *Enchylaena tomentosa, Eremophila clarkei, E. forrestii, E. lanceolata, Evolvulus alsinoides, Hibiscus sturtii, Maireana planifolia, M. villosa, Ptilotus obovatus, Sida fibulifera, Solanum ferocissimum, S. lasiophyllum*
Perennial grasses:	Dominant – *Chrysopogon fallax, Themeda triandra* Common – *Aristida latifolia, Chrysopogon fallax, Digitaria ammophila, Eragrostis setifolia, E. xerophila, Eriachne benthamii, E. obtusa, Themeda triandra*
Other plant forms:	Common – *Rhynchosia minima* (creeper)

Common annuals include *Aristida contorta, Bidens bipinnata, Chloris virgata, Dactyloctenium radulans, Dichanthium sericeum, Enneapogon polyphyllus, Iseilema* spp., *Malvastrum americanum, Nicotiana* spp., *Portulaca oleracea, Ptilotus exaltatus, P. gaudichaudii* and *P. macrocephalus.*

Patterns of grazing impact

Traverse condition summary (110 assessments):

Vegetation - good 30%; fair 41%; poor 29%.
Soil erosion - nil 93%; minor 4%, moderate 2%, severe 1%.

The perennial grasses in this site type are preferentially grazed by livestock and native animals and can be reduced or lost if grazing is excessive. Palatable shrubs could also be expected to be lost by preferential grazing but the abundance of low shrubs may be as much a function of tall shrub or tree density as of grazing history.

Occasionally this site type may degrade to the extent that it loses its ability to trap sheet flow and nutrients and the grove structure collapses.

Table 4. Summary of attributes for GMGW variation recorded from condition (C) and some inventory (I) sites

Vegetation attributes	Observations on natural variation and grazing impact
Demarcation of margin/edges to the inter-grove areas	Sharper when in good condition, with denser grove vegetation and little or no intergrove soil redeposition/ingress unless very degraded.
Soil-vegetation surface microtopography	Flat surfaces on sites with medium-textured soils or (5 of 12 sites) with cracking clay soils and gilgaied depressions frequent and particularly between /adjacent to large mulga trees; gilgai structures stabilized by perennial grasses and/or climbers.
Microphytic crust development	Lichen and algal crust patches frequent on grove and intergrove bare soil (C63, C219) unless very degraded.
Alluvial interception-detritus entrapment functioning	Entrapment function along the contour with litter and gilgai patches dominates unless stock pads and degraded surface patches allow throughflow. In severe cases of alluvial process interception or collapse, gross erosion of gilgai surfaces and gutter development (I32).
Dominant tree/tall shrub	Mainly *Acacia aneura* or *Acacia catenulata* (<10% of sites, C63).
Perennial shrub (& climber) species richness	Mainly 10-20 species unless grove is very degraded.
Shrubs probably increasers	*Dodonaea petiolaris, Senna artemisioides, Solanum sturtianum.*
Shrubs/climbers/sedges palatable and probably decreasers	*Vigna lanceolata* (I210) and *Fimbristylis dichotoma* (C219). And similar suite of shrub species to GMUW.
Perennial grass species frequency	*Chrysopogon fallax* up to 54% *Themeda triandra* up to 46% *Aristida jerichoensis* up to 64% *Eriachne benthamii* up to 40% *Monachather paradoxa* up to 36% and <20%: *Aristida latifolia* *Digitaria ammophila* *Digitaria brownii* *Eragrostis setifolia* *Eragrostis xerophila* *Eragrostis eriopoda* *Eriachne obtusa* *Eriachne helmsii* *Triodia pungens*
Perennial grass species richness	Up to 6 (C55) but mainly 2-4 species per site.
Perennial grasses grazed preferentially with decreaser response	*Chrysopogon fallax* *Themeda triandra* *Eragrostis setifolia* *Eragrostis xerophila*
Perennial grass species with increaser response	*Triodia pungens* (I363)
Fire evidence and impact	Some mulga deaths on one site with evidence of past fire (C10).
Presence of Priority Species	*Eriachne tenuiculmis:* a P3 species (at I sites and at one C site, C10).
Perennial vegetation replacement by an annual herbfield	Enhanced biomass of annuals where very degraded (I32).

Nature conservation

GMGW appears to be an important habitat for native fauna. It is also favoured by domestic livestock and understoreys are frequently modified by grazing. This fertile site type supports weeds including *Bidens bipinnata* and *Malvastrum americanum.*

The threatened flora species *Eriachne tenuiculmis* (P3) was recorded on GMGW.

GMGW is represented on conservation reserves within the survey area. Eight of the 110 traverse assessments were recorded on Karijini National Park. Two traverse assessments were recorded on unallocated Crown land.

Gradational associations

GMGW is most similar to acacia dominated drainage site types such as *Drainage eucalypt and acacia grassy woodland/shrubland* (DEGW) but is distinctive and clearly defined.

Land systems

GMGW is the most extensive site type on Jurrawarrina land system and is a minor component of 15 other systems.

Grove mulga grassy woodland site type (GMGW) is a small but important type found on land systems such as Fan, Jurrawarrina, Wannamunna and Washplain. It is depositional in nature receiving run-on and nutrients from adjacent surfaces. Deep loam or clay soils support dense woodlands of mostly Acacia aneura *(mulga) and, when in good condition, grasses such as* Chrysopogon fallax *(ribbon grass) and* Themeda triandra *(kangaroo grass). This site type is favoured by livestock and native fauna.*

18. Grove mulga woodland/shrubland (GMUW)

Sampling

4 inventory sites, 12 condition sites, 64 traverse points

General information

GMUW is synonymous with mulga grove site types described in other rangeland survey areas such as Sandstone-Yalgoo-Paynes Find (Payne *et al.* 1998) and the north-eastern Goldfields (Pringle, Van Vreeswyk and Gilligan 1994). It occurs on hardpan washplains subject to sheet water flow as bands of dense vegetation (groves) separated by inter-grove plains supporting much sparser vegetation (Mabbutt and Fanning 1987). The groves receive run-on from the inter-grove areas and have much deeper soils to hardpan. They also have an abundance of tall shrubs or trees with morphology well suited to funnelling intercepted rain into the ground. This enhances soil moisture content in these fertile patches.

Soils are loamy earths usually without surface mantles. It is likely that a combination of shade, well-developed cryptogamic crusts and leaf litter enhances retention of soil moisture by insulating against evaporation. Thus GMUW not only receive and hold a disproportionate amount of resources, they use them longer into dry periods than the comparatively harsh inter-grove areas.

This site type is most common in southern parts of the Pilbara survey area where groves can extend to 40 m wide and 4 km long but are commonly much less.

Physiognomy and composition

GMUW occurs as a moderately close to closed (20->50% PFC) acacia woodland or tall shrubland. The dominant acacia is most commonly *Acacaia aneura* (mulga) but may occasionally be *A. catenulata* (black mulga). There is generally a very scattered to scattered layer of mid and low shrubs with a combined PFC of 10-20%. Perennial tussock grasses may be present but are very patchy and do not form a stratum.

55 perennial species were recorded at the 4 inventory sites, with and average of 22 species per site, considerably higher than the survey average of 16. 30 annual species were recorded, with an average of 9 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – *Acacia aneura* Common – *A. aneura, A. pruinocarpa, Hakea lorea* subsp. *suberea*
Tall shrubs:	Dominant – *Acacia aneura*, occasionally *A. catenulata* Common – *A. aneura, A. catenulata*
Mid shrubs:	Dominant – variable Common – *Eremophila forrestii, E. latrobei, Psydrax latifolia, Rhagodia eremaea, Sida calyxhymenia, Stylobasium spathulatum*
Low shrubs:	Dominant – variable Common – *Enchylaena tomentosa, Eremophila forrestii, Evolvulus alsinoides, Hibiscus burtonii, Maireana planifolia, M. villosa, Ptilotus obovatus, Senna artemisioides* subsp. x *sturtii, Sida fibulifera, Solanum lasiophyllum*
Perennial grasses:	Dominant – not present as a recognisable stratum Common – *Chrysopogon fallax, Monachather paradoxa*
Other plant forms:	Common – *Cheilanthes austrotenuifolia* (fern)

Common annuals include *Abutilon otocarpum, Aristida contorta, Enneapogon cylindricus, E. polyphyllus, Ptilotus* spp. and *Trichodesma zeylanicum*.

Patterns of grazing impact

Traverse condition summary (64 assessments):

Vegetation	-	good 47%; fair 28%; poor 25%.
Soil erosion	-	nil 94%; minor 5%; severe 1%.

GMUW is a site type favoured by animals for shelter and grazing. Palatable understorey shrubs such as *Eremophila latrobei, Sida calyxhymenia* and *Maireana planifolia* and occasional grasses may be removed under sustained heavy grazing. Seriously degraded groves may develop rills through them, lose their ability to entrap sheet wash and nutrients and may gradually decline to the extent that trees and shrubs die and the grove collapses. This type of ecosystem collapse is rarely encountered and would indicate exceptionally poor land management.

Nature conservation

This relatively small site type appears to be an important habitat for native fauna and is also favoured by domestic

Table 5. Summary of attributes for GMUW variation recorded from condition (C) and some inventory (I) sites

Vegetation attributes	Observations on natural variation and grazing impact
Demarcation of margin/edges to the inter-grove areas	Sharper, with denser grove vegetation and little or no intergrove soil redeposition/ ingress unless very degraded, when sandy infill from adjacent banks can occur (C4).
Soil-vegetation surface microtopography	Flat, with some minor cracking (but not gilgaied).
Microphytic crust development	Lichen and algal crust (plus mosses locally) patches frequent on grove and intergrove bare soil unless degraded (C7).
Alluvial interception-detritus entrapment functioning	Entrapment function along the micro-contours, with litter patches frequent unless stock pads and degraded surface patches allow through-flow (C4). In severe cases of alluvial process interception or collapse, mulga dies.
Dominant tree/tall shrub	Varies, either *Acacia aneura* (weeping form locally) or *Acacia catenulata* (~30% of sites).
Perennial shrub (and climber) species richness	Up to 25 species and mainly 10-20 species unless grove is very degraded.
Shrubs probably increasers	*Dodonaea petiolaris, Senna artemisioides, Solanum sturtianum.*
Shrubs palatable and probably decreasers	*Eremophila latrobei, Maireana planifolia, M. villosa, Sida calyxhymenia, Rhagodia eremaea, Canthium lineare, Enchylaena tomentosa, Eremophila forrestii, Ptilotus schwartzii, P. obovatus, P. roeii.*
Perennial grass species-occurrence	Low cover-frequency and not all sites - can be absent when in good condition as normal variation.
Perennial grass species richness	Mainly 2-4 species.
Perennial grasses grazed preferentially with decreaser response	(Where present probably as for GMGW).
Fire evidence and impact	Mulga deaths on one fire-affected site (C13) and cohorts of volunteered regenerating young mulga (C215, C216).
Perennial vegetation replacement by an annual herbfield	Sometimes develops in intergrove areas where degraded (C7) and/or grove shrub understorey replacement by *Aristida contorta* (C215, C216).

livestock. It is prone to preferential over-use if grazing is uncontrolled and will degrade if overland sheet flow is disrupted or diverted away from the grove. Although it was not actually recorded it is represented in the Karijini National Park. Ten traverse assessments were recorded on unallocated Crown land.

Gradational associations

GMUW is similar to *Grove mulga grassy woodland/shrubland* (GMGW) except that soils are less clayey, not gilgaied and there is no defined perennial grass layer. It is also similar to acacia dominated site types such as *Drainage eucalypt and acacia grassy woodland/shrubland* (DEGW) but is distinctive and clearly defined.

Land systems

GMUW occurs as a minor component on 14 land systems.

19. Plain mulga shrubland with chenopod low shrubs (PMCS)

Sampling

1 inventory sites, 19 traverse points

General information

PMCS is a minor site type in the Pilbara survey area but has been previously described in the Murchison, Sandstone-Yalgoo-Paynes Find and north-eastern Goldfields survey areas (Payne *et al.* 1998, Pringle, Van Vreeswyk and Gilligan 1994). In the Pilbara it occurs on plains and drainage tracts (usually tracts less than 500 m wide). Slopes are up to 1%. When in good condition soils are usually underlain by hardpan and may be slightly saline. The plains have stone mantles.

Physiognomy and composition

PMCS occurs as a scattered tall *Acacia aneura* (mulga) shrubland with a few mid shrubs and a low shrub layer dominated by chenopod shrubs.

32 perennial species and 2 annual species were recorded at the inventory site.

The following species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – *Acacia aneura* Common – *A. tetragonophylla, A. victoriae, Acacia xiphophylla*
Mid shrubs:	Dominant – *Senna glutinosa* subsp. x *luerssenii* Common – *Eremophila latrobei, Rhagodia eremaea, Senna glutinosa* subsp. x *luerssenii*
Low shrubs:	Dominant – *Maireana triptera* Common – *Enchylaena tomentosa, Eremophila forrestii, Maireana georgei, M. melanocoma, M. pyramidata, M. tomentosa, Ptilotus obovatus, Senna artemisioides* subsp. *filifolia, Senna artemisioides* subsp. x *sturtii, Solanum lasiophyllum*

Common annuals include *Aristida contorta* and *Sclerolaena* spp.

Patterns of grazing impact

Traverse condition summary (19 assessments):

Vegetation - good 68%; fair 21%; poor 11%.
Soil erosion - nil 95%; minor 5%.

The palatable low shrubs, particularly the preferentially grazed chenopod shrubs, can be removed through excessive grazing pressure.

Nature conservation

PMCS is represented in conservation areas within the survey area. Nine of the 19 traverse assessments were recorded on Karijini National Park. PMCS was not recorded on unallocated Crown land.

Gradational associations

PMCS grades upslope into *Hardpan plain mulga shrubland* (HPMS) as soils are no longer slightly saline and grade downslope into *Plain mixed halophyte shrubland* (PXHS) as soils become more saline.

Land systems

PMCS is a minor site type on 7 land systems Collier, Cowra, Cundelbar, Ford, Paraburdoo, Prairie and Weelaranna.

G. SANDPLAIN AND DUNE GRASSLAND SITE TYPES

The site types in this group occur on sandplains and dunes from coastal areas to inland desert areas. Soils are deep sands.

Four of the 5 site types in this group are comprised of hummock (spinifex) grasslands, while the fifth group is tussock grassland dominated by the introduced species buffel grass (*Cenchrus ciliaris*). The hummock grasslands based on hard spinifex types (e.g. *Triodia lanigera*) are largely unaffected by grazing as they are unattractive to stock. Soft spinifex (*T. pungens*) grasslands are moderately attractive, especially for a few years following fire, but are resilient and are usually little or only lightly impacted. The buffel grass grasslands are an altered vegetation community which is now generally resistance to grazing due to the resilience of buffel grass. The sand dunes which are now covered with buffel grass previously supported soft spinifex communities.

Hummock grassland site types on sandplains cover extensive areas in the centre and north-east on land systems such as Divide, Little Sandy and Nita. This Sandplain soft spinifex site (SSSG) shows a stand of Triodia pungens *(soft spinifex) which was burnt about two years ago. Fire can remove acacia and other shrub overstoreys and temporarily alter plant species composition by encouraging suites of annual and short lived plants which provide forage for livestock and native fauna.*

20. Sandplain hard spinifex grassland (SHSG)

Sampling

9 inventory sites, 422 traverse points

General information

SHSG is common in the far east and south-east of the survey area on sandplains, gravelly sandplains and dunes. Soils are deep red sands. Sandplains and dunes have no surface mantles and gravelly sandplains have fine ironstone gravel mantles which range in density from few to abundant (2-90%). Slopes of the sandplains are usually less than 1% but may be up to 2%. Dunes may be up to 20 m high with side slopes up to about 18%.

Physiognomy and composition

SHSG occurs as a *Triodia* hummock grassland with variable shrub layers. The dominant spinifex species is variable but is often *Triodia lanigera* or *T.* sp. weeping Indee. The PFC of the spinifex ranges from 0-60%, depending largely on the time elapsed since the last fire, but is generally 10-40%. There may be tree and/or shrub layers, which range in density from isolated to moderately close (<2.5-30% PFC). Shrub density is usually also influenced by the time since the last fire.

114 perennial species were recorded at the 9 inventory sites, with an average of 20 species per site, four above the survey average. 19 annual species were recorded, with an average of 2 species per site.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – occasionally present as a recognisable stratum; *Allocasuarina, Corymbia* and *Eucalyptus* spp. Common – *Allocasuarina decaisneana, Corymbia chippendalei* (on dunes), *Eucalyptus gamophylla, Hakea lorea* subsp. *suberea*
Tall shrubs:	Dominant – may be present; variable, often acacias Common – *Acacia ancistrocarpa, A. inaequilatera, Grevillea eriostachya*
Mid shrubs:	Dominant – variable, often acacias Common – *Acacia stellaticeps, A. tumida*
Low shrubs:	Dominant – variable Common – *Acacia stellaticeps, Bonamia rosea, Corchorus* spp., *Halgania* spp., *Indigofera monophylla, Ptilotus aphyllus, Scaevola parviflora* subsp. *parviflora, Sida cardiophylla*
Perennial grasses:	Dominant – *Triodia* spp. Common – *Aristida holathera* var. *holathera, Eragrostis eriopoda, Paraneurachne muelleri, Triodia lanigera, T. pungens, T.* sp. weeping Indee

Common annuals include *Bulbostylis burbidgeae, Dysphania kalpari, D. rhadinostachya, Eriachne aristidea, Ptilotus exaltatus, Senna notabilis, Sporobolus australasicus, Trianthema pilosa, Trichodesma zeylanicum* and *Yakirra australiensis.*

Patterns of grazing impact

Traverse condition summary (412 assessments):

Vegetation	-	good 97%; fair 3%.
Soil erosion	-	nil 100%.

SHSG is largely unattractive to stock and is very little impacted by grazing.

Nature conservation

This site type is habitat for a wide range of fauna dependent on spinifex for food (termites) or shelter (small native reptiles and mammals). The threatened flora species *Bulbostylis burbidgeae* (P3) was recorded on this site type.

SHSG was not recorded on conservation reserves within the survey area. SHSG is represented on the Rudall River National Park to the east of the survey area. SHSG occurs extensively on unallocated Crown land; 174 of 422 traverse assessments were recorded on unallocated Crown land.

Gradational associations

SHSG is similar to and grades into *Sandplain soft spinifex grassland* (SSSG) where spinifex species change to soft types such as *Triodia pungens* possibly as a result of slightly more favourable soil moisture conditions. Many tree and shrub species are common to both site types but SSSG has more diversity.

Land systems

SHSG is the most extensive site type on Buckshot, Divide, Gregory and Little Sandy land systems. It is common on Weelarrana land system and is a minor component of 8 other systems.

21. Sandplain soft spinifex grassland (SSSG)

Sampling

29 inventory sites, 7 condition sites, 708 traverse points

General information

SSSG is a common and fairly widespread site type which occurs on sandplains and dunes. Soils are deep sands and sandy earths without surface mantles and usually without cryptogamic crusting. Slopes on sandplains are usually less than 1%. Dune slopes may be up to 15%, with the dunes up to 10 m high.

Physiognomy and composition

SSSG occurs as a hummock grassland of *Triodia pungens, T. epactia* or *T. schinzii* with variable shrubs and occasional trees. The PFC of the spinifex ranges from 5-50% depending largely on the time elapsed (or the cumulative rainfall) since the last fire. There may be a patchy tree layer of eucalypts or occasionally *Owenia reticulata* (desert walnut) or *Bauhinia cunninghamii* (bauhinia). There may be tall, mid or low shrub layers, mostly of acacias or grevilleas, but not all layers are always present or they may be poorly developed. Shrub density varies from isolated to moderately close (<2.5-30% PFC) and density and height of shrubs is a function of time since the last fire.

The composition of perennials is rich and varied: 213 perennial species were recorded at the 29 inventory sites, with an average of 20 species per site, 4 above the survey average. 57 annual species were recorded, with an average of 4 species per site.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – occasionally present as a recognisable stratum; *Corymbia zygophylla, Bauhinia cunninghamii, Owenia reticulata* Common – *Acacia coriacea, Corymbia zygophylla, Hakea lorea* subsp. *suberea*
Tall shrubs:	Dominant – acacias or grevilleas Common – *Acacia ancistrocarpa, A. holosericea, A. tumida, Grevillea pyramidalis, G. wickhamii*
Mid shrubs:	Dominant – variable; often acacias Common – *Acacia ancistrocarpa, A. inaequilatera, Carissa lanceolata, Sida pilbarensis*
Low shrubs:	Dominant – variable, often *Acacia stellaticeps* Common – *Acacia stellaticeps, Bonamia eremaea, Corchorus walcottii, Dicrastylis* spp., *Evolvulus alsinoides, Indigofera monophylla, Mollugo molluginis, Ptilotus astrolasius, Scaevola parvifolia* subsp. *parvifolia, Solanum diversiflorum*
Perennial grasses:	Dominant – *T. pungens, Triodia epactia, T. schinzii* Common – *Aristida holathera* var. *holathera, Chrysopogon fallax, Eragrostis eriopoda, Eriachne obtusa, Paraneurachne muelleri*

Common annuals include *Aristida contorta, Eriachne aristidea, Ptilotus polystachyus, Senna notabilis, Trianthema pilosa* and *Yakirra australiensis*.

Patterns of burning and grazing impacts

Traverse condition summary (708 assessments):

Vegetation - good 88%; fair 9%; poor 3%.
Soil erosion - nil 99%; minor 1%.

SSSG is susceptible to wind erosion after burning but this is not usually a major problem as stability is quickly restored by post-fire regrowth unless grazing pressure is excessive.

SSSG sites with young soft spinifex are moderately attractive to livestock but mature stands are unattractive and of little grazing value. The high frequency of fires means that the presence of absence of particular plants may be more closely linked to season of firing and post-fire stages rather than to grazing pressure. Suijdendorp (1967, 1981) suggests that summer burning coupled with deferred grazing for a few months after rain will facilitate the establishment of several species (some of which are palatable to livestock) in competition with spinifex and delay its resumption of dominance.

Generally SSSG appears to be resilient under grazing but it can become degraded when small patches are burnt and stock congregate heavily on these preventing the spinifex and other palatable plants from establishing. This can result in bare patches or changes in species composition towards unpalatable plants.

Suijdendorp (1981) suggests that shrub invasions can occur after winter fires. The unpalatable low shrub *Acacia stellaticeps* (poverty bush) may thrive and establish thick stands at the expense of the spinifex. A stable, less productive disclimax is reached. Winter burning may promote prolific growth of other unpalatable plants such as *Senna notabilis* (cockroach bush) and *Corchorus walcottii* (woolly corchorus).

Nature conservation

This site type is habitat for a wide range of fauna dependent on spinifex for food (termites) or shelter (small native reptiles and mammals). The threatened flora species *Bulbostylis burbidgeae* (P3) and *Sida* sp. Wittenoom PN (P3) were recorded on SSSG.

SSSG is poorly represented in conservation reserves within the survey area. It was recorded at 1 traverse assessment on Cane River Nature Reserve. Forty-four of the 708 traverse assessments were recorded on unallocated Crown land.

Gradational associations

SSSG is similar to and grades into *Sandplain hard spinifex grassland* (SHSG) where spinifex species change to hard types possibly as a result of less favourable soil moisture conditions. Many tree and shrub species are common to both site types but SSSG has more diversity.

Land systems

SSSG is the most extensive site type on Cheerawarra, Dune, Lime, Nita and Onslow land systems. It is common on Gregory, Little Sandy and Uaroo land systems and is a minor component of 14 other systems.

22. Coastal dune soft spinifex grassland (CDSG)

Sampling

11 inventory sites, 2 traverse points

General information

CDSG occurs on coastal dunes, limestone ridges, swales and narrow sandplains. The dunes are usually between 5 to 10 m high with side slopes up to 25%. Soils are calcareous deep sands and deep sands and may have very few to common (<2-20%) shell fragments through the profile and on the surface. Soils on limestone ridges have few to common (2-20%) limestone fragments on the surface and limestone substrate.

Physiognomy and composition

CDSG occurs as hummock grasslands of *Triodia pungens* or *T. epactia* (soft spinifex) with occasional shrubs or patches of shrubs such as *Acacia coriacea* (coastal jam) or *Crotalaria cunninghamii* (green bird flower). The PFC of the spinifex ranges from 5->60% depending on the time elapsed since the last fire. There is commonly a low shrub layer but generally no mid or tall shrub layer or trees. The total cover of shrubs is isolated to scattered (<2.5-20% PFC).

100 perennial species were recorded at the 11 inventory sites, with an average of 17 species per site, slightly above the survey average. 27 annual species were recorded, with an average of 3 species per site.

The following species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – not present as a recognisable stratum Common – *Acacia coriacea*
Mid shrubs:	Dominant – not usually present as a recognisable stratum Common – *Acacia coriacea, Crotalaria cunninghamii*
Low shrubs:	Dominant – variable, including *Aerva javanica* Common – *Acacia stellaticeps, Adriana tomentosa, Aerva javanica, Cajanus cinereus, Indigofera boviperda, I. linnaei, Pterocaulon sphacelatum, Ptilotus axillaris, Scaevola crassifolia, Tephrosia rosea*
Perennial grasses:	Dominant – *Triodia epactia, T. pungens* Common – *Cenchrus ciliaris, Spinifex longifolius, Whiteochloa airoides*
Other plant forms:	Common – *Cassytha capillaris, Rhynchosia minima* (creepers)

Common annuals include *Calandrinia* sp., *Decazesia hecatocephala, Goodenia microptera, Indigofera colutea, Ptilotus exaltatus* and *Salsola tragus*.

Patterns of grazing impact

Insufficient traverse assessments.

CDSG is little impacted by grazing unless pressure is severe in which case soft spinifex can be considerably reduced and is often replaced by buffel grass. Disturbance caused by grazing, vehicles and/or fire can occasionally result in dune blowouts on this site type.

Nature conservation

Grazing is not a major threat to this site type but invasion by *Cenchrus ciliaris* (buffel grass), especially in disturbed situations, is a threat. CDSG is closely associated with coastal fringes which include specialised communities such as mangroves and salt marshes (Craig 1983) all of which have high conservation value for biodiversity and fauna habitat and warrant reservation.

CDSG is believed to be not represented on conservation reserves within the survey area. It was recorded at 2 traverse assessments, both of these were on Mandora pastoral lease.

Gradational associations

CDSG changes abruptly into *Saline plain sporobolus grassland* (SPSG) or *Plain samphire shrubland* (PSPS) as soils become less sandy and increasingly saline and waterlogged.

Land systems

CDSG is a major site type on Dune land system and a minor site type on Eighty Mile and Littoral land systems.

23. Coastal dune buffel grass grassland (CDBG)

Sampling

1 inventory sites, 26 traverse points

General information

CDBG occurs on coastal dunes, swales and narrow sandplains. The dunes are usually between 5-10 m high with side slopes up to 25%. Soils are calcareous deep sands and deep sands and may have very few to common (<2-20%) shell fragments through the profile and on the surface.

Physiognomy and composition

CDBG occurs as a *Cenchrus ciliaris* tussock grass grassland with isolated (<2.5% PFC) shrubs. The grass layer has a basal cover between 5-10%.

16 perennial species and 1 annual species were recorded at the inventory site.

The following species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – not present as a recognisable stratum Common – *Acacia coriacea*
Mid shrubs:	Dominant – not usually present as a recognisable stratum Common – *Acacia coriacea, Crotalaria cunninghamii*
Low shrubs:	Dominant – not usually present as a recognisable stratum Common – *Acacia stellaticeps, Aerva javanica, Cajanus cinereus, Indigofera boviperda, I. linnaei, Pterocaulon sphacelatum, Scaevola crassifolia, Trianthema turgidifolia*
Perennial grasses:	Dominant – *Cenchrus ciliaris* Common – *Aristida holathera* var. *holathera, Triodia epactia, T. pungens, Whiteochloa airoides*
Other plant forms:	Common – *Abrus precatorius, Rhynchosia minima* (creepers)

The annual species recorded at the inventory site was *Indigofera colutea.*

Patterns of grazing impact

Traverse condition summary (26 assessments):

Vegetation - good 92%; fair 8%.
Soil erosion - nil 100%.

CDBG is a site type which has replaced *Coastal dune spinifex grassland* (CDSG) in some coastal areas. The original CDSG has been profoundly altered in terms of grass composition from *Triodia pungens* (soft spinifex) to *Cenchrus ciliaris* (buffel grass). It is likely that disturbance of CDSG due to overgrazing and/or fire has enabled buffel grass to colonise and then replace the spinifex.

Buffel grass is resilient under grazing and CDBG is little impacted unless grazing pressure is grossly excessive. The dense cover provided by buffel grass confers resistance to wind erosion. However, the site type is likely to be moderately or highly susceptible to wind erosion for periods immediately following fire.

Nature conservation

This site type probably has low conservation value and the replacement by buffel grass may have been associated with a loss of diversity in fauna groups such as invertebrates, reptiles and small mammals.

CDBG was not recorded on conservation reserves or unallocated Crown land within the survey area.

Gradational associations

CDBG changes abruptly into *Saline plain sporobolus grassland* (SPSG) or *Plain samphire shrubland* (PSPS) as soils become less sandy and increasingly saline and waterlogged.

Land systems

CDBG is the most extensive site type on the Eighty Mile land system and is a minor site type on the Anna and Dune land systems.

24. Sandy bank acacia spinifex shrubland (SBAS)

Sampling

3 inventory sites, 23 traverse points

General information

SBAS occurs on low sandy banks. Slopes are up to 2% and the banks are up to 2 m high. Soils are deep sands with no surface mantles.

Physiognomy and composition

SBAS occurs as a scattered to moderately close (10-30% PFC) acacia shrubland with a hummock grass layer. The acacias are commonly *Acacia aneura*. *Triodia* species include *Triodia basedowii, T. lanigera* and *T. pungens.*

50 perennial species were recorded at the 3 inventory sites, with an average of 22 species per site, considerably higher than the survey average of 16. 22 annual species were recorded, with an average of 8 species per site.

The following species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – acacias, commonly *Acacia aneura* Common – *Acacia aneura, A. pruinocarpa, A. sclerosperma*
Mid shrubs:	Dominant – acacias or eremophilas Common – *Acacia aneura, Eremophila latrobei, Rhagodia eremaea*
Low shrubs:	Dominant – acacias or eremophilas Common – *Abutilon otocarpum, Eremophila pensilis, Hibiscus burtonii, H. sturtii, Maireana planifolia, M. villosa, Senna artemisioides* subsp. *helmsii*
Perennial grasses:	Dominant – triodias including *Triodia basedowii, T. lanigera, T. pungens* Common – *Digitaria brownii, Eragrostis eriopoda*

Common annuals include *Aristida contorta, Enneapogon caerulescens, E. cylindricus, E. polyphyllus, Eragrostis pergracilis, Eriachne pulchella, Ptilotus exaltatus* and *Trichodesma zeylanicum.*

Patterns of grazing impact

Traverse condition summary (23 assessments):

Vegetation - good 91%; fair 9%.
Soil erosion - nil 100%.

SBAS is largely unattractive to grazing animals and is inherently stable. Although a few palatable plants may be reduced under grazing, it is generally little impacted.

Nature conservation

SBAS was not recorded on conservation reserves or unallocated Crown land within the survey area.

Gradational associations

SBAS is a distinct site type on sandy banks and changes abruptly to other site types on plains.

Land systems

SBAS is the most extensive site type on Cadgie and Zebra land systems and is a minor component on Fan, Narbung and Talawana land systems.

H. ALLUVIAL PLAIN HUMMOCK GRASSLAND (AND OCCASIONALLY GRASSY SHRUBLAND) SITE TYPES

This group of site types occurs in depositional landscapes and support hummock grass grasslands. Soils are most commonly texture contrast (duplex) soils or clays.

The hummock grasslands are unattractive or only moderately attrative to stock, however, they can be degraded and eroded by inappropriate grazing or burning practices. If small patches are burnt and then heavily stocked the grasses and herbs associated with the spinifex may be unable to re-establish. This may lead to bare patches which are than susceptible to scalding. In the case of soft spinifex, the young soft spinifex is attractive to grazing animals and can also be removed leaving bare areas or occasionally allowing invasion by unpalatable species such as *Acacia stellaticeps* (poverty bush) and *Senna notabilis* (cockroach bush). Soils are susceptible to water erosion where the alluvial plains receive more active distributary flow from creeks and rivers.

25. Alluvial plain hard spinifex grassland (AHSG)

Sampling

21 inventory sites, 255 traverse points

General information

AHSG occurs fairly widely on alluvial plains and drainage tracts usually with non-cracking, weakly saline, sandy duplex and clay soils. Slopes are up to 3% but generally less than 1%. There is often a surface mantle, which varies from very few to abundant (<2-90%) small to large (2-60 mm) pebbles.

Physiognomy and composition

AHSG occurs as a hummock grassland with up to 60% PFC when mature. There may be a low shrub layer, and occasionally a mid shrub and/or tall shrub layer predominantly of *Acacia* species. The shrubs are generally isolated to scattered (up to 20% PFC). The dominant spinifex is most often *Triodia longifolia* (knitting needle spinifex) or *T. secunda* (porcupine spinifex).

106 perennial species were recorded at the 21 inventory sites, with an average of 10 species per site, considerably lower than the survey average of 16. 58 annual species were recorded, with an average of 5 species per site.

The following species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – occasionally present as a recognisable stratum; acacias including *Acacia ancistrocarpa, A. arida* Common – *Acacia ancistrocarpa, A. inaequilatera*
Mid shrubs:	Dominant – occasionally present as a recognisable stratum; acacias including *Acacia bivenosa* Common – *Acacia bivenosa*
Low shrubs:	Dominant – variable Common – *Acacia stellaticeps, Corchorus walcottii, Hibiscus sturtii, Mollugo molluginis, Pluchea tetrandera, Sida rohlenae*
Perennial grasses:	Dominant – *Triodia lanigera, T. longifolia, T. secunda* Common – *Aristida holathera* var. *holathera, Cenchrus ciliaris, Chrysopogon fallax, Triodia pungens*
Other plant forms:	Common – *Rhynchosia minima* (creeper)

Common annuals include *Calandrinia quadrivalvis, Dysphania rhadinostachya, Eragrostis dielsii, Pterocaulon sphacelatum, Ptilotus exaltatus, Senna notabilis, Sporobolus australasicus, Streptoglossa decurrens* and *Trianthema triquetra*.

Patterns of grazing impact

Traverse condition summary (255 assessments):

Vegetation - good 81%; fair 14%; poor 5%.
Soil erosion - nil 78%; minor 20%; moderate 1%; severe 1%.

Due to the unpalatable nature of hard spinifex this site type is not preferred by livestock. However, some associated grasses and herbs are moderately attractive and AHSG can be degraded by inappropriate grazing or burning practices. If small patches are burnt and then heavily stocked the grasses and herbs associated with the hard spinifex may be unable to re-establish. This may lead to bare patches which are then susceptible to scalding. Occasionally the spinifex may be replaced by *Acacia stellaticeps* (poverty bush) or *Sclerolaena hostilis* (giant bindii) though more frequently degraded sites consist of patches of old hard spinifex plants with large areas of bare scalded ground between the hummocks.

Nature conservation

The threatened flora species *Bulbostylis burbidgeae* (P3) and *Sida* sp. Wittenoom PN (P3) were recorded on AHSG.

AHSG is represented on conservation reserves within the survey area. It was recorded on Cane River Nature Reserve and on the Meentheena pastoral lease. It was also recorded on unallocated Crown land.

Gradational associations

AHSG grades laterally into *Alluvial plain soft spinifex grassland* (ASSH) as soils become less clayey and less saline and upslope away from alluvial tracts into *Plain hard spinifex grassland* (PHSG) or *Plain mulga spinifex shrubland/grassland* (PMSS).

Land systems

AHSG is a major site type on Cheerawarra land system and a minor site type on 14 other systems.

26. Alluvial plain soft spinifex grassland (ASSG)

Sampling

49 inventory sites, 525 traverse points

General information

ASSG occurs widely on alluvial plains and drainage floors on many land systems in the survey area. Soils are sandy earths, loamy earths and sandy duplexes which are generally less saline (or non-saline) and less clayey than the soils supporting *Alluvial plain hard spinifex grassland* (AHSG). Surface mantles vary from very few to abundant (<2-90%), small to large (2-60 mm) pebbles often of quartz or ironstone. Slopes are generally less than 1%.

Physiognomy and composition

This site type occurs as a hummock grassland or shrubby hummock grassland of *Triodia pungens* (soft spinifex). The PFC of the spinifex varies from about 10->60% when mature. Shrubs and trees are mostly isolated to scattered (<2.5-20% PFC) and may constitute an obvious low and mid shrub layer and occasionally a tall shrub and/or tree layer.

212 perennial species were recorded at the 49 inventory sites, with an average of 15 species per site, slightly below

the survey average. 120 annual species were recorded, with an average of 7 species per site.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – occasionally present as a recognisable stratum; *Corymbia hamersleyana, Hakea lorea* subsp. *suberea* Common – *Corymbia hamersleyana, Hakea lorea* subsp. *suberea*
Tall shrubs:	Dominant – occasionally present as a recognisable stratum; acacias Common – *Acacia ancistrocarpa, A. inaequilatera*
Mid shrubs:	Dominant – acacias Common – *Acacia inaequilatera, A. victoriae*
Low shrubs:	Dominant – variable; often *Acacia stellaticeps* Common – *Acacia stellaticeps, Corchorus sidoides, Hibiscus sturtii, Indigofera monophylla, Mollugo molluginis, Pluchea tetranthera, Senna artemisioides* subsp. *oligophylla, Sida fibulifera*
Perennial grasses:	Dominant – *Triodia pungens* Common – *Cenchrus ciliaris, Chrysopogon fallax, Eragrostis xerophila*
Other plant forms:	Common – *Fimbristylis* spp. (sedges), *Rhynchosia minima* (creeper)

Common annuals include *Aristida contorta, Dactyloctenium radulans, Gomphrena canescens, Iseilema* spp, *Pterocaulon sphacelatum, Senna notabilis, Sporobolus australasicus* and *Trianthema triquetra.*

Patterns of grazing impact

Traverse condition summary (525 assessments):

Vegetation - good 76%; fair 17%; poor 7%.
Soil erosion - nil 78%; minor 15%; moderate 5%; severe 2%.

Young soft spinifex is attractive to grazing animals and ASSG also supports other palatable grasses, low shrubs and herbs. It is moderately susceptible to degradation if grazing or burning practices are inappropriate. Suijdendorp (1967) recommends burning in summer rather than winter and deferment of grazing for 6-8 weeks following effective rainfall to ensure that spinifex seedlings and other species have time to establish and develop. Excessive grazing, particularly on sites with duplex soils, may result in bare patches which are susceptible to erosion in the form of sheeting, scalding and wind hummocking or to invasion by unpalatable shrubs such as *Acacia stellaticeps* (poverty bush) or *Senna notabilis* (cockroach bush).

Nature conservation

The threatened flora species *Abutilon trudgenii* ms (P3) and *Sida* sp. Wittenoom PN (P3) were recorded on ASSG.

ASSG is represented, although poorly, on conservation reserves within the survey area. It was recorded on Cane River Nature Reserve and on the Meentheena pastoral lease. It was also recorded on unallocated Crown land. Of the 525 traverse assessments, 19 were recorded on conservation reserves and 15 were recorded on unallocated Crown land.

Gradational associations

ASSG grades laterally into *Alluvial plain hard spinifex grassland* (AHSG) where soils are more clayey and saline and upslope away from alluvial plains and drainage floors into *Plain soft spinifex grassland* (PSSG) or *Plain mulga spinifex shrubland/grassland* (PMSS).

Land systems

ASSG is the most extensive site type on Paradise land system. It is a major site type on Mallina, Pullgarah and Urandy land systems, common on River land system, and minor on 23 other systems.

27. Alluvial plain snakewood hummock grass shrubland (ASHS)

Sampling

14 inventory sites, 96 traverse points

General information

ASHS occurs on stony and gravelly plains, and on alluvial plains. They have variable density mantles, but generally medium pebbles or gravel (6-20 mm). Slopes are 0-1%. Soils are clays and cracking clays which often become somewhat saline at depth.

Physiognomy and composition

ASHS occurs as a scattered to moderately close (5-30% PFC) tall or mid height *Acacia xiphophylla* (snakewood) shrubland with a hummock grass layer or as a hummock grassland with *Acacia xiphophylla* tall or mid shrubs (very scattered to scattered with 2.5-20% PFC). There is commonly a low shrub layer. The dominant *Triodia* species varies but is often *Triodia pungens* or *T. wiseana*. The PFC of the spinifex layer varies from <5-60%.

82 perennial species were recorded at the 14 inventory sites, with an average of 14 species per site, 2 below the survey average. 37 annual species were recorded, with an average of 6 species per site.

The following perennial species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – *Acacia xiphophylla* Common – *Acacia farnesiana, A. victoriae*
Mid shrubs:	Dominant – *Acacia xiphophylla* Common – *Acacia bivenosa, A. victoriae, Carissa lanceolata, Rhagodia eremaea*
Low shrubs:	Dominant – *Acacia xiphophylla* or sennas Common – *Abutilon* spp., *Enchylaena tomentosa, Maireana planifolia, Senna*

	artemisioides subsp. *helmsii*, *Senna artemisioides* subsp. *oligophylla*, *Senna* sp. Meekatharra, *Sida fibulifera*, *Solanum horridum*
Perennial grasses:	Dominant – *Triodia pungens* or *T. wiseana*, occasionally *T. lanigera* or *T. longiceps* Common – *Cenchrus ciliaris, Enteropogon acicularis, Eragrostis xerophila*
Other plant forms:	Common – *Rhynchosia minima* (creeper)

Common annuals include *Aristida contorta, Brachyachne prostrata, Dysphania rhadinostachya, Eriachne pulchella, Malvastrum americanum, Pterocaulon sphacelatum, Ptilotus aervoides, P. exaltatus, Sporobolus australasicus* and *Streptoglossa bubakii*.

Patterns of grazing impact

Traverse condition summary (96 assessments):

Vegetation - good 35%; fair 38%; poor 27%.
Soil erosion - nil 81%; minor 12%; moderate 1%; severe 6%.

ASHS is a site type which includes shrubs and grasses which are preferentially grazed by livestock. Excessive grazing can reduce the density of palatable plants, reduce ground cover and initiate erosion.

Nature conservation

ASHS is represented on conservation reserves within the survey area; it was recorded on Cane River Nature Reserve. Two of the 96 traverse assessments were recorded on unallocated Crown land.

Acacia xiphophylla (snakewood) shrubland site types (SSTS, PSCS, ASHS) are common throughout the Pilbara. SSTS sites with gilgaied clay soils support understoreys of perennial grasses such as Eragrostis xerophila (Roebourne Plains grass). PSCS sites with duplex soils invariably have the potential to support chenopod low shrubs clumped under the snakewoods. The site shown here (ASHS) has a Triodia pungens (soft spinifex) hummock grass understorey which may have replaced chenopod shrubs which have been removed by preferential overgrazing.

Gradational association

ASHS grades into *Alluvial plain hard spinifex grassland* (AHSG), *Alluvial plain soft spinifex grassland* (ASSG) or, where soils become gilgaied, into *Alluvial plain Roebourne Plains grass grassland* (ARPG).

Land systems

ASHS is the most extensive site type on Cane land system. It is a major site type on Dollar land system and common on Kanjenjie land system. It occurs as a minor component on 7 other systems.

I. ALLUVIAL PLAIN TUSSOCK GRASSLAND (AND OCCASIONALLY GRASSY SHRUBLAND) SITE TYPES

This broad group of site types occurs in depositional landscapes and support tussock grasslands, and occasionally grassy shrublands. Soils are most commonly cracking clays or texture contrast (duplex) soils. Vegetation is usually dominated by tussock grasses of the genera *Astrebla, Cenchrus, Chrysopogon, Eriachne, Eragrostis, Eulalia, Sporobolus* and *Themeda*. The site types are preferred by grazing animals, both domestic and native, and are frequently heavily impacted. The generally salty nature of the vegetation associated with *Sporobolus* grasslands, and sometimes difficulty in obtaining good quality stock water, means that grazing is restricted and this site type is generally not heavily impacted by grazing.

The Alluvial plain tussock grassland site type (APTG) is fairly common on level plains with clay or loamy earth soils. It can be subdivided into types depending on which grass species is dominant in the stand. This example shows an Astrebla pectinata (barley Mitchell grass) site type (APMG) in good condition. Such sites are preferred by livestock and can degrade if grazing is uncontrolled.

28. Alluvial plain tussock grassland (APTG)

Sampling

34 inventory sites, 28 condition sites and 410 traverse points.

General information

This site type occurs throughout the survey area on level (slopes <1%) flood plains, alluvial plains and drainage tracts associated with major rivers such as the Fortescue, Yule and De Grey. The plains and drainage tracts are frequently gilgaied. Soils are most often cracking clays and occasionally loamy earths and clays. Surface mantles are generally nil to few (0-10%) as pebbles (6-60 mm) of ironstone and other rocks or occasionally as much larger calcrete floaters.

Physiognomy and composition

APTG occurs as a tussock grass grassland with few shrubs or trees. APTG usually consists of communities of mixed tussock grass species, with the tussock grass layer often dominated by single species such as *Astrebla* spp. (Mitchell grass), *Chrysopogon fallax* (ribbon grass), *Eragrostis setifolia* (neverfail), *Eriachne benthamii* (swamp grass), *Eulalia aurea* (silky browntop) or *Themeda triandra* (kangaroo grass). Within any one site it is normal to find different patches or phases which are dominated by different species and which relate to the microtopography and patterned surface characteristics of cracking clay plains. Shrubs and trees are generally isolated to very scattered (<2.5-10% PFC) and rarely form prominent layers. The basal cover of the grass is usually in the range of 1-10% depending on condition status.

Seven sub-types were recognised within this broad site type but are not separately described:

APTG	Sub-types	Traverse points	Inventory sites
APXG	Alluvial plain mixed grass grassland	157	14
APMG	Alluvial plain Mitchell grass grassland	48	3
APRG	Alluvial plain ribbon grass grassland	112	5
APNG	Alluvial plain neverfail grass grassland	33	3
APSG	Alluvial plain swamp grass grassland	23	5
APEG	Alluvial plain silky browntop grass grassland	14	1
APKG	Alluvial plain kangaroo grass grassland	23	3

162 perennial species were recorded at the 34 inventory sites, with an average of 12 species per site, 4 below the survey average. 120 annual species were recorded, with an average of 8 species per site.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – occasionally present as a recognisable stratum; *Corymbia* spp., *Eucalyptus victrix, Hakea lorea* subsp. *suberea* Common – *Eucalyptus victrix, Hakea lorea* subsp. *suberea*
Tall shrubs:	Dominant – occasionally present as a recognisable stratum; acacias Common – *Acacia farnesiana, A. tetragonophylla, A. victoriae*
Mid shrubs:	Dominant – occasionally present as a recognisable stratum; acacias Common – *Acacia farnesiana, A. inaequilatera, Rhagodia eremaea*
Low shrubs:	Dominant – occasionally present as a recognisable stratum; variable Common – *Neptunia dimorphantha, Senna artemisioides* subsp. *oligophylla, Sida fibulifera, Solanum esuriale, S. lasiophyllum*
Perennial grasses:	Dominant – variable including *Astrebla pectinata, Chrysopogon fallax, Eragrostis setifolia, Eriachne benthamii, Eulalia aurea, Themeda triandra* Common – *Aristida latifolia, Astrebla elymoides, A. pectinata, Cenchrus ciliaris, C. setigerus, Chrysopogon fallax, Eragrostis setifolia, E. xerophila, Eriachne benthamii, Eulalia aurea, Panicum decompositum*
Other plant forms:	Common – *Glycine falcata, Ipomoea muelleri, Rhynchosia minima,* (creepers)

Common annuals include *Aristida contorta, Cullen cinerea, Dichanthium sericeum* subsp. *sericeum, Flaveria australasica, Iseilema* spp., *Panicum laevinode, Pterocaulon sphacelatum, Ptilotus carnosa, P. gomphrena* and *Streptoglossa bubakii*.

Patterns of grazing impact

Traverse condition summary (410 assessments):

Vegetation - good 52%; fair 17%; poor 31%.
Soil erosion - nil 84%; minor 8%; moderate 5%; severe 3%.

This site type has been substantially impacted by grazing. The sub-types have different susceptibilities to grazing and erosion. APSG and APEG are only moderately attractive to stock and are generally in good condition and not eroded. APMG, APRG and APNG are preferentially grazed and are more often in fair or poor condition than in good condition and may be eroded. APKG is generally in good or fair condition, and is generally not eroded as the cracking clay soils on which it occurs are inherently stable.

In terms of palatability to stock, field observations were that where they occurred together, kangaroo grass *Themeda* spp. appeared to be grazed preferentially over the other major species which occur with it in mixed associations: ribbon grass, Roebourne Plains grass, weeping Mitchell grass, neverfail grass and feathertop three awn (which is evidently unpalatable in any association).

These grasslands are noticeably susceptible to 'patch grazing' where livestock or kangaroos graze the same plants or large patches of grazed down plants. Grazing encourages tender young shoots so the animals are again attracted to that individual. Over time this can lead to bare patches which are then susceptible to erosion. At many sites, naturally less productive barer subunits of gilgai plain microtopography occur; these may be stonier than adjacent phases and can be confused with eroding patches of slumped self-mulching soils on more severely impacted sites.

However, some sites had clear evidence of very high utilisation rates and death or removal of the tussock grass stand which evidently can collapse completely. On average, 3.5 species of tussock grasses occurred per site, with up to 7 species at a site (C71) while 3 sites (C9, C61 and C201) had no tussock grasses remaining and had been totally reduced to herbfields.

Trees, shrubs and all other perennials averaged 4.1 species per site and up to 8 species per site. Some of this variation may be due to the proximity of the site sampled to other adjacent land units, although some sub-types such as *Alluvial plain kangaroo grass grassland* (APKG) where well-developed and in good condition, normally exhibit very few or no trees and shrubs.

Table 6. Summary of perennial grass species data for APTG (from condition sites)

Main species of perennial grass	Rate of occurrence as % of condition sites	Mean % frequency (cover-density)
Eragrostis xerophila	61	28
Chrysopogon fallax	39	54
Eragrostis setifolia	39	28
Eriachne benthamii	35	22
Aristida latifolia	32	16
Astrebla elymoides	29	20
Themeda triandra	19	38
Astrebla pectinata	19	12
Astrebla lappacea	13	54
Cenchrus ciliaris	10	2
Themeda sp. Hamersley station	3	46

Table 7. Summary of attributes for APTG variation recorded from condition (C) sites

Vegetation attributes	Observations on natural variation and grazing impact
Grass association with patchy micro-topography of soil patches and gilgai development	Species predominances strongly controlled by micro-topography eg. *Themeda* and/or *Chrysopogon* along drainage lines and on more strongly gilgaied areas, *Astrebla elymoides*, *Eriachne benthamii* and *Eragrostis setifolia* (C14) mainly on lowest-lying flood-prone parts. Gilgai slumping associated with death/removal of perennial grasses (C213).
Perennial grass species site dominance	Ubiquitous, except where degraded when perennial grassland has been killed, wholly or partly tending towards annual herbfields (C9, C61, C201).
Perennial grass species richness	1-7 species per site, from *Aristida latifolia, Astrebla pectinata, A. elymoides, A. lappacea, Cenchrus ciliaris, C. setigerus, Chrysopogon fallax, Dichanthium* spp., *Eragrostis setifolia, E. xerophila, Eriachne benthamii, E. obtusa, Eulalia aurea, Panicum decompositum, Themeda* sp. *Hamersley station, T. triandra, Triodia pungens.* Sites with only one or two species present and at high cover-densities may be natural variation not necessarily adversely impacted by prior grazing usage.
Perennial grass frequency (density)	*Chrysopogon fallax* up to 100% (C211), *Eragrostis setifolia* up to 100% (C14), *Eragrostis xerophila* up to 78% (C19), *Themeda* sp. Hamersley station up to 98% (C211), *Astrebla pectinata* up to 96% (C214), *Aristida latifolia* up to 88% (C74), *Eriachne benthamii* up to 88% (C71), *Themeda triandra* up to 86% (C72), *Astrebla lappacea* up to 82% (C206), *Astrebla elymoides* up to 62% (C213).

The *Alluvial plains tussock grassland* site type (APTG) did not normally show evidence of shrub invasion, presumably because of soil type. However, *Sida fibulifera* invasions of herbfields on degraded areas were a consistent exception to the rule.

The introduced buffel grass *Cenchrus ciliaris* was found at low frequency on 10% of APTG sites.

Much of the observed variation in tussock grass cover and composition and evident occurrence of sub-types may be natural. Important determinants of grassland phases and site potential appear to be landscape factors and soil variation, particularly in relation to surface hydrology and waterlogging, soil surface patterning and gilgai type and characteristics.

As indicated by Table 6, some species tend to occur at higher levels of abundance than others where they naturally occur together. While the two species of kangaroo grasses were each only found on 10% of sites, they occurred at frequencies up to 86% and 98% repectively; *Themeda triandra* was also found at high frequency where in co-dominance with *Chrysopogon fallax*. They were not found to occur in *Eragrostis setifolia* communities. *Eragrostis xerophila* is the most widely occurring tussock grass across all sub-types but mainly only at relatively low frequencies and not as a site dominant. (*Eragrostis xerophila* is the dominant in the separately described *Alluvial plain Roebourne Plains grass grassland*, ARPG).

All three species of Mitchell grasses occur as site dominants, although *Astrebla lappacea* (curly Mitchell grass) is endemic and more restricted in its distribution than the other two. *Astrebla pectinata* (Barley Mitchell grass) and *A. elymoides* (weeping Mitchell grass) both occur mainly on higher units of alluvial gilgai plains of the Brockman land system and not usually among the sub-types dominated by *Eragrostis setifolia, Chrysopgon fallax* or *Eriachne benthamii.*

Nature conservation

The following threatened flora were recorded on APTG: *Abutilon trudgenii* ms (P3), *Astrebla lappacea* (P3), *Glycine falcata* (P3) and *Goodenia pascua* (P3). *Astrebla lappacea* and *Glycine falcata* were exclusive to this site type.

The *Alluvial plain kangaroo grass grassland* (APKG) sub-type where it occurs on Brockman land system on Hamersley Station is listed as a Threatened Ecological Community that has been categorised as vulnerable.

This high pastoral value site type is very poorly represented on conservation reserves within the survey area. Of the 410 traverse assessments, 3 were recorded on conservation reserves and 6 were recorded on unallocated Crown land. This site type is preferentially grazed and supports threatened species and should be considered for further reservation.

Gradational associations

The sub types within this site type grade into each other depending mainly on soil drainage characteristics. Frequently inundated sites or sites which tend to be waterlogged usually support APSG or APEG. Somewhat more freely drained sites are dominated by APMG or APXG. The site type grades into other grassland sites such as the distinctive *Alluvial plains Roebourne Plains grass grassland* (ARPG), and *Alluvial plain buffel grass grassland* (APBG) where soils are more sandy or loamy or into *Saline plain sporobolus grassland* (SPSG) where soils are more saline.

Land systems

APTG is the most extensive site type on the Brockman land system (in the form of APMG, APKG and APXG) and on the Fortescue land system (in the form of APRG). It is co-dominant with *Alluvial plain buffel grass grassland* (APBG) on Anna and Yamerina land systems and is common on Horseflat land system. It occurs as a minor component on 15 other systems.

29. Alluvial plain Roebourne Plains grass grassland (ARPG)

Sampling

16 inventory sites, 30 condition sites, 335 traverse points.

General information

This fairly common site type occurs on level (slopes <1%) alluvial plains with gilgai microrelief. The development of microrelief is very variable and is associated with patterns in grassland species and density. More densely grassed gilgai areas are mixed or dispersed between higher (runoff) soil phases with much less grass and prominent stony mantles. Soils are cracking clays and clays which frequently become saline with depth. Surface mantles are very variable and vary from none to very abundant (0->90%) pebbles (2-60 mm) of mixed lithology.

Physiognomy and composition

ARPG occurs as an *Eragrostis xerophila* tussock grassland usually with other minor grass species and occasionally with a poorly developed low shrub stratum. Basal cover of the grass may be up to 10% but is most commonly less than 5%. Shrubs and trees, if present, are isolated to very scattered (<2.5-10% PFC). There may be a low shrub stratum but other strata are not generally present unless they have proliferated as a result of grazing pressure.

75 perennial species were recorded at the 16 inventory sites, with an average of 10 species per site, considerably lower than the survey average of 16. 82 annual species were recorded, with an average of 10 species per site.

The following species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – not usually present as a recognisable stratum Common – *Acacia victoriae*
Low shrubs:	Dominant – occasionally present as a recognisable stratum; variable, often sennas Common – *Indigofera trita, Neptunia dimorphantha, Senna artemisioides* subsp. *helmsii, Senna artemisioides* subsp. *oligophylla, S. hamersleyensis, Sida fibulifera, Solanum lasiophyllum, Tephrosia clementii*

Perennial grasses:	Dominant – *Eragrostis xerophila* Common – *Cenchrus ciliaris, Chrysopogon fallax, Eragrostis setifolia, Eriachne benthamii, Triodia pungens*
Other plant forms:	Common – *Desmodium campylocaulon, Ipomoea muelleri, Rhynchosia minima* (creepers)

Common annuals include *Aristida contorta, Brachyachne convergens, Cleome viscosa, Dichanthium sericeum* subsp. *sericeum, Gomphrena canescens, Iseilema* spp., *Malvastrum americanum, Ptilotus exaltatus, P. gomphrenoides, Salsola tragus* and *Sporobolus australasicus*.

Patterns of grazing impact

Traverse condition summary (335 assessments):

Vegetation - good 30%; fair 25%; poor 45%.
Soil erosion - nil 73%; minor 11%; moderate 9%; severe 7%.

ARPG sites vary in their evident seasonal palatability and utilisation rates under grazing management. *Eragrostis xerophila* is relatively unpalatable when the plants are large and mature, thus giving it protection in dry conditions. The suite of seasonal annuals are mainly palatable species except on degraded sites.

Patch grazing was frequently observed, although on some sites more even utilisation rates of the tussocks was evident. Patch grazing can lead to the development of small degraded patches with altered soil surfaces and with pedestalled grass butts even amid well-covered sites otherwise evidently in good condition. *Eragrostis xerophila* can be removed or become patchy under excessive grazing pressure. On more degraded areas, sites can lose much of their tussock grass cover, the gilgai microrelief can slump and flattened patches develop into larger sealed bare patches with more or less saline crusted surfaces. These are susceptible to erosion when trampled. Sites do not normally degenerate into herbfields as readily as some of the other tussock grasslands.

Grasses other than *Eragrostis xerophila* occur on the majority of sites, invariably as minor components at much lower frequencies. Of these, *Eragrostis setifolia* and *Eriachne benthamii* are the most common and the presence of the former may be a useful and responsive condition indicator, being recorded as absent from sites that were obviously degrading.

This site type is occasionally susceptible to invasion by woody weeds such as *Senna artemisioides* subsp. *helmsii* and *Acacia farnesiana*, and to the introduced weed mesquite (*Prosopis* spp.) which was observed establishing on sites otherwise in excellent condition (C230).

The traverse data indicates that ARPG has been considerably impacted by grazing, both in terms of loss of grass cover and soil erosion.

Nature conservation

The threatened flora species *Goodenia pascua* (P3) was recorded on ARPG.

ARPG was not recorded but is known to occasionally occur on conservation reserves within the survey area. Of the 335 traverse assessments 4 were recorded on unallocated Crown land. Much of this preferentially grazed site type is degraded by overgrazing. The site type should be considered for further reservation.

Gradational associations

ARPG grades into various sub types of *Alluvial plain tussock grassland* (APTG) depending largely on soil drainage characteristics.

Land systems

ARPG is the most extensive site type on Horseflat, Pullgarah and Hooley land systems and is common on Paraburdoo land system. It occurs as a minor component on 22 other systems.

Table 8. Summary of perennial grass species data for ARPG (from condition sites)

Main species of perennial grass	Rate of occurrence as % of condition sites	Mean % frequency (cover-density)
Eragrostis xerophila	100	63
Eriachne benthamii	37	4
Eragrostis setifolia	33	3
Chrysopogon fallax	13	-
Astrebla elymoides	10	-
Triodia spp.	10	-
Astrebla pectinata	10	-
Triodia pungens	10	-
Cenchrus ciliaris	10	-
Aristida latifolia	7	-
Dichanthium fecundum	3	-

Table 9. Summary of attributes for ARPG variation recorded from condition (C) sites

Vegetation attributes	Observations on natural variation and grazing impact
Grass association with patchy micro-topography of soil patches and gilgai development	Tussock cover and minor species strongly controlled by micro-topography. Many sites have less productive patches of stony phase soil with higher runoff and lower productivity. Gilgai slumping associated with death/removal of perennial grasses.
Perennial grass species site dominance	All sites with at least some cover of *Eragrostis xerophila* but annual grasses (particularly *Aristida contorta*) can dominate where perennial cover is grossly reduced (C239). Exceptionally, found invaded by *Triodia pungens* (C88).
Perennial grass species richness	1-5 species per site including *Eragrostis xerophila* with *Aristida latifolia, Astrebla elymoides, Cenchrus ciliaris, Chrysopogon fallax, Dichanthium fecundum, Eragrostis setifolia, Eriachne benthamii, Triodia pungens, T. wiseana, Triodia* spp. Sites with no other species present and at high cover densities may be natural variation not necessarily adversely impacted by prior grazing usage.
Perennial grass frequency (density)	*Eragrostis xerophila* up to 100% (C12, C25,C42,C79, C230, C231), *Eragrostis setifolia* up to 10%, *Eriachne benthamii* up to 38%, *Cenchrus ciliaris* up to 24%.

30. Alluvial plain buffel grass grassland (APBG)

Sampling

17 inventory sites, 283 traverse points

General information

This site type which is dominated by the introduced *Cenchrus ciliaris* (buffel grass) occurs on near level (slopes up to 1%) alluvial plains, flood plains, levees and drainage tracts throughout the survey area. On these land units APBG is largely confined to deep sands, sandy and loamy earths, sandy and loamy duplexes, and juvenile soils (associated with levees and drainage tracts) mostly without surface mantles. It is rare on clay soils.

Physiognomy and composition

APBG occurs as a *Cenchrus ciliaris* tussock grassland with a few shrubs and trees. Basal cover of the grass can be up to 5-10%. Shrubs and trees are generally isolated to very scattered (up to 10% PFC). There may be obvious low and mid shrub layers, and occasionally a tall shrub layer.

99 perennial species were recorded at the 17 inventory sites, with an average of 12 species per site, 4 below the survey average. 42 annual species were recorded with an average of 4 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – not usually present as a recognisable stratum Common – *Atalaya hemiglauca, Hakea lorea* subsp. *suberea*
Tall shrubs:	Dominant – acacias Common – *Acacia farnesiana, A. inaequilatera, A. sclerosperma, A. victoriae*
Mid shrubs:	Dominant – commonly acacias Common – *Acacia farnesiana, A. victoriae, Carissa lanceolata*
Low shrubs:	Dominant – variable Common – *Senna artemisioides* subsp. *oligophylla, Sida fibulifera, Solanum esuriale, Trianthema turgidifolia*
Perennial grasses:	Dominant – *Cenchrus ciliaris* Common – *Cenchrus setigerus, Chrysopogon fallax, Eragrostis eriopoda, E. xerophila, Panicum decompositum, Triodia pungens*
Other plant forms:	Common – *Rhynchosia minima* (creeper)

Common annual include *Alysicarpus muelleri*, *Aristida contorta, Cleome viscosa, Crotalaria medicaginea, Iseilema* spp., *Salsola tragus, Sclerolaena densiflora* and *Trianthema triquetra*.

Patterns of grazing impact

Traverse condition summary (283 assessments):

Vegetation - good 79%; fair 17%; poor 4%.
Soil erosion - nil 93%.; minor 5%; moderate 1%; severe 1%.

APBG is generally resilient under grazing as buffel grass is more resistant to grazing than many native grasses. Tussocks are able to flower even when they are heavily grazed, unlike most native tussock grasses. Buffel grass is an effective coloniser and stabiliser on areas that have been previously degraded and eroded. Plains which now support this site type presumably once supported native tussock grasses and/or saltbush shrubs before the introduction of buffel grass. Anecdotal information suggests that such sites close to permanent water supplies in major rivers were preferentially overgrazed and substantially degraded in the early days of settlement. Buffel grass has aggressively colonised these disturbed sites and, in most cases, now forms dense stands which protect soils from erosion.

Nature conservation

There are concerns that buffel grass is taking over soft spinifex grasslands on the coast where these communities have been degraded by inappropriate grazing management in the past. It has replaced degraded native vegetation along many creeks and rivers in the Pilbara and also appears to have the ability to invade relatively undisturbed sites where soil types are suitable.

APBG was not recorded on conservation reserves within the survey area. Of the 283 traverse assessments, 3 were recorded on unallocated Crown land.

Gradational associations

APBG grades into *Alluvial plain soft spinifex grassland* (ASSG) and *Alluvial plain buffel grass grassland with eucalypt overstorey* (AEBG) on areas receiving more frequent flooding.

Land systems

APBG is the most extensive site type on River land system and is co-dominant with *Alluvial plain tussock grassland* (APTG) on Anna and Yamerina land systems. It is a major component on Eighty Mile land system and a minor component on 7 other systems.

The introduced Cenchrus ciliaris (buffel grass) is common throughout the Pilbara (APBG, AEBG) on coastal plains and dunes and on alluvial deposits along major rivers and watercourses. Buffel grass is an effective coloniser and soil stabiliser of degraded and eroded areas where native vegetation has been depleted. This site (APBG) shows buffel grass on a broad plain of the Anna land system. These plains most likely originally supported native tussock grasses and possibly some Atriplex species (saltbush) and may now be less botanically diverse than previously.

31. Alluvial plain buffel grass grassland with eucalypt overstorey (AEBG)

Sampling

8 inventory sites, 42 traverse points

General information

AEBG occurs on near level (slopes up to 1%) floodplains, alluvial plains, levees and drainage tracts. Soils are loamy earths and juvenile soils (associated with levees and drainage tracts) generally with no stony mantle.

Physiognomy and composition

AEBG occurs as a *Cenchrus ciliaris* (buffel grass) tussock grass grassland with an overstorey of eucalypt trees or occasionally as a eucalypt woodland with a prominent buffel grass ground layer. The grass layer has basal cover up to 10% (commonly 3-5%). The eucalypts are most often *Eucalyptus camaldulensis* (river gum) or *E. victrix* (coolibah). There may also be a tall shrub layer and occasionally a low and/or mid shrub layers. The trees and shrubs are very scattered to moderately close (5-30% PFC). The tree layer alone is generally very scattered to scattered (5-15% PFC) and is usually between 6-12 m high.

81 perennial species were recorded at the 8 inventory sites, with an average of 15 species per site, slightly below the survey average. 30 annual species were recorded with an average of 4 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – *Eucalyptus camaldulensis, E. victrix* Common – *Atalaya hemiglauca, Hakea lorea* subsp. *suberea, Bauhinia cunninghamii*
Tall shrubs:	Dominant – acacias Common – *Acacia inaequilatera, A. sclerosperma, A. trachycarpa*
Mid shrubs:	Dominant – not usually present as a recognisable stratum; variable when present Common – *Acacia farnesiana, Carissa lanceolata, Rhagodia eremaea, Tephrosia rosea*
Low shrubs:	Dominant – not usually present as a recognisable stratum; variable when present Common – *Aerva javanica, Atriplex bunburyana, Mukia maderaspatana, Senna artemisioides* subsp. *oligophylla*
Perennial grasses:	Dominant – *Cenchrus ciliaris* Common – *Bothriochloa bladhii* subsp. *bladhii, Cenchrus setigerus, Chrysopogon fallax, Eriachne benthamii, Triodia pungens*
Other plant forms:	Common – *Ipomoea muelleri* (creeper)

Common annuals include *Centipeda cunninghamii, Eragrostis tenellula, Pterocaulon sphacelatum, Rotala diandra, Stemodia kingii, Stemodia viscosa* and *Wahlenbergia tumidifructa.*

Patterns of grazing impact

Traverse condition summary (42 assessments):

Vegetation - good 90%; fair 5%; poor 5%.
Soil erosion - nil 88%; minor 10%; severe 2%.

This site type most probably supported native tussock grasses before the introduction of buffel grass. Anecdotal evidence suggests that such sites close to permanent water supplies in major rivers were preferentially overgrazed and substantially degraded in the early days of settlement. Buffel grass has aggressively colonised these disturbed sites and in most cases, now forms dense stands beneath eucalypts which protect soil from erosion. However, some areas still have degraded vegetation and active soil erosion (see traverse condition summary above). Where soils are still deep and seed sources are still available such sites have the potential to recover relatively rapidly given appropriate grazing management and reasonable seasons.

Nature conservation

The threatened flora species *Eriachne tenuiculmis* (P3) was recorded on AEBG.

This site type is now dominated by the introduced buffel grass. Of the 42 traverse assessments, one was recorded on the Meentheena pastoral lease and none were recorded on unallocated Crown land.

Gradational associations

AEBG grades into *Alluvial plain buffel grass grassland* (APBG) or *Alluvial plain soft spinifex grassland* (ASSG) as flooding becomes less frequent away from rivers. Closer to drainage tracts or major rivers AEBG grades into **Drainage shrubland and woodland site types** (Group K).

Land systems

AEBG occurs as a minor site type on River and Yamerina land systems.

32. Plain mosaic grassland (PMOG)

Sampling

6 inventory sites, 127 traverse points

General information

PMOG occurs on stony alluvial plains with a patchy mosaic of gilgaied and non-gilgaied surfaces. Each surface type may occur in patches 5-50 m in extent and in terms of relative areas non gilgaied surfaces usually, but not always, predominate. Soils are calcareus loamy earths, cracking clays and clays and surface mantles vary from few to abundant (2-90%) large pebbles (6-60 mm) of ironstone, basalt, quartz or other rock material. Slopes are <1%.

Physiognomy and composition

PMOG occurs as patchy *Eragrostis xerophila* tussock grass grasslands. The more dense grasslands occur on patches with well developed gilgais, while very sparse tussock grass communities, *Triodia pungens* (soft spinifex), or annual grassland/herbfield communities occur on the non-gilgaied or less developed gilgaied patches. Shrubs and trees are generally isolated to very scattered (up to 10% PFC) and there are commonly no distinct shrub or tree layers. Basal cover of the tussock grasses overall is <0.5-3%.

38 perennial species were recorded at the 6 inventory sites, with an average of 11 species per site, 5 lower than the survey average. 49 annual species were recorded, with an average of 14 species per site.

The following species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – not usually present as a recognisable stratum Common – *Acacia victoriae*
Low shrubs:	Dominant – sennas when present Common – *Neptunia dimorphantha, Phyllanthus maderaspatensis, Senna artemisioides* subsp. *oligophylla, S. hamersleyensis, Sida fibulifera, Tephrosia clementii*
Perennial grasses:	Dominant – *Eragrostis xerophila* Common – *Aristida latifolia, Astrebla pectinata, Cenchrus ciliaris, Eriachne benthamii, Triodia pungens*
Other plant forms:	Common – *Rhynchosia minima* (creeper)

Common annuals include *Aristida contorta, Brachyachne convergens, Cleome viscosa, Dichanthium sericeum* subsp. *sericeum, Enneapogon caerulescens, Iseilema dolichotrichum, Ptilotus aervoides* and *Sporobolus australasicus.*

Patterns of grazing impact

Traverse condition summary (127 assessments):

Vegetation - good 21%; fair 35%; poor 44%.
Soil erosion - nil 80%; minor 14%; moderate 5%; severe 1%.

The density of the palatable tussock grasses and palatable low shrubs such as *Senna hamersleyensis* in PMOG can be reduced by excessive grazing pressure. The mix of species in the gilgai areas where plants generally remain greener for longer as the gilgais hold soil moisture longer, make these patches more attractive to grazing and thus more susceptible to grazing impact than the non-gilgai areas. Thus the gilgai patches may become degraded while the non-gilgai patches remain largely unaltered. *Triodia pungens* may become dominant on the gilgai patches if grazing pressure continues to be excessive.

Nature conservation status

PMOG is poorly represented in conservation reserves within the survey area. Of the 127 traverse assessments, 3 were recorded on Millstream-Chichester National Park. PMOG was not recorded on unallocated Crown land.

Gradational associations

PMOG grades into *Alluvial plain tussock grassland* (APTG) or *Alluvial plain Roebourne Plains grass grassland* (ARPG) where all surfaces become gilgaied.

Land systems

PMOG is a minor site type on Balfour, Elimunna, Horseflat, Jigalong and Turee land systems.

33. Saline plain sporobolus grassland (SPSG)

Sampling

1 inventory site, 35 traverse points

General information

SPSG occurs on coastal saline alluvial plains and drainage foci and inland on the floodplains of the marsh on the upper reaches of the Fortescue River (Marsh land system). Soils are deep sandy duplexes and clays without surface mantles. Slopes are level to 1%.

Physiognomy and composition

SPSG occurs as a grassland of *Sporobolus* spp. grasses with creeping rhizomes. The dominant species are *Sporobolus mitchellii* or *S. virginicus*. Trees and shrubs are isolated to moderately close (<2.5-25% PFC) and may form prominent layers with *Melaleuca* spp., *Acacia ampliceps, Muellerolimon salicornaceum* (false lignum) or *Muehlenbeckia cunninghamii* (lignum).

14 perennial species and 1 annual species were recorded at the inventory site.

The following species (by stratum) are dominant and/or common:

Trees:	Dominant – occasionally present as a recognisable stratum; *Melaleuca lasiandra* Common – *none*
Tall shrubs:	Dominant – occasionally present as a recognisable stratum; *Acacia ampliceps, Melaleuca alsinoides* Common – *none*
Mid shrubs:	Dominant – *Muellerolimon salicornaceum* Common – *none*
Low shrubs:	Dominant – variable Common – *Halosarcia* spp., *Scaevola amblyanthera, Solanum esuriale, Trianthema turgidifolia*
Perennial grasses:	Dominant – *Sporobolus mitchellii, S. virginicus* Common – *Cenchrus ciliaris, Enneapogon pallidus, Whiteochloa airoides, Xerochloa laniflora*

The annual species recorded at the inventory site was *Sporobolus australasicus*.

Patterns of grazing impact

Traverse condition summary (35 assessments):

Vegetation - good 86%; fair 11%; poor 3%.
Soil erosion - nil 94%; minor 3%; moderate 3%.

Sporobolus species and associated grasses are moderately attractive to livestock but are resilient under grazing. The generally salty nature of the vegetation and sometimes difficulty in obtaining good quality stock water means that animal intake and grazing radii may be restricted. The site type is generally not heavily impacted by grazing.

Nature conservation

SPSG on the Marsh land system along the Fortescue River in the inland Pilbara includes some unusual or uncommon plants, e.g. *Halosarcia* species. The system is also unique as wetland habitat and warrants nature reservation.

The site type was not recorded on conservation reserves or unallocated Crown land within the survey area.

Gradational associations

SPSG grades sharply downslope into *Plain samphire shrubland* (PSPS) as soils become more saline and waterlogged and upslope into *Plain mixed halophyte shrubland* (PXHS) or *Plain snakewood shrubland with chenopod low shrubs* (PSCS) when soils become less waterlogged or less saline.

Land systems

SPSG is the most extensive site type on Roebuck land system and is co-dominant with *Plain samphire shrubland* (PSPS) on Marsh land system. It is a minor component on Anna, Eighty Mile and Onslow land systems.

34. Stony alluvial plain snakewood grassy shrubland (SSTS)

Sampling

11 inventory sites, 171 traverse points

General information

SSTS occurs on level (slopes <1%) stony alluvial plains which are most often gilgaied. The gilgais may occur in patches between areas which are not gilgaied. Soils are cracking clays and clays or occasionally deep loamy duplexes. Stony surface mantles vary from few to very abundant (2->90%), but are mostly many to abundant (20-90%).

Physiognomy and composition

This site type occurs as a mid or tall *Acacia xiphophylla* (snakewood) shrubland with a prominent perennial grass layer. The dominant tussock grass is most often *Eragrostis xerophila* (Roebourne Plains grass) but may occasionally be other grasses such as *Astrebla pectinata* (barley Mitchell grass). The PFC of the shrub layers ranges from very scattered to moderately close (2.5-30% PFC) and the basal cover of the grass layer is up to 5%.

69 perennial species were recorded at the 11 inventory sites, with an average of 14 species per site, 2 below the survey average. 64 annual species were recorded, with an average of 12 species per site.

The following perennial species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – *Acacia xiphophylla* Common – none
Mid shrubs:	Dominant – *Acacia xiphophylla* Common – *Rhagodia eremaea*

Low shrubs:	Dominant – variable Common – E*nchylaena tomentosa, Neptunia dimorphantha, Senna artemisioides* subsp. *helmsii, S. artemisioides* subsp *oligophylla, Sida fibulifera*
Perennial grasses:	Dominant – *Eragrostis xerophila*, occasionally *Astrebla pectinata* Common – *Aristida latifolia, Astrebla pectinata, Cenchrus ciliaris, Chrysopogon fallax, Enteropogon acicularis, Eragrostis setifolia, E. xerophila, Eriachne benthamii*
Other plant forms:	Common – *Rhynchosia minima* (creeper)

Common annuals include *Aristida contorta, Malvastrum americanum, Ptilotus aervoides, P. carinatus, P. exaltatus, P. gomphrena, Solanum horridum, Streptoglossa bubakii* and *S. odora.*

Patterns of grazing impact

Traverse condition summary (171 assessments):

Vegetation - good 17%; fair 27%; poor 56%.
Soil erosion - nil 73%; minor 8%; moderate 9%; severe 10%.

This site type is quite highly preferred by grazing animals and is often severely impacted (see traverse condition summary above). Excessive grazing can markedly reduce the density of desirable grasses such as *Astrebla pectinata, Enteropogon acicularis* and *Eragrostis xerophila*, and palatable shrubs such as *Enchylaena tomentosa* and *Senna hamersleyensis*. In some cases the tussock grasses can be replaced by *Triodia longiceps* and *T. pungens*.

Nature conservation

SSTS is represented in the Millstream-Chichester National Park on the Wona land system. SSTS is not well represented on unallocated Crown land; 2 of the 171 traverse assessments were recorded on unallocated Crown land.

Gradational associations

SSTS grades into tussock grasslands without shrubs such as *Alluvial plain Roebourne Plains grass grasslands* (ARPG) and *Alluvial plain tussock grass grassland* (APTG).

Land systems

SSTS is the most extensive site type on Kanjenjie land system. It is common on Christmas and Horseflat land systems and is a minor component of 8 other systems.

J. ALLUVIAL PLAIN HALOPHYTIC SHRUBLAND SITE TYPES

This group of site types occurs in depositional landscapes and is characterised by an often dominant low shrub stratum of succulent or semi-succulent (‘chenopod’) shrubs, referred to as ‘succulent steppe’ by Beard (1991). Site types of this group extend from the Pilbara e.g. the marsh of the Fortescue River on Roy Hill Station (Payne and Mitchell 1993) through to the north-eastern Goldfields (Pringle, Van Vreeswyk and Gilligan 1994).

Chenopod plains are most commonly associated with texture contrast (duplex) soils, but also occur on clay soils. Soil stability varies according to the intensity of run-on that areas receive. Alluvial plains adjacent to salt lakes are almost level and subject to relatively low energy surface flows and are usually quite stable, while plains receiving distributary flow from ephemeral creeks and rivers receive more energetic flow and are more frequently eroded. Preferential grazing of the latter exacerbates the problem and few extensive areas of these site types remain intact in the Pilbara or in other survey areas (e.g. Pringle, Van Vreeswyk and Gilligan 1994).

Chenopod shrublands are minor but very productive site types in the Pilbara. They are found low in the landscape as relatively fertile depositional plains associated with broad terminal drainage sumps and lakes of the Marsh and Weelarrana land systems or as floodplains associated with major rivers. Soils are frequently duplex types with well developed cryptogamic surface crusts. This example is a grassy shrubland (PCGS) dominated by Atriplex bunburyana *(silver saltbush) with* Cenchrus ciliaris *(buffel grass) and* Eragrostis falcata *(sickle lovegrass). These site types may also support* Rhagodia eremea *(tall saltbush),* Acacia victoriae *(prickly acacia),* Maireana *spp. (bluebush) and* Eragrostis xerophila *(Roebourne Plains grass).*

35. Plain snakewood shrubland with chenopod low shrubs (PSCS)

Sampling

8 inventory sites, 138 traverse points

General information

PSCS occurs on stony and gravelly plains and on alluvial plains. The stony plains have surface mantles of abundant to very abundant (50->90%) pebbles of mixed lithology, the gravelly plains have abundant (50-90%) mantles of fine to medium (2-20 mm) ironstone gravel and the alluvial plains generally have little mantle. Slopes are up to 1%. Soils are deep loamy earths, duplexes and clays, some of which are saline.

Physiognomy and composition

PSCS occurs as a mid or tall very scattered to scattered (5-20% PFC) shrubland of snakewood (*Acacia xiphophylla*) with a patchy understorey of chenopod low shrubs, other low shrubs and a few perennial grasses. The low shrubs often tend to be clumped beneath the protection of the taller snakewoods and are somewhat sparser in the inter-snakewood spaces. The overall density of shrubs is usually scattered to moderately close with 10-25% PFC.

52 perennial species were recorded at the 8 inventory sites, with an average of 13 species per site, 3 below the survey average. 33 annual species were recorded, with an average of 6 species per site.

The following species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – *Acacia xiphophylla* Common – *Acacia tetragonophylla, A. victoriae*
Mid shrubs:	Dominant – *A. xiphophylla* Common – *Rhagodia eremaea, Senna glutinosa* subsp. x *luerssenii*
Low shrubs:	Dominant – variable Common – *Atriplex bunburyana, Enchylaena tomentosa, Neptunia dimorphantha, Maireana georgei, M. pyramidata, M. tomentosa, Maireana triptera, Senna hamersleyensis, Sida fibulifera, Solanum lasiophyllum*
Perennial grasses:	Dominant – not present as a recognisable stratum Common – *Cenchrus ciliaris, Enteropogon acicularis, Eragrostis xerophila, Triodia pungens*

Common annuals include *Aristida contorta, Atriplex codonocarpa, Brachyachne prostrata, Enneapogon cylindricus, Ptilotus exaltatus, Salsola tragus, Sclerolaena cuneata* and *S. densiflora.*

Patterns of grazing impact

Traverse condition summary (138 assessments):

Vegetation - good 20%; fair 22%; poor 58%.
Soil erosion - nil 74%; minor 16%; moderate 4%; severe 6%.

PSCS is a site type which is prone to degradation as many of the low shrubs and grasses which it supports are preferentially grazed by stock. The traverse condition summary indicates that much of PSCS has been severely impacted by grazing. Degradation is evidenced by an almost complete loss of palatable plants from beneath the snakewoods and from the inter-snakewood spaces. It is likely that hard spinifex invades and replaces the lost shrubs on some PSCS sites or there may be increases in unpalatable *Senna* species. Soil erosion is common on degraded PSCS sites.

Nature conservation

While of little specific conservation value in terms of plant species, the fact that PSCS is preferentially grazed and has relatively fragile soils, makes it a threatened site type under extensive pastoral land use.

PSCS is represented in Karijini National Park and Cane River Nature Reserve. PSCS was not recorded on unallocated Crown land.

Gradational associations

PSCS grades downslope into more halophytic site types such as *Plain mixed halophyte shrubland* (PXHS) and *Plain samphire shrubland* (PSPS) as soils become more saline and upslope into hardpan site types such as *Hardpan plain mulga shrubland* (HPMS).

Land systems

PSCS is the most extensive site type on Christmas, Cowra and Marillana land systems. It is co-dominant with *Plain acacia-cassia grassy shrubland* (PAGS) on Narbung land system and co-dominant with *Plain hard spinifex grassland* (PHSG) on Sherlock land system. It is a minor component on 10 other systems.

36. Plain mixed halophyte shrubland (PXHS)

Sampling

8 inventory sites, 126 traverse points

General information

PXHS is a site type found in patches in the south-eastern Pilbara but rarely over areas more than a few kilometres in extent. It is considerably more extensive in southern rangelands. PXHS has previously been described in detail as MXHS in the Murchison River catchment (Curry *et al.* 1994) and north-eastern Goldfields surveys (Pringle, Van Vreeswyk and Gilligan 1994). In both cases, grazing ecology was investigated in some detail. PXHS characterises many of the alluvial plains with saline texture contract (duplex) soils, often over hardpan adjacent to salt lakes. It usually consists of a mosaic of sub-communities, all with different dominant species. These differences probably reflect subtle patterns relating to soil hydrology and salinity (Hacker 1979).

In the Pilbara PXHS occurs on level (slopes up to 1%) alluvial plains and drainage floors which have common to very abundant (10->90%) surface mantles of gravel or pebbles (2-60 mm) of mixed lithology. Soils are usually saline and are loamy earths, sandy duplexes and loamy duplexes.

Physiognomy and composition

PXHS occurs as a very scattered to scattered (5-20% PFC) low shrubland of saltbush (*Atriplex* spp.) and bluebush (*Maireana* spp.) usually without any other conspicuous strata. Sparse perennial grasses such as *Enteropogon acicularis, Eragrostis eriopoda* and *E. xerophila* are fairly common.

63 perennial species were recorded at the 8 inventory sites, with an average of 15 species per site, slightly below the survey average. 24 annual species were recorded, with an average of 5 species per site.

The following species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – not usually present as a recognisable stratum Common – *Acacia aneura, A. victoriae, Hakea preissii*

Mid shrubs: Dominant – not usually present as a recognisable stratum
Common – *Rhagodia eremaea*

Low shrubs: Dominant – variable; usually maireanas or sennas
Common – *Atriplex bunburyana, Enchylaena tomentosa, Eremophila cuneifolia, E. maculata, Frankenia* spp., *Maireana carnosa, M. glomerifolia, M. planifolia, M. pyramidata, Senna artemisioides* subsp. *helmsii, S.* sp. Meekatharra, *Solanum lasiophyllum, Streptoglossa cylindriceps*

Perennial grasses: Dominant – not present as a recognisable stratum
Common – *Enteropogon acicularis, Eragrostis eriopoda, E. xerophila*

Common annuals include *Aristida contorta, Atriplex codonocarpa, A. holocarpa, Brachyachne prostrata, Sclerolaena cuneata* and *S. densiflora.*

Patterns of grazing impact

Traverse condition summary (126 assessments):

Vegetation - good 17%; fair 21%; poor 62%.
Soil erosion - nil 78%; minor 11%; moderate 7%; severe 4%.

PXHS is a site type favoured by grazing animals. In the Murchison Curry *et al.* (1994) suggested that excessive grazing reduces projected foliar cover and that when a threshold is reached (7.5% was proposed) PXHS becomes susceptible to combinations of accelerated soil erosion and/or increases in unpalatable shrubs with invasive tendencies. In the north-eastern Goldfields Pringle, Van Vreeswyk and Gilligan (1994) found that the most sensitive indicator of grazing impact was the prominence of key decreaser species and, to a lesser extent, increaser species. In the Pilbara PXHS has been heavily impacted by grazing. Decreaser species include *Atriplex bunburyana*, *Enchylaena tomentosa* and *Maireana glomerifolia*. Increaser species include *Acacia victoriae* and *Senna* sp. Meekatharra. Erosion of the susceptible duplex soils of the site type is common.

Nature conservation

The threatened flora species *Eremophila spongiocarpa* ms (P1) was recorded on PXHS.

PXHS was not recorded on conservation reserves in the survey area and was recorded only once on unallocated Crown land.

Gradational associations

PXHS grades laterally into other chenopod communities such as *Plain chenopod grassy shrubland* (PCGS) or downslope, where soils become more saline, into *Plain samphire shrubland* (PSPS).

Land systems

PXHS is the most extensive site type on Cundelbar and Jigalong land systems and is common on Cowra land system. It is a minor component on 9 other systems.

37. Plain samphire shrubland (PSPS)

Sampling

8 inventory sites, 50 traverse points

General information

PSPS occurs on coastal areas and inland on areas associated with salt lakes and the Fortescue Marsh on highly saline plains and drainage tracts. Slopes are <1%. Soils are highly saline clays most often without a surface mantle but occasionally with a fine gravel mantle of ironstone.

Physiognomy and composition

PSPS occurs as a low shrubland of samphire with density varying between very scattered to moderately close (2.5-25% PFC). There are no other shrub or tree layers. Occasionally there may be a prominent perennial grass layer with basal cover up to 5%.

27 perennial species were recorded at the 8 inventory sites, with an average of 6 species per site which was well below the survey average of 16. 20 annual species were recorded, with an average of 3 species per site.

The following species (by stratum) are dominant and/or common:

Low shrubs: Dominant – *Halosarcia* spp., including *H. halocnemoides* subsp. *tenuis, H. pterygosperma, H. pterygosperma* subsp. *denticulata*
Common – *Atriplex bunburyana, Eremophila spongiocarpa, Frankenia* spp., *Maireana amoena, M. tomentosa, Sclerolaena bicornis, Sida fibulifera, Solanum esuriale*

Perennial grasses: Dominant – *Eragrostis falcata* when present
Common – *Cenchrus ciliaris, Panicum decompositum, Sporobolus virginicus*

Common annuals include *Atriplex holocarpa, Dissocarpus paradoxus, Enneapogon caerulescens, E. polyphyllus, Eragrostis pergracilis, Lawrencia densiflora, Nicotiana rosulata* and *Streptoglossa cylindriceps.*

Patterns of grazing impact

Traverse condition summary (50 assessments):

Vegetation - good 92%; fair 6%; poor 2%.
Soil erosion - nil 100%.

PSPS is resilient to grazing as the major component, samphire, is generally unattractive to livestock. However, annual grasses and herbs in season and occasional perennial grasses between the samphire shrubs are moderately attractive. Some breaking of the surface crust and minor scalding may occur but generally the clay soils are inherently stable.

Nature conservation

The generally highly saline nature of this site type means that it is only moderately attractive to livestock and hence grazing impacts are less of a conservation threat than in more preferred vegetation found upslope.

The threatened flora species *Eremophila spongiocarpa* ms (P1) was recorded on PSPS. Some unusual or new *Halosaria* species may occur on this site type on the Marsh land system.

PSPS was was not recorded on land set aside for nature conservation nor on unallocated Crown land.

Gradational associations

PSPS grades upslope where soils are less saline into site types such as *Plain mixed halophyte shrubland* (PXHS) or *Plain chenopod grassy shrubland* (PCGS) dominated by *Maireana* and *Atriplex* species.

Land systems

PSPS is the most extensive site type on Weelarrana land system and is co-dominant with *Saline plain sporobolus grassland* (SPSG) on Marsh land system. It is common on Mannerie land system and is a minor component on 9 other systems.

38. Plain chenopod grassy shrubland (PCGS)

Sampling

14 inventory sites, 81 traverse points

General information

This relatively uncommon site type occurs on level alluvial plains, flood plains and drainage tracts in a few inland and coastal parts of the survey area. Soils are loamy earths, and sandy and loamy duplexes, occasionally with fine gravel mantles. They are subject to occasional flooding or concentrated sheet flow.

Physiognomy and composition

PCGS occurs as a low chenopod shrubland with a prominent perennial grass layer. The dominant chenopod species is most commonly *Atriplex bunburyana* (silver saltbush). The low shrubs may be very scattered to scattered (2.5-20% PFC). Mid shrub and tall shrub strata are absent or poorly developed except where the site type has been invaded by *Prosopis* spp. (mesquite) or on drainage lines where there may be an acacia overstorey. The perennial grass layer has a basal cover up to 5% and may occasionally be dominant. The grass layer may be dominated by *Eragrostis xerophila*, or occasionally by the introduced grass *Cenchrus ciliaris* (buffel grass).

86 perennial species were recorded at the 14 inventory sites, with an average of 13 species per site, 3 below the survey average. 50 annual species were recorded, with an average of 7 species per site.

The following species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – acacias or *Prosopis* spp. when present Common – *Acacia tetragonophylla, A. victoriae*
Mid shrubs:	Dominant – acacias or *Prosopis* spp. when present Common – *Rhagodia eremaea, Acacia victoriae*
Low shrubs:	Dominant – usually *Atriplex bunburyana* Common – *Enchylaena tomentosa, Maireana aphylla, M. tomentosa, Sclerolaena cuneata, Sida fibulifera, Trianthema turgidifolia*
Perennial grasses:	Dominant – *Cenchrus ciliaris* or *Eragrostis xerophila* Common – *Cenchrus ciliaris, C. setigerus, Chrysopogon fallax, Enteropogon acicularis, Eragrostis falcata, E. setifolia, E. xerophila, Eriachne benthamii, Panicum decompositum, Triodia pungens*

Common annuals include *Aristida contorta, Dactyloctenium radulans, Dichanthium sericeum* subsp. *sericeum, Gomphrena canescens, Iseilema* spp., *Ptilotus gomphrenoides, Sclerolaena densiflora, Trianthema triquetra* and *Xerochloa laniflora*.

Patterns of grazing impact

Traverse condition summary (81 assessments):

Vegetation - good 47%; fair 12%; poor 41%.
Soil erosion - nil 47%; minor 23%; moderate 15%; severe 15%.

PCGS is susceptible to overgrazing as the dominant low shrubs and perennial grasses are preferentially grazed. Silver saltbush may be removed through overgrazing. Soils are susceptible to sheeting, scalding and rilling once the vegetation cover is lost. This site type has been invaded by mesquite (*Prosopis* spp.) in some areas near the coast.

Nature conservation

The following threatened flora were recorded on PCGS: *Bulbostylis burbidgeae* (P3), *Eremophila spongiocarpa* ms (P1) and *Sida* sp. Wittenoom PN (P3).

PCGS was not encountered in nature reserves or national parks or on unallocated Crown land within the survey area. Considering its susceptibility to degradation, reservation is justified.

Gradational associations

PCGS grades upslope into other chenopod site types such as *Plain mixed halophyte shrubland* (PXHS) or *Plain snakewood shrubland with chenopod low shrubs* (PSCS). It grades downsope into more saline sites such as *Plain samphire shrubland* (PSPS).

Land systems

PCGS is the most extensive site type on Talawana land system. It is common on Marsh land system and a minor type on the Jigalong, Onslow, Turee and Yamerina systems.

K. DRAINAGE SHRUBLAND AND WOODLAND SITE TYPES

This group of site types occurs as drainage tracts in the lowest parts of the landscape. They make up a small proportion of the survey area but are widespread as a minor component on more than 50% of the land systems of the area. They are distinctive fertile zones and are likely to have particular conservation value as fauna habitat. They are often moderately impacted by direct grazing and disturbance, as animals use them as grazing, rest and refuge areas.

Drainage shrubland and woodland site types (eg DAHW, DEGW, DEAW) support moderately dense tall shrublands or woodlands of acacias and eucalypts. In the most open woodlands (or after fire), there may be diverse low shrubs and grasses but, where the woodlands are dense, the under layers are often depauperate.

39. Drainage acacia hummock grass shrubland/woodland (DAHW)

Sampling

19 inventory sites, 253 traverse points

General information

DAHW occurs on narrow drainage floors (usually less than 500 m wide) throughout the survey area and occasionally on groves on wash plains. Slopes are generally less than 2% except in uplands where they may be up to 5%. The floors may be channelled or unchannelled and receive concentrated through flow. Soils are deep sands, loamy earths and juvenile soils, often with surface mantles of few to very abundant (2->90%) pebbles.

Physiognomy and composition

DAHW occurs as an acacia shrubland or woodland with a hummock grass layer. Occasionally the hummock grass layer is dominant and it occurs as a hummock grassland with an overstorey of acacia tall shrubs or trees. Dominant acacias include *Acacia aneura*, *A. atkinsiana*, *A. citrinoviridis*, *A. trachycarpa* and *A. tumida.* The trees and shrubs are scattered to close (15-50% PFC). The dominant hummock grass is most commonly *Triodia pungens* (soft spinifex) but is occasionally a hard spinifex species. The hummock grass has a PFC varying from 10-50%.

179 annual species were recorded at the 19 inventory sites, with an average of 21 species per site, 5 above the survey average. 41 annual species were recorded, with an average of 3 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – acacias or eucalypts Common – *Acacia aneura, Corymbia hamersleyana*
Tall shrubs:	Dominant – acacias Common – *Acacia ancistrocarpa, A. aneura, A. citrinoviridis, A. holosericea, A. trachycarpa, A. tumida, Hakea lorea* subsp. *suberea*
Mid shrubs:	Dominant – variable; often acacias Common – *Acacia acradenia, A. atkinsiana, A. bivenosa, A. trachycarpa, Grevillea pyrifolia, G. wickhamii, Senna artemisioides* subsp. *glutinosa*
Low shrubs:	Dominant – variable Common – *Corchorus sidoides, Evolvulus alsinoides, Goodenia stobbsiana, Hybanthus aurantiacus, Indigofera monophylla, Mollugo molluginis, Senna artemisioides* subsp. *helmsii, Senna artemisioides* subsp. *oligophylla, Sida fibulifera, Solanum lasiophyllum*
Perennial grasses:	Dominant – *Triodia pungens* Common – *Cenchrus ciliaris, Chrysopogon fallax, Paraneurachne muelleri, Triodia pungens, T. wiseana*
Other plant forms:	Common – *Rhynchosia minima* (creeper)

Common annuals include *Aristida contorta, Enneapogon polyphyllus, Euphorbia australis, Senna notabilis, Sporobolus australasicus* and *Trichodesma zeylanicum*.

Patterns of grazing impact

Traverse condition summary (253 assessments):

Vegetation - good 91%; fair 7%; poor 2%.
Soil erosion - nil 98%; minor 2%.

Young *Triodia pungens* is moderately attractive to grazing animals but old stands are unpalatable. Hard spinifex species which occasionally occur, are unattractive at any stage of growth. In general this site type is little impacted by grazing and is not eroded.

Nature conservation

The threatened flora species *Bulbostylis burbidgeae* (P3) and *Eriachne tenuiculmis* (P3) were recorded on DAHW.

DAHW is well represented on conservation reserves within the survey area. It was recorded in Karijini National Park and on the Meentheena pastoral lease, and also on unallocated Crown land.

Gradational associations

DAHW grades into other drainage line shrubland/woodland site types as the tree dominants change from acacias to eucalypts and the hummock grass layer changes to tussock grasses. DAHW also grades upslope into many more xeric site types in site type groups such as **Plain hummock grasslands** (Group D) and **Stony plain and low rise sclerophyll shrublands** (Group E).

Land systems

DAHW is widespread and occurs as a minor component on 36 land systems (about one-third of all systems in the Pilbara).

40. Drainage spinifex grassland with eucalypt overstorey (DESG)

Sampling

8 inventory sites, 120 traverse points

General information

This fairly common site type occurs on drainage tracts and floor mostly narrow (<500 m wide) but occasionally wider. Slopes are generally <1.5%. The site type receives concentrated through flow as sheet flow or overbank flooding from associated minor channels and creeks. Soils are deep sands, loamy earths and juvenile soils. Surface mantles vary from none to common (<20%) pebbles. Minor channels associated with the site type may have bed loads of sand or pebbles and cobbles.

Physiognomy and composition

DESG occurs as a hummock grassland with an overstorey of eucalyptus trees. The dominant hummock grass is often *Triodia pungens* (soft spinifex) but may be other *Triodia* species with a PFC of 20-60%. The dominant eucalypts may be *Corymbia hamersleyana*, *Eucalyptus victrix* or *E. camaldulensis*. The eucalypts are isolated to scattered (<20% PFC) and are 4 to 10 m tall. There are usually tall shrub, mid shrub and low shrub layers and total PFC of the shrubs and trees is scattered to moderately close (10-30%).

117 annual species were recorded at the 8 inventory sites, with and average of 23 species per site, considerably higher than the survey average of 16. 30 annual species were recorded, with an average of 4 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – eucalypts Common – *Corymbia flavescens, C. hamersleyana, Eucalyptus camaldulensis, E. victrix, Hakea lorea* subsp. *suberea*
Tall shrubs:	Dominant – acacias Common – *Acacia inaequilatera, A. pyrifolia, A. tumida*
Mid shrubs:	Dominant – variable, including acacias Common – *Gossypium australe, G. robinsonii, Petalostylis labicheoides. Rhagodia eremaea*
Low shrubs:	Dominant – variable including *Corchorus* spp. Common – *Bonamia erecta, Corchorus crozophorifolius, C. laniflorus, C. sidoides, Euphorbia australis, Indigofera monophylla, Ptilotus australasicus*
Perennial grasses:	Dominant – triodias; often *Triodia pungens* Common – *Cenchrus ciliaris, Chrysopogon fallax, Triodia pungens*
Other plant forms:	Common – *Rhynchosia minima* (creeper)

Common annuals include *Cullen pogonocarpum, Dysphania rhadinostachya, Eragrostis cumingii, Goodenia lamprosperma, Indigofera colutea, Pterocaulon sphacelatum* and *Swainsona formosa*.

Patterns of grazing impact

Traverse condition summary (120 assessments):

Vegetation - good 97%; fair 3%.
Soil erosion - nil 98%; minor 2%.

Young *Triodia pungens* is moderately attractive to grazing animals but mature plants and all hard spinifex species are not preferred. Generally DESG is little impacted by grazing but, like all spinifex site types, it is regularly impacted by fire.

Nature conservation

The threatened flora species *Sida* sp. Wittenoom PN (P3) was recorded on DESG.

DESG is represented in conservation reserves within the survey area. It was recorded on Millstream-Chichester National Park and on the Meentheena pastoral lease and also on unallocated Crown land.

Gradational associations

DESG is similar to and grades into other shrubland/woodland site types as tree dominants change from eucalypts to acacias and the grass layer changes from tussock grasses to hummock grasses. DESG also grades upslope into many more xeric site types in site type groups such as **Plain hummock grasslands** (Group D), **Stony plain and low rise sclerophyll shrublands** (Group E) and **Alluvial plain hummock grasslands (and occasionally grassy shrublands)** (Group H).

Land systems

DESG occurs as a minor component on twelve land systems.

41. Drainage eucalypt and acacia grassy woodland/shrubland (DEGW)

Sampling

41 inventory sites, 490 traverse points

General information

This widespread site type occurs on drainage tracts, mainly narrow drainage floors (<500 m wide), but also wider drainage floors, floodplains, alluvial plains, levees, and on drainage foci such as claypans and swamps. It is subject to fairly regular inundation. The drainage tracts may be channelled or un-channelled. Slopes are up to 5% but generally less than 2%. The site type receives concentrated through flow as sheet water flow or as overbank flooding from minor or major channels. Soils are sandy and loamy earths, clays and juvenile soils mostly without surface mantles. Associated channels have sandy or pebbly bed loads. Mantles are more common where drainage tracts pass through stony hill or plain systems than where they are associated with broad alluvial plain or sandplain systems.

Physiognomy and composition

DEGW generally occurs as an acacia and/or eucalypt woodland or tall shrubland with a tussock grass layer. Occasionally the tussock grass layer is dominant but tree and tall shrub layers are prominent. The dominant acacia is often *Acacia aneura* (mulga), but may also be *A. citrinoviridis, A. coriacea, A. distans, A. holosericea* or *A. tumida*. The dominant eucalypt is variable but includes *Corymbia hamersleyana* (Hamersley bloodwood), *Eucalyptus camaldulensis* (river red gum) or *E. victrix* (coolibah). The tree and/or tall shrub layers are often scattered to moderately close (10-30% PFC). There is generally a mid and low shrub strata. The dominant grasses are most often *Chrysopogon fallax* (ribbon grass), *Cenchrus ciliaris* (buffel grass) or *Eriachne benthamii* (swamp grass). The tussock grass layer has a basal cover up to 10% but often less than 5%.

270 perennial species were recorded at the 41 inventory sites, with an average of 19 species per site, 3 above the survey average. 153 annual species were recorded, with an average of 8 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – acacias or eucalypts including *Acacia aneura, A. coriacea, Corymbia aspera, C. flavescens, C. hamersleyana, E. camaldulensis, E. victrix* Common – *Corymbia hamersleyana, Eucalyptus victrix, Hakea lorea* subsp. *suberea*
Tall shrubs:	Dominant – acacias including *Acacia aneura, A. citrinoviridis, A. distans, A. tetragonophylla, A. tumida* Common – *A. ancistrocarpa, A. aneura, A. farnesiana, A. inaequilatera, A. pyrifolia, A. tetragonophylla, A. tumida, A. victoriae*
Mid shrubs:	Dominant – commonly acacias, occasionally sennas or *Carissa lanceolata* Common – *Acacia aneura, A. inaequilatera, A. trachycarpa, Rhagodia eremaea*
Low shrubs:	Dominant – variable including eremophilas, maireanas and sennas Common – *Eremophila forrestii, Indigofera monophylla, Maireana planifolia, M. villosa, Ptilotus obovatus, Senna artemisioides* subsp. *helmsii, S. artemisioides* subsp. *oligophylla, Sida fibulifera, Solanum lasiophyllum, Tephrosia rosea*
Perennial grasses:	Dominant – variable; often *Cenchrus ciliaris, Chrysopogon fallax, Eriachne benthamii* Common – *Cenchrus ciliaris, Chrysopogon fallax, Eragrostis xerophila, Eriachne benthamii, Eulalia aurea, Themeda triandra, Triodia pungens*
Other plant forms:	Common – *Rhynchosia minima* (creeper)

Common annuals include *Alternanthera nodiflora, Aristida contorta, Cleome viscosa, Malvastrum americanum, Rhodanthe charsleyae, Pterocaulon sphacelatum, Ptilotus exaltatus, P. gomphrenoides* and *P. macrocephalus*.

Patterns of grazing impact

Traverse condition summary (490 assessments):

Vegetation - good 65%; fair 16%; poor 19%.
Soil erosion - nil 93%; minor 3%; moderate 2%; severe 2%.

The site type provides shelter and grazing for livestock but is moderately resilient. The site type varies from preferred to not preferred by livestock depending on the species of the dominant grass, e.g. *Chrysopogon fallax* and *Cenchrus ciliaris* are moderately to highly preferred whereas *Eriachne benthamii* is not attractive. Excessive grazing can reduce the cover of palatable grasses and soil erosion may occur. Under heavy grazing palatable perennial tussock grasses can be removed. Degraded sites with loam soils can become dominated and stabilised by *Cenchrus ciliaris*.

Nature conservation

The following threatened flora were recorded on DEGW: *Eriachne tenuiculmis* (P3), *Goodenia pascua* (P3) and *Goodenia stellata* (P4). *Goodenia stellata* was exclusive to this site type.

This common site type is well represented on conservation reserves within the survey area. It was recorded on Karijini National Park, Cane River Nature Reserve, Meentheena pastoral lease and on unallocated Crown land.

Gradational associations

DEGW grades into other drainage tract shrubland/woodland site types as the grass layer changes from tussock grass to hummock grass dominance. DEGW grades upslope into many more xeric site types in site type groups such as **Stony plain and low rise sclerophyll shrublands** (Group E), **Sheet flood hardpan plain sclerophyll shrublands or woodlands** (Group F) and **Alluvial plain hummock grasslands (and occasionally grassy shrublands)** (Group H). Towards major river channels DEGW grades into *Gallery melaleuca eucalypt woodland* (GMEW).

Land systems

DEGW is the most extensive site type on Coolibah land system and is common Fortescue land system. It is a minor component on 46 other systems.

42. Drainage eucalypt and acacia woodland/shrubland (DEAW)

Sampling

7 inventory sites, 58 traverse points

General information

DEAW occurs on near level drainage tracts and floors (which may be channelled or unchannelled) mostly less than 500 m wide but occasionally wider. It also occurs on level drainage foci such as claypans and swamps. It is subject to fairly regular inundation by sheet flow or from overbank flooding from minor or major channels and some sites may be waterlogged for short periods. Soils are sandy and loamy earths and clays with no or very few (<2%) surface mantles.

Physiognomy and composition

DEAW occurs as a eucalypt and/or acacia woodland or tall shrubland. The dominant eucalypt is often *E. victrix* (coolibah) and the dominant acacia is often *Acacia aneura* (mulga). The tree and/or tall shrub layers are generally scattered to closed (10->50% PFC). There is generally a low shrub layer but no perennial grass layer which differentiates DEAW from other drainage site types. The lack of a grass layer is probably due to direct competition from dense trees or tall shrubs.

47 perennial species were recorded at the 7 inventory sites, with an average of 8 species per site which is well below the survey average of 16. 58 annual species were recorded, with an average of 9 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – acacias or eucalypts; often *Eucalyptus victrix* or *Acacia aneura* Common – *Eucalyptus victrix, Hakea lorea* subsp. *suberea*
Tall shrubs:	Dominant – acacias; often *Acacia aneura* Common – *A. ancistrocarpa, A. aneura, A. sclerosperma, A. tumida*
Mid shrubs:	Dominant – not usually present as a recognisable stratum Common – *Muehlenbeckia florulenta*
Low shrubs:	Dominant – variable Common – *Chenopodium auricomum, Eremophila lanceolata, Indigofera monophylla, Mukia maderaspatana, Maireana villosa, Sida* spp., *Solanum lasiophyllum, Tephrosia bidwillii*
Perennial grasses:	Dominant – not present as a recognisable stratum Common – *Chrysopogon fallax*

Common annuals include *Alternanthera nodiflora, Aristida contorta, Centipeda minima, Haloragis* sp., *Nicotiana* sp., *Pterocaulon sphacelatum, P. macrocephalus, Salsola tragus, Setaria dielsii* and *Stenopetalum* sp..

Patterns of grazing impact

Traverse condition summary (58 assessments):

Vegetation - good 57%; fair 31%; poor 12%.
Soil erosion - nil 97%; moderate 3%.

The site type provides shelter and grazing for livestock. Palatable shrubs and grasses can be removed through excessive grazing pressure. Soil erosion is uncommon.

Nature conservation

This site type is represented in national parks and other reserves in the Pilbara and is common on unallocated Crown land.

Gradational associations

DEAW grades into other drainage tract shrubland/woodland site types as a grass layer becomes present generally towards the north of the survey area.

Land systems

DEAW is a minor component on 16 land systems.

43. Drainage melaleuca shrubland (DMES)

Sampling

4 inventory sites, 25 traverse points

General information

DMES occurs on level (<1% slope) drainage features such as narrow drainage floors, drainage foci and swamps, and on alluvial plains and floodplains. Soils are loamy earths and loamy duplexes usually without surface mantles. The areas are often subject to inundation and waterlogging and may be seepage zones.

Physiognomy and composition

DMES occurs as a scattered to closed (10->50% PFC) tall melaleuca shrubland. The dominant shrub is usually *Melaleuca alsophila* or *M. lasiandra*. There is generally a mid shrub layer dominated by melaleuca or *Acacia ampliceps* (black wattle) but no low shrub layer. The grass layer is often very patchy and poorly developed or, where melaleuca shrubs are very dense, grasses are absent.

21 perennial species were recorded at the 4 inventory sites, with and average of 9 species per site, considerably lower than the survey average of 16. 11 annual species were recorded, with an average of 3 species per site.

The following perennial species (by stratum) are dominant and/or common:

Tall shrubs:	Dominant – melaleucas Common – *Acacia ampliceps, Melaleuca alsophila, M. lasiandra*
Mid shrubs:	Dominant – melaleucas or *Acacia ampliceps* Common – *Melaleuca alsophila, M. lasiandra*
Low shrubs:	Dominant – not present as a recognisable stratum Common – *Trianthema turgidifolia*
Perennial grasses:	Dominant – not usually present as a recognisable stratum Common – *Cenchrus ciliaris, Eragrostis falcata, Sporobolus mitchellii, S. virginicus*
Other plant forms:	Common – *Cassytha capillaris* (creeper)

Common annuals include *Centaurium spicatum, Chenopodium melanocarpum, Chloris pumilio, Enneapogon cylindricus, Flaveria australasica, Sporobolus australasicus* and *Triraphis mollis*.

Patterns of grazing impact

Traverse condition summary (25 assessments):

Vegetation - good 60%; fair 24%; poor 16%.
Soil erosion - nil 96%; moderate 4%.

Excessive grazing pressure can reduce perennial grasses but DMES is moderately resilient and is mostly in good or fair condition without erosion.

Nature conservation

This uncommon site type is not represented in conservation reserves within the survey area. It was recorded on unallocated Crown land. It may include uncommon highly habitat specific plants and constitute refuge for native animals and warrants reservation.

Gradational associations

DMES grades into or has sharp boundaries with *Sandplain soft spinifex grassland* (SSSG) where seepage zones stop or soils become predominantly sand. Away from seepage zones DMES also grades into *Plain samphire shrubland* (PSPS) or *Alluvial plain tussock grassland* (APTG).

Land systems

DMES is the most extensive site type of Mannerie land system. It is a minor component of the Lime and Little Sandy systems.

44. Gallery (riverbank and channel) melaleuca eucalypt woodland (GMEW)

Sampling

6 inventory sites, 34 traverse points

General information

GMEW occurs along banks and channels of major rivers. The channels are usually >10 m wide and can be up to 1 km wide on rivers such as the Oakover, De Grey and Turner. Soils on river banks are juvenile soils mostly without surface mantles. Channels have bedloads of sand and water worn gravel, pebbles and cobbles of mixed lithology.

Physiognomy and composition

GMEW occurs as a *Melaleuca argentea* or *Eucalyptus camaldulensis* woodland. The trees are variable density but may be closed (>50% PFC) and 6->12 m tall. There is occasionally a tall shrub layer of *Acacia* spp. or *Melaeuca glomerata* and generally no mid or low shrub layer. There may be a patchy layer of sedges (e.g. *Cyperus virginatus*) along channels and perennial grasses such as *Themeda triandra* (kangaroo grass) and the introduced *Cenchrus ciliaris* (buffel grass) on banks.

100 annual species were recorded at the 6 inventory sites, with and average of 22 species per site, considerably higher than the survey average of 16. 13 annual species were recorded, with an average of 2 species per site.

The following perennial species (by stratum) are dominant and/or common:

Trees:	Dominant – *Eucalyptus camaldulensis, Melaleuca argentea* Common – *Acacia coriacea, Atalaya hemiglauca, Eucalyptus camaldulensis, Ficus platypoda, Melaleuca argentea, Sesbania formosa*
Tall shrubs:	Dominant – acacias or melaleucas Common – *Acacia holosericea, A. pyrifolia, A. trachycarpa, Melaleuca glomerata, M. linophylla*
Mid shrubs:	Dominant – not usually present as a recognisable stratum Common – *Capparis lasiantha, Capparis spinosa, Petalostylis labicheoides*
Low shrubs:	Dominant – not usually present as a recognisable stratum Common – *Jasminum didymum* subsp. *lineare*
Perennial grasses:	Dominant – variable Common – *Cenchrus ciliaris, Cymbopogon procerus, Eulalia aurea, Themeda triandra, Triodia pungens*
Other plant forms:	Common – *Cyperus vaginatus* (sedge), *Ipomoea muelleri* (creeper)

Common annuals include *Cleome viscosa, Eragrostis tenellula, Euphorbia alsiniflora, Mukia maderaspatana, Nicotiana* sp., *Paspalidium clementii* and *Trichodesma zeylanicum*.

Patterns of grazing impact:

Traverse condition summary (34 assessments):

Vegetation - good 94%; fair 6%.
Soil erosion - nil 100%.

GMEW is usually little affected by grazing although there may be localised areas of degradation and occasional erosion around permanent water holes. Many banks and minor levees associated with GMEW are colonised and stabilised by introduced *Cenchrus ciliaris* which is resilient under grazing.

Nature conservation

GMEW vegetation is not particularly threatened by pastoral land use, although there may be locally altered environments near water holes. The site type is important as refuge for native fauna.

GMEW is represented in the Karijini and Millstream-Chichester National Parks. It is well represented on unallocated Crown land; 6 of the 34 traverse assessments were recorded on unallocated Crown land.

Gradational associations

GMEW occurs as distinctive fringing communities along rivers and contrasts strongly in composition and structure with vegetation on adjacent plains.

Land systems

GMEW is a minor component on Cane, Fortescue, River and Yamerina land systems.

Major rivers, pools and seepage spring areas have narrow fringes of dense melaleuca and eucalypt gallery woodlands (GMEW). Trees are Eucalyptus camaldulensis *(river red gum),* E. victrix *(coolibah) and* Melaleuca argentea *(river paperbark). Ground layers are patchy sedges, perennial grasses and herbs. Livestock impacts on vegetation seem minimal but physical damage to sandy banks and levees may occur at waterholes. The site type is an important habitat and drought refuge for native fauna.*

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Land systems

A.L. Payne

Diagrams by K.A. Leighton

Within the survey area 102 land systems have been identified, 53 of which are described for the first time and the other 49 having been described previously 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.

Land systems are grouped into land types according to a combination of landforms, soils, vegetation and drainage patterns. Table 1 shows the land types and their component land systems. This amalgamation of the 102 land systems into 20 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 2 gives 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:

- Pastoral 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 1)
- major geological formation or land surface types
- geomorphology overview
- brief description of land management considerations such as susceptibility to soil erosion
- traverse condition summary
- the extent of area mapped as severely degraded and eroded (sde)
- a locality map showing the distribution of the land system
- a plan or block diagram showing the physical features of the system, and with each land unit identified.
- a 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 4 of the Methodology chapter); formation (refer to the Vegetation chapter) and dominant species e.g. 'moderately close tall shrublands of *Acacia aneura* (DEAW)'. The four-letter code for the site type (refer to the Site type ecology chapter) is also listed.

Table 1. Land types and their land systems

Land type	Description and land systems
1	**Hills and ranges with spinifex grasslands** Land systems - Black, Boolaloo, Capricorn, Granitic, Houndstooth, McKay, Newman, Robertson, Rocklea, Ruth and Talga
2	**Hills and ranges with acacia shrublands** Land systems - Augustus, Charley and Marandoo
3	**Plateaux, mesas and breakaways with spinifex grasslands** Land systems - Callawa, Coongimah, Kumina, Nanutarra, Oakover and Robe
4	**Plateaux, mesas and breakaways with acacia shrublands** Land systems - Laterite and Table
5	**Dissected plains with spinifex grasslands** Land systems - Billygoat, Egerton and Platform
6	**Stony plains and hills with spinifex grasslands** Land systems - Adrian, Bonney, Mosquito, Nirran and Tanpool
7	**Stony plains and low hills with acacia shrublands** Land systems - Collier and Prairie
8	**Stony plains with spinifex grasslands** Land systems - Boolgeeda, Lochinvar, Macroy, Paterson, Peedamulla, Pyramid, Satirist, Stuart and Taylor
9	**Stony gilgai plains with tussock grasslands and spinifex grasslands** Land systems - White Springs and Wona
10	**Stony plains with acacia shrublands** Land systems - Dollar, Elimunna, Ford, Kanjenjie, Paraburdoo and Sylvania
11	**Sandplains with spinifex grasslands** Land systems - Buckshot, Divide, Giralia, Gregory, Little Sandy, Nita and Uaroo
12	**Wash plains on hardpan with groved mulga shrublands (sometimes with spinifex understorey)** Land systems - Cadgie, Fan, Jamindie, Jurrawarrina, Nooingnin, Pindering, Spearhole, Three Rivers, Wannamunna, Washplain and Zebra
13	**Alluvial plains with soft spinifex grasslands** Land systems - Mallina, Paradise and Urandy
14	**Alluvial plains with tussock grasslands or grassy shrublands** Land systems - Balfour, Brockman, Horseflat, Pullgarah and Turee
15	**Alluvial plains with snakewood shrublands** Land systems - Christmas, Cowra, Hooley, Marillana, Narbung and Sherlock
16	**Alluvial plains with halophytic shrublands** Land systems - Cundelbar, Mannerie and Talawana
17	**River plains with grassy woodlands and shrublands, and tussock grasslands** Land systems - Cane, Coolibah, Fortescue, Jigalong, River and Yamerina
18	**Calcreted drainage plains with shrublands or spinifex grasslands** Land systems - Calcrete, Lime and Warri
19	**Coastal plains, dunes, mudflats and beaches with tussock grasslands, soft spinifex grasslands and halophytic shrublands** Land systems - Anna, Cheerawarra, Dune, Eighty Mile, Littoral, Onslow and Roebuck
20	**Salt lakes and fringing alluvial plains with halophytic shrublands** Land systems - Marsh and Weelarrana

Table 2. Land units and their code

Code	Land unit
BAI	interbank
BAS	sandy bank
BRX	breakaway
CAP	calcrete platform
CHJ	major channel (>10 m)
CHM	minor channel (<10 m)
CLA	claypan
DOM	granite dome
DRF	drainage foci
DRN	narrow drainage floor (<500 m)
DRW	wide drainage floor (>500 m)
DUN	dune
FAA	alluvial fan
FOL	lower footslope
FOO	footslope
FOU	upper footslope
GGR	gilgaied grove
GRO	grove
HCR	hillcrest
HIL	hill
HSL	hillslope
LEV	levee
PGA	stony alluvial plain
PGC	calcareous stony plain
PGI	stony gilgai plain
PGM	stony plain with a mosaic of gilgai and non-gilgai patches
PGR	gritty-surfaced plain with shallow soil
PGS	saline stony plain
PHG	stony hardpan plain
PHL	gravelly hardpan plain
PIG	intergilgai plain
PKI	gilgai plain based on calcrete
PLA	saline alluvial plain
PLC	plain based on calcrete, with calcrete rubble
PLF	flood plain
PLG	stony plain
PLH	hardpan plain
PLI	gilgai plain
PLL	gravelly plain with sandy soils
PLO	plain with sandy loam soil
PLS	highly saline plain
PSL	gravelly saline alluvial plain
PTX	plateau
RDG	ridge
RIL	low rise
SCF	scarp face
SCR	scree slope
SSH	sand sheet
SSL	gravelly sand sheet
SWA	swale
SWP	swamp
TER	terrace
TFL	tidal flat
TOR	low hill consisting of boulders/core stones and bare rock

Sampling intensity

Table 3 indicates the area and intensity of sampling on each system in the survey area. A summary of the condition of each land system is presented in the Resource condition chapter.

Table 3. Land system areas and sampling intensity

Land system	Area (km^2)	% of total area	No. of inventory sites	Traverse sampling intensity		
				No. of assessments	km^2 per rating	Density index*
Adrian	235	0.1	1	15	16	1.07
Anna	598	0.3	13	140	4	0.29
Augustus	61	<0.1	0	0		
Balfour	1,480	0.8	13	221	7	0.46
Billygoat	2,235	1.2	20	269	8	0.57
Black	165	0.1	4	12	14	0.94
Bonney	753	0.4	4	122	6	0.42
Boolaloo	1,502	0.8	9	71	21	1.45
Boolgeeda	7,748	4.3	19	596	13	0.89
Brockman	735	0.4	15	149	5	0.34
Buckshot	2,780	1.5	7	91	31	2.09
Cadgie	495	0.3	2	24	21	1.41
Calcrete	1,444	0.8	12	177	8	0.56
Callawa	1,003	0.6	3	19	53	3.62
Cane	812	0.4	12	129	6	0.43
Capricorn	5,296	2.9	16	138	38	2.63
Charley	218	0.1	6	12	18	1.24
Cheerawarra	197	0.1	4	29	7	0.47
Christmas	232	0.1	0	49	5	0.32
Collier	169	0.1	0	0		
Coolibah	1,014	0.6	14	182	6	0.38
Coongimah	3,244	1.8	5	130	25	1.71
Cowra	203	0.1	3	37	5	0.38
Cundelbar	37	<0.1	3	3	12	0.84
Divide	5,293	2.9	7	177	30	2.05
Dollar	87	<0.1	0	17	5	0.35
Dune	138	0.1	2	22	6	0.43
Egerton	466	0.3	3	19	25	1.68
Eighty Mile	352	0.2	9	80	4	0.30
Elimunna	617	0.3	5	84	7	0.50
Fan	1,482	0.8	9	140	11	0.73
Ford	85	<0.1	0	7	12	0.83
Fortescue	504	0.3	14	111	5	0.31
Giralia	66	<0.1	0	4	16	1.13
Granitic	4,020	2.2	9	113	36	2.44
Gregory	113	0.1	2	4	28	1.93
Hooley	590	0.3	9	121	5	0.33
Horseflat	1,261	0.7	10	248	5	0.35
Houndstooth	427	0.2	3	46	9	0.64
Jamindie	2,074	1.1	9	221	9	0.64
Jigalong	713	0.4	7	90	8	0.54
Jurrawarrina	664	0.4	6	117	6	0.39
Kanjenjie	152	0.1	5	31	5	0.34
Kumina	151	0.1	2	3	50	3.45
Laterite	355	0.2	5	27	13	0.90
Lime	50	<0.1	3	5	10	0.68
Little Sandy	13,283	7.3	9	173	77	5.26
Littoral	1,577	0.9	10	49	32	2.20
Lochinvar	287	0.2	0	0		
Macroy	13,095	7.2	61	1,502	9	0.60
Mallina	2,557	1.4	22	423	6	0.41
Mannerie	190	0.1	4	35	5	0.37

Table 3. continued...

Land system	Area (km^2)	% of total area	No. of inventory sites	Traverse sampling intensity		
				No. of assessments	km^2 per rating	Density index*
Marandoo	459	0.3	4	8	57	3.93
Marillana	419	0.2	3	33	13	0.87
Marsh	977	0.5	7	23	42	2.91
McKay	4,202	2.3	7	132	32	2.18
Mosquito	1,840	1.0	8	153	12	0.82
Nanutarra	697	0.4	3	5	139	9.55
Narbung	159	0.1	2	25	6	0.44
Newman	14,580	8.0	14	228	64	4.38
Nirran	163	0.1	1	29	6	0.38
Nita	11,250	6.2	10	300	38	2.57
Nooingnin	898	0.5	0	115	8	0.53
Oakover	1,529	0.8	10	120	13	0.87
Onslow	424	0.2	6	47	9	0.62
Paraburdoo	565	0.3	2	84	7	0.46
Paradise	1,479	0.8	18	225	7	0.45
Paterson	818	0.4	15	133	6	0.42
Peedamulla	587	0.3	11	64	9	0.63
Pindering	351	0.2	6	61	6	0.39
Platform	1,570	0.9	9	95	17	1.13
Prairie	1,221	0.7	4	83	15	1.01
Pullgarah	563	0.3	13	93	6	0.41
Pyramid	142	0.1	2	3	47	3.24
River	4,088	2.3	26	401	10	0.70
Robe	865	0.5	10	98	9	0.60
Robertson	2,714	1.5	8	44	62	4.22
Rocklea	22,993	12.7	27	880	26	1.79
Roebuck	31	<0.1	0			
Ruth	346	0.2	2	18	19	1.32
Satirist	377	0.2	6	53	7	0.49
Sherlock	192	0.1	3	27	7	0.49
Spearhole	1,270	0.7	3	107	12	0.81
Stuart	1,794	1.0	10	211	9	0.58
Sylvania	1,077	0.6	7	111	10	0.66
Table	77	<0.1	0	1	77	5.27
Talawana	161	0.1	3	3	54	3.68
Talga	2,124	1.2	14	144	15	1.01
Tanpool	68	<0.1	1	13	5	0.36
Taylor	129	0.1	4	35	4	0.25
Three Rivers	88	<0.1	1	3	29	2.01
Turee	581	0.3	3	106	5	0.38
Uaroo	7,681	4.2	31	808	10	0.65
Urandy	1,311	0.7	11	134	10	0.67
Wannamunna	577	0.3	13	62	9	0.64
Warri	305	0.2	3	57	5	0.37
Washplain	917	0.5	3	89	10	0.71
Weelarrana	48	<0.1	1	6	8	0.55
White Springs	266	0.1	6	52	5	0.35
Wona	1,815	1.0	13	205	9	0.61
Yamerina	1,207	0.7	18	179	7	0.46
Zebra	374	0.2	6	55	7	0.47
Total	181,674		798	12,445		

* Density index: measure of sampling intensity relative to the mean of the survey area (14.6 km^2 per assessment)

ADRIAN LAND SYSTEM (235 km^2, 0.1% of the survey area)

Stony plains and low silcrete hills supporting hard spinifex grasslands.

Land type: 6

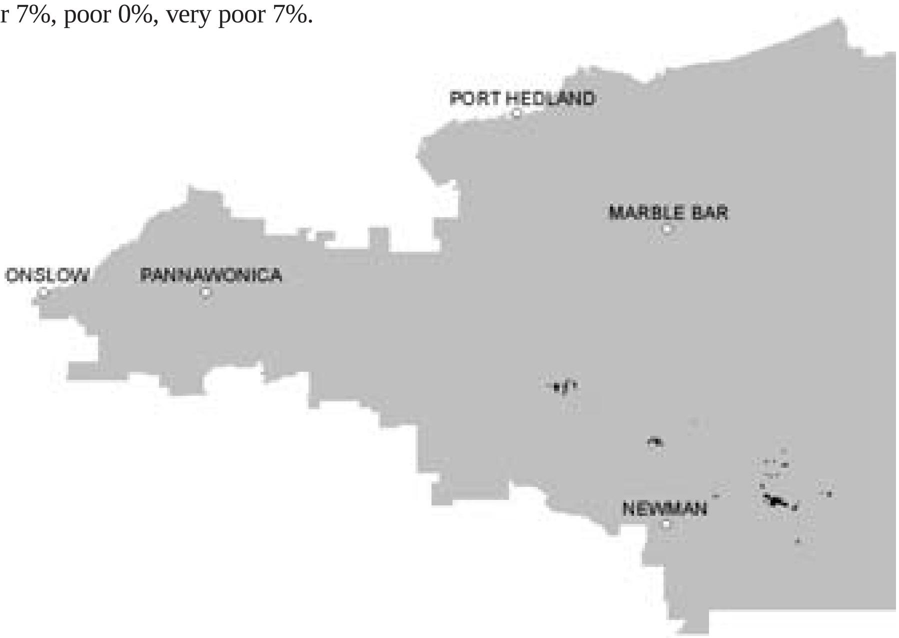
Geology: Tertiary silcrete, chert breccia and colluvium.

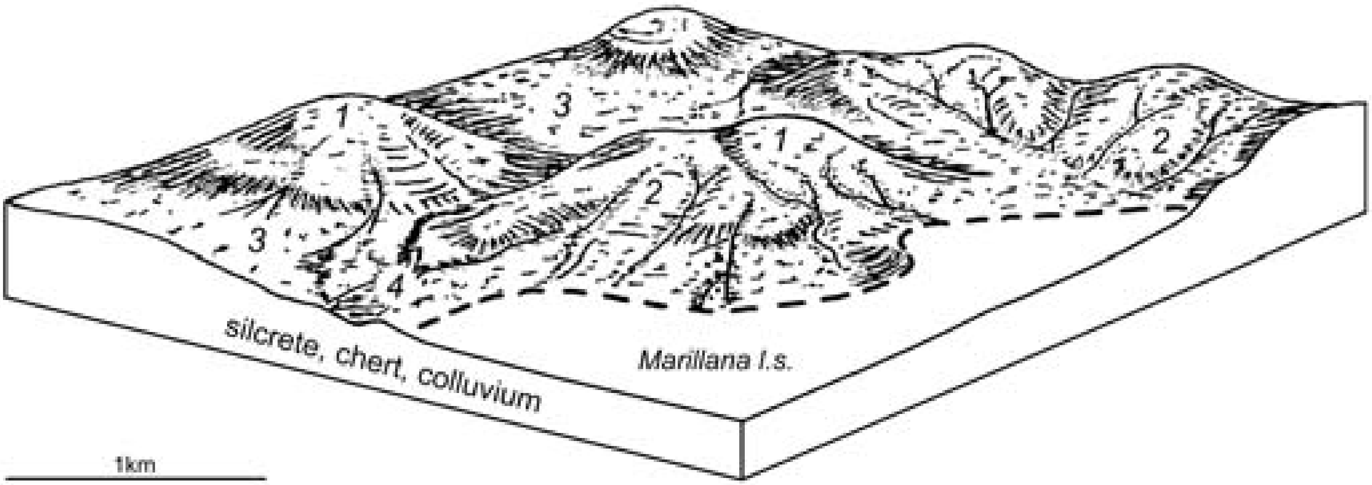
Geomorphology: Erosional surfaces; low rounded hills and rises, gently undulating to almost level stony plains, and short drainage lines with radial patterns away from hills. Relief up to 40 m but usually much less.

Land management: Vegetation on this system is not preferred by livestock and is generally not prone to degradation. The system has a low risk of erosion.

Traverse condition summary: (15 assessments)
Vegetation - very good 66%, good 20%, fair 7%, poor 0%, very poor 7%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low hill	5	-
2.	Footslope	4	1
3.	Stony plain	6	-
4.	Drainage line	-	-
	Total	15	1

Adrian land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	40%	**Low hills** - hills and rises with rounded summits and moderately inclined upper slopes with mantles of abundant silcrete cobbles and pebbles; relief up to 40 m.	Stony soils (203).	Hummock grasslands mostly *Triodia wiseana* (hard spinifex) with sparse acacia shrubs and occasional eucalypts, *Eucalyptus gamophylla*, (twin leaf mallee), *Corymbia hamersleyana* (Hamersley bloodwood), (HSPG).
2.	20%	**Footslopes** - gently inclined slopes with mantles of abundant silcrete rock fragments.	Stony soils (203).	Similar to unit 1 (HSPG).
3.	38%	**Stony plains** - gently undulating to almost level plains with mantles of few to abundant silcrete pebbles.	Red shallow loams (522) with some stony soils (203).	Similar to unit 1 (PHSG).
4.	2%	**Drainage lines** - narrow (mostly <50 m wide) drainage zones with shallow channels in higher sectors.	Red shallow loams (522).	Hummock grasslands with *T. wiseana, T. pungens* (hard and soft spinifex) and scattered to moderately close acacia shrubs and occasional eucalypts (DAHW).

ANNA LAND SYSTEM (598 km^2, 0.3% of the survey area)

(modified from Cotching unpublished)

Coastal plains with saline soils supporting tussock grasslands and minor halophytic low shrublands.

Land type: 19

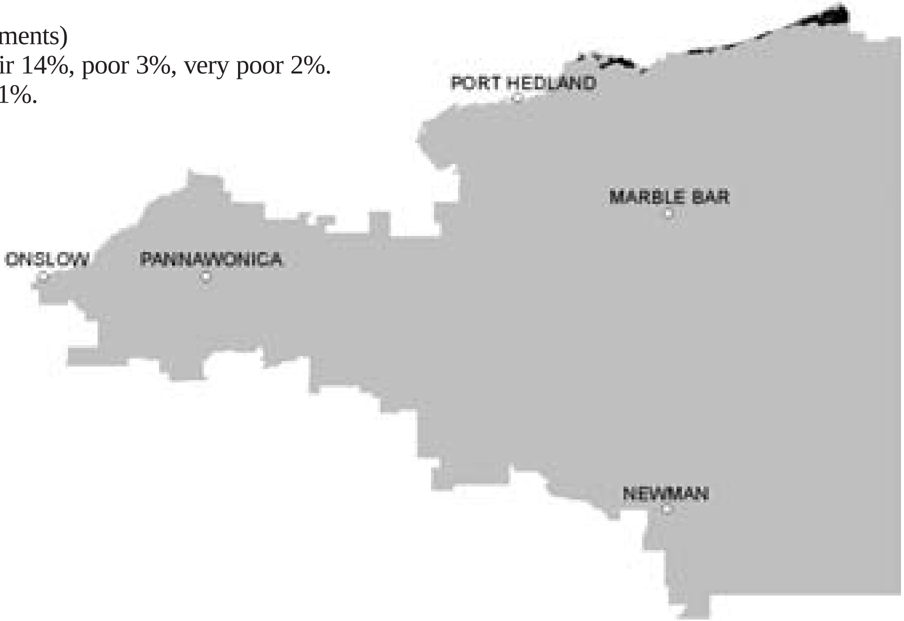
Geology: Quaternary supratidal littoral deposits and old alluvium; clay, silt and sand.

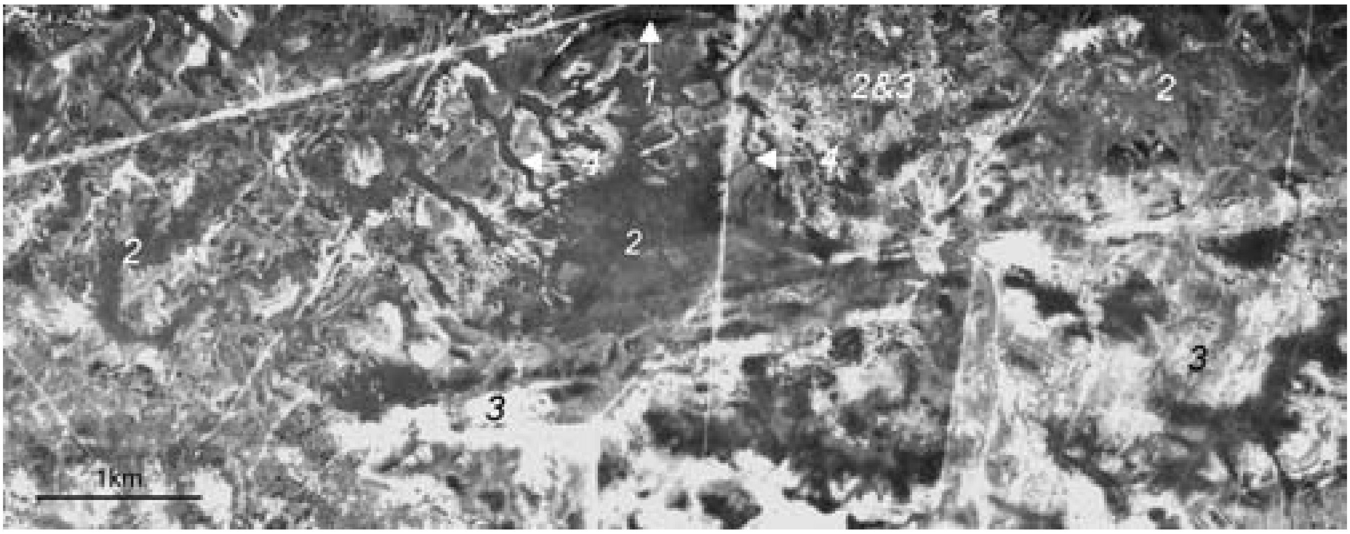
Geomorphology: Depositional surfaces; broad, coastal supratidal plains on saline and calcareous littoral and alluvial deposits, minor sand sheets and sandy banks, a few narrow sluggish internal drainage depressions but no organised drainage features.

Land management: Grasslands of the system are highly preferred by grazing animals but are resilient under grazing except if grazing pressure is grossly excessive. Grassy halophytic shrublands on the system are more prone to degradation and have slight susceptibility to wind erosion when degraded. The system is subject to inundation; waterlogging for prolonged periods can adversely effect vegetation and prevent access.

Traverse condition summary: (140 assessments)
Vegetation - very good 51%, good 30%, fair 14%, poor 3%, very poor 2%.
Soil erosion - nil 98%, slight 1%, moderate 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Sand sheet and bank	5	-
2.	Coastal plain	94	9
3.	Saline plain	37	4
4.	Drainage line	4	-
	Total	140	13

Anna land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	2%	**Sand sheets and banks** - isolated level sand sheets up to 1.5 km in extent or linear banks up to 600 m long by 100 m wide, raised up to a few metres above adjacent plains (units 2 and 3).	Calcareous deep sands (442).	Tussock or hummock grasslands of *Cenchrus ciliaris* (buffel grass) or *Triodia pungens* (soft spinifex) with isolated to very scattered shrubs (CDBG, SSSG).
2.	70%	**Coastal plains** - level plains up to 10 km in extent or as smaller areas as a mosaic with saline plains (unit 3).	Grey deep loamy duplex (509), calcareous loamy earths (542), red deep sandy duplex (405) and some red/brown non-cracking clay (622).	Tussock grasslands of *Cenchrus ciliaris* or other grasses such as *Eulalia aurea* (silky brown top), *Chrysopogon fallax* (ribbon grass), *Eriachne benthamii* (swamp grass), *Eragrostis xerophila* (Roebourne Plains grass) and *Sporobolus virginicus* (salt water couch) (APBG, APXG, SPSG).
3.	26%	**Saline plains** - level plains up to 5-6 km in extent but also as much smaller mosaics within coastal plains (unit 2).	Calcareous loamy earths (542).	Scattered low shrublands of *Halosarcia* spp. (samphire), *Frankenia* sp. (frankenia) and occasional taller shrubs of *Melaleuca lasiandra* and patchy grasses including *Sporobolus virginicus* (PSPS). Also patchy tussock grasslands with *S. virginicus, Eragrostis falcata* (sickle love grass) and *Cenchrus ciliaris* (SPSG, APBG, APXG).
4.	2%	**Drainage lines** - sinuous, poorly defined internal drainage lines and depressions, mostly <100 m wide, no sharp incision.	Grey deep loamy duplex (509) soils and some grey non-cracking clays (621).	Mixed grasslands with *Sporobolus virginicus, Eriachne benthamii, Eulalia aurea* or grassy low shrublands with *Halosarcia* and *Frankenia* spp. (APXG, PSPS).

AUGUSTUS LAND SYSTEM (61 km², 0.03% of the survey area)

(modified from Wilcox and McKinnon 1972)

Rugged ranges, hills, ridges and plateaux supporting mulga shrublands and hard spinifex grasslands.

Land type: 2

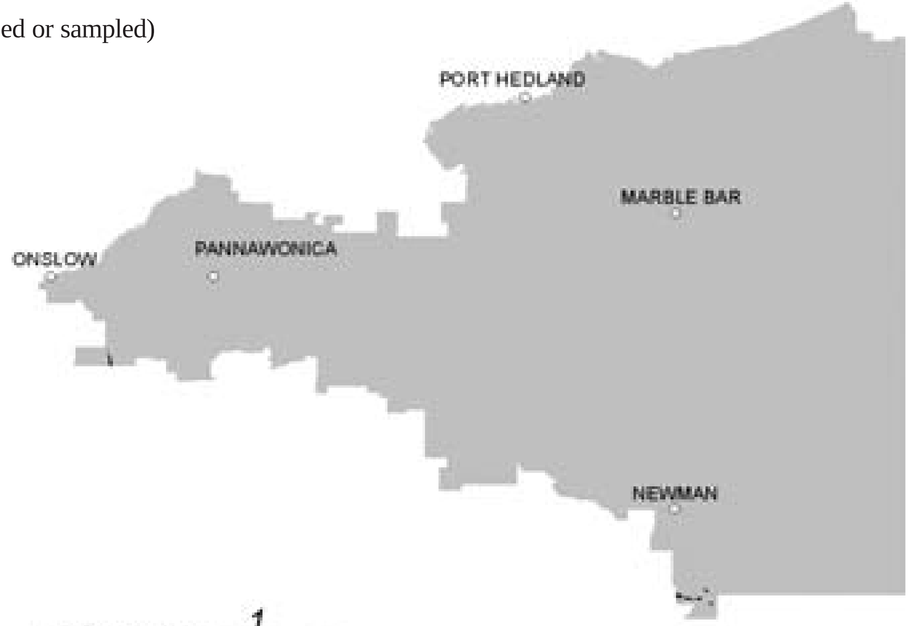
Geology: Middle Proterozoic sandstone, quartzite, shale and dolomite.

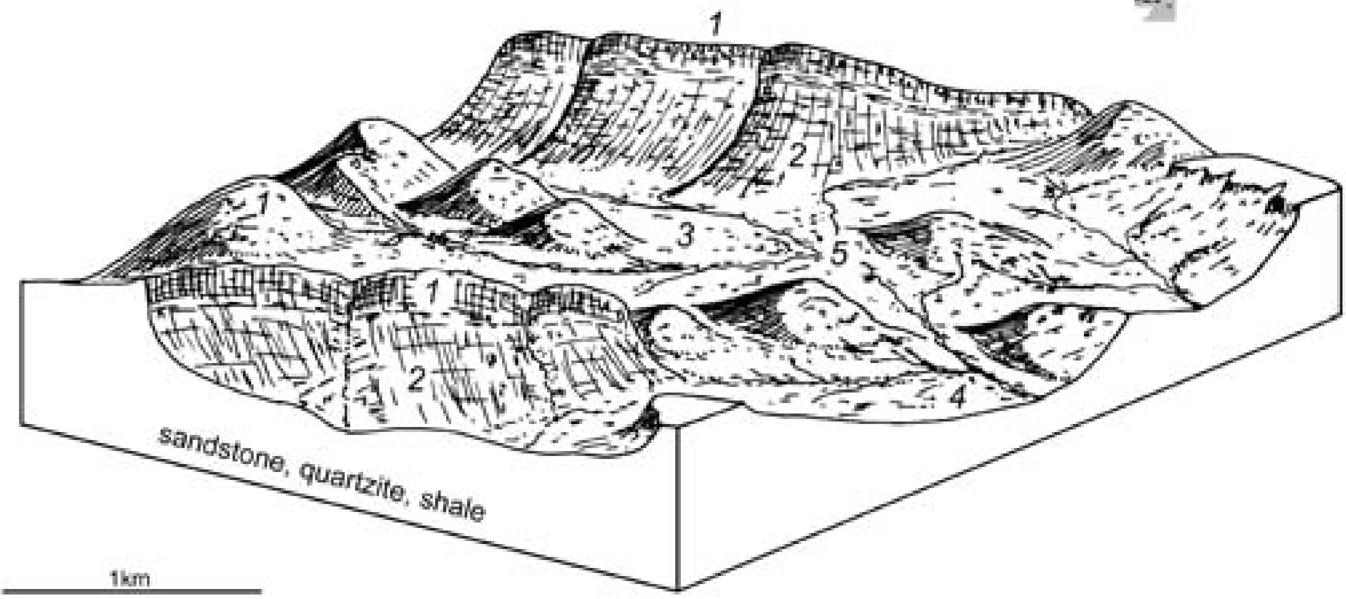
Geomorphology: Erosional surfaces; mountain ranges and hills with steep escarpments and upper slopes, restricted lower slopes and valley plains; moderately spaced patterns of tributary drainage floors. Relief up to 350 m.

Land management: Due to its rugged nature, much of the system is poorly accessible. Mulga shrublands are moderately preferred by livestock but hard spinifex vegetation is unattractive. The system is generally not prone to vegetation degradation or soil erosion except for drainage floors (unit 4) which are moderately susceptible.

Traverse condition summary: (not traversed or sampled)
Vegetation - no records
Soil erosion - no records

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Range, hill, ridge and rocky upland	-	-
2.	Lower footslope	-	-
3.	Stony undulating plain and interfluve	-	-
4.	Drainage floor	-	-
5.	Channel and creek	-	-
	Total	-	-

Augustus land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	65%	**Ranges, hills, ridges and rocky uplands** - gently rounded summits, near vertical escarpments, steep upper scree slopes; relief up to 350 m.	Stony soils (203).	Very scattered shrublands of *Acacia aneura* (mulga) with sparse low shrubs (PSMS). Also hummock grasslands mostly *Triodia wiseana, T.* spp. (hard spinifex) with isolated to very scattered shrubs (HSPG).
2.	20%	**Lower footslopes** - very gently to gently inclined slopes up to 1 km long; rock outcrop and very abundant colluvial mantles.	Stony soils (203).	Very scattered tall shrublands of *Acacia aneura* and other acacias with sparse low shrubs (PSMS).
3.	10%	**Stony undulating plains and interfluves** - gently undulating surfaces up to 2 km long with surface mantles of abundant pebbles and cobbles; sloping margins dissected to 20 m.	Red shallow loams (522).	Very scattered tall shrublands of *A. aneura* and other acacias with sparse low shrubs (PSMS).
4.	2%	**Drainage floors** - almost level floors up to 500 m wide.	Red loamy earths (544).	Scattered tall shrublands and woodlands of *Acacia citrinoviridis* (black mulga), *A. kempeana* (witchetty bush) and *A. aneura* with variable low shrubs (DEAW).
5.	3%	**Channels and creeks** - channels up to 100 m wide and 10 m deep.	River bed soils (705).	Fringing woodlands of *Acacia coriacea* (river jam), *A. citrinoviridis* and *Eucalyptus camaldulensis* (red river gum) with numerous low shrubs (DEGW).

BALFOUR LAND SYSTEM (1,480 km^2, 0.8% of the survey area)

Shale, gravel and clay plains supporting eremophila-cassia shrublands, tussock grasslands, and halophytic shrublands.

Land type: 14

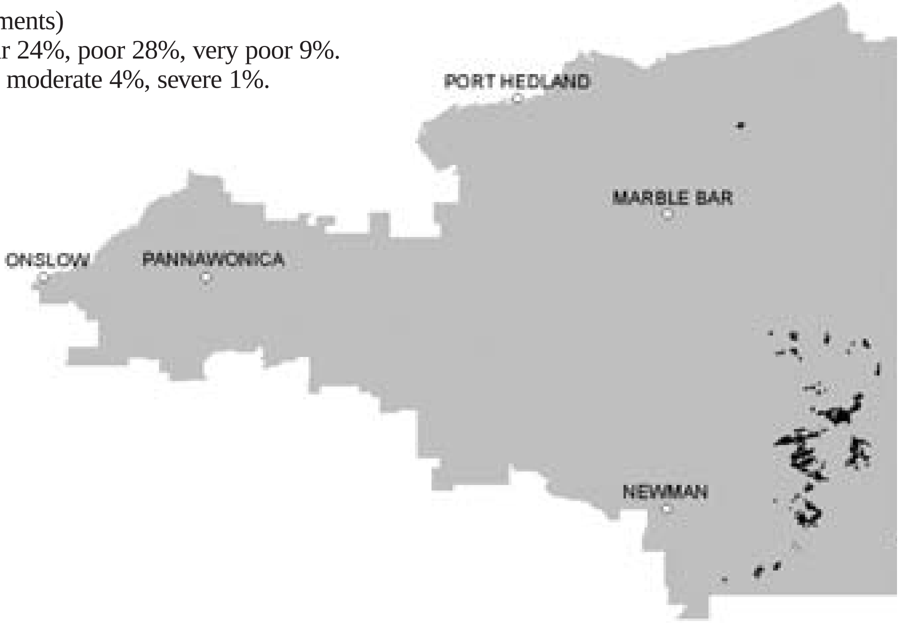
Geology: Quaternary alluvium, colluvium and eluvium, Lower Proterozoic shale.

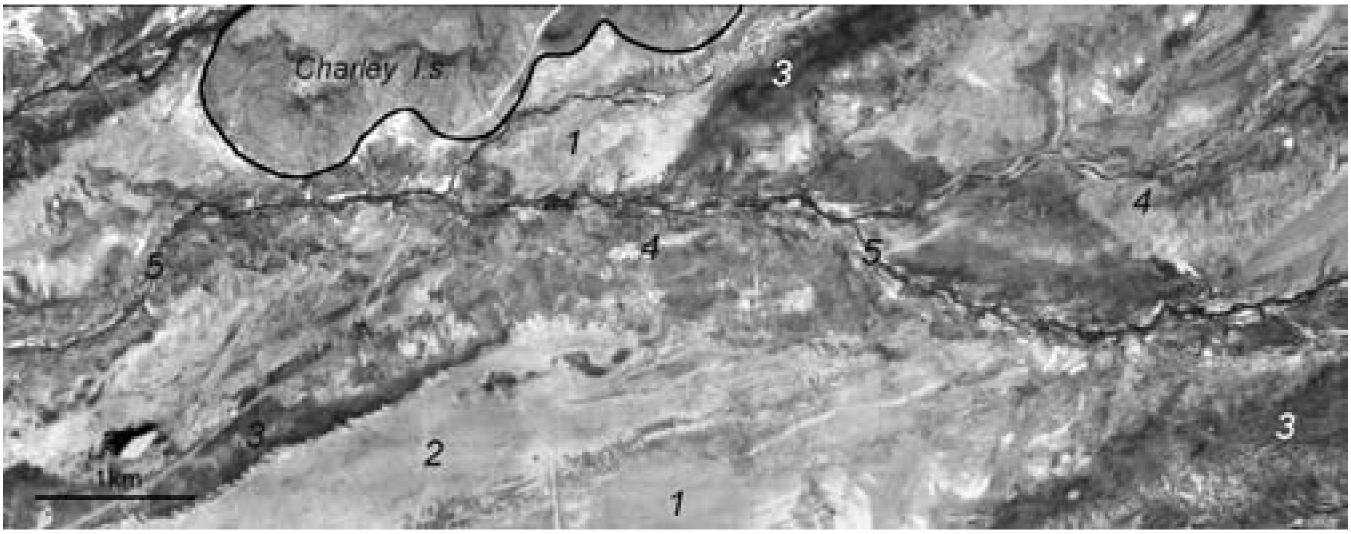
Geomorphology: Mostly depositional surfaces; level to very gently inclined stony plains on shale, level plains with gilgaied clay soils, plains with saline alluvium and sluggish drainage tracts with minor channels.

Land management: Drainage tracts (unit 5) support vegetation preferred by grazing animals and are moderately susceptible to erosion if overgrazed. Gilgai plains and alluvial plains (units 2 and 4) also support vegetation favoured by herbivores. Some gilgai plains, gravelly plains and alluvial plains (units 2, 3 and 4) are slightly to moderately susceptible to erosion if vegetative cover is lost.

Traverse condition summary: (221 assessments)
Vegetation - very good 13%, good 26%, fair 24%, poor 28%, very poor 9%.
Soil erosion - nil 87%, slight 3%, minor 5%, moderate 4%, severe 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Stony plain	76	5
2.	Gilgai plain	17	2
3.	Gravelly plain	86	4
4.	Alluvial plain	19	-
5.	Drainage tract and creekline	18	2
	Other	5	-
	Total	221	13

Balfour land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	35%	**Stony plains** - level to gently inclined plains with mantles of abundant platy shale, quartz and ironstone pebbles and cobbles.	Red deep loamy duplex soils (506), red shallow loams (522) and red/brown non-cracking clays (622).	Isolated to very scattered low shrublands of *Eremophila* 'jigalong', *E. cuneifolia*, (royal poverty bush), *Senna artemisioides* subsp. *helmsii* (crinkled cassia) and other *Senna* spp. (SAES).
2.	10%	**Gilgai plains** - level clay plains with gilgai microrelief sometimes with mantles of ironstone or shale pebbles.	Self-mulching cracking clays (602) and red/brown non-cracking clays (622).	Patchy tussock grasslands with *Enneapogon* spp., *Astrebla pectinata* (curly Mitchell grass) and *Eragrostis xerophila* (Roebourne Plains grass) (ARPG, PMOG).
3.	35%	**Gravelly plains** - level to gently inclined plains sometimes with 'puffy' surfaces and with mantles of abundant ironstone gravel.	Red loamy earths (544) and self-mulching cracking clays (602).	Patchy annual grasslands - herbfields. More saline sites patchy and very scattered low shrublands of *Halosarcia* sp. (samphire), *Frankenia* sp. (frankenia), *Maireana glomerifolia* (ball leaf bluebush), *Atriplex bunburyana* (silver saltbush), *Eremophila* sp. and *Sclerolaena cuneata* (yellow bindii) (PXHS).
4.	10%	**Alluvial plains** - level plains subject to irregular flooding, non-gilgaied surfaces with mantles of few to many ironstone gravels.	Red deep sandy duplex soils (405) and red/brown non-cracking clays (622).	Patchy tussock grasslands including *Eragrostis xerophila, E. setifolia* (neverfail) and occasional shrubs (APXG, PMOG).
5.	10%	**Drainage tracts and creeklines** - level drainage floors (usually <200 m wide) with occasional small gutters, channels and creeklines, mantles of few to many ironstone gravels. Larger channels up to 30 m wide and incised to 2 m, sandy bedloads.	Red deep sandy duplex soils (405) and red loamy earths (544). Some river bed soils (705).	Moderately close to close *Acacia aneura* (mulga) tall shrublands with other acacias, numerous mid and low shrubs including *Senna* spp., occasional perennial grasses or spinifex (DEGW).

BILLYGOAT LAND SYSTEM (2,235 km^2, 1.2% of the survey area)

Dissected plains and slopes supporting hard spinifex grasslands.

Land type: 5

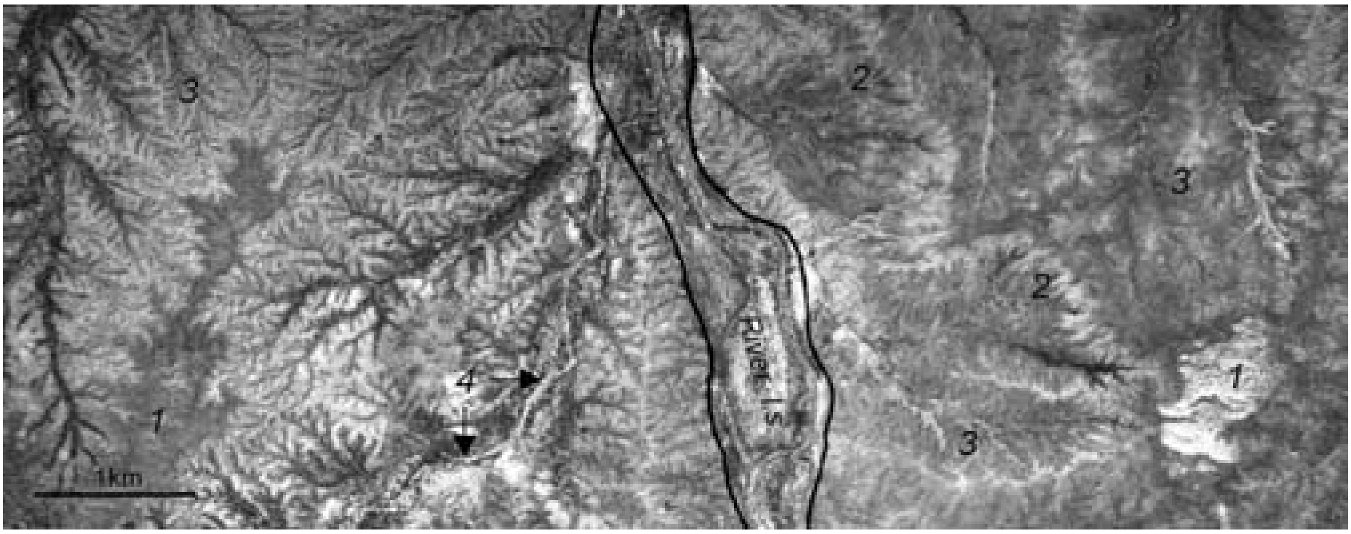
Geology: Partially consolidated and cemented Quaternary colluvium, minor alluvium.

Geomorphology: Erosional surfaces; minor plateaux surfaces and residual upper plains, occasional low breakaways, extensive dissected gravelly/stony plains consisting of narrow interfluves and slopes with numerous dendritic drainage patterns, narrow drainage lines leading to wider through drainage tracts; slopes marginal to major drainage lines are often calcreted. Relief up to 20 m.

Land management: Most vegetation on this system is not preferred by livestock and is not degraded. The system is generally not susceptible to accelerated erosion.

Traverse condition summary: (269 assessments)
Vegetation - very good 84%, good 10%, fair 3%, poor 3%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Residual surface	49	1
2.	Breakaway and footslope	30	2
3.	Dissected gravelly/stony plain	151	12
4.	Drainage floor and channel	36	5
	Other	3	-
	Total	269	20

Billygoat land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	20%	**Residual surfaces** - level to gently rounded residual surfaces and low plateaux on hardpan, mantles of abundant ironstone and quartz gravel and pebbles.	Red-brown hardpan shallow loams (523) and some stony soils (203).	Hummock grasslands of *Triodia plurinervata, T. wiseana* (hard spinifex) with isolated to very scattered acacia shrubs (PHSG).
2.	10%	**Breakaways and footslopes** - low breakaways with vertical faces to 8 m high and gently to moderately inclined dissected footslopes, abundant exposures of hardpan, mantles of abundant ironstone and quartz gravel.	Bare rock and red shallow loams (522).	Sparse hummock grasslands of *T. plurinervata, T. wiseana* with isolated acacia shrubs including occasionally *Acacia aneura* (mulga) (PHSG, PMSS).
3.	55%	**Dissected gravelly/stony plains** - gently undulating dissected plains and rises extending downslope from units 1 and 2, narrow interfluves and short side slopes into numerous small drainage lines, mantles of abundant ironstone and other gravels and pebbles.	Red shallow loams (522), shallow gravel soils (304), red shallow sandy duplex soils (406) and red loamy earths (544).	Hummock grasslands of *T. plurinervata, T. brizoides, T. wiseana* with very scattered acacia shrubs including *A. aneura* (PHSG, PMSS).
4.	15%	**Drainage floors and channels** - numerous, very narrow (<10 m wide) dendritic drainage lines through units 2 and 3, becoming wider (up to 150 m) and with more defined channels downslope.	Red shallow loams (522), red shallow sands (423) and river bed soils (705).	Scattered to moderately close mid height or tall shrublands of various *Acacia* spp. with understorey of *Triodia* spp. (hard and soft spinifex) (DAHW). Occasionally shrubby hummock grasslands of *T. pungens* (soft spinifex) (ASSG).

BLACK LAND SYSTEM (165 km², 0.1% of the survey area)

Linear ridges of dolerite or basalt supporting hard spinifex grasslands, with unvegetated boulder slopes and rock piles along summits.

Land type: 1

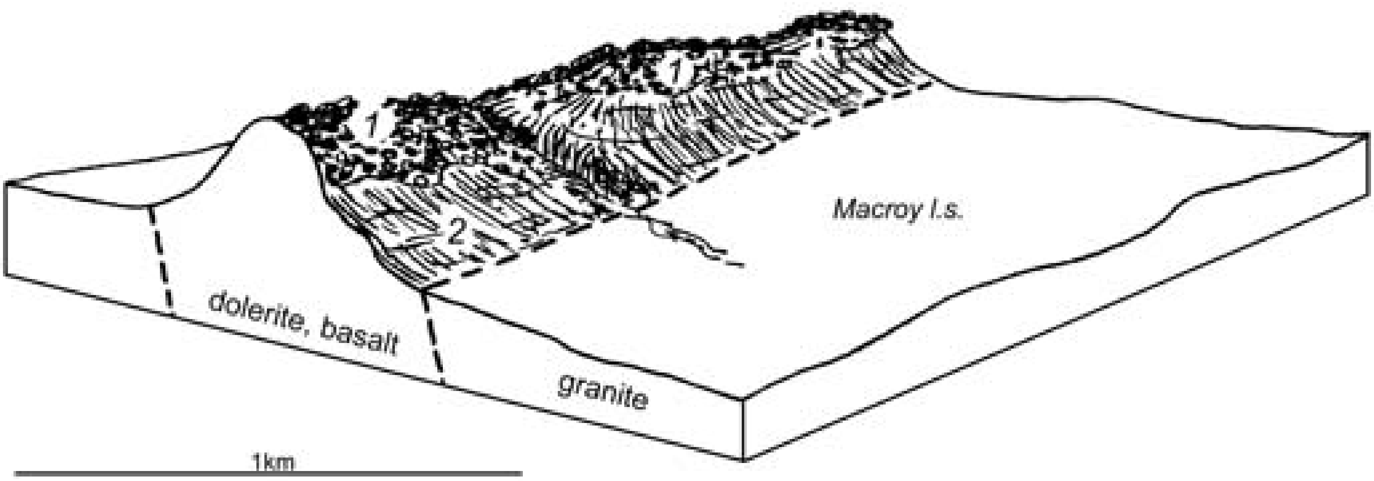
Geology: Proterozoic dolerite or basalt.

Geomorphology: Erosional surfaces; linear ridges and hill tracts (usually <500 m wide) but extending for many kilometres in a generally south-west to north-east direction as prominent intrusions through granitic and other landscapes; steep, unvegetated slopes of black boulders and rock piles along summits. Relief up to 90 m.

Land management: Rocky mantles provide effective protection against soil erosion; disturbance or removal of stone mantles on footslopes may initiate erosion.

Traverse condition summary: (12 assessments)
Vegetation - Very good 84%, good 8%, fair 8%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Ridge	1	2
2.	Footslope	10	2
	Other	1	-
	Total	12	4

Black land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	80%	**Ridges** - ridges with linear crests and summits up to 90 m above adjacent plains, with very steep upper slopes, uneven surfaces with mantles of very abundant dolerite pebbles, cobbles and stones or rock piles of dolerite boulders.	Stony soils (203) with pockets of red loamy earth (544).	Patchy stands of *Triodia wiseana, T. brizoides* (hard spinifex) between rocks (HSPG). Rock piles frequently unvegetated except for occasional *Terminalia canescens* and *Ficus* sp. trees.
2.	20%	**Footslopes** - gently inclined to steep footslopes with mantles of abundant dolerite pebbles, cobbles and stones.	Red shallow loams (522) grading to red shallow sandy duplex soils (406) and red deep sandy duplex soils (405) on lower footslopes.	Hummock grasslands of *T. wiseana, T. brizoides* (hard spinifex) and isolated shrubs (HSPG). Less frequently hummock grasslands of *T. pungens* (soft spinifex) (HSPG).

BONNEY LAND SYSTEM (753 km^2, 0.4% of the survey area)

Low rounded hills and undulating stony plains supporting soft spinifex grasslands.

Land type: 6

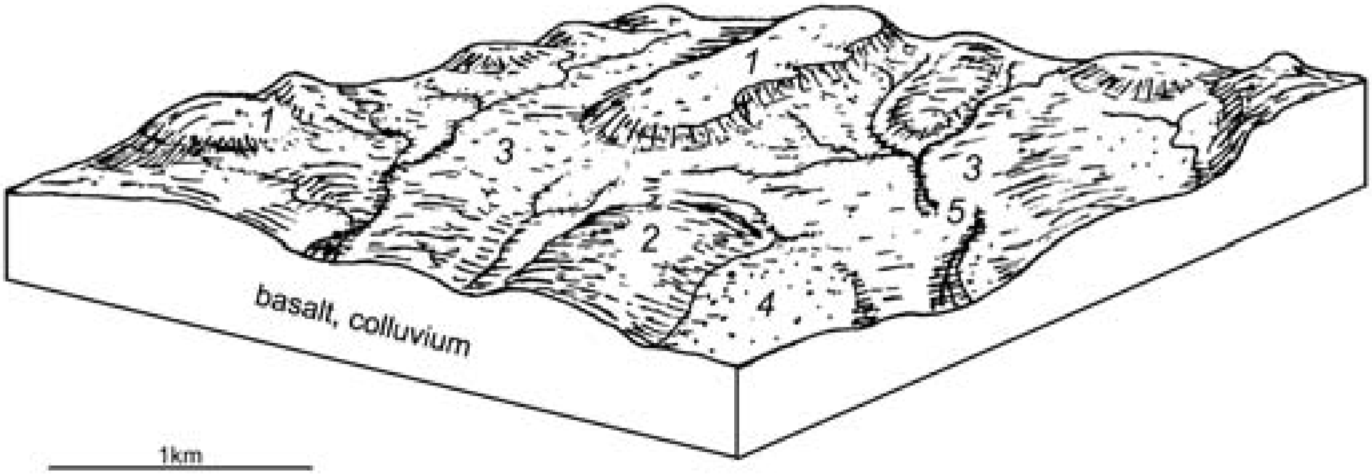
Geology: Lower Proterozoic basalt, tuff, lava and sedimentary rocks.

Geomorphology: Erosional surfaces; low hills, undulating rises and gently undulating stony plains; widely spaced tributary drainage patterns of narrow drainage floors with minor channels. Relief up to 30 m.

Land management: Young soft spinifex vegetation is moderately attractive to grazing animals but is not generally prone to grazing induced degradation or erosion. Spinifex is highly flammable and fires occur fairly regularly.

Traverse condition summary: (122 assessments)
Vegetation - very good 65%, good 30%, fair 4%, poor 0%, very poor 1%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Hill	12	1
2.	Low rise	14	-
3.	Stony plain	76	3
4.	Stony gilgai plain	5	-
5.	Drainage floor	15	-
	Total	122	4

Bonney land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	26%	**Hills** - low (up to 25 m) rounded hills with gently to moderately inclined footslopes, mantles of abundant basalt and other pebbles and rocks, also rock outcrop.	Stony soils (203).	Hummock grasslands mostly of *Triodia pungens* (soft spinifex) occasionally with isolated *Eucalyptus leucophloia* (snappy gum) trees (HSPG).
2.	10%	**Low rises** - undulating rises and stony plains with mantles of common to abundant pebbles of basalt and other pebbles and rocks.	Shallow red/brown non-cracking clays (622).	Hummock grasslands of *T. pungens* with isolated shrubs (PSSG).
3.	50%	**Stony plains** - gently undulating stony plains downslope from units 1 and 2 with mantles of few to abundant pebbles of basalt (occasionally calcrete).	Calcareous loamy earths (542) and red loamy earths (544).	Hummock grasslands of *T. pungens* with isolated acacia shrubs (PSSG).
4.	4%	**Stony gilgai plains** - level clay plains with gilgai micro relief and mantles of common basalt pebbles.	Self-mulching cracking clays (602) or red/brown non-cracking clays (622).	Patchy tussock grasslands of *Eragrostis xerophila* (Roebourne Plains grass) and other perennial grasses (BUTG).
5.	10%	**Drainage floors** - narrow (<500 m wide) floors and minor channels up to 50 m wide and incised 2-3 m.	Deep red/brown non-cracking clays (622) with minor river bed soils (705).	Hummock grasslands of *T. pungens* and isolated shrubs (ASSG). Less frequently tall shrublands or woodlands of acacias and eucalypts with prominent ground layer of *T. pungens* or tussock grasses (DESG, DEGW).

BOOLALOO LAND SYSTEM (1,502 km^2, 0.8% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Granite hills, domes and tor fields and sandy plains with shrubby spinifex grasslands.

Land type: 1

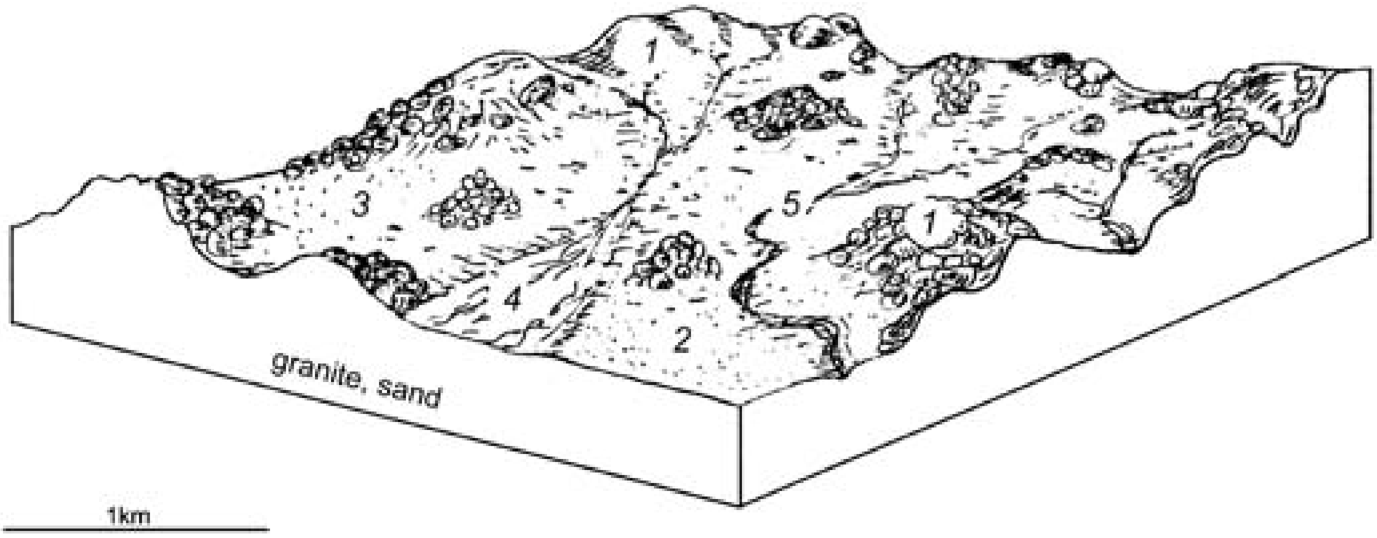
Geology: Archaean granite and gneiss, minor Quaternary sand.

Geomorphology: Erosional surfaces; granite hills with boulder strewn slopes, tor heaps and bare domes surrounded by restricted stony and sandy plains; widely spaced tributary drainage patterns of narrow drainage floors and channels. Relief mostly <50 m, occasionally up to 100 m.

Land management: Hills and tor heaps are poorly accessible to livestock, elsewhere on the system the spinifex vegetation is not usually prone to grazing induced degradation but is subject to fairly frequent burning.

Traverse condition summary: (71 assessments)
Vegetation - very good 100%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Hill, tor heap and hill slope	8	6
2.	Sandy plain	17	-
3.	Stony plain	39	3
4.	Run-on tract	-	-
5.	Narrow drainage floor and channel	7	-
	Total	71	9

Boolaloo land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	70%	**Hills, tor heaps and hill slopes** - rounded hill crests with gently inclined to steep stone and boulder strewn slopes, bare domes and tor heaps. Relief mostly <50 m, occasionally higher.	Bare rock, stony soils (203) and red shallow sands (423).	Scattered hummocks of *Triodia pungens* (soft spinifex) with isolated *Acacia* spp. and other shrubs, occasional *Terminalia canescens* trees (HSPG).
2.	10%	**Sandy plains** - Level to very gently inclined sandy plains between hills and tor heaps.	Red deep sands (445).	Hummock grasslands of *Triodia* sp. (hard spinifex) with very scattered to scattered *Acacia* spp. and other shrubs (PHSG). Occasionally *T. pungens* (soft spinifex) (PSSG).
3.	13%	**Stony plains** - level to undulating plains with gritty surfaces and mantles of variable density granitic or quartz pebbles and cobbles, occasional granite outcrops.	Red shallow sands (423).	Hummock grasslands of *T. wiseana, T. brizoides* (hard spinifex) or *T. pungens* (soft spinifex) with very scattered shrubs such as *Acacia orthocarpa, A. maitlandii* (PHSG, PSSG).
4.	5%	**Tracts receiving run-on** - level tracts receiving run-on, usually unchannelled but may have a few rills and gutters.	Red shallow sands (423).	Hummock grasslands of *T. pungens* with scattered *Acacia* spp. and other shrubs (ASSG).
5.	2%	**Narrow drainage floors and channels** - level drainage floors up to 200 m wide, channels up to 50 m wide and 3 m deep.	Red sandy earths (463). Channels with river bed soils (705).	Scattered shrublands or hummock grasslands with *Acacia* spp. and *Triodia* spp. (soft and hard spinifex) (DAHW, AHSG). Larger channels have fringing woodlands of eucalypts and melaleucas (GMEW).

BOOLGEEDA LAND SYSTEM (7,748 km^2, 4.3% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands and mulga shrublands.

Land type: 8

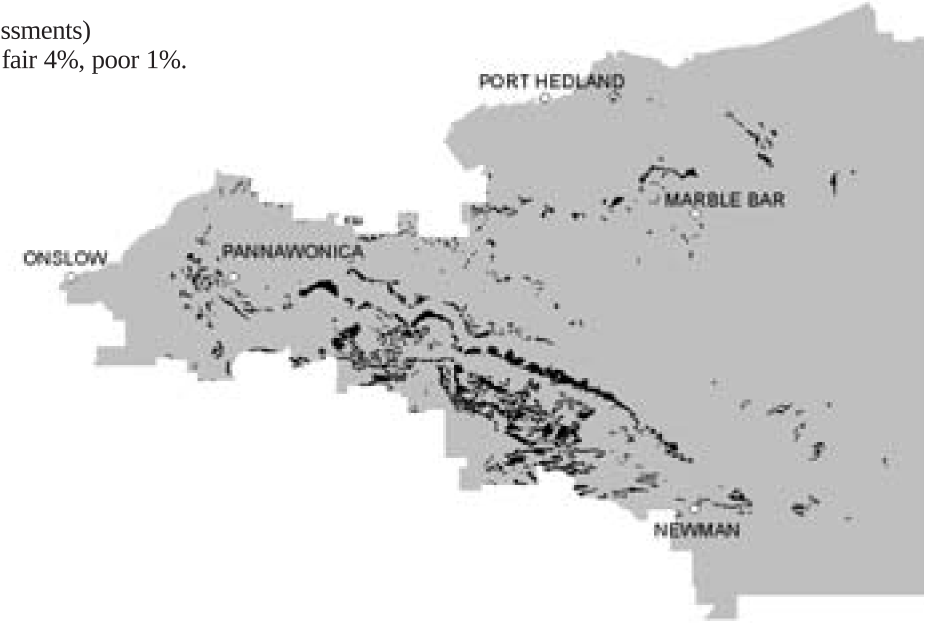
Geology: Quaternary colluvium.

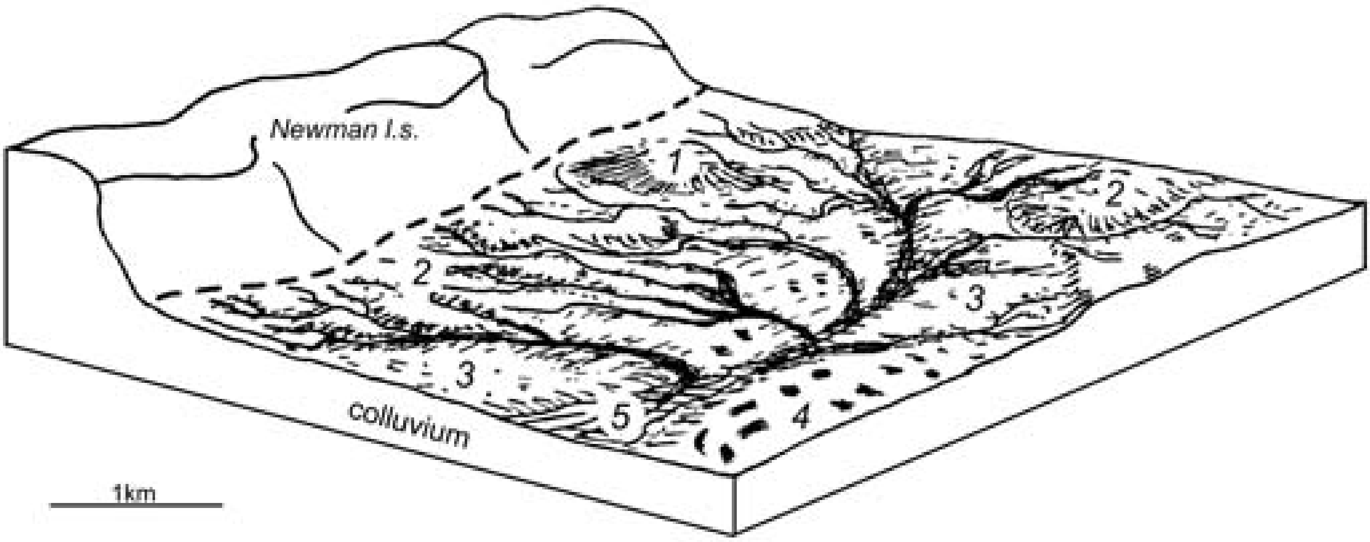
Geomorphology: Predominantly depositional surfaces; very gently inclined stony slopes and plains below hill systems becoming almost level further downslope; closely spaced, dendritic and sub-parallel drainage lines. Relief up to about 20 m.

Land management: Hard spinifex grasslands are not preferred by livestock but soft spinifex is moderately preferred for a few years following fire. Vegetation is generally not prone to degradation and the system is not susceptible to erosion. The system is subject to fairly frequent burning.

Traverse condition summary: (596 assessments)
Vegetation - very good 82%, good 13%, fair 4%, poor 1%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low hill and rise	11	1
2.	Stony slope and upper plain	105	6
3.	Stony lower plain	382	6
4.	Grove	8	3
5.	Narrow drainage floor and channel	82	3
	Other	8	-
	Total	596	19

Boolgeeda land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	4%	**Low hills and rises** - isolated hills and low rises usually <500 m in extent, surface mantles of very abundant pebbles and cobbles of ironstone, basalt and other rocks; relief up to 20 m.	Stony soils (203) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana* (hard spinifex) and other *Triodia* spp. with very scattered acacia shrubs (HSPG, PHSG).
2.	20%	**Stony slopes and upper plains** - very gently inclined slopes and upper interfluves immediately downslope from adjacent hill systems, dissected up to 5 m by dendritic or sub-parallel small creeklines, surface mantles of common to very abundant pebbles of chert ironstone, quartz and other rocks.	Red shallow loams (522) or red loamy earths (544).	Hummock grasslands of *T. lanigera, T. wiseana* (hard spinifex) (PHSG) or scattered tall shrublands of *Acacia aneura* (mulga), *A. ancistrocarpa* (shiny leaf wattle), *A. atkinsiana* and other acacias, occasional eucalypt trees and prominent hard spinifex ground layer (HESG, PMSS).
3.	65%	**Stony lower plains** - almost level plains downslope from unit 2, surface mantles vary from few to very abundant ironstone and other pebbles; subject to sheet and channelised flow from units 1 and 2.	Red loamy earths (544).	Hummock grasslands *T. wiseana, T. lanigera* (hard spinifex) or *T. pungens* (soft spinifex) (PHSG, PSSG). Also scattered to moderately close tall shrublands of *A. aneura* and other acacias with hard and soft spinifex ground layer (PHSG, PMSS).
4.	1%	**Groves** - small (up to 20 m long) arcuate drainage foci occurring infrequently on units 2 and 3.	Red loamy earths (544).	Moderately close woodlands or tall shrublands of *A. aneura* with sparse low shrubs and tussock or hummock grasses (GMUW, GMGW, DAHW).
5.	10%	**Narrow drainage floors and channels** - dendritic and parallel flow zones and creeklines on slopes and plains (units 2 and 3), only 5-10 m wide in upper parts becoming wider on lower plains, larger channels may be braided and incised up to 3 m.	Red loamy earths (544) and minor self-mulching cracking clays (602). Channels with river bed soils (705).	Scattered to close tall shrublands or woodlands of *A. aneura, A. atkinsiana, Corymbia hamersleyana* (Hamersley bloodwood) with sparse low shrubs and hummock and tussock grasses, (DAHW, DEGW, DESG). Occasionally hummock grasslands of *T. pungens* (ASSG).

BROCKMAN LAND SYSTEM (735 km^2, 0.4% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Alluvial plains with cracking clay soils supporting tussock grasslands.

Land type: 14

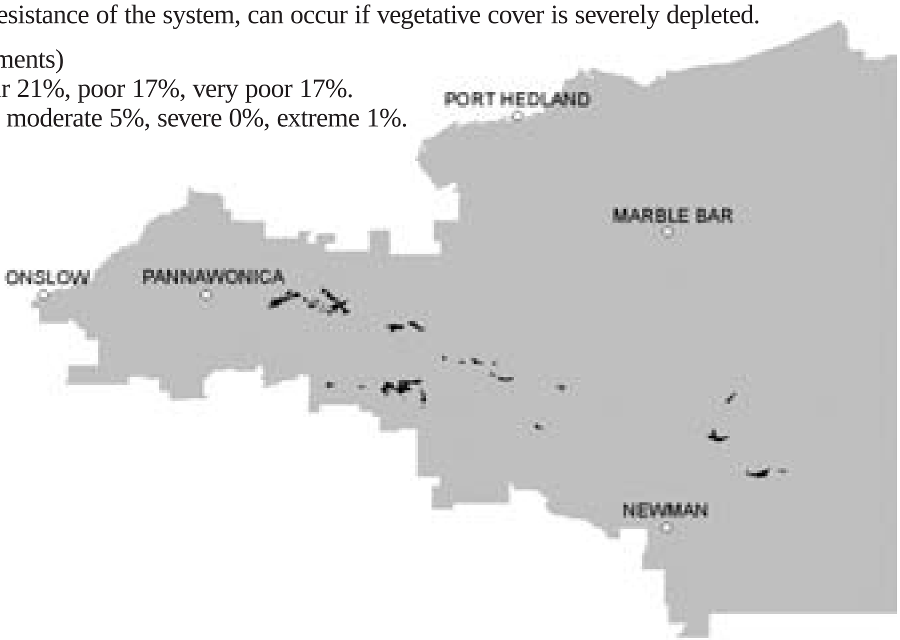
Geology: Quaternary alluvium.

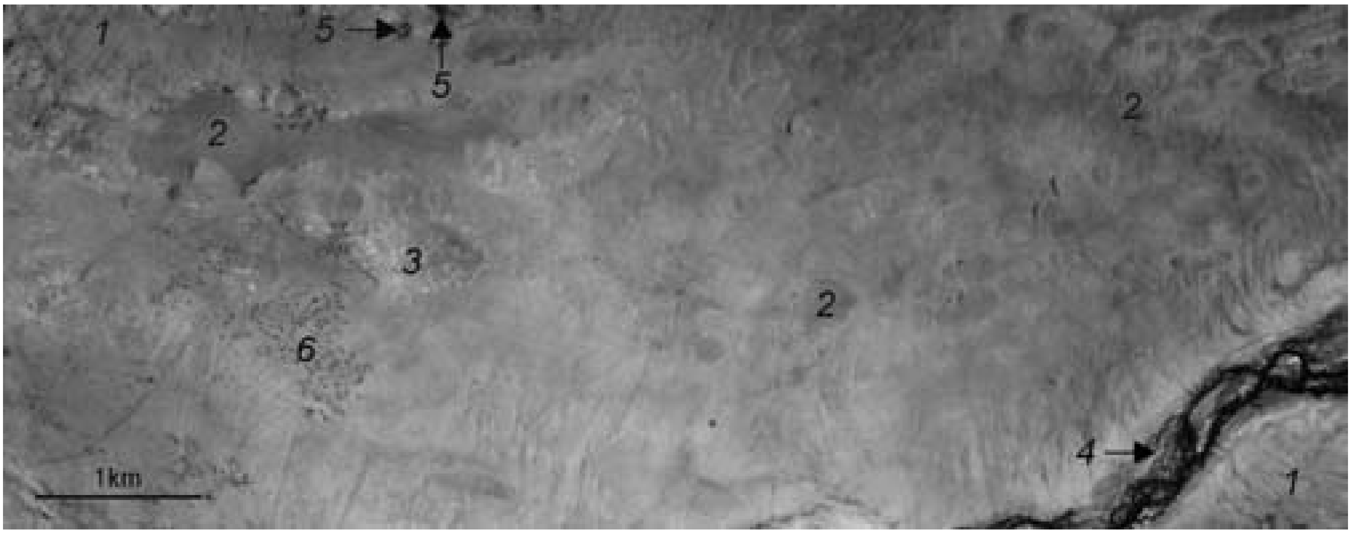
Geomorphology: Depositional surfaces; level, non-saline alluvial plains with clay soils and gilgai microrelief and flanked by slightly more elevated hardpan wash plains, sluggish internal drainage zones on plains and occasional through going trunk channels.

Land management: Tussock grasslands on this system are highly preferred by livestock and other animals and are susceptible to overgrazing and degradation. Overgrazing can be prevented by appropriate land management including control of total grazing pressure. Soil erosion, despite the inherent resistance of the system, can occur if vegetative cover is severely depleted.

Traverse condition summary: (149 assessments)
Vegetation - very good 19%, good 26%, fair 21%, poor 17%, very poor 17%.
Soil erosion - nil 89%, slight 2%, minor 3%, moderate 5%, severe 0%, extreme 1%.

Area mapped as sde: 442 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Hardpan plain	3	-
2.	Gilgai plain	124	11
3.	Stony plain	9	2
4.	Narrow drainage tract and channel	8	-
5.	Grove	-	1
6.	Swamp	1	1
	Other	4	-
	Total	149	15

Brockman land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	10%	**Hardpan plains** - level plains, subject to sheet flow, on outer margins of system, mantles of variable density ironstone pebbles.	Red loamy earths (544).	Very scattered *Acacia aneura* (mulga) tall shrublands with low shrubs such as *Ptilotus obovatus* (cotton bush) (HPMS); occasionally sparse *Triodia* spp. (spinifex) in ground layer.
2.	75%	**Gilgai plains** - level plains with gilgai microrelief; surface mantles absent or present as few to many ironstone or calcrete pebbles and cobbles.	Self-mulching cracking clays (602) and some red/brown non-cracking clay (622).	Tussock grasslands of *Eragrostis xerophila* (Roebourne Plains grass) (ARPG); *Astrebla pectinata* (barley Mitchell grass) (APMG), *Themeda triandra* (kangaroo grass) (APKG) or mixtures including *Chrysopogon fallax* (ribbon grass) and *Eriachne benthamii* (swamp grass) (APXG).
3.	10%	**Stony plains** - level plains often as a slightly elevated mosaic within unit 2, surface mantles of abundant or very abundant ironstone pebbles and cobbles.	Red loamy earths (544) and deep red/brown non-cracking clays (622).	Hummock grasslands of *Triodia wiseana* (hard spinifex) with isolated *Acacia* spp. shrubs (PHSG). Occasionally *T. pungens* (soft spinifex).
4.	3%	**Narrow drainage tracts and channels** - narrow (mostly <200 m wide) drainage tracts and river terraces subject to flooding from central channels; channels up to 50 m wide and incised to 3 m.	Self-mulching cracking clays (602).	Tussock grasslands of *E. xerophila* and other perennial grasses (APXG), or scattered tall shrublands *Acacia* spp. with understorey of perennial grasses (DEGW). Larger creeklines with fringing woodlands of *Eucalyptus camaldulensis* (river red gum), *E. victrix* (coolibah), *Acacia coriacea* (river jam) and *A. citrinoviridis* (black mulga).
5.	1%	**Groves** - drainage foci occurring on unit 1; up to 50 m long x 20 m wide but commonly smaller, gilgai microrelief.	Deep red/brown non-cracking clays (622).	Moderately close to close tall shrublands/woodlands of *Acacia aneura* with patchy understorey of low shrubs and tussock grasses such as *Chrysopogon fallax* (GMGW).
6.	1%	**Swamps** - slight depressions up to 500 m in extent occurring within unit 2.	Deep red/brown non-cracking clays (622).	Scattered low woodlands of *Eucalyptus victrix* with ground layers of tussock grasses such as *Eriachne benthamii* (DEGW).

BUCKSHOT LAND SYSTEM (2,780 km^2, 1.5% of the survey area)

Gravelly sandplains and occasional sand dunes supporting hard spinifex grasslands.

Land type: 11

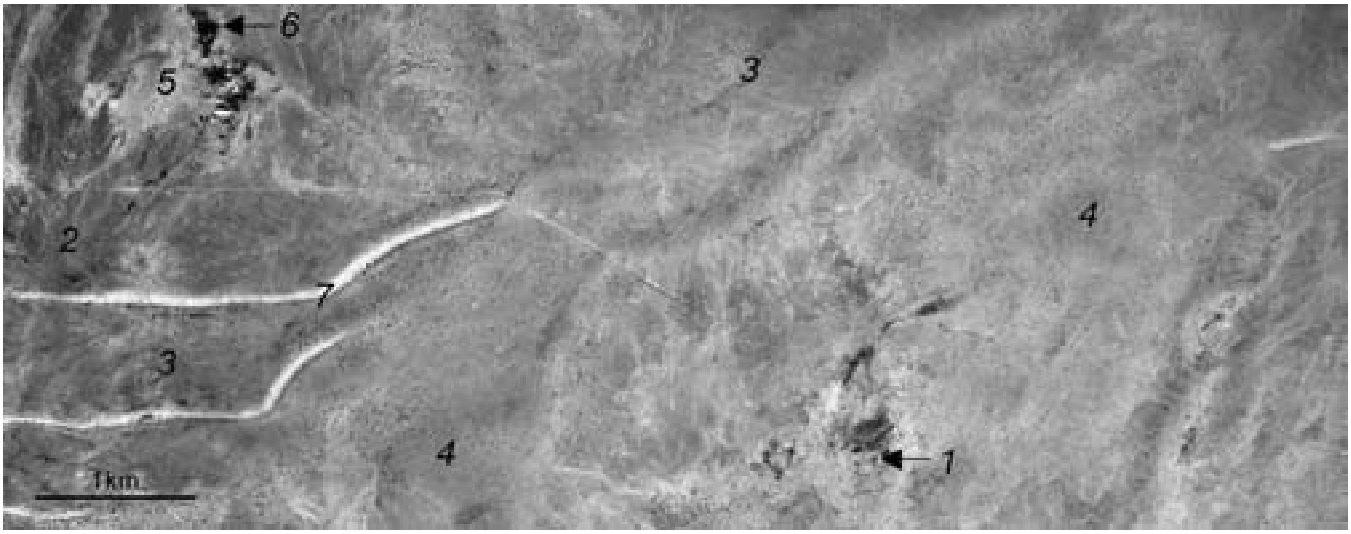
Geology: Quaternary sand and gravel, Tertiary laterite.

Geomorphology: Depositional surfaces; level to gently undulating gravel plains and gravelly sand plains with occasional low hills and rounded rises on laterite and linear sand dunes; no organised drainage patterns. Relief up to 15 m.

Land management: Hard spinifex grasslands are not preferred by livestock nor prone to degradation. They may be subject to fairly frequent burning, but recover rapidly after rain; generally low erosion hazard although minor susceptibility to water erosion if gravel surface mantles are removed along slopes.

Traverse condition summary: (91 assessments)
Vegetation - very good 97%, good 1%, fair 1%, poor 1%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Low hill	-	-
2.	Low rise	3	1
3.	Stony/gravelly plain	27	2
4.	Gravelly sandplain	56	2
5.	Hardpan plain	4	-
6.	Grove	-	1
7.	Sand dune	-	-
	Other	1	1
	Total	91	7

Buckshot land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	<1%	**Low hills** - isolated low hills and rock piles of sandstone or ferruginised sandstone up to 500 m in extent and 15 m relief; surface mantles of abundant pebbles and cobbles.	Stony soils (203) or shallow gravel soils (304).	Sparse hummock grasses, *Triodia* spp. (hard spinifex) and isolated shrubs (HSPG).
2.	3%	**Low rises** - undulating plains and rises with level crests and gentle side slopes, relief up to 10 m; surface mantles of abundant lateritic gravels.	Shallow gravel soils (304) or red shallow loams (522).	Hummock grasslands of *Triodia lanigera* and other *T.* spp. (hard spinifex) with very scattered mixed low and mid height shrubs (PHSG).
3.	30%	**Stony/gravelly plains** - very gently inclined plains with surface mantles of abundant pebbles of mixed lithology.	Red loamy earths (544).	Hummock grasslands of *T. lanigera* and other *T.* spp. (hard spinifex) with very scattered to scattered *Acacia* spp. and other mixed shrubs (PHSG).
4.	60%	**Gravelly sandplains** - very gently inclined sandplains extending up to 5 km, surface mantles of few to abundant ironstone gravels and grit.	Red deep sands (445) or red loamy earths (544).	Hummock grasslands of *T. wiseana* and other *T*. spp. (hard spinifex) with isolated to very scattered *Acacia ancistrocarpa* (shiny leaf wattle) and other acacias and other shrubs (SHSG).
5.	4%	**Hardpan plains** - level plains receiving run-on from units 2 and 3, usually some surface mantles of pebbles and grit.	Red deep sandy duplex soils (405) and red loamy earths (544).	Hummock grasslands with *T.* spp. (hard spinifex) and very scattered shrubs such as *A. aneura* (mulga) (PHSG) or very scattered tall shrublands *A. aneura* with low shrubs including *Senna* spp. (HPMS).
6.	<1%	**Groves** - prominent drainage foci up to 100 m in extent on unit 5.	Red loamy earths (544).	Moderately close to close tall shrublands of *A. aneura* with numerous low shrubs including *Eremophila latrobei* (warty fuchsia bush), *E. forrestii* (Wilcox bush) and *Senna* spp. (GMUW).
7.	2%	**Sand dunes** - linear and occasionally reticulate dunes up to 10 km long and 10 m high with uneven crests and moderately inclined side slopes.	Red deep sands (445).	Hummock grasslands with *Triodia schinzii, T. melvillei* (soft or hard spinifex) with scattered shrubs including *Grevillea* and *Acacia* spp. and occasional tree of *Corymbia chippendalei* (sand dune bloodwood) (SSSG, SHSG).

CADGIE LAND SYSTEM (495 km^2, 0.3% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Hardpan plains with thin sand cover and sandy banks supporting mulga shrublands with soft and hard spinifex.

Land type: 12

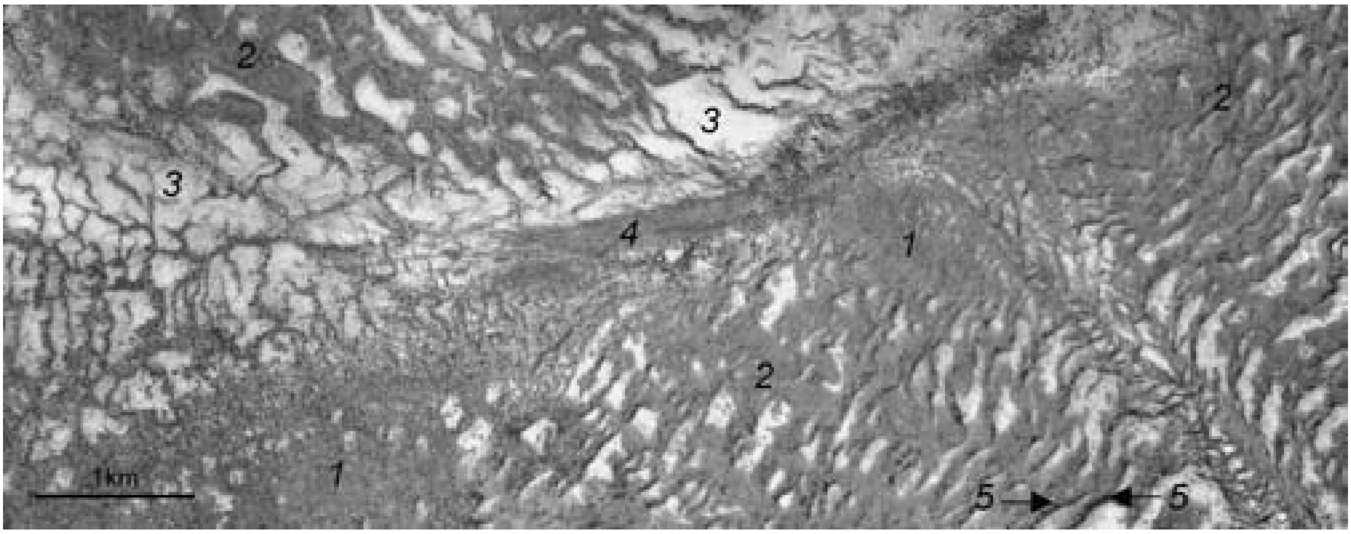
Geology: Tertiary cemented colluvium and alluvium.

Geomorphology: Depositional surfaces; almost level, non-saline alluvial plains with hardpan at shallow depth, surfaces with thin sand cover, washplains subject to sheet flow interspersed with low sandy banks; minor drainage tracts subject to more concentrated through flow, usually unchannelled but occasionally with shallow incision into hardpan. Relief up to 5 m.

Land management: Soft spinifex grasslands are moderately attractive to grazing animals but are not generally prone to degradation; low erosion hazard.

Traverse condition summary: (24 assessments)
Vegetation - very good 46%, good 54%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Plain with thin sand cover	8	-
2.	Sandy bank	11	1
3.	Hardpan plain	5	1
4.	Tract subject to more concentrated flow	-	-
5.	Grove	-	-
	Total	24	2

Cadgie land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	30%	**Plains with thin sand cover** - level or very gently inclined plains up to 3 km by 2 km but commonly smaller, occasionally with surface mantle of few small pebbles and grit of quartz.	Red shallow sands (423) over hardpan.	Very scattered to scattered *Acacia aneura* (mulga) tall shrublands with low shrubs such as *Ptilotus obovatus* (cotton bush), also *Triodia pungens* (soft spinifex) and *T.* spp. (hard spinifex) (HPMS, PMSS).
2.	42%	**Sandy banks** - banks and minor sand sheets up to 1 km long by 500 m wide forming reticulate patterns more or less at right angles to sheet flow, loose surfaces elevated up to 0.5 m above adjacent interbank hardpan plains (unit 3).	Red deep sands (445).	Scattered to moderately close tall shrublands with *A. aneura, A. sclerosperma* (limestone wattle) and other acacias with diverse mid height and low shrubs including *Eremophila* and *Senna* spp., *Triodia* spp. (soft and hard spinifex) ground layer (SBAS).
3.	25%	**Hardpan plains** - level plains between sandy banks, occasionally with surface mantles of common quartz pebbles and hardpan exposures.	Red-brown hardpan shallow loams (523).	Very scattered *A. aneura* tall shrublands and sparse low shrubs commonly *Ptilotus* and *Eremophila* spp. (HPMS).
4.	2%	**Tracts subject to more concentrated flow** - level tracts usually <500 m wide, sealed surfaces and shallow runnels, occasional channels incised up to 1 m in hardpan.	Red-brown hardpan shallow loams (523).	As for unit 3 (HPMS).
5.	1%	**Groves** - arcuate drainage foci usually less than 200 m long and 20 m wide occurring on unit 3.	Red loamy earths (544).	Moderately close *A. aneura* tall shrublands with undershrubs and occasional grasses (GMUW).

CALCRETE LAND SYSTEM (1,444 km^2, 0.8% of the survey area)

(modified from Payne and Tille 1992)

Low calcrete platforms and plains supporting shrubby hard spinifex grasslands.

Land type: 18

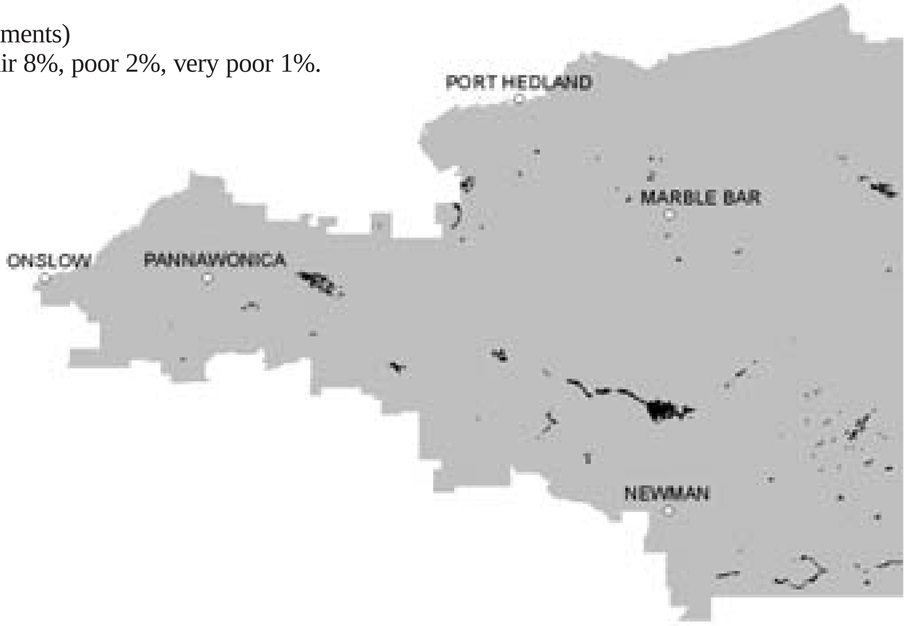
Geology: Tertiary calcrete, minor Quaternary alluvium.

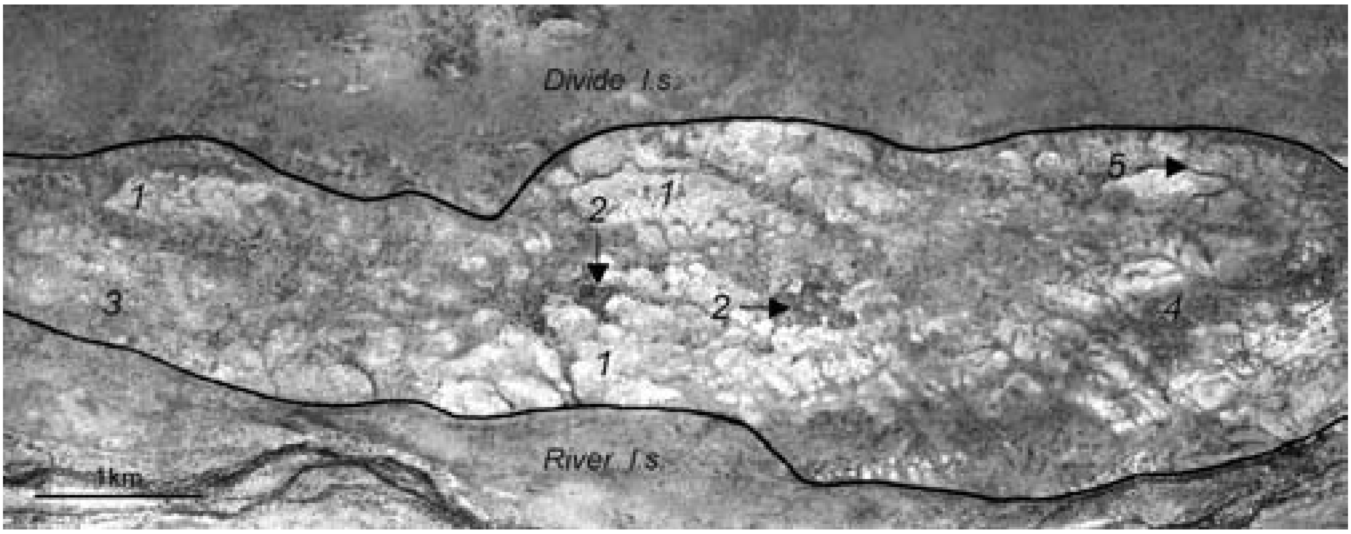
Geomorphology: Depositional surfaces; valley fill deposits - stony plains as a mosaic of calcrete tables and low rises elevated up to 10 m above the surrounding surfaces of narrow inter-table drainage areas and restricted sandy plains; drainage patterns absent to sparse tributary tracts and occasional through going trunk channels.

Land management: Some shrubs and grasses associated with the spinifex grasslands of this system are attractive to grazing animals and may be depleted if grazing levels are excessive. Low erosion risk.

Traverse condition summary: (177 assessments)
Vegetation - very good 72%, good 17%, fair 8%, poor 2%, very poor 1%.
Soil erosion - nil 99%, minor 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Calcrete plain, platform, low rise	122	9
2.	Drainage focus	2	-
3.	Sandy plain/sandplain	19	1
4.	Drainage tract	23	2
5.	Channel	-	-
	Other	11	-
	Total	177	12

Calcrete land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	80%	**Calcrete plains, platforms and low rises** - level to very gently inclined plains, slightly raised platforms and low rises up to 10 km in extent but usually much smaller; outcropping calcrete and surface mantles of many to abundant pebbles and cobbles of calcrete; relief up to 10 m but usually much less.	Calcareous shallow loams (521) with minor calcareous loamy earths (542) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana, T. plurinervata* (hard spinifex) or, less frequently, *T. pungens* (soft spinifex) with *Acacia bivenosa* (two vein wattle) and other acacia shrubs and occasional trees *Corymbia hamersleyana* (Hamersley bloodwood) (CASG).
2.	1%	**Drainage foci** - (i) Small (<30 m in diameter) depressions and minor sink holes on calcrete platforms (unit 1), surfaces with calcrete cobbles and stones.	Red loamy earths (544).	Similar to unit 1, some additional grasses and/or low shrubs (CASG).
		(ii) foci and swamps up to 250 m in extent occurring within units 1 and 3, sometimes with gilgai microrelief.	Deep red/brown non-cracking clays (622) and self-mulching cracking clays (602).	Scattered to moderately close tall shrublands/woodlands with *Acacia aneura* (mulga) or *Eucalyptus victrix* (coolibah), sparse variable undershrubs and grasses such as *Eriachne benthamii* (swamp grass) (DEAW).
3.	9%	**Sandy plains/sandplains** - level plains with sandy surfaces and sand sheets up to 500 m in extent.	Red deep sands (445) and red sandy earths (463).	Hummock grasslands of *Triodia.* spp. (hard spinifex) with scattered *Acacia* spp. shrubs (SHSG, PHSG).
4.	8%	**Drainage tracts** - almost level, channelled or unchannelled floors, inter-platform areas and alluvial plains up to 400 m wide; mantles of very few to common calcrete pebbles.	Self-mulching cracking clays (602) and calcareous loamy earths (542).	Variable scattered to moderately close shrublands with numerous *Acacia* spp. occasional eucalypts, *Hakea suberea* (corkwood) and scattered hummock and tussock grasses (DEGW, DESG).
5.	2%	**Channels** - minor creeklines and channels usually <50 m wide.	River bed soils (705).	Scattered to moderately close tall shrublands with *Corymbia hamersleyana* (Hamersley bloodwood), *Acacia holosericea* (candelbra wattle), *A. trachycarpa, A. tumida* (pindan wattle) and *Triodia pungens* (DAHW).

CALLAWA LAND SYSTEM (1,003 km^2, 0.6% of the survey area)

Highly dissected low hills, mesas and gravelly plains of sandstone and conglomerate supporting soft and hard spinifex grasslands.

Land type: 3

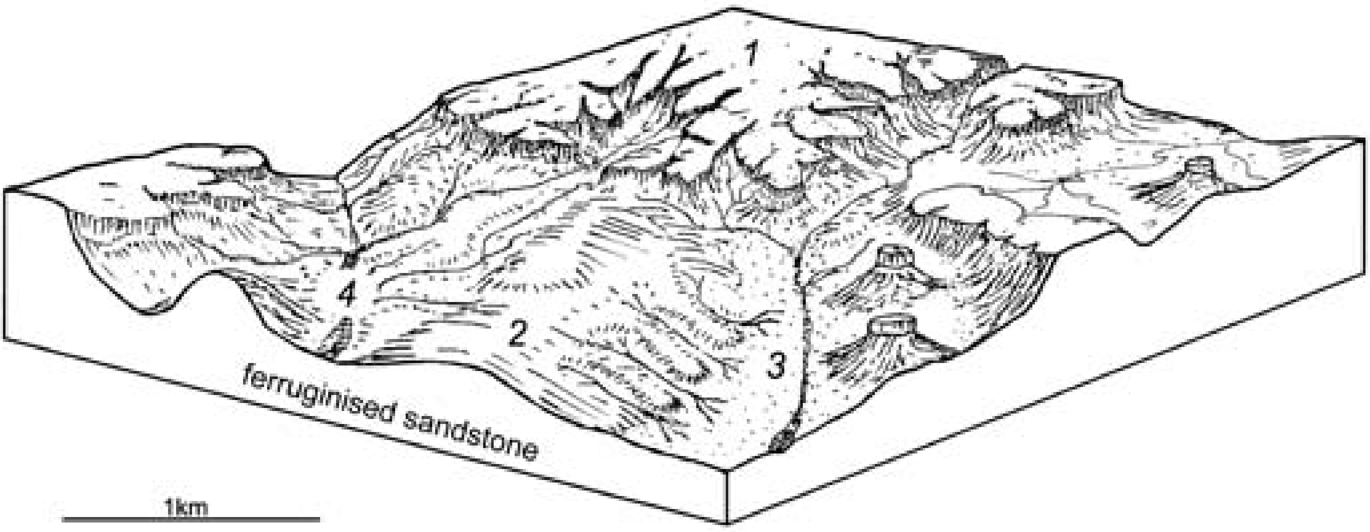
Geology: Jurassic sandstone, conglomerate and mudstone, Tertiary ferruginous duricrust.

Geomorphology: Erosional surfaces; low hills, mesas, plateaux remnants, hill spurs and slopes dissected by short, closely spaced tributary and distributing drainage lines; also rounded gravelly plains and minor sandplain. Relief up to 60 m.

Land management: Soft spinifex vegetation is moderately preferred by grazing animals for a few years following burning; hard spinifex is unattractive. The system is not prone to degradation or erosion and is subject to fairly regular burning.

Traverse condition summary: (19 assessments)
Vegetation - very good 95%, good 5%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Hill, mesa and plateau	6	2
2.	Gravelly rise and plain	5	1
3.	Sand sheet	8	-
4.	Drainage line	-	-
	Total	19	3

Callawa land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	65%	**Hills, mesas and plateaux** - rounded hills with gently to moderately inclined slopes and hill spurs; mesas and plateaux remnants with level crests and near vertical scarp faces and more gently inclined lower slopes dissected by numerous small creeklines, surface mantles of very abundant sandstone pebbles and rocks. Relief up to 60 m.	Stony soils (203) and red shallow loams (522).	Hummock grasslands of *Triodia pungens* (soft spinifex) or *T.* spp. (hard spinifex) (PHSG).
2.	20%	**Gravelly rises and plains** - gently undulating rises and plains with surface mantles of very abundant sandstone and ironstone gravels.	Red shallow loams (522).	Hummock grasslands of *T. pungens, T. epactia* (soft spinifex) with isolated acacia shrubs (PSSG).
3.	10%	**Sand sheets** - small (generally less than 250 m in extent) sandplains between units 1 and 2.	Red deep sands (445) and red sandy earths (463).	Hummock grasslands of *T. pungens, T. epactia* with very scattered to scattered acacia shrubs (SSSG).
4.	5%	**Drainage lines** - drainage lines, narrow (5-10 m wide) and finely dendritic in upper parts, incised 1-10 m with rounded side slopes to adjacent interfluves and hill slopes, becoming broader downslope.	Red shallow sandy duplex soils (406).	Moderately close tall shrublands of *Acacia monticola*, *A. tumida* (pindan wattle), *A. holosericea* (candelbra wattle) with spinifex understorey (DAHW).

CANE LAND SYSTEM (812 km^2, 0.4% of the survey area)

Alluvial plains and flood plains supporting snakewood shrublands, soft and hard spinifex grasslands and tussock grasslands.

Land type: 17

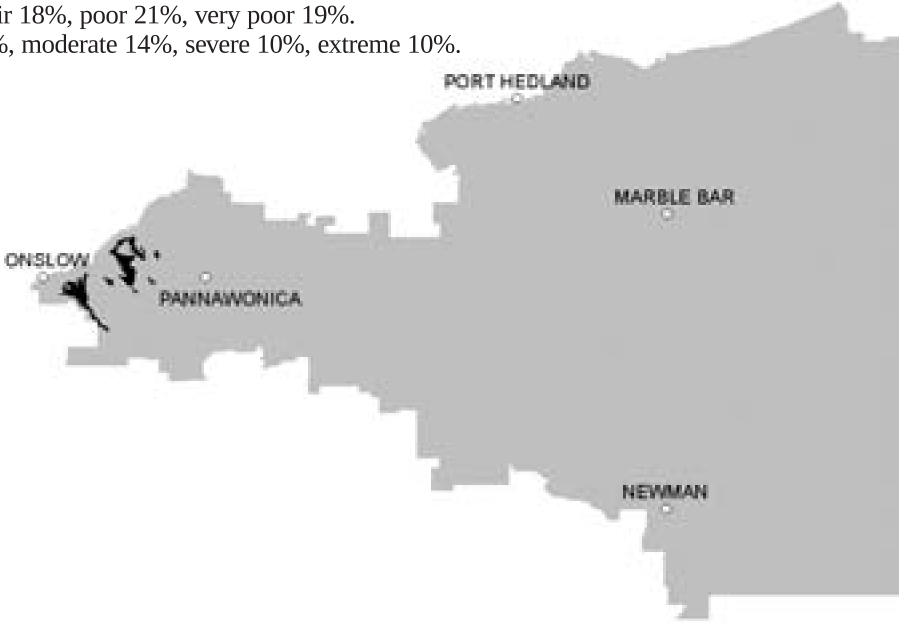
Geology: Quaternary alluvium.

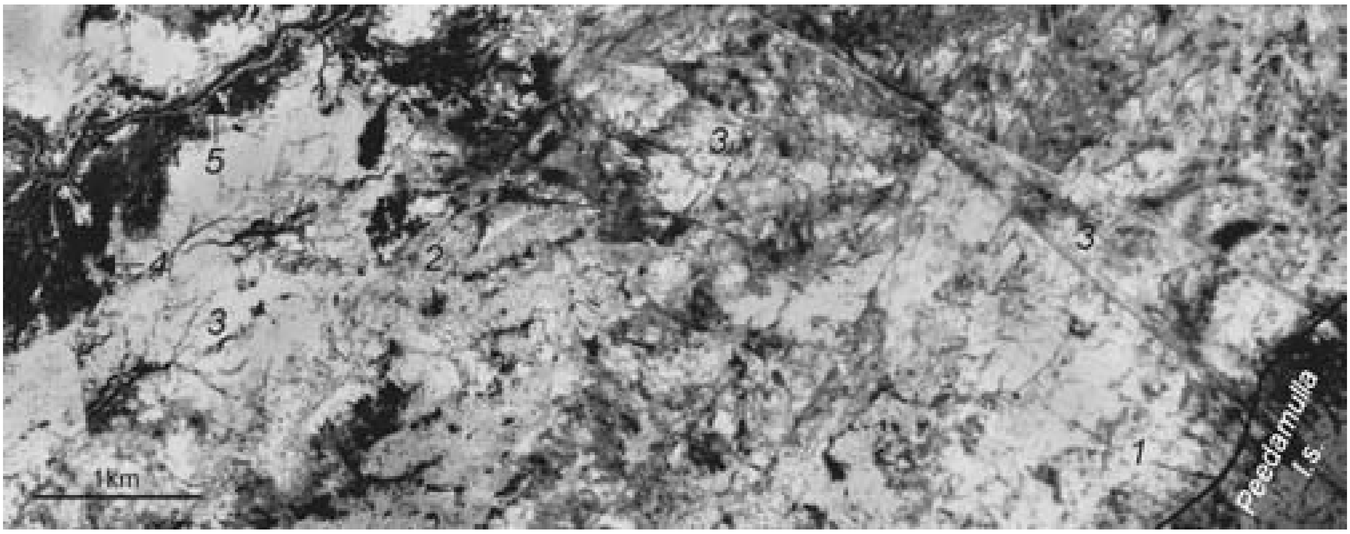
Geomorphology: Depositional surfaces; flood plains subject to fairly regular flooding and often with windblown scalds and hummocks and/or water erosion, slightly more elevated stony plains and plains with gilgai microrelief, tracts receiving more concentrated through flow; very widely spaced to sparse patterns of non tributary, distributing and reticulated channels and larger through going trunk channels.

Land management: Many of the plant communities on this system include shrub and grass species which are highly attractive to grazing animals and are prone to degradation if overgrazed. Flood plains (unit 3) with duplex soils and gilgai plains with few surface mantles (unit 2) are highly susceptible to erosion if vegetation cover is depleted.

Traverse condition summary: (129 assessments)
Vegetation - very good 26%, good 16%, fair 18%, poor 21%, very poor 19%.
Soil erosion - nil 45%, slight 5%, minor 16%, moderate 14%, severe 10%, extreme 10%.

Area mapped as sde: 5,768 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Loamy plain	8	1
2.	Stony plain and stony gilgai plain	36	2
3.	Flood plain	75	7
4.	Tract receiving more concentrated flow	8	2
5.	Channel	2	-
	Total	129	12

Cane land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	5%	**Loamy plains** - level plains usually on outer margins of system and slightly more elevated than other units, loamy surfaces sometimes with mantles of few to common ironstone gravel.	Red loamy earths (544).	Hummock grasslands of *Triodia lanigera* (hard spinifex) with *Acacia* spp. shrubs (PHSG).
2.	28%	**Stony plains and stony gilgai plains** - level to very gently inclined plains extending up to 2-3 km as a mosaic of stony surfaces and smaller areas of stony gilgai surfaces; mantles vary from few to very abundant pebbles and cobbles.	Red deep loamy duplex soils (506) and self-mulching cracking clays (602).	Scattered tall or mid height shrublands of *Acacia xiphophylla* (snakewood) with patchy tussock grasses particularly *Eragrostis xerophila* (Roebourne Plains grass) (SSTS). Also tussocks grasslands of *E. xerophila* (ARPG).
3.	55%	**Flood plains** - level plains extending up to 4-5 km, subject to sheet flow and occasional overbank flooding. Surfaces often scalded, guttered and hummocked, surface mantles absent or few.	Deep red/brown non-cracking clays (622) and red loamy earths (544).	Hummock grasslands of *Triodia pungens* (soft spinifex (ASSG), less frequently *T. lanigera* (hard spinifex) (AHSG). Also scattered mid height *A. xiphophylla* shrublands with understoreys of spinifex (ASHS) or *Atriplex* spp. (saltbush) (PSCS).
4.	10%	**Tracts receiving more concentrated flow** - drainage tracts up to 1 km wide on flood plains (unit 3) receiving more concentrated through flow than adjacent surfaces, often with gutters and channels.	Deep red/brown non-cracking clays (622) and red loamy earths (544).	Scattered to moderately close woodlands of *Eucalyptus victrix* (coolibah) or *Acacia* spp. with grass understoreys including *Chrysopogon fallax* (ribbon grass) and *Eriachne benthamii* (swamp grass) (DEGW).
5.	2%	**Channels** - channels up to 300 m wide on flood plains and tracts receiving more concentrated flow (units 3 and 4).	River bed soils (705).	Banks, terraces and levees with scattered to moderately close grassy woodlands including *E. victrix, E. camaldulensis* (river red gum) and *Melaleuca* spp. (paperbark) (GMEW).

CAPRICORN LAND SYSTEM (5,296 km^2, 2.9% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Hills and ridges of sandstone and dolomite supporting shrubby hard and soft spinifex grasslands.

Land type: 1

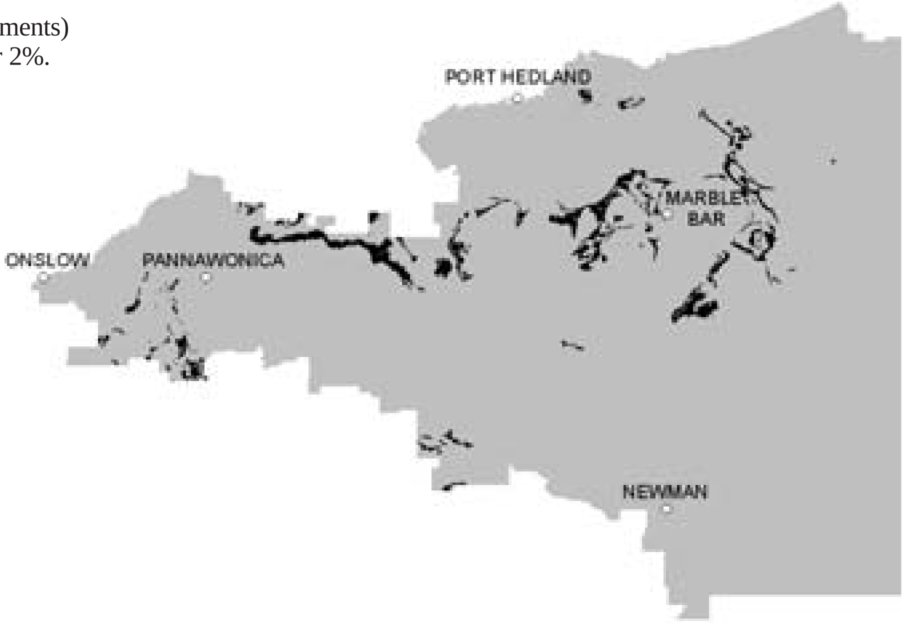
Geology: Lower Proterozoic sandstone, greywacke, dolomite and shale.

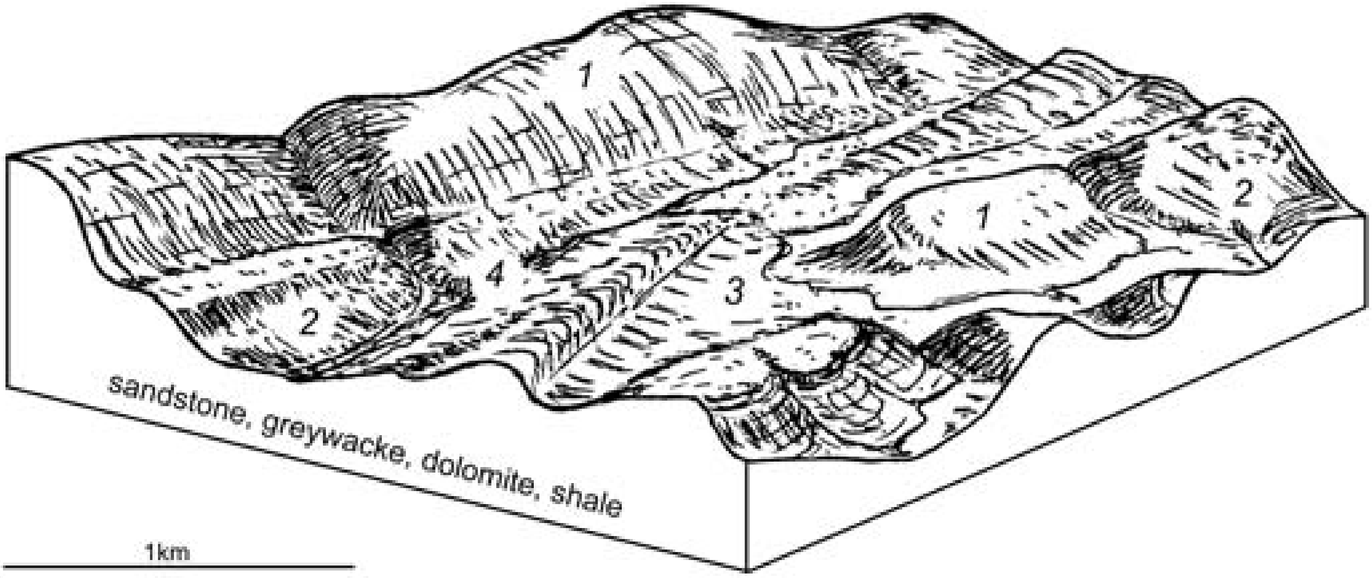
Geomorphology: Erosional surfaces; ranges and hills with steep rocky upper slopes, more gently sloping stony footslopes, restricted stony lower plains and valleys; moderately spaced tributary drainage patterns. Relief up to 180 m.

Land management: Rugged, poorly accessible country with vegetation which is not preferred by livestock; stoniness confers resistance to erosion.

Traverse condition summary: (138 assessments)
Vegetation - very good 94%, good 4%, fair 2%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Ridge, hill and upper slope	13	9
2.	Lower footslope	41	2
3.	Stony plain	46	4
4.	Narrow drainage floor and channel	34	1
	Other	4	-
	Total	138	16

Capricorn land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	70%	**Ridges, hills and upper slopes** - rocky summits and hills and ridges extending for many kilometres with moderately inclined to very steep upper slopes and surface mantles of abundant to very abundant pebbles, cobbles and stones, frequent exposures of bedrock; relief up to 150 m.	Stony soils (203).	Hummock grasslands of *Triodia wiseana, T. brizoides* (hard spinifex) or *T. pungens* (soft spinifex) with scattered *Acacia inaequilatera* (kanji) and other *Acacia* spp. and *Grevillea wickhamii* (Wickham's grevillea) (HSPG).
2.	20%	**Lower footslopes** - very gently to gently inclined concave or benched lower slopes below hills, mantles of abundant pebbles and cobbles and exposures of bedrock.	Red shallow loams (522).	As for unit 1 (HSPG).
3.	5%	**Stony plains** - gently undulating to undulating plains and interfluves extending for up to 1 km below hills and hill slopes, mantles of abundant pebbles and cobbles.	Red shallow sands (423) and red shallow loams (522).	Hummock grasslands of *T. wiseana* or *T. pungens* with scattered *Acacia* spp. shrubs (PHSG, PSSG).
4.	5%	**Narrow drainage floors and channels** - drainage floors usually less than 200 m wide with channels incised in bedrock in upper parts and up to 50 m wide in lower parts.	River bed soils (705).	Scattered tall shrublands or low woodlands with *Acacia* spp., *Corymbia hamersleyana* (Hamersley bloodwood), numerous other shrubs and soft spinifex (DAHW, DESG).

CHARLEY LAND SYSTEM (218 km^2, 0.1% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Dolerite hills and ridges and restricted plains supporting mulga and cassia shrublands and spinifex grasslands.

Land type: 2

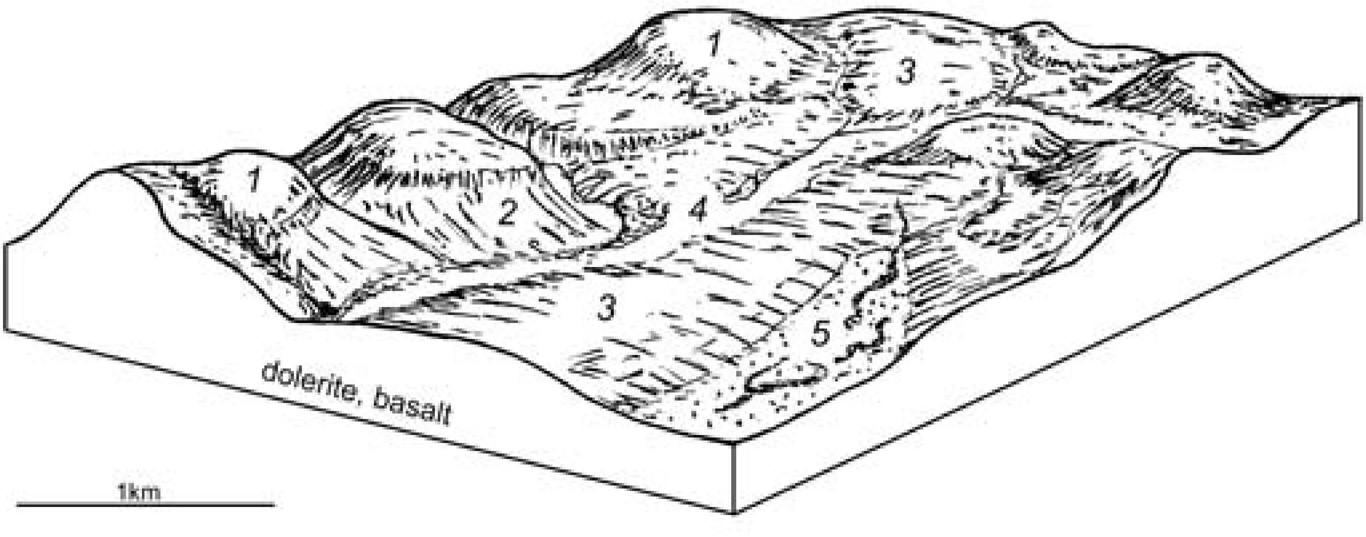
Geology: Proterozoic dolerite and basalt.

Geomorphology: Erosional surfaces; hills and ridges with steep upper slopes and more gently inclined lower footslopes, restricted areas of gently undulating lower plains and nearly flat plains; moderately spaced tributary drainage lines, sluggish internal drainage patterns on flat plains. Relief usually less than 50 m.

Land management: Drainage floors (unit 4) supports tussock grasses and shrubs which are attractive to livestock and can become degraded if grazing pressure is excessive. Most of the system is inherently resistant to erosion.

Traverse condition summary: (12 assessments)
Vegetation - very good 25%, good 42%, fair 33%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Hill and ridge	-	2
2.	Lower footslope	-	1
3.	Low rise and plain	10	3
4.	Drainage floor and channel	1	-
5.	Gilgai plain	1	-
	Total	12	6

Charley land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	60%	**Hills and ridges** - rounded stony summits and crests, steep upper slopes with mantles of abundant dolerite pebbles and cobbles; relief usually less than 50 m.	Red shallow loams (522).	Hummock grasslands of *Triodia wiseana* (hard spinifex) with isolated to very scattered low shrubs such as *Senna* spp. (HSPG). Also shrublands of *Acacia aneura* (mulga) and other acacias with sparse low shrubs *Senna* spp.
2.	15%	**Lower footslopes** - very gently inclined to gently inclined slopes extending up to 500 m downslope from unit 1, mantles of abundant dolerite pebbles and cobbles.	Red sandy earths (463) and red loamy earths (544).	Scattered to moderately close mixed height grassy shrublands with *Acacia aneura* (mulga), other acacias and *Senna* spp. (PAGS).
3.	20%	**Low rises and plains** - gently undulating plains up to 3 km in extent with mantles of sparse dolerite and other pebbles.	Calcareous loamy earths (542) and calcareous shallow loams (521).	Scattered to moderately close low or mid height grassy shrublands with *Senna* and *Acacia* spp. (PAGS).
4.	3%	**Drainage floors and channels** - almost level floors up to 300 m wide with channels 5-25 m wide and incised to 1 m.	Calcareous loamy earths (542), calcareous shallow loams (521) and river bed soils (705).	Moderately close tall shrublands of *A. aneura* and other acacias with grassy low shrub understorey (DEAW).
5.	2%	**Gilgai plains** - level, plains up to 1 km in extent with gilgai microrelief and ill defined sluggish internal drainage, patches of dolerite pebbles and cobbles.	Self-mulching cracking clays (602) and red/brown non-cracking clays (622).	Tussock grasslands mostly *Eragrostis xerophila* (Roebourne Plains grass) and isolated low shrubs such as *Eremophila maculata* (fuchsia bush) (ARPG).

CHEERAWARRA LAND SYSTEM (197 km^2, 0.1% of the survey area)

(modified from Payne and Tille 1992)

Sandy coastal plains and saline clay plains supporting soft and hard spinifex grasslands and minor tussock grasslands.

Land type: 19

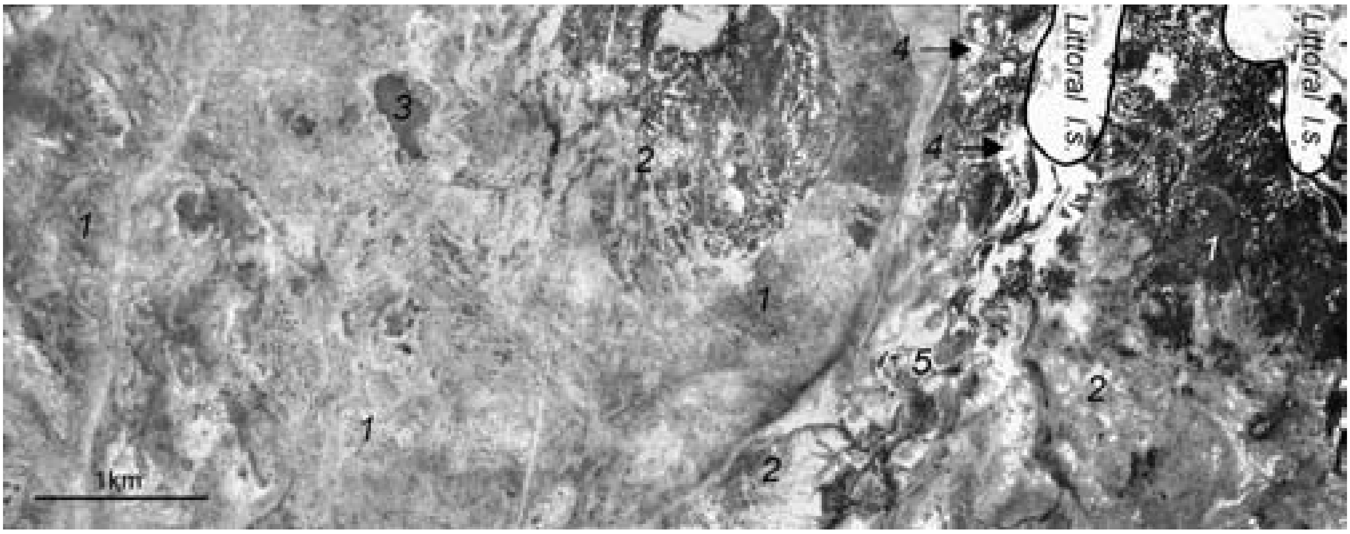
Geology: Quaternary eolian sand and alluvium.

Geomorphology: Depositional surfaces; gently undulating, sandy surfaced coastal plains and level plains with saline clay soils and bare saline scalds with wind hummocks; very rare distributary drainage lines.

Land management: Most units of the system are highly susceptible to wind erosion if vegetative cover is depleted.

Traverse condition summary: (29 assessments)
Vegetation - very good 34%, good 34%; fair 14%; poor 14%, very poor 4%.
Soil erosion - nil 90%; minor 3%; moderate 7%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Sandplain	15	1
2.	Sandy surfaced alluvial plain	11	2
3.	Saline clay plain	2	1
4.	Saline scald and sand hummock	-	-
5.	Drainage tract	1	-
	Total	29	4

Cheerawarra land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	52%	**Sandplains** - level to gently undulating plains extending up to 4 km with uneven, slightly moundy surfaces.	Red sandy earths (463) and some calcareous loamy earths (542).	Hummock grasslands of *T. pungens, T. epactia* with isolated low shrubs (SSSG). Less frequently *T.* sp. (hard spinifex) (SHSG).
2.	30%	**Sandy surfaced alluvial plains** - level plains extending up to several km, sandy veneers over more clayey soils, local mounding and occasional scalding.	Red deep sandy duplex soils (405) and deep red/brown non-cracking clays (622).	Hummock grasslands of *T. secunda, T. longiceps* (hard spinifex) with isolated low shrubs (AHSG).
3.	10%	**Saline clay plains** - level plains with weakly gilgaied microrelief in patches, often scalded.	Deep red/brown non-cracking clays (622).	Patchy tussock grasslands mostly *Eragrostis xerophila* (Roebourne Plains grass) with occasional *Sclerolaena hostilis* (giant bindii) and other halophytes (ARPG).
4.	5%	**Saline scalds and sand hummocks** - flat saline scalds occurring on units 3 as discrete areas or more diffuse tracts up to 1 km in extent, weakly crusted 'puffy' surfaces with few to common mantles of pebbles; scalds often with sand hummocks with relief up to 2 m above scald.	Scalds of deep saline red/brown non-calcareous clays (622) and hummocks of red deep sands (445).	Much bare ground. A few patches of *E. xerophila* tussocks, elsewhere sparse cover of halophytic annuals including *Sclerolaena* and *Trianthema* spp. Sand hummocks support *Triodia pungens*.
5.	3%	**Drainage tracts** - diffuse drainage tracts within units 2 and 3 mostly 20-50 m wide but becoming wider near Littoral land system; hummocky margins with flatter channelled or unchannelled floors.	Red deep sandy duplex soils (405) and deep red/brown non-cracking clays (622).	Dense tussock grasslands of *Eragrostis xerophila, Eriachne benthamii* (swamp grass) and *Chrysopogon fallax* (ribbon grass), occasional acacia shrubs along channels (APXG, DEGW). More saline sites support sparse halophytic low shrublands of *Halosarcia* spp. (samphire) and *Frankenia* sp. (frankenia) (PSPS).

CHRISTMAS LAND SYSTEM (232 km^2, 0.1% of the survey area)

Stony alluvial plains supporting snakewood and mulga shrublands with sparse tussock grasses.

Land type: 15

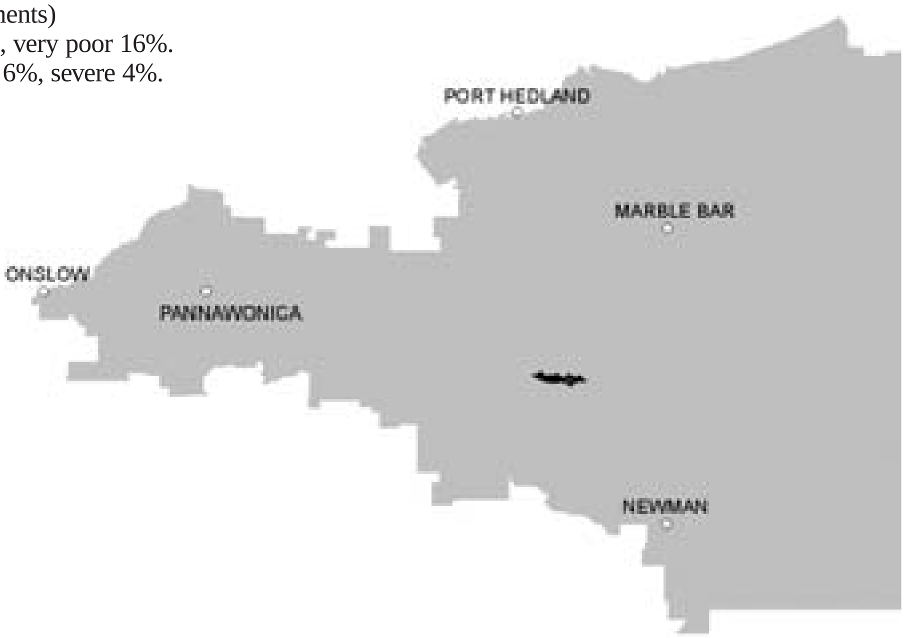
Geology: Quaternary alluvium and colluvium.

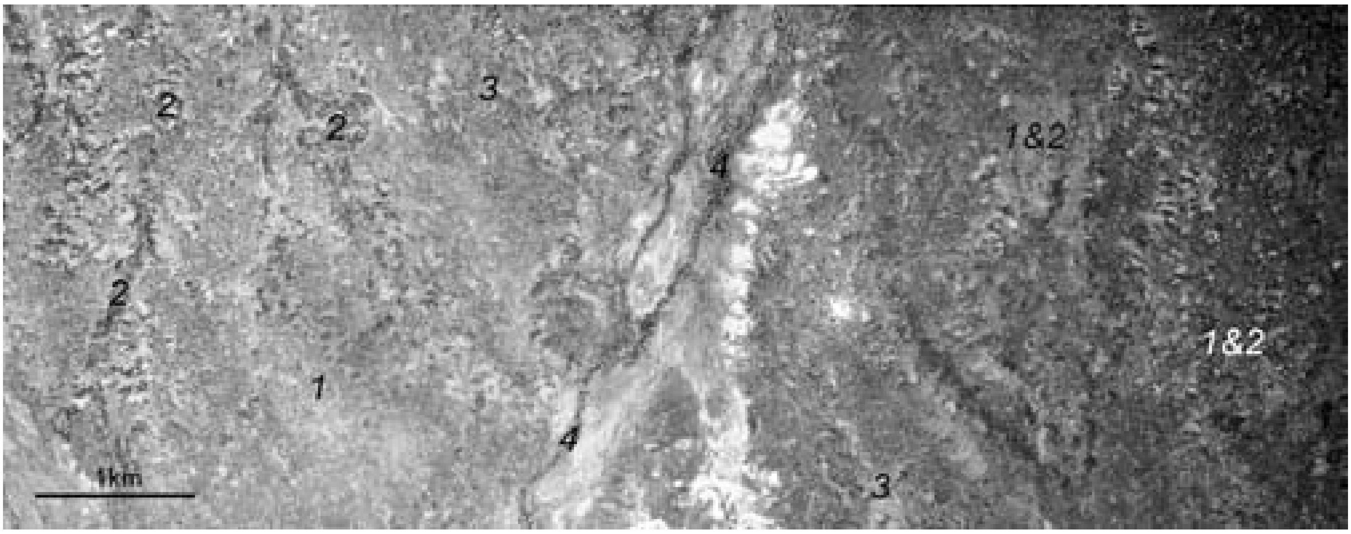
Geomorphology: Depositional surfaces; level to gently inclined stony plains subject to sheet flow with numerous small, diffuse drainage foci and groves, stony clay plains with gilgai microrelief; sparse or rare drainage tracts with tributary, distributary and reticulated channels.

Land management: The system supports low shrubs and tussock grasses which are preferred by grazing animals and is susceptible to vegetation degradation if grazing pressure is excessive. Drainage tracts (unit 4) are moderately to highly susceptible to erosion; other units are generally resistant.

Traverse condition summary: (49 assessments)
Vegetation - good 6%, fair 27%, poor 51%, very poor 16%.
Soil erosion - nil 86%, minor 4%, moderate 6%, severe 4%.

Area mapped as sde: 1,238 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Stony alluvial plain	21	-
2.	Grove and drainage focus	10	-
3.	Stony gilgai plain	10	-
4.	Drainage tract	8	-
	Total	49	-

Christmas land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	50%	**Stony alluvial plains** - level to gently inclined plains extending for up to 5 km, subject to sheet flow, surface mantles of abundant to very abundant pebbles and cobbles of ironstone and other rocks; occasional small patches with gilgai microrelief.	Red deep loamy duplex soils (506), deep red/brown non-cracking clays (622) and small zones of self-mulching cracking clays (602).	Scattered to moderately close tall shrublands of *Acacia xiphophylla* (snakewood) and *A. aneura* (mulga) with undershrubs *Senna* spp., *Enchylaena tomentosa* (ruby saltbush) and occasional tussock grasses such as *Eragrostis xerophila* (Roebourne Plains grass) (PSMS, PSCS, SSTS).
2.	20%	**Groves and drainage foci** - groves up to 150 m long by 50 m wide and diffuse foci 20-150 m in diameter, receiving run-on from adjacent plains (units 1 and 4); surface mantles of many to abundant pebbles of ironstone, gilgai microrelief.	Self-mulching cracking clays (602) and deep red/brown non-cracking clays (622).	Moderately close to close tall shrublands of *Acacia xiphophylla* or *A. aneura* with *Senna* spp. and other low shrubs and scattered tussock grasses (GMGW, GMUW).
3.	14%	**Stony gilgai plains** - level plains up to 600 m in extent, surface mantles of many to abundant pebbles of ironstone, gilgai microrelief.	Self-mulching cracking clays (602) and deep red/brown non-cracking clays (622).	Scattered tall shrublands of *Acacia xiphophylla* with *Eragrostis xerophila* tussock grasses (SSTS) or tussock grasslands of E. xerophila (ARPG).
4.	16%	**Drainage tracts** - level tracts up to 2.5 km wide as drainage corridors through stony alluvial plains (unit 1), surface mantles of few to abundant ironstone pebbles, some sealed and scalded surfaces; central anastomosing channels.	Deep red/brown non-cracking clays (622).	Very scattered to scattered tall shrublands of *Acacia xiphophylla* with sparse *Senna* spp. and chenopod low shrubs and occasional tussock grasses (PSCS).

COLLIER LAND SYSTEM (169 km^2, 0.1% of the survey area)

(after Payne, Mitchell and Holman 1988)

Undulating stony uplands, low hills and ridges and stony plains supporting mulga shrublands.

Land type: 7

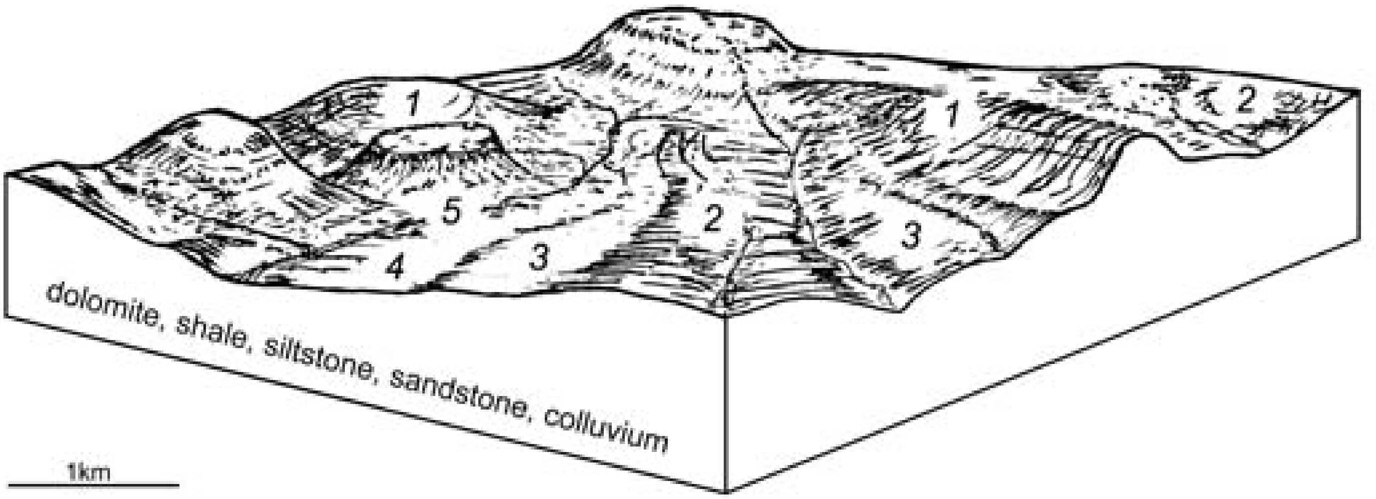
Geology: Middle Proterozoic dolomite, shale, siltstone, sandstone and chert and Quaternary colluvium.

Geomorphology: Erosional surfaces; undulating stony uplands, low hills and ridges with stony lower slopes and lower plains mostly non-saline but occasionally saline; restricted saline and non-saline drainage floors; widely spaced to very widely spaced tributary drainage floors and channels. Relief up to 50 m.

Land management: Drainage floors and lower plains (unit 4) with chenopod vegetation are preferentially grazed and prone to degradation. The system is inherently resistant to erosion although some erosion may occur on some drainage floors and lower plains (unit 4).

Traverse condition summary: (not traversed or sampled)
Vegetation - no records
Soil erosion - no records

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Low hill and ridge	-	-
2.	Undulating stony upland	-	-
3.	Stony plain	-	-
4.	Drainage floor and lower plain	-	-
5.	Channel and bank		
	Total	-	-

Collier land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	30%	**Low hills and ridges** - hill crests with steep convex and concave upper slopes, gently inclined lower slopes, outcrop and abundant mantles of stone, relief up to 50 m; isolated ridges up to 6 km long and 1 km wide with stony slopes and relief up to 25 m.	Stony soils (203) and red shallow loams (522) or red shallow sands (423).	Tall shrublands of *Acacia aneura* (mulga) (PSMS). Also some *Triodia wiseana* (hard spinifex) grasslands (HSPG).
2.	25%	**Undulating stony uplands** - elevated, almost level or gently rounded stony surfaces above units 3, 4 and 5, abundant surface mantles.	Red shallow loams (522).	Very scattered *A. aneura* and other *Acacia* spp. tall shrublands (PSMS).
3.	25%	**Stony plains** - very gently inclined plains and interfluves extending up to 3 km downslope, gently inclined slopes at margins where dissected up to 5 m by creeklines, abundant stony mantles.	Red/brown non-cracking clays (622) and calcareous loamy earths (542).	Very scattered to scattered tall shrublands of *A. aneura* and other *Acacia* spp. Some low shrublands of *Halosarcia* spp. (samphire) (PSMS, PSPS).
4.	15%	**Drainage floors and lower plains** - almost level saline and non-saline plains up to 1.5 km in extent, variable surface mantles.	Red loamy earths (544), red/brown non-cracking clays (622) and self-mulching cracking clays (602).	Scattered tall shrublands of *A. aneura* or *A. xiphophylla* (snakewood), ground storey often halophytic including *Atriplex bunburyana* (silver saltbush), *Maireana pyramidata* (sago bush) (PMCS), also *Triodia pungens* (soft spinifex).
5.	5%	**Channels and banks** - 10-20 m wide in upper parts with shallow incision into bedrock, major creeklines up to 100 m wide.	River bed soils (705).	Moderately close woodlands/tall shrublands of *A. aneura, A. kempeana* (witchetty bush) and other *Acacia* spp., numerous low shrubs and sparse perennial grasses (DEAW).

COOLIBAH LAND SYSTEM (1,014 km^2, 0.6% of the survey area)

(modified from Payne and Mitchell 1992)

Flood plains with weakly gilgaied clay soils supporting coolibah woodlands with tussock grass understorey.

Land type: 17

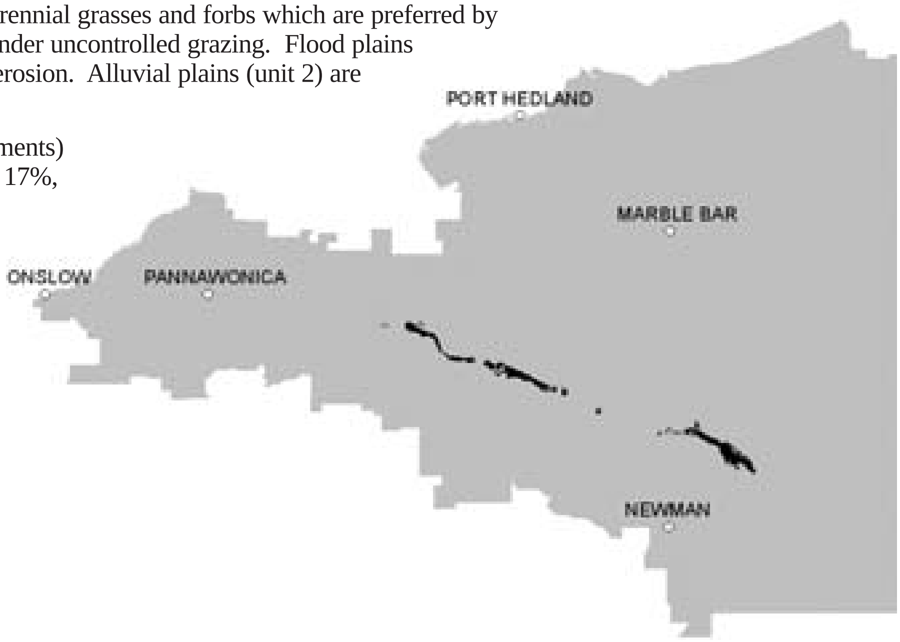
Geology: Quaternary alluvium, minor calcrete.

Geomorphology: Depositional surfaces; active flood plains and alluvial plains with shallow, meandering and anastomosing central channels of the Fortescue River.

Land management: Vegetation includes perennial grasses and forbs which are preferred by grazing animals and are prone to depletion under uncontrolled grazing. Flood plains (unit 1) generally have low susceptibility to erosion. Alluvial plains (unit 2) are highly susceptible to erosion.

Traverse condition summary: (182 assessments)
Vegetation - very good 9%, good 14%, fair 17%, poor 34%, very poor 26%.
Soil erosion - nil 72%, slight 5%, minor 6%, moderate 10%, severe 6%, extreme 1%.

Area mapped as sde: 2,582 ha.



No.	Unit name	Traverse recordings	Inventory sites
1.	Flood plain	45	3
2.	Alluvial plain	44	1
3.	Gilgai back plain	42	2
4.	Stony plain	16	-
5.	Calcrete platform	12	3
6.	Depression and drainage foci	17	3
7.	Channel, bank, minor river terrace	1	1
	Other	5	1
	Total	182	14

Coolibah land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	50%	**Flood plains** - level plains up to 4-5 km wide, subject to regular flooding, weakly gilgaied microrelief sometimes with surface mantles of few calcrete or ironstone pebbles and cobbles.	Deep red/brown non-cracking clays (622).	Moderately close woodlands of *Eucalyptus victrix* (coolibah) or *Acacia distans* with tussock grasses *Eragrostis xerophila* (Roebourne Plains grass), *Eriachne benthamii* (swamp grass), *Chrysopogon fallax* (ribbon grass) (DEGW).
2.	14%	**Alluvial plains** - level plains up to 3-4 km in extent and mostly on outer margins of system, sometimes with patchy mantles of ironstone gravel, subject to fairly regular flooding; frequently with numerous small claypans, sandy banks and scalded tracts.	Red deep loamy duplex soils (506) and deep red/brown non-cracking clays (622).	Very scattered and patchy tall shrublands with *Acacia aneura* (mulga), *A. victoriae* (prickly acacia), *A. xiphophylla* (snakewood) and patchy undershrubs *Senna* spp. and perennial grasses. Also very scattered low shrublands of mixed halophytic shrubs including *Atriplex bunburyana* (silver salt bush) (PXHS).
3.	16%	**Gilgai back plains** - level plains up to 2 km in extent subject to less regular flooding than units 1 and 2; gilgai microrelief sometimes with mantles of few to common pebbles and cobbles of calcrete.	Self-mulching cracking clays (602) and some red/brown non-cracking clay (622).	Tussock grasslands with *Astrebla* spp. (Mitchell grasses) *Eragrostis setifolia* (neverfail), *E. xerophila, Eriachne benthamii, Chrysopogon fallax* (APNG, APMG, APRG, ARPG).
4.	5%	**Stony plains** - level or gently rounded plains up to 1 km in extent and marginally higher than adjacent units 1 and 2; very abundant mantles of ironstone gravel.	Red loamy earths (544).	Often no perennial vegetation or isolated to very scattered shrublands with *Acacia xiphophylla, A. aneura* and occasional spinifex (PMSS).
5.	3%	**Calcrete platforms** - small platforms and calcareous plains up to 100 m in extent and 1-2 m higher than adjacent units; mantles of many to abundant pebbles and cobbles of calcrete.	Red shallow sand (423).	Moderately close shrublands of *Senna* and *Acacia* spp. with *Enneapogon* sp. grasses or *Triodia pungens* (soft spinifex) or *T. wiseana* (hard spinifex) (CACS, CASG).
6.	10%	**Depressions and drainage foci** - low lying depressions and drainage foci up to 1.5 km in extent but usually smaller, within units 1 and 2.	Deep red/brown non-cracking clays (622).	Moderately close or close woodlands of *Eucalyptus victrix, Acacia distans, A. aneura* with tussock grass understoreys or *Muehlenbeckia cunninghamii* (lignum) (DEGW, DEAW).
7.	2%	**Channel, bank and minor river terrace** - meandering, braided channels 2-50 m wide and incised 1-4 m passing more or less centrally through unit 1; larger channels flanked by narrow poorly developed terraces, levees and banks.	River bed soils (705).	Moderately close or close fringing woodlands of *Eucalyptus victrix, E. camaldulensis* (red river gum) and *Acacia* spp. with understorey of tussock grasses (DEGW, GMEW).

COONGIMAH LAND SYSTEM (3,244 km², 1.8% of the survey area)

Plateau surfaces, low hills with steep slopes and undulating uplands supporting hard spinifex grasslands.

Land type: 3

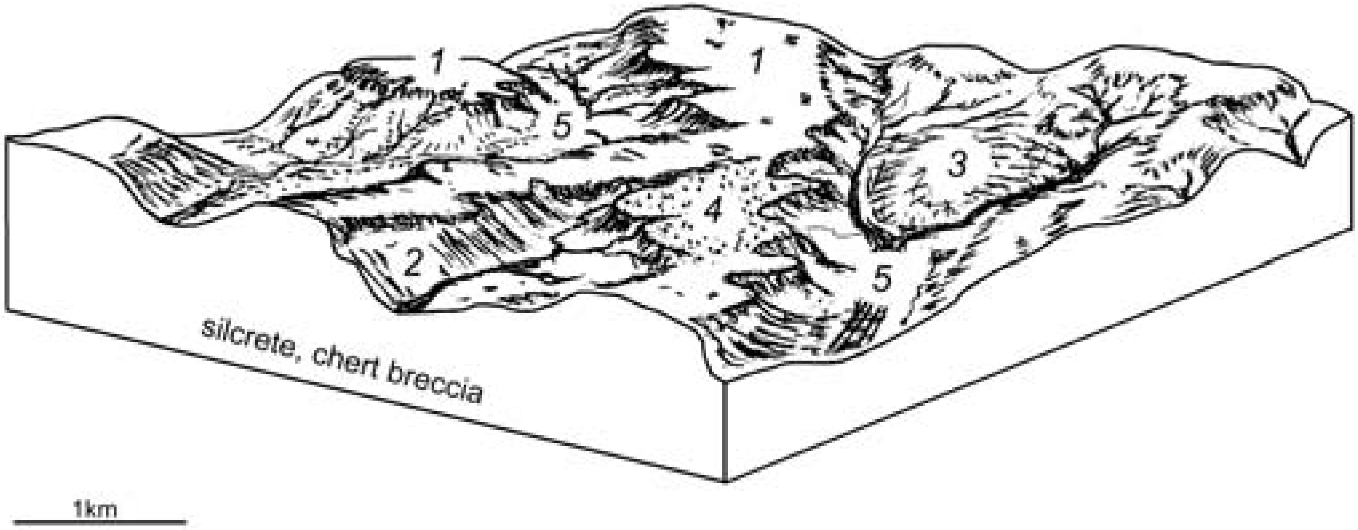
Geology: Tertiary siliceous caprock and lateritized colluvium, Proterozoic chert breccia and minor dolomite.

Geomorphology: Erosional surfaces; plateaux remnants, undulating low hills and uplands with steep slopes, more gently undulating lower stony plains; closely spaced drainage lines incised into bedrock in narrow valleys in upper parts becoming broader downslope, minor areas of sand sheet. Relief up to 80 m.

Land management: Hard spinifex grasslands are not preferred by livestock and not prone to degradation although may be subject to fairly regular burning. The system has a very low erosion risk.

Traverse condition summary: (130 assessments)
Vegetation - very good 92%, good 5%, fair 2%, poor 1%.
Soil erosion - nil 99%, slight 1%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Plateau and hillcrest	15	2
2.	Footslope	10	-
3.	Stony plain	79	2
4.	Sand sheet	4	-
5.	Drainage line	21	1
	Other	1	-
	Total	130	5

Coongimah land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	30%	**Plateaux and hillcrests** - level plateaux and crests with rounded edges and moderately inclined to very steep upper slopes, mantles of very abundant pebbles, cobbles and stones of silcrete, chert, dolomite or ironstone, frequent rock outcrop; relief up to 80 m.	Stony soils (203), red shallow sands (423) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana, T. plurinervata* (hard spinifex) with very scattered mid height shrubs such as *Acacia orthocarpa, A. arida* (PHSG, HSPG).
2.	20%	**Footslopes** - Very gently to gently inclined footslopes extending for up to 1 km below unit 1, mantles of abundant pebbles and cobbles of silcrete, chert or ironstone.	Red shallow loams (522).	As for unit 1. Also occasionally *T. pungens* (soft spinifex) (HSPG).
3.	32%	**Stony plains** - gently undulating uplands, interfluves and rises extending for up to 3 km, mantles of very abundant pebbles and cobbles of silcrete, chert or ironstone; relief up to 40 m.	Red shallow loams (522) and red shallow sands (423).	Hummock grassland of *T. wiseana, T. plurinervata* with very scattered mid height acacia shrubs (PHSG).
4.	3%	**Sand sheets** - level sandplains and plains with thin sand cover up to 500 m in extent.	Red shallow sands (423).	Hummock grasslands of *Triodia* spp. (hard and soft spinifex) with very scattered shrubs (SHSG, PHSG, PSSG).
5.	15%	**Drainage lines** - drainage floors and channels 20-50 m wide, finely dendritic and incised in narrow valleys in upper parts becoming flatter and wider (up to 300 m) downslope.	River bed soils (705).	Scattered to moderately close *Acacia* spp. tall shrublands/woodlands with hummock and tussock grass understorey (DAHW, DEGW).

COWRA LAND SYSTEM (203 km², 0.1% of the survey area)

Plains fringing the Marsh land system and supporting snakewood and mulga shrublands with some halophytic undershrubs.

Land type: 15

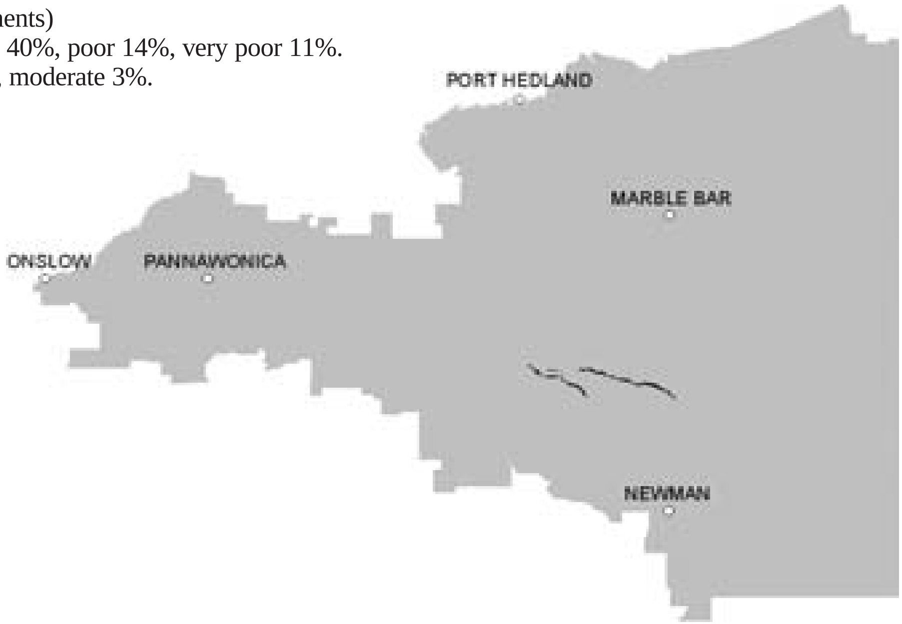
Geology: Quaternary colluvium and alluvium.

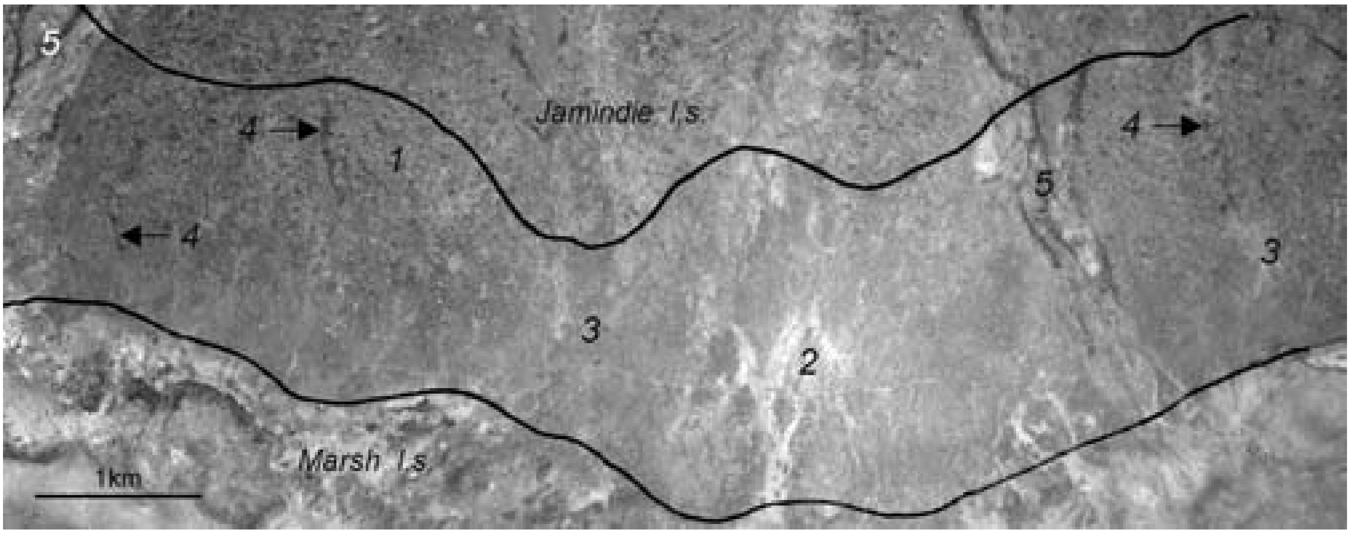
Geomorphology: Depositional surfaces; almost level plains of non-saline and weakly saline alluvium with gravelly surfaces, subject to overland sheet flow; drainage foci as small groves of dense vegetation and through drainage tracts with minor non-tributary and distributing channels.

Land management: The system supports vegetation which is preferred by grazing animals and is prone to degradation if grazing is uncontrolled. Surface mantles of gravel generally protect the system from erosion; however, if the mantle is removed or disturbed (particularly on unit 3) erosion can occur.

Traverse condition summary: (37 assessments)
Vegetation - very good 8%, good 27%, fair 40%, poor 14%, very poor 11%.
Soil erosion - nil 87%, slight 5%, minor 5%, moderate 3%.

Area mapped as sde: 624 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Stony hardpan plain	9	1
2.	Stony gilgai plain	6	-
3.	Saline alluvial plain	21	2
4.	Grove	1	-
5.	Drainage tract	-	-
	Total	37	3

Cowra land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	20%	**Stony hardpan plains** - almost level plains subject to sheet flow, usually upslope from other units, mantles of many to very abundant ironstone gravel.	Red loamy earths (544).	Hummock grasslands of *Triodia* spp. (hard spinifex) with scattered acacia shrubs (PHSG) or scattered tall shrublands of *Acacia aneura* (mulga) and other acacias (PSMS).
2.	15%	**Stony gilgai plains** - level plains with mosaic of surfaces with gilgied and non-gilgaied microrelief, subject to sheet flow; mantles of abundant ironstone gravel.	Self-mulching cracking clays (602) and deep red/brown non-cracking clays (622).	Scattered tall shrublands of *Acacia aneura, A. xiphophylla* (snakewood) with patchy tussock grass ground layer (PMGS, SSTS).
3.	55%	**Saline alluvial plains** - level plains subject to sheet flow, mantles of abundant to very abundant ironstone gravel.	Red deep sandy duplex (405) or red shallow sandy duplex soils (406).	Scattered, somewhat patchy tall shrublands of *A. xiphophylla* with undershrubs *Atriplex bunburyana* (silver salt bush), *Maireana pyramidata* (sago bush) and other *Maireana* spp. (PSCS). Also scattered low shrublands of *A. bunburyana, Maireana* spp. (bluebushes) and *Frankenia* sp. (frankenia) (PXHS).
4.	2%	**Groves** - drainage foci usually arranged as narrow bands (up to 200 m long but usually much less) more or less at right angles to direction of sheet flow on units 1, 2 or 3, sometimes with gilgai microrelief, patchy mantles of ironstone gravel.	Red loamy earths (544) with minor self-mulching cracking clays (602).	Moderately close to close tall shrublands of *Acacia aneura, A. xiphophylla* with tussock grasses (GMGW).
5.	8%	**Drainage tracts** - almost level tracts up to 1 km wide as corridors through units 1 and 3, receiving more concentrated through flow, often with shallow gutters and channels.	Red loamy earths (544).	Scattered low shrublands of *Atriplex* and *Maireana* spp. (PXHS). Also scattered tall shrublands of *Acacia aneura, A. xiphophylla* with chenopod undershrubs (PMCS).

CUNDELBAR LAND SYSTEM (37 km^2, 0.02% of the survey area)

Saline alluvial plains supporting halophytic shrublands.

Land type: 16

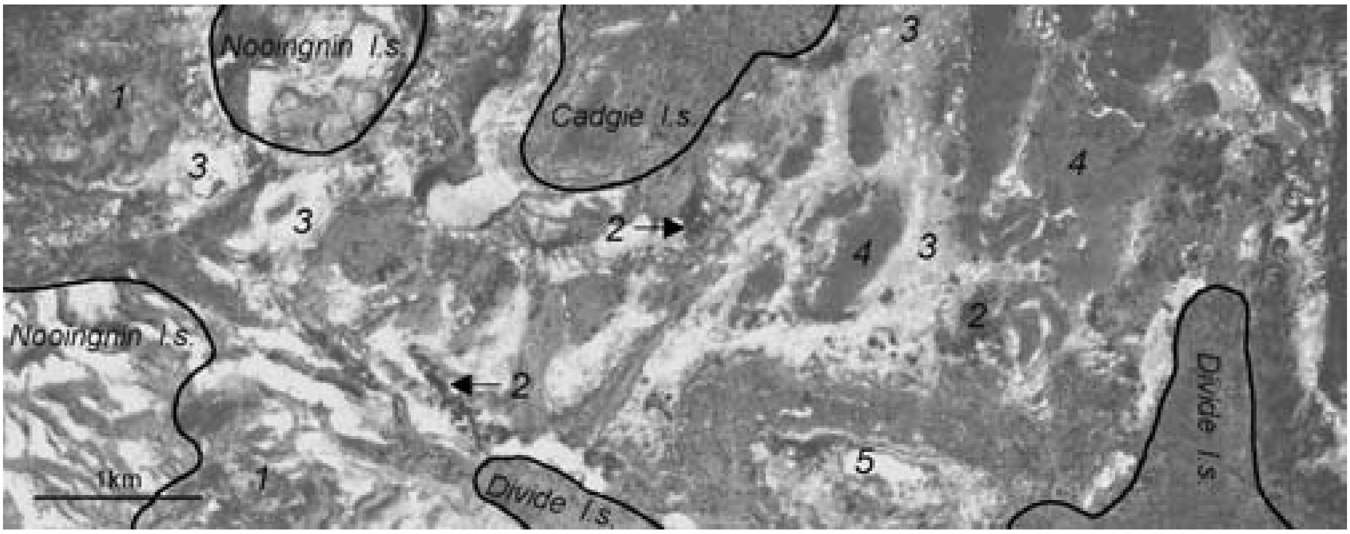
Geology: Quaternary mixed lacustrine and eolian deposits - clay, silt, sand.

Geomorphology: Depositional surfaces; level gravelly plains and plains on saline alluvium, minor sand sheets and occasional pans, no organised drainage patterns.

Land management: The system supports vegetation which is preferred by grazing animals and is prone to degradation if grazing pressure is excessive. Alluvial plains (unit 3) are moderately susceptible to erosion if vegetative cover is depleted.

Traverse condition summary: (3 assessments)
Vegetation - very good 34%, good 33%, poor 33%.
Soil erosion - nil 67%, minor 33%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Gravelly plain	-	-
2.	Grove	-	-
3.	Saline alluvial plain	2	2
4.	Sand sheet and bank	1	1
5.	Pan	-	-
	Total	3	3

Cundelbar land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	23%	**Gravelly plains** - level plains up to 2 km in extent, surface mantles of abundant to very abundant grit and pebbles of ironstone, subject to sheet flow.	Red loamy earths (544).	Very scattered to scattered tall shrublands of *Acacia aneura* (mulga) with low shrubs *Senna* and *Eremophila* spp., *Maireana pyramidata* (sago bush) and *M. georgei* (golden blue bush) (SAES, PMCS).
2.	3%	**Groves** - drainage foci up to 500 m long on gravelly plains and saline alluvial plans (units 1 and 3), receiving run-on from adjacent surfaces.	Red loamy earths (544).	Close to closed tall shrublands/woodlands of *Acacia aneura* with *Eremophila, Sida* and *Ptilotus* spp. undershrubs and sparse tussock grasses (GMUW).
3.	50%	**Saline alluvial plains** - level plains up to 2 km in extent, surface mantles of common to abundant ironstone pebbles; internally drained.	Red deep sandy duplex soils (405) and red shallow loams (522).	Scattered low shrublands of *Maireana glomerifolia* (ball-leaf bluebush), *M. pyramidata, Frankenia* spp. (frankenia) and *Halosarcia* spp. (samphire) (PXHS).
4.	22%	**Sand sheets and banks** - sandy surfaces extending for up to 1 km but frequently as smaller patches elevated up to 1.5 m above adjacent plains (units 1 and 3); moundy surfaces.	Red sandy earths (463).	Hummock grasslands of *Triodia pungens* (soft spinifex) with scattered shrubs including *Eremophila forrestii* (Wilcox bush) and *Acacia* spp. (PMSS).
5.	2%	**Pans** - occasional level pans up to 1.5 km long by 400 m wide receiving run-on from adjacent surfaces.	Deep red/brown non-cracking clays (622).	Very scattered shrublands of *Halosarcia* spp. (samphire) with patchy tussock grasses (PSPS).

DIVIDE LAND SYSTEM (5,293 km², 2.9% of the survey area)

(modified from Wilcox and McKinnon 1972)

Sandplains and occasional dunes supporting shrubby hard spinifex grasslands.

Land type: 11

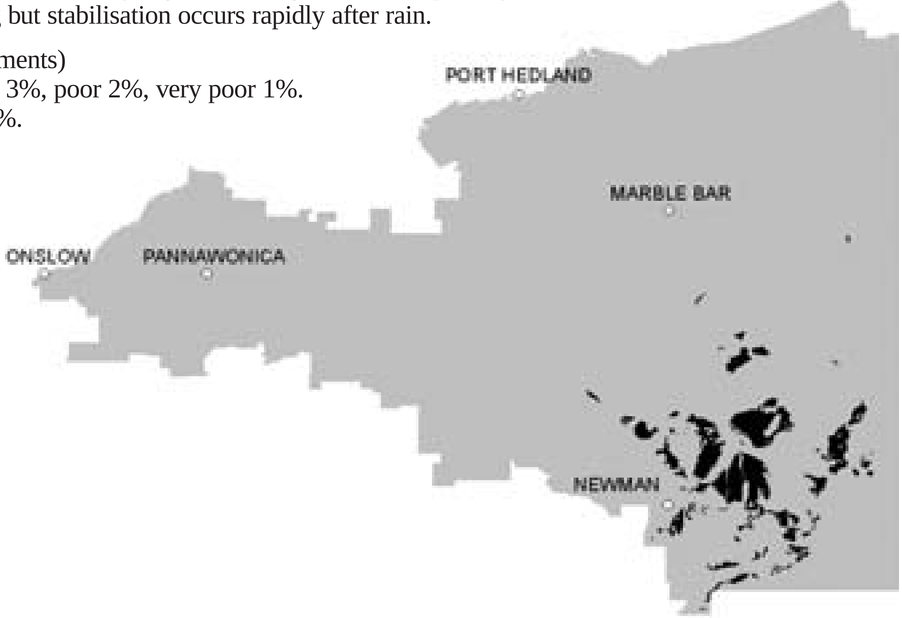
Geology: Quaternary eolian sand.

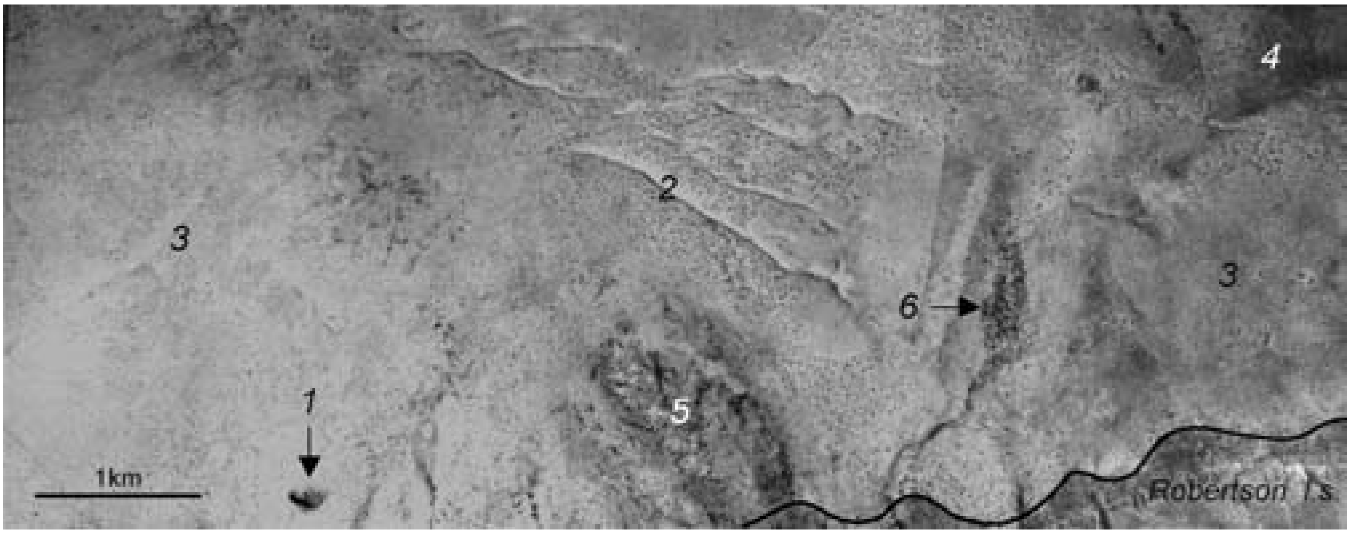
Geomorphology: Depositional surfaces; level to gently undulating sandplain with occasional linear dunes and plains with thin sand cover, very little organised drainage but some tracts receiving run-on from adjacent more elevated systems, these tracts mostly unchannelled but locally with sandy channels. Relief up to 20 m.

Land management: Hard spinifex vegetation is not preferred by livestock except for one or two years following burning. Vegetation not usually degraded although subject to fairly regular burning; some susceptibility to wind erosion immediately following burning but stabilisation occurs rapidly after rain.

Traverse condition summary: (177 assessments)
Vegetation - very good 91%, good 3%, fair 3%, poor 2%, very poor 1%.
Soil erosion - nil 98%, slight 1%, extreme 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low hill	4	-
2.	Sand dune	-	1
3.	Sandplain	126	4
4.	Plain with thin sand cover	30	2
5.	Stony plain	7	-
6.	Tract receiving run-on	8	-
	Other	2	-
	Total	177	7

Divide land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	<1%	**Low hills** - isolated low hills and stony rises up to 500 m in extent, surface mantles of pebbles and cobbles; relief up to 15 m.	Stony soils (203) and red shallow sands (423).	Hummock grasslands of *Triodia* spp. (hard spinifex) (HSPG).
2.	1%	**Sand dunes** - linear dunes up to 15 m high with moderately inclined slopes, hummocky crests and loose surfaces.	Red deep sands (445).	Hummock grasslands of *T. melvillei* (hard spinifex) or *T. schinzii* (soft spinifex) with numerous shrubs including *Grevillea* and *Acacia* spp. (SHSG, SSSG).
3.	76%	**Sandplains** - level or gently undulating plains up to 10 km in extent, hummocky loose surfaces.	Red deep sands (445) and red sandy earths (463).	Hummock grasslands of *Triodia lanigera, T. basedowii* (hard spinifex) with *Acacia* spp. and other shrubs, occasional mallee eucalypts (SHSG). Occasionally *T. schinzii* (soft spinifex) (SSSG).
4.	15%	**Plains with thin sand cover** - level to gently undulating plains up to 2 km in extent with gravel or rock at shallow depth.	Red shallow sands (423) and shallow gravel soils (304).	Hummock grasslands of *T. lanigera, T. wiseana* (hard spinifex) (PHSG) or scattered to moderately close tall shrublands including *Acacia aneura* (mulga) with hard spinifex ground layer (PMSS).
5.	4%	**Stony plains** - restricted, level or gently undulating plains with surface mantles of many to very abundant pebbles and cobbles.	Shallow gravel soils (304).	Hummock grasslands of *T. lanigera, T. wiseana* (hard spinifex) (PHSG) or scattered to moderately close tall shrublands including *Acacia aneura* (mulga) with hard spinifex ground layer (PMSS).
6.	3%	**Tracts receiving run-on** - very gently inclined tracts up to 4 km in extent receiving run-on from adjacent upland land systems, mostly unchannelled but sometimes with sandy channels and out-wash gutters incised to 1.5 m.	Red sandy earths (463) with minor river bed soils (705).	Scattered to close tall shrublands of *A. aneura, A. kempeana* (witchetty bush) and low shrubs such as *Eremophila forrestii* (Wilcox bush) and ground layer *Triodia* spp. (spinifex) and *Monachather paradoxa* (broad leaved wanderrie) (DAHW, DEAW).

DOLLAR LAND SYSTEM (87 km^2, 0.05% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Stony plains supporting acacia shrublands.

Land type: 10

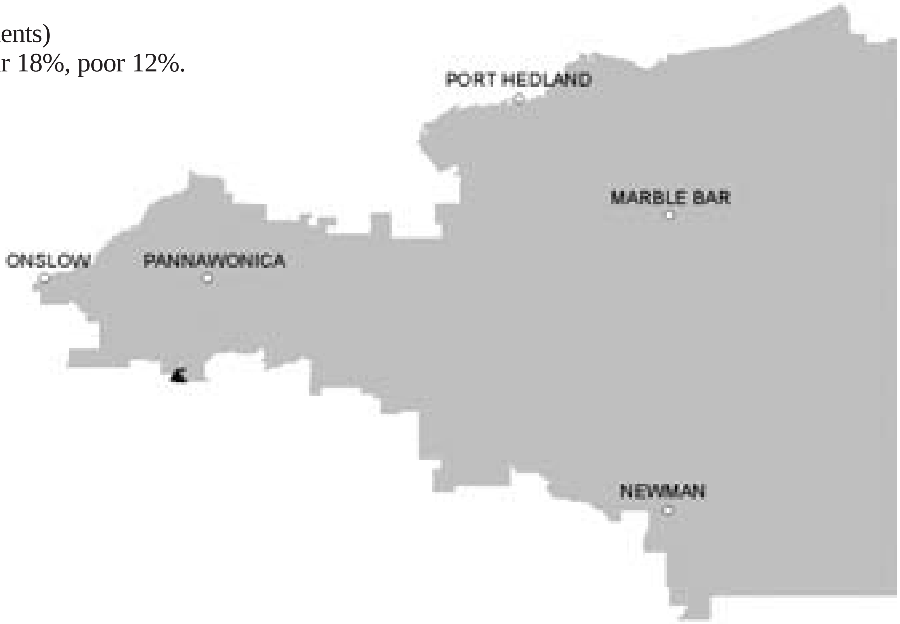
Geology: Quaternary colluvium and alluvium, minor Lower Proterozoic dolomite.

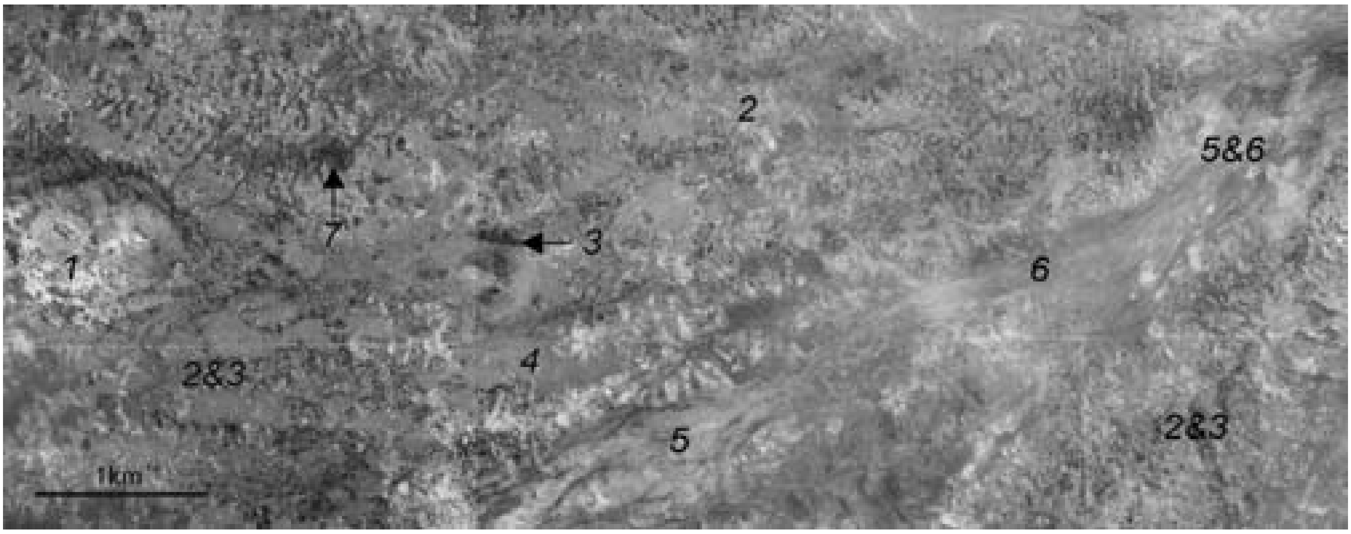
Geomorphology: Depositional surfaces; level stony plains of unconsolidated colluvium, minor alluvial zones, outcrop plains and low dolomitic rises; sparse, through going sub parallel drainage with single and braided channels. Relief usually less than 5 m but sometimes up to 10 m.

Land management: The system supports vegetation attractive to grazing animals and is prone to degradation if grazing pressure is excessive. Most units are inherently resistant to erosion.

Traverse condition summary: (17 assessments)
Vegetation - very good 24%, good 46%, fair 18%, poor 12%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Outcrop plain and low rise	-	-
2.	Stony plain	14	-
3.	Drainage focus	1	-
4.	Gilgai plain	2	-
5.	Drainage floor	-	-
6.	Braided channel	-	-
7.	Swamp and depression	-	-
	Total	17	-

Dollar land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	6%	**Outcrop plains and low rises** - gently undulating plains and low rises up to 1 km in extent, surface mantles of dolomitic rock fragments; relief up to 10 m.	Stony soils (203) and red shallow loams (522).	Low shrublands of *Acacia tetragonophylla* (curara), *A. victoriae* (prickly acacia) and *Senna* spp. (PAGS).
2.	72%	**Stony plains** - level plains up to several km in extent, surface mantles of abundant to very abundant pebbles; drainage foci (unit 3) sparsely scattered over this unit.	Red loamy earths (544).	Very scattered to scattered tall shrublands of *Acacia aneura* (mulga) or *A. xiphophylla* (snakewood) with *Triodia pungens* (soft spinifex), *Eremophila* and *Senna* spp. understorey (PSSG, ASHS).
3.	8%	**Drainage foci** - discrete, variable shaped foci on unit 2, commonly 50-200 m in extent, receiving run-on from adjacent surfaces.	Red loamy earths (544) and red/brown non-cracking clays (622).	Moderately close tall shrublands of *A. xiphophylla* and other *Acacia* spp. with numerous low shrubs (GMUW).
4.	5%	**Gilgai plains** - level plains up to 1 km in extent, gilgai microrelief and stony mantles.	Self-mulching cracking clays (602) and red/brown non-cracking clays (622).	Very scattered shrublands or tussock grasslands with *A. victoriae, Senna* spp. and *Eragrostis xerophila* (Roebourne Plains grass) (ARPG).
5.	5%	**Drainage floors** - gently inclined floors up to 400 m wide, central tracts with braided channels.	Red loamy earths (544) and self-mulching cracking clays (602).	Scattered tall shrublands *Acacia* spp. with low shrubs and *Triodia pungens* (soft spinifex) (DAHW).
6.	3%	**Braided channels** - multiple channels 5-10 m wide over tracts up to 300 m wide, also individual major channels up to 50 m wide.	Red shallow loams (522), red sandy earths (463) and river bed soils (705).	Moderately close tall shrublands including *Acacia wanyu* and numerous other *Acacia* spp. and sparse low shrubs (DEAW).
7.	<1%	**Swamp and depressions** - up to 500 m in extent, moundy or gilgai microrelief.	Deep red/brown non-cracking clays (622) and self-mulching cracking clays (602).	*Eucalyptus victrix* (coolibah) woodlands and tall shrublands of *Acacia* spp. and tussock grasses (DEGW).

DUNE LAND SYSTEM (138 km^2, 0.1% of the survey area)

(after Payne, Mitchell and Holman 1988)

Dune fields supporting soft spinifex grasslands.

Land type: 19

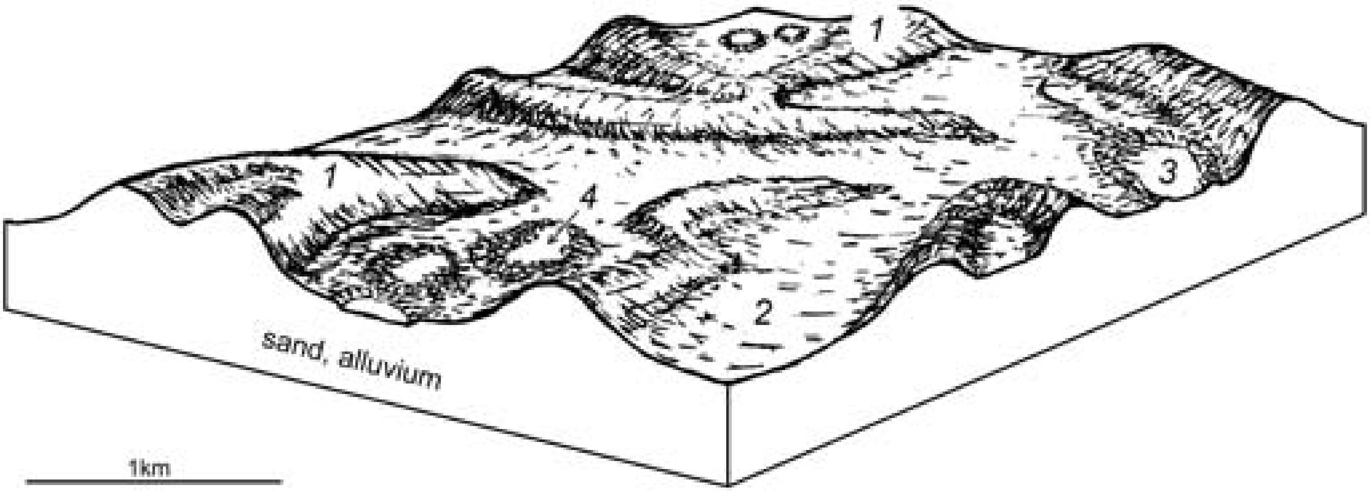
Geology: Quaternary eolian sand.

Geomorphology: Depositional surfaces; sand dunes and swales with no organised drainage, dunes trending approximately north-south and frequently becoming reticulate; narrow swales with minor areas of claypans, swamps and depressions. Relief up to 15 m.

Land management: Young soft spinifex is moderately attractive to grazing animals but mature stands are unattractive. Spinifex is subject to fairly regular burning; some susceptibility to wind erosion immediately following burning but stabilisation occurs rapidly after rain.

Traverse condition summary: (22 assessments)
Vegetation - very good 95%, fair 5%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Linear and reticulate dune	8	1
2.	Swale and sandplain	13	1
3.	Swamp and depression	1	-
4.	Claypan	-	-
	Total	22	2

Dune land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	55%	**Linear and reticulate dunes** - dunes up to 15 m high and 2.5 km long, hummocky uneven crests with gently to moderately inclined slopes steepest on western sides.	Red deep sands (445).	Hummock grasslands *Triodia schinzii* or *T. pungens* (soft spinifex) with numerous low and mid height shrubs (CDSG). Occasionally *Cenchrus ciliaris* is dominant (CDBG).
2.	32%	**Swales and sandplains** - level to gently inclined sandy plains 50-400 m wide between dunes.	Red deep sands (445).	Hummock grasslands mostly *T. pungens* (soft spinifex) but some *T. lanigera* (hard spinifex), sparse low shrubs such as *Acacia stellaticeps* (poverty bush) (SSSG).
3.	8%	**Swamps and depressions** - low lying drainage foci between dunes, circular or oval and up to 500 m in diameter or extent.	Self-mulching cracking clays (602) and red/brown non-cracking clays (622).	Scattered low woodlands of *Eucalyptus victrix* (coolibah) with *Muehlenbeckia cunninghamii* (lignum) and tussock grasses such as *Sporobolus mitchellii* and *Eriachne benthamii* (swamp grass) (DEGW).
4.	5%	**Claypans** - bare, circular, oval or elongated surfaces mostly less than 150 m in diameter or length but up to 500 m, up to 1.5 m below adjacent sandplains or swales with abrupt marginal slopes.	Deep red/brown non-cracking clays (622).	No vegetation.

EGERTON LAND SYSTEM (466 km^2, 0.3% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Dissected hardpan plains supporting mulga shrublands and hard spinifex hummock grasslands.

Land type: 5

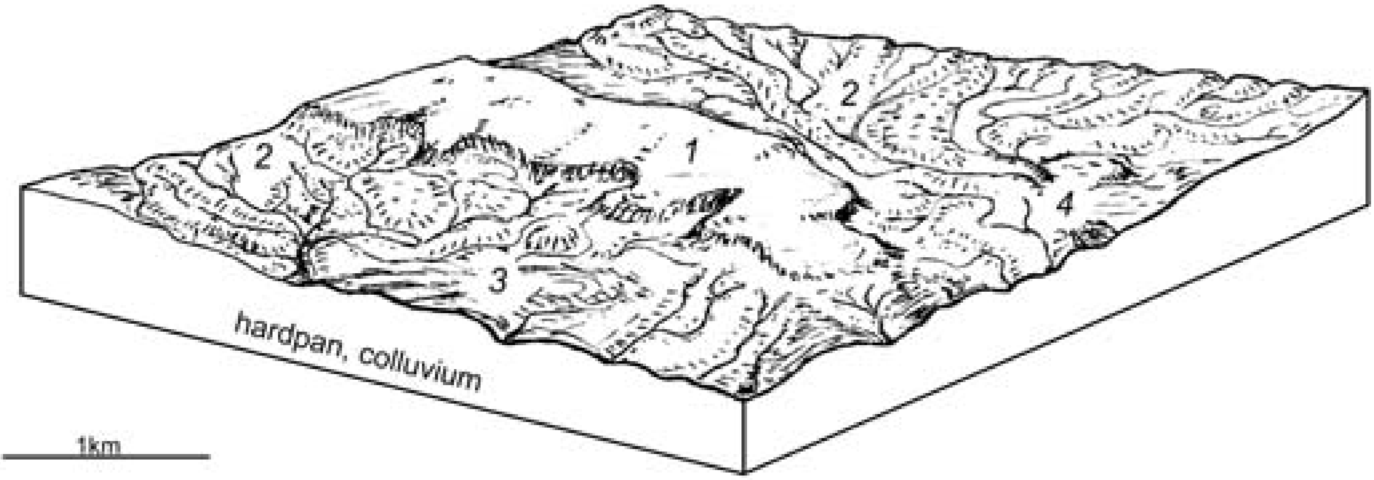
Geology: Partly consolidated and cemented Tertiary colluvium.

Geomorphology: Erosional surfaces; surfaces formed by dissection of the old Tertiary plateau; minor residual hardpan plains with extensive marginal dissection zones consisting of narrow interfluves and slopes; very closely spaced tributary drainage patterns becoming more widely spaced downslope to narrow drainage floors leading to major through drainage; dissected slopes adjacent to major drainage lines are often calcreted. Relief up to 20 m.

Land management: The vegetation on this system is not preferred by livestock and is not prone to grazing induced degradation. The system is not susceptible to erosion.

Traverse condition summary: (19 assessments)
Vegetation - very good 89%, good 11%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Hardpan plain	3	1
2.	Dissected slope	12	1
3.	Calcreted drainage margin	1	1
4.	Drainage floor and channel	3	-
	Total	19	3

Egerton land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	10%	**Hardpan plains** - narrow, level or gently inclined residual plains and divides elevated between extensive dissected slopes (unit 2); mantles of abundant ironstone pebbles.	Red-brown hardpan shallow loams (523) and red shallow loams (522).	Very scattered to scattered tall shrublands of *Acacia aneura* (mulga) and other *Acacia* spp. with prominent ground layer of *Triodia* spp. (hard spinifex) (PMSS).
2.	75%	**Dissected slopes** - zones up to 3-4 km in extent consisting of stable narrow interfluves and short rounded slopes with numerous dendritic drainage lines incised up to 10 m. Slopes mostly very gently or gently inclined, sometimes steep in upper parts with small breakaway faces up to 3 m high, mantles of abundant pebbles of ironstone and other rocks, occasional hardpan exposures.	Red shallow loams (522) and red shallow sands (423).	Hummock grasslands of *Triodia brizoides, T. wiseana* (hard spinifex) with isolated acacia shrubs and eucalypts (PHSG).
3.	6%	**Calcreted drainage margins** - up to 2 km in extent, narrow interfluves and dissected slopes adjacent to major drainage lines; mantles of abundant calcrete and other rock fragments.	Calcareous shallow loams (521) and red shallow loams (522).	Hummock grasslands of *T. wiseana* with sparse *Eucalyptus socialis* trees or mallees and isolated low shrubs (CASG).
4.	9%	**Drainage floor and channels** - gently inclined floors up to 500 m wide but mostly much less with central channels; major trunk drainage channels up to 50 m wide.	Red loamy earths (544) with some river bed soils (705).	Moderately close woodlands/tall shrublands of *A. aneura* with other shrubs including *Senna* spp., *Ptilotus obovatus* (cotton bush), *Eremophila forrestii* (Wilcox bush) with *Triodia* spp. (spinifex) ground layer (DAHW).

EIGHTY MILE LAND SYSTEM (352 km^2, 0.2% of the survey area)

(modified from Cotching unpublished)

Beach foredunes, coastal dunes and sandy plains supporting buffel grass grasslands and soft spinifex grasslands.

Land type: 19

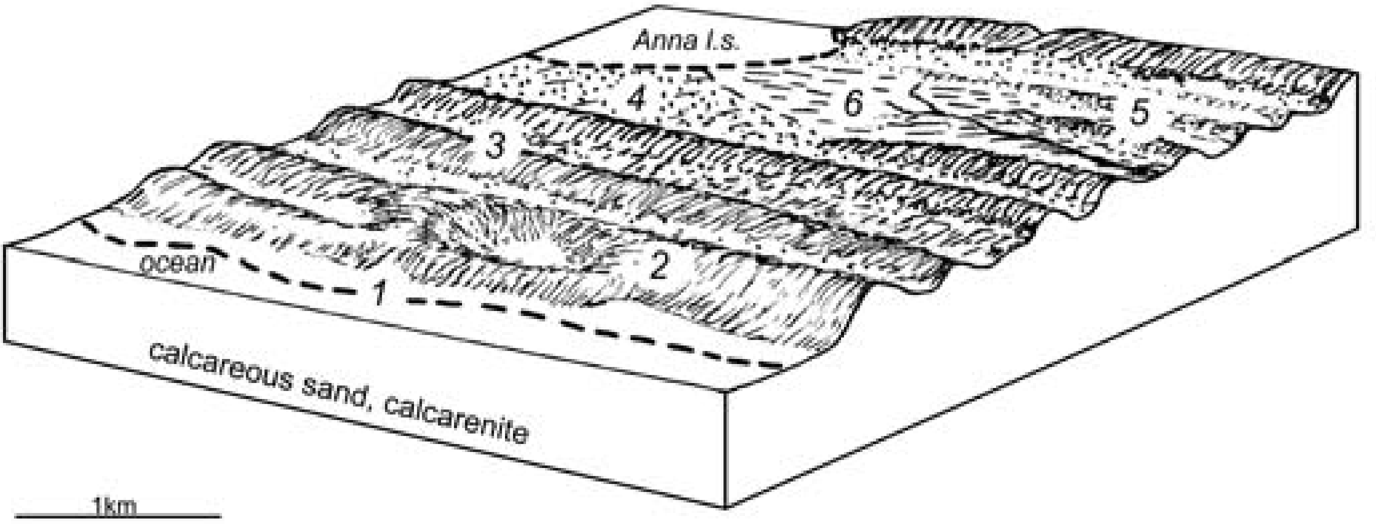
Geology: Quaternary eolian calcareous sand, quartzose calcarenite, minor clay and silt.

Geomorphology: Depositional surfaces; beaches, unconsolidated (but largely stabilised) foredunes and unconsolidated to partly consolidated hind dunes mostly parallel but also reticulate; narrow sandy swales and broader sandy plains, minor interdunal corridors with more saline soils, narrow limestone ridges; no organised drainage. Relief up to 15 m.

Land management: Dunes stable when heavily vegetated but highly susceptible to wind erosion if vegetation is lost by overgrazing, fire or other disturbance and can result in large blow-outs and sand drifts.

Traverse condition summary: (80 assessments)
Vegetation - very good 79%, good 14%, fair 6%, poor 1%.
Soil erosion - nil 100%.

Area mapped as sde: 497 ha.



No.	Unit name	Traverse recordings	Inventory sites
1.	Beach	-	-
2.	Foredune	1	2
3.	Hind dune and swale	35	3
4.	Sandy plain	31	-
5.	Limestone ridge	1	3
6.	Saline plain	10	1
	Other	2	-
	Total	80	9

Eighty Mile land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Beaches** - narrow shelly sand beaches on seaward side of foredunes.	Calcareous deep sands (442).	No vegetation.
2.	5%	**Foredunes** - unconsolidated dunes extending up to 150 m inland from beaches with gently to moderately inclined slopes and uneven, hummocky crests; relief up to 15 m.	Calcareous deep sands (442).	Hummock grasslands with *Spinifex longifolius* (coastal spinifex), *Whiteochloa airoides* (dune tussock grass), *Triodia pungens* and *T. epactia* (soft spinifex) (CDSG).
3.	42%	**Hind dunes and swales** - parallel and reticulate hind dunes and old beach ridges with gently to moderately inclined slopes and narrow (25-200 m wide) level swales between crests; relief up to 15 m.	Calcareous deep sands (442).	Tussock grasslands of *Cenchrus ciliaris* (buffel grass) with isolated shrubs (SDBG). Less frequently hummock grasslands of *T. pungens, T. epactia* with isolated shrubs (CDSG, SSSG).
4.	30%	**Sandy plains** - level or very gently inclined plains extending for 1-2 km between other units or as plains adjacent to the Anna land system.	Calcareous deep sands (442).	Tussock grasslands of *Cenchrus ciliaris*, some other perennial grasses such as *Dichanthium* and *Sporobolus* spp. (APBG).
5.	10%	**Limestone ridges** - narrow (usually <100 m wide) ridges up to 4 km long with gently inclined slopes, abundant outcrop of rough limestone with solution holes and sink holes.	Red shallow sands (423).	Hummock grasslands of *T. epactia, T. pungens* with very scattered shrubs (CASG).
6.	12%	**Saline plains** - level plains with saline alluvium occurring as inclusions up to 500 m in extent within sandy plains (unit 4) or as narrow corridors between dunes of unit 3.	Grey calcareous loamy earths (542) and grey deep loamy duplex soils (509).	Grasslands and low grassy shrublands with *Sporobolus virginicus* (salt water couch), *Eragrostis falcata* (sickle lovegrass), *Halosarcia* spp. (samphire) and *Frankenia* spp. (frankenia) (SPSG, PSPS).

ELIMUNNA LAND SYSTEM (617 km², 0.3% of the survey area)

Stony plains on basalt supporting sparse acacia and cassia shrublands and patchy tussock grasslands.

Land type: 10

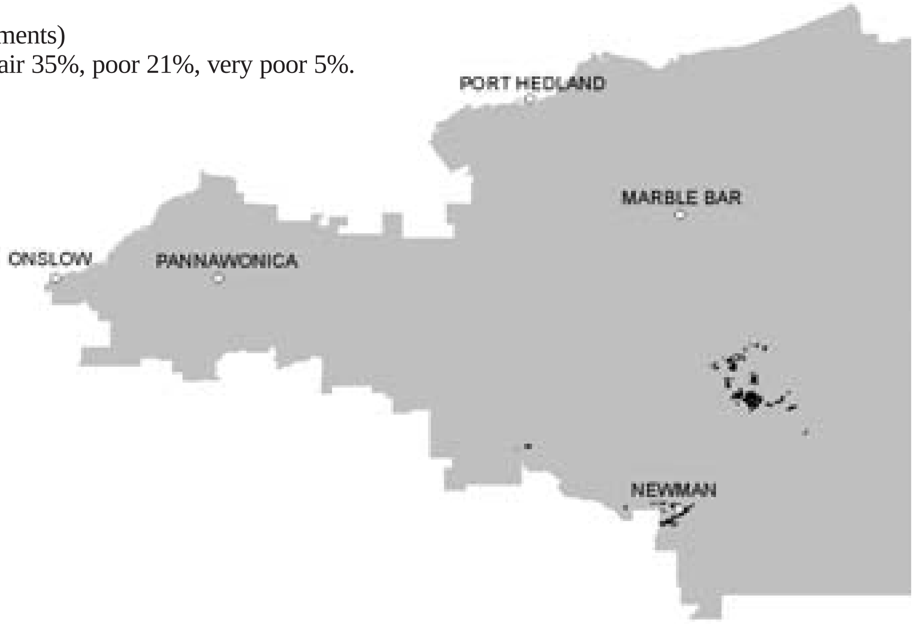
Geology: Quaternary colluvium, eluvium and alluvium, Archaean basalt and dolerite.

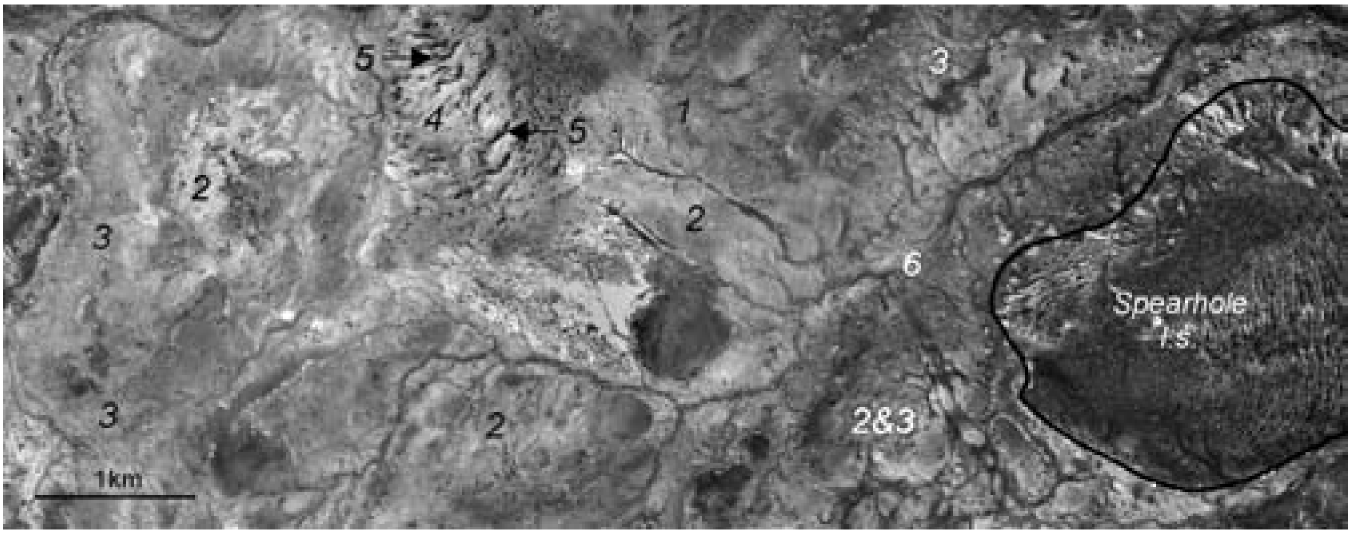
Geomorphology: Mainly depositional surfaces; level to gently undulating stony plains, other level plains with a mosaic of surfaces with and without gilgai microrelief, widely or very widely spaced tributary and non-tributary drainage floors with clay soils and central through channels; also sluggish internal drainage patterns on gilgai plains; occasional low hills and rises on basalt. Relief up to 15 m.

Land management: Gilgai plains (unit 3) and drainage floors (unit 6) support tussock grass vegetation attractive to grazing animals and prone to degradation if grazing pressure is excessive. Some drainage floors (unit 6) are slightly susceptible to erosion but most of the system is inherently resistant.

Traverse condition summary: (84 assessments)
Vegetation - very good 14%, good 25%, fair 35%, poor 21%, very poor 5%.
Soil erosion - nil 99%, minor 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Hill and low rise	7	-
2.	Stony plain	38	1
3.	Gilgai plain	21	1
4.	Hardpan plain	6	1
5.	Grove	3	1
6.	Drainage floor	9	1
	Total	84	5

Elimunna land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	10%	**Hills and low rises** - low (up to 15 m) isolated hills and rounded rises with surface mantles of abundant or very abundant pebbles and cobbles of basalt and other rocks.	Stony soils (203) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana* (hard spinifex) (HSPG) or very scattered shrublands of *Acacia* and *Senna* spp. (SAES).
2.	45%	**Stony plains** - level to gently undulating plains extending up to 4 km, mantles of abundant pebbles of basalt, quartz and ironstone.	Red/brown non-cracking clays (622).	Very scattered to scattered mixed height shrublands with *Acacia aneura* (mulga) other acacias, *Senna* spp. (cassias) and *Eremophila* spp. (SAES, PSMS). Occasionally with patchy *Triodia* spp. (hard spinifex) understorey (PMSS).
3.	26%	**Gilgai plains** - level plains with gilgai microrelief with or without surface mantles; up to 1 km in extent or as a mosaic of patches 10-50 m in size occurring on unit 2.	Self-mulching cracking clays (602) and red deep loamy duplex soils (506).	Patchy tussock grasslands with *Eragrostis xerophila* (Roebourne Plains grass), *E. setifolia* (neverfail), *Astrebla pectinata* (barley Mitchell grass) with isolated shrubs mainly *Eremophila* and *Senna* spp. (PMOG, ARPG, APXG).
4.	6%	**Hardpan plains** - level plains subject to sheet flow, mantles of many to abundant ironstone pebbles.	Red loamy earths (544).	Very scattered tall shrublands of *A. aneura* and other acacias (LHAS, HPMS).
5.	1%	**Groves** - discrete drainage foci (up to 50 m long by 5-15 m wide) arranged more or less at right angles to sheet flow on stony plains and hardpan plains (units 2 and 4).	Red loamy earths (544).	Moderately close to close tall shrublands of *A. aneura* with numerous other shrubs and patchy perennial grasses (GMUW, GMGW).
6.	12%	**Drainage floors** - level tracts within units 2 and 3 with variable surface mantles and patches of gilgai microrelief, with central channels or sluggish internal drainage lines.	Self-mulching cracking clays (602).	Tussock grasslands with *Astrebla* and *Eragrostis* spp. (APXG) or very scattered to moderately close tall shrublands of *Acacia* spp. with various low shrubs and patchy tussock and/or hummock grasses (DEGW, DAHW).

FAN LAND SYSTEM (1,482 km^2, 0.8% of the survey area)

Washplains and gilgai plains supporting groved mulga shrublands and minor tussock grasslands.

Land type: 12

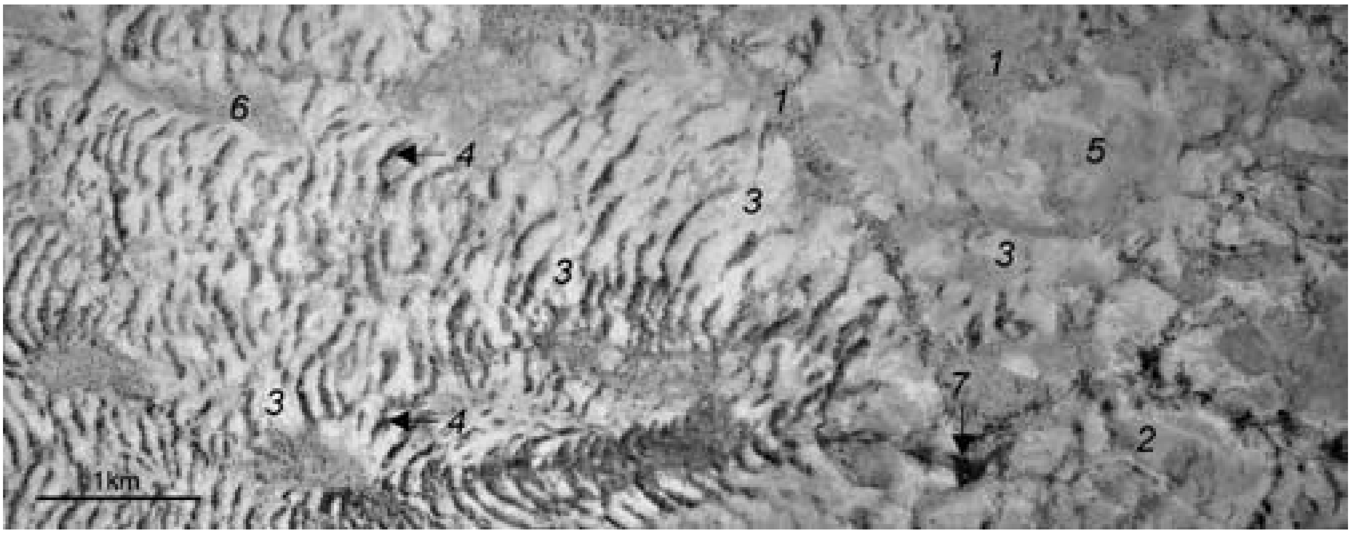
Geology: Quaternary alluvium, minor colluvium and sand.

Geomorphology: Depositional surfaces; level washplains subject to overland sheet flow and with numerous drainage foci (groves of dense vegetation) arranged as arcuate bands transverse to the direction of sheet flow, level plains with gilgai microrelief, minor areas of sand sheet and sandy banks; sparse to very rare drainage tracts subject to more concentrated sheet flow and with occasional shallow channels. Relief less than 10 m.

Land management: Mulga shrublands are moderately preferred, and tussock grasslands highly preferred by grazing animals, and are prone to degradation if overgrazed. Washplains (unit 3) and drainage tracts (unit 6) are moderately susceptible to soil erosion if vegetative cover is depleted.

Traverse condition summary: (140 assessments)
Vegetation - very good 4%, good 20%, fair 31%, poor 37%, very poor 8%.
Soil erosion - nil 84%, slight 4%, minor 6%, moderate 5%, severe 1%.

Area mapped as sde: 331 ha.



No.	Unit name	Traverse recordings	Inventory sites
1.	Sand sheet and sandy bank	6	1
2.	Loamy plain	13	2
3.	Washplain	70	2
4.	Grove	21	2
5.	Gilgai plain	11	1
6.	Drainage tract	15	-
7.	Drainage foci	4	1
	Total	140	9*

* Seven of these sites described from field work done in 1990 as part of an assessment of the impact of Ophthalmia Dam on the flood plains of the Fortescue River (see Payne and Mitchell 1992).

Fan land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	6%	**Sand sheets and sandy banks** - level patches of sand sheet up to 500 m in extent or broad (up to 300 m wide) somewhat sinuous sandy banks extending 1-3 km; slightly more elevated (up to 1 m) above units 2 and 3.	Red deep sands (445) with minor red sandy earths (463).	Shrubby hummock grasslands of *Triodia* spp. (hard spinifex) (SHSG) or scattered tall shrublands with *Acacia aneura* (mulga), *Senna* spp. and prominent ground layer of *Triodia* spp. (SBAS).
2.	10%	**Loamy plains** - almost level plains with loamy surfaces.	Red loamy earths (544) and red sandy earths (463).	Hummock grasslands of *Triodia* spp. (hard and soft spinifex) with scattered acacias and mallee eucalypts (PHSG, PSSG) or tall shrublands of *A. aneura* with low shrubs or hard spinifex understoreys (HPMS, PMSS).
3.	60%	**Washplains** - almost level alluvial plains subject to overland sheet flow, extending for up to 5-6 km, occasionally with surface mantles of few to abundant pebbles of quartz and ironstone.	Red loamy earths (544).	Very scattered to scattered tall shrublands of *A. aneura* and other acacias with sparse *Senna* and *Ptilotus* spp. low shrubs (HPMS, PSMS). Also *A. xiphophylla* (snakewood) tall shrublands with chenopod low shrubs (PSCS).
4.	15%	**Groves** - drainage foci occurring as prominent bands on units 2 and 3, mostly arcuate in shape, 10-50 m wide by up to 750 m long and arranged transverse to direction of sheet flow.	Red loamy earths (544).	Moderately close to close tall shrublands/woodlands of *A. aneura* with tussock grasses in ground layer (GMGW, GMUW).
5.	5%	**Gilgai plains** - level plains up to 750 m in extent, gilgai microrelief.	Self-mulching cracking clays (602) and red/brown non-cracking clays (622).	Tussock grasslands of *Eragrostis xerophila* (Roebourne Plains grass) and *E. setifolia* (neverfail) (ARPG).
6.	3%	**Drainage tracts** - almost level drainage corridors up to 500 m wide on units 2 and 3, receiving more concentrated sheet flow, occasionally with shallow channels.	Red loamy earths (544).	Scattered to moderately close tall shrublands with *A. aneura* and *A. xiphophylla*, tussock grasses in ground layer (DEGW, GMGW).
7.	1%	**Drainage foci** - depressions and irregular foci up to 750 m in extent occasionally found on units 3 and 6, often with gilgai microrelief.	Deep red/brown clays (622) with some self-mulching cracking clays (602).	Moderately close to close tall shrublands/woodlands of *A. xiphophylla, A. aneura* with tussock grasses (SSTS, GMGW).

FORD LAND SYSTEM (85 km^2, 0.05% of the survey area)

(after Payne, Mitchell and Holman 1988)

Gently undulating shaly plains with isolated low hills supporting mulga shrublands.

Land type: 10

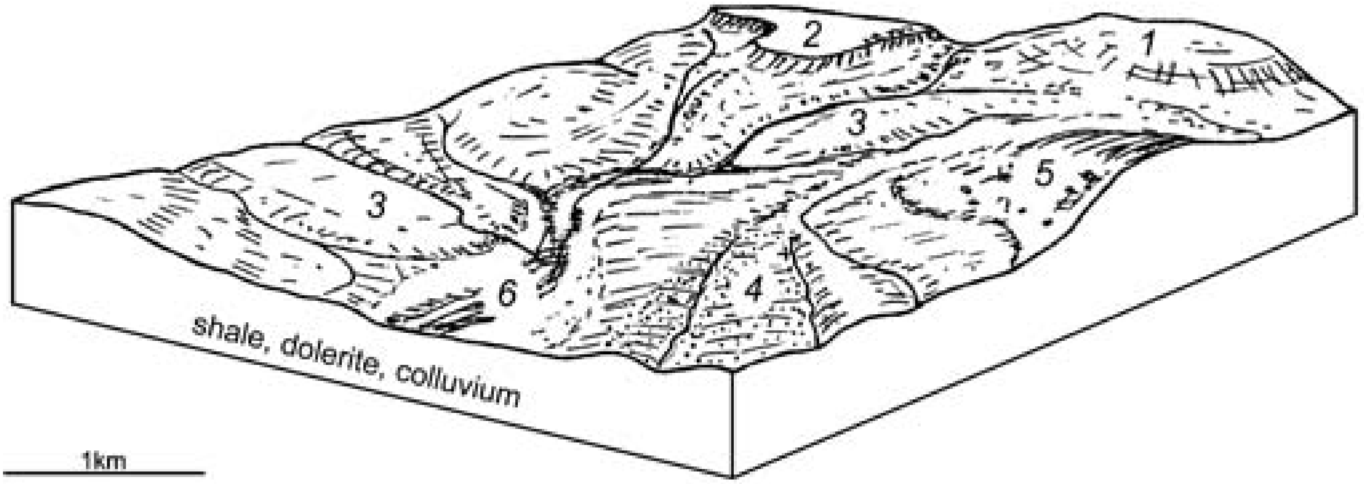
Geology: Middle Proterozoic shale and minor dolerite, Quaternary colluvium and minor alluvium.

Geomorphology: Erosional surfaces; gently undulating plains and interfluves on shale, cobble plains, widely spaced tributary drainage floors and channels on saline alluvium, occasional low shale hills, minor dissected hardpan residuals and minor plains on dolerite. Relief mostly below 20 m.

Land management: Most vegetation is only moderately preferred by livestock except for minor inclusions of chenopod low shrublands which are highly preferred and prone to degradation if overgrazed. The system is generally resistant to erosion because of its stony nature.

Traverse condition summary: (7 assessments)
Vegetation - good 14%, fair 57%, poor 29%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Low hill	-	-
2.	Residual hardpan plain	1	-
3.	Interfluve and plain on shale	5	-
4.	Cobble plain	-	-
5.	Plain on dolerite	-	-
6.	Saline drainage floor with braided channel	1	-
	Total	7	-

Ford land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	5%	**Low hills** - hills up to 20 m high and 1.5 km in extent, short moderately inclined footslopes, dense colluvial mantles of shale rock fragments.	Stony soils (203) and red shallow loams (522).	Low woodland of *Acacia aneura* (mulga) with low shrubs *Senna* and *Eremophila* spp., forbs and sparse annual grasses (SAES).
2.	2%	**Residual hardpan plains** - minor areas of hardpan plain up to 500 m in extent with dissected margins and breakaways up to 3 m high.	Red-brown hardpan shallow loams (523).	Very scattered tall shrublands of *A. aneura* and other acacias, low shrubs *Senna* and *Eremophila* spp., forbs and sparse annual grasses (SAES).
3.	50%	**Interfluves and plains on shales** - gently undulating plains up to 2 km long but mostly less than 500 m between drainage lines; dense colluvial mantles of shale fragments.	Red shallow loams (522).	Very scattered woodlands/tall shrublands of *A. aneura* and other acacias, low shrubs *Senna* and *Eremophila* spp., forbs and sparse annual grasses (SAES).
4.	25%	**Cobble plains** - up to 2 km long by 500 m wide, almost level crests with slopping margins dissected to 2-3 m; dense pavement of pebbles and cobbles.	Red shallow loams (522).	Depauperate shrublands with isolated or very scattered *A. aneura, A.* aff. *palustris, Senna* spp., *Eremophila* spp. and forbs (PSMS).
5.	3%	**Plains on dolerite** - gently undulating surfaces on dolerite up to 1 km in extent; variable density surface mantle of dolerite fragments.	Red shallow loams (522).	Low very scattered shrublands of *Senna artemisioides* subsp. *oligophylla* (blood bush) with occasional *Eremophila* and *Acacia* spp., also *Rhagodia eremaea* (tall salt bush) and annual grasses.
6.	15%	**Saline drainage floors with braided channels** - level floors, mostly less than 200 m wide but up to 750 m and 2-3 km long, braided channels incised up to 1 m; major single channels up to 40 m wide and 2-3 m deep.	Red/brown non-cracking clays (622), red shallow sandy duplex soils (406) and river bed soils (705) within channels.	Drainage floors: very scattered to scattered low shrublands of *Halosarcia* spp. (samphire) (PSPS) or very scattered to scattered tall shrublands of *Acacia* spp. with understorey of numerous chenopod low shrubs, forbs and annual grasses (PMCS). Braided channels: moderately close to close fringing tall shrublands with *A. aneura, A. coriacea* (river jam), *A. sclerosperma* (limestone wattle) and *A. citrinoviridis* (black mulga), numerous low shrubs, forbs and annual grasses (DEAW).

FORTESCUE LAND SYSTEM (504 km^2, 0.3% of the survey area)

(modified from Payne and Mitchell 1992)

Alluvial plains and flood plains supporting patchy grassy woodlands and shrublands and tussock grasslands.

Land type: 17

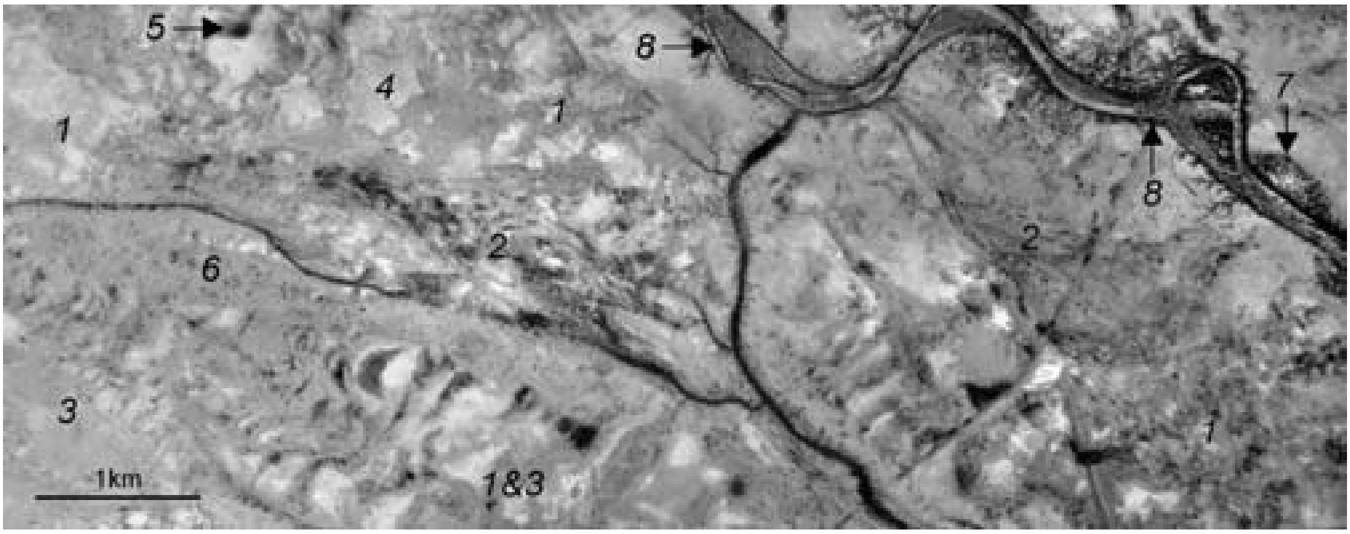
Geology: Quaternary alluvium.

Geomorphology: Depositional surfaces; alluvial plains, active flood plains and depressions with minor levees and major river channels.

Land management: Some parts of this system are subject to fairly regular flooding and are consequently inaccessible for some periods. Much of the vegetation on the system is highly attractive to grazing animals and is prone to degradation if overgrazed. Alluvial plains (unit 1) and levees (unit 7) are highly susceptible to erosion if vegetative cover is lost.

Traverse condition summary:
(111 assessments)
Vegetation - very good 7%, good 20%, fair 23%, poor 36%, very poor 14%.
Soil erosion - nil 65%, slight 10%, minor 10%, moderate 9%, severe 5%, extreme 1%.

Area mapped as sde: 221 ha.



No.	Unit name	Traverse recordings	Inventory sites
1.	Alluvial plain	49	5
2.	Flood plain, outwash river fan and depression	32	2
3.	Gilgai plain	11	-
4.	Hardpan plain	7	-
5.	Grove	1	2
6.	Sandy bank and sheet	3	3
7.	Levee	5	2
8.	Channel	2	-
	Other	1	-
	Total	111	14*

* Ten of these sites described from field work done in 1990 as part of an assessment of the impact of Ophthalmia Dam on the flood plains of the Fortescue River (see Payne and Mitchell 1992).

Fortescue land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	50%	**Alluvial plains** - level plains up to 5 km wide on either side of major channels, subject to occasional flooding, some surfaces scalded and hummocked.	Deep red/brown non-cracking clays (622), red deep sandy duplex soils (405) and infrequent red shallow sands (423).	Patchy tussock grasslands of *Chrysopogon fallax* (ribbon grass), *Eragrostis xerophila* (Roebourne Plains grass) with very scattered *Acacia citrinoviridis*, (black mulga), *A. aneura* (mulga) and *Senna* spp. shrubs or scattered tall, mid height or low shrublands of *Acacia* and *Senna* spp. with patchy tussock grasses (APRG, PMGS).
2.	25%	**Flood plains, outwash river fans and depressions** - level plains, fans and depressions, extending 2-3 km, marginally lower than unit 1 and receiving more regular over bank flooding, some surfaces with gilgai microrelief.	Deep red/brown non-cracking clays (622) and self-mulching cracking clays (602).	Scattered to moderately close tall shrublands/woodlands of *A. citrinoviridis, A. aneura* and *Eucalyptus victrix* (coolibah) and understorey of tussock grasses (mostly *Chrysopogon fallax*) (DEGW, APRG).
3.	10%	**Gilgai plains** - level backplains extending up to 500 m, gilgai microrelief.	Self-mulching cracking clays (602) with minor deep red/brown non-cracking clays (622).	Tussock grasslands of *Eragrostis xerophila* or *Astrebla* spp. (Mitchell grass) (ARPG, APMG).
4.	7%	**Hardpan plains** - almost level wash plains receiving sheet flow; on outer margins of system.	Red loamy earths (544).	Very scattered tall shrublands of *A. aneura* with a few *Eremophila* and *Senna* spp. low shrubs (HPMS).
5.	1%	**Groves** - drainage foci occurring on hardpan plains (unit 4), up to 200 m long and 50 m wide but commonly less with long axes at right angles to direction of sheet flow.	Red loamy earths (544).	Close or closed tall shrublands or woodlands of *Acacia aneura* with mid and low shrubs, *Eremophila forrestii* (Wilcox bush), *Senna* and *Sida* spp. and scattered tussock grasses such as *Chrysopogon fallax* (GMGW).
6.	2%	**Sandy banks and sheets** - irregular sandy banks and patches on alluvial plains (unit 1) up to 2 km in extent and raised up to 1 m above surrounding plains, moundy surfaces.	Red deep sands (445) with some red sandy earths (463) on sand sheets.	Hummock grasslands of *Triodia* sp. (hard spinifex) or *T. pungens* (soft spinifex) with isolated to scattered shrubs of *Acacia* and *Senna* spp. (SHSG, SSSG).
7.	2%	**Levees** - ill-defined levees 25-150 m wide flanking major channels (unit 8) and raised 1-2 m above adjacent plains (units 1 and 2), moundy surfaces.	Red deep sands (445) and red sandy earths (463).	Scattered woodlands with *Eucalyptus victrix* (coolibah), *Acacia citrinoviridis* and other trees with scattered shrubs and *Chrysopogon fallax* and *Cenchrus ciliaris* (buffel grass) tussock grasses (DEGW).
8.	3%	**Channels** - major and minor river channels up to 200 m wide with banks 2-5 m high.	River bed soils (705).	Fringing woodlands with *Eucalyptus camaldulensis* (river red gum), *E. victrix, Acacia coriacea* (river jam) and *A. citrinoviridis* with *Chrysopogon fallax* and *Cenchrus ciliaris* tussock grasses (GMEW, DEGW).

GIRALIA LAND SYSTEM (66 km², 0.04% of the survey area)

(after Payne, Mitchell and Holman 1988)

Linear dunes and broad sandy plains supporting hard and soft spinifex grasslands.

Land type: 11

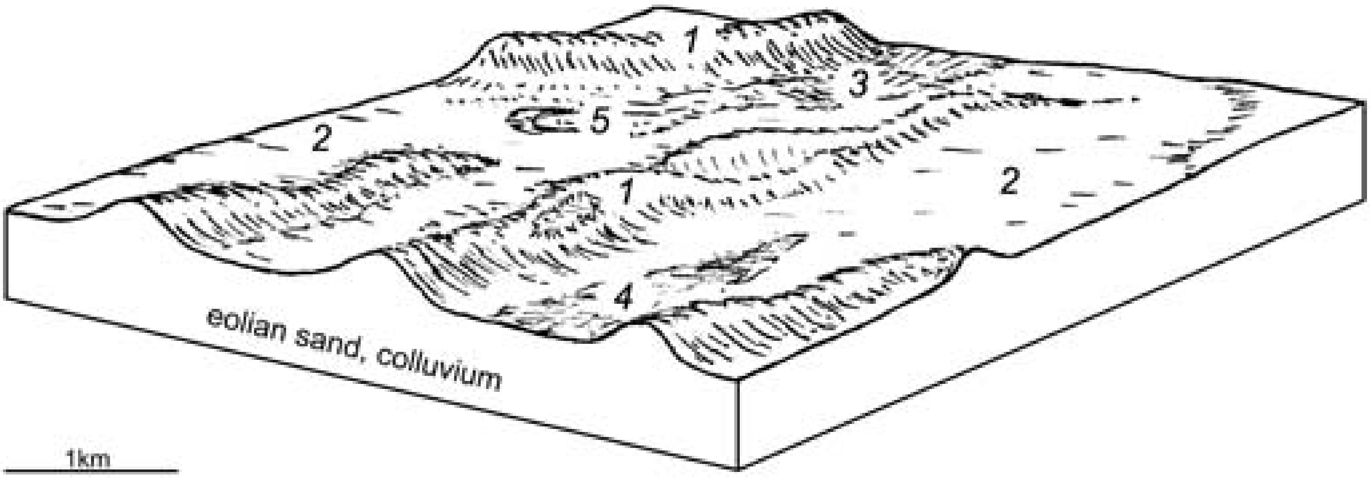
Geology: Quaternary colluvium and eolian sand.

Geomorphology: Depositional surfaces; sandy plains formed by sheet flood and wind action; broad plains with thin sand cover and linear dunes; no organised drainage but through flow areas receiving more concentrated sheet flow than adjacent plains, calcrete plains and minor calcreted drainage zones. Dune relief up to 30 m.

Land management: Hard spinifex vegetation is not preferred by livestock; soft spinifex is moderately preferred for a few years following burning. The system is prone to fire and is burnt on a fairly regular basis, some susceptibility to wind erosion (especially dune crests) after fires but rapid stabilisation usually occurs after rain.

Traverse condition summary: (4 assessments)
Vegetation - very good 100%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Sand dune	1	-
2.	Plain with thin sand cover	3	-
3.	Calcrete plain	-	-
4.	Broad through flow zone	-	-
5.	Narrow drainage floor associated with calcrete plain	-	-
	Total	4	-

Giralia land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	15%	**Sand dunes** - linear and occasionally reticulate dunes up to 30 m high and 4 km long, trending north-west to south-east, moderately inclined dune flanks, hummocky surfaces especially on dune crests.	Red deep sands (445).	Hummock grasslands of *Plectrachne schinzii* (soft spinifex) with an overstorey of *Grevillea gordoniana*, *Pityrodia* and *Tephrosia* spp, *Calytrix longiflora* and numerous annuals after fire (SSSG).
2.	70%	**Plains with thin sand cover** - level to very gently inclined sandy plains 1-3 km wide and up to 5 km long running between dunes.	Red sandy earths (463) and red deep sands (445).	Hummock grasslands of *Triodia lanigera* (hard spinifex) and some *T. pungens* (soft spinifex) with an overstorey of *Acacia inaequilatera*, (kanji), *A. stellaticeps*, (poverty bush), *A. victoriae*, (prickly acacia), *Hakea suberea* (corkwood) and numerous annuals after fire (PHSG, PSSG).
3.	5%	**Calcrete plains** - restricted, level to very gently inclined plains with irregular exposures of calcrete producing moundy microrelief.	Red shallow sands on calcrete (423).	Hummock grasslands of *T. pungens* with *Acacia bivenosa*, (two vein wattle), *Senna glutinosa* subsp. *pruinosa, Chorizema* sp. and *Calytrix longiflora*, many herbs and annual grasses after fire (CASG).
4.	10%	**Broad through flow zones** - level areas without channels, up to 500 m wide and 2.5 km long, receiving occasional through flow.	Red deep sands (445) and red sandy earths (463).	Hummock grasslands of *T. pungens*, sparse tussock grasses, low shrubs, forbs and annual grasses. Also tall shrublands of *Acacia inaequilatera, A. sclerosperma*, (limestone wattle) *A. victoriae* (prickly acacia) or trees *Eucalyptus victrix* (coolibah), *E. setosa* with hummock grass understorey (ASSG, DAHW).
5.	>1%	**Narrow drainage floors associated with calcrete plains** - level floors up to 150 m wide, up to 3 m below adjacent calcrete plains usually unchannelled.	Deep red/brown non-cracking clays (622).	Hummock grasslands of *T. pungens*, sparse tussock grasses, numerous low and tall shrubs *Acacia bivenosa, A. victoriae, A. sclerosperma, Senna* spp., forbs and annual grasses (ASSG, DAHW).

GRANITIC LAND SYSTEM (4,020 km^2, 2.2% of the survey area)

Rugged granitic hills supporting shrubby hard and soft spinifex grasslands.

Land type: 1

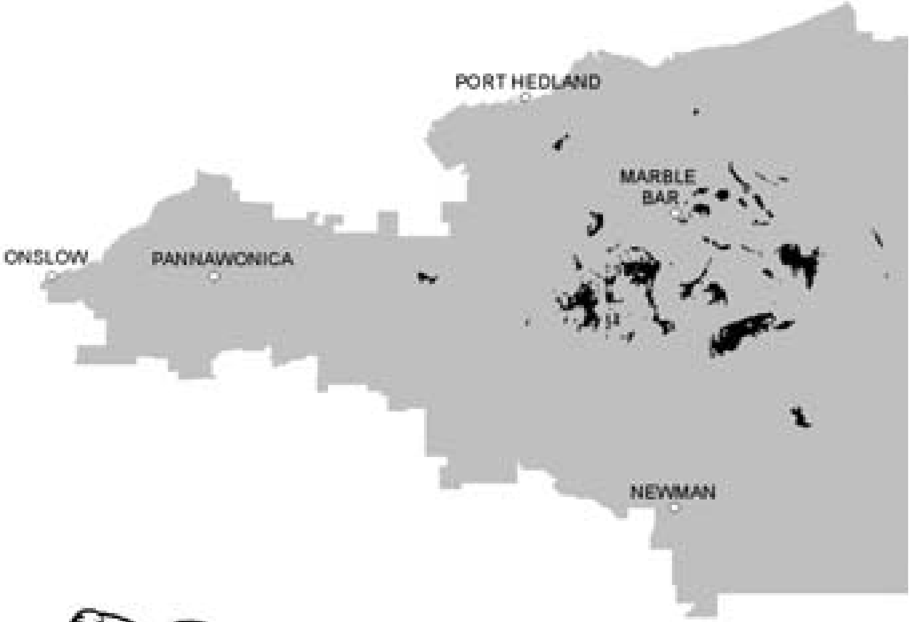
Geology: Archaean and Proterozoic granite, gneiss, granodiorite and porphyry.

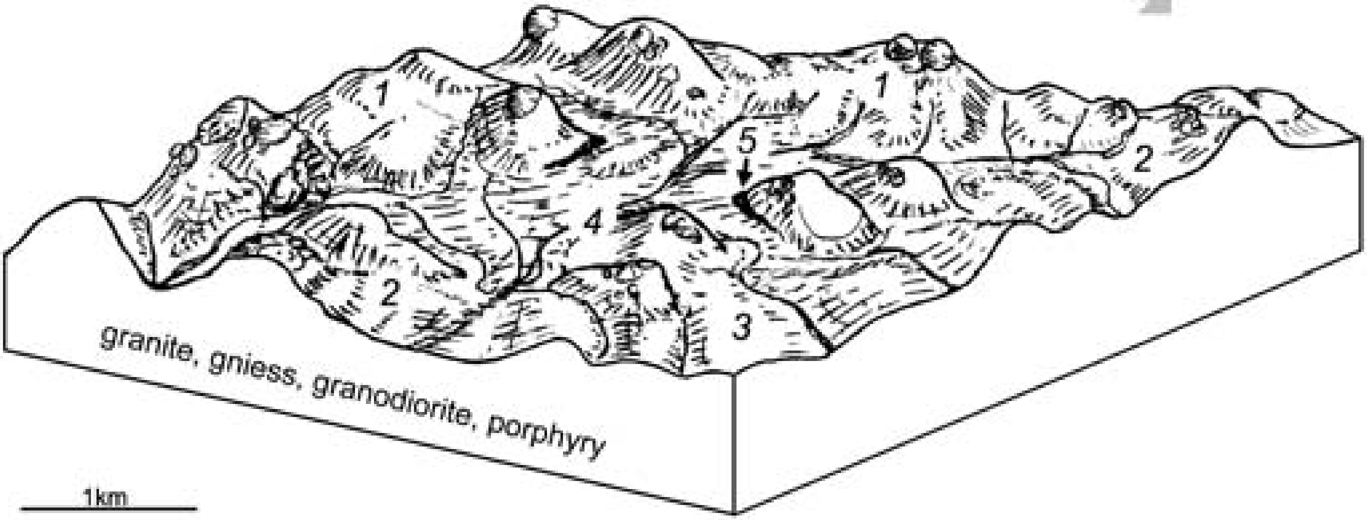
Geomorphology: Erosional surfaces; hill tracts and domes on granitic rocks with rough crests, associated rocky hill slopes, restricted lower stony plains; narrow, widely spaced tributary drainage floors and channels. Relief up to 100 m.

Land management: Much of the system is poorly accessible; hard spinifex vegetation is not preferred by livestock, soft spinifex is moderately preferred. The system is subject to fairly frequent burning and is not susceptible to erosion.

Traverse condition summary: (113 assessments)
Vegetation - very good 97%, good 2%, fair 1%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Hill, ridge, dome and upper slope	22	4
2.	Lower slope	26	1
3.	Stony plain	43	2
4.	Narrow drainage floor and channel	20	1
5.	Drainage focus	-	1
	Other	2	-
	Total	113	9

Granitic land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	40%	**Hills, ridges, domes and upper slopes** - hill crests and ridge summits with mantles of abundant pebbles, cobbles and stones and outcrop of granitic rocks; tor heaps and bare rounded dome surfaces of exposed rock; moderately inclined to steep upper slope with mantles of abundant pebbles, cobbles and stones; relief up to 80 m.	Stony soils (203), red shallow sands (423) and bare rock.	Hummock grasslands predominantly *Triodia* spp. (hard spinifex), less frequently *Triodia pungens* (soft spinifex) with isolated or very scattered shrubs such as *Acacia inaequilatera* (kanji), *A. trachycarpa* and other acacias (HSPG).
2.	40%	**Lower slopes** - very gently to gently inclined rocky slopes with mantles of abundant pebbles, cobbles and stones and outcrops of granitic rocks, extending for up to 2 km below unit 1.	Red shallow sands (423).	Hummock grasslands as for unit 1 (HSPG). Occasionally low or mid height shrublands of *Acacia* and *Eremophila* spp. with prominent ground layer of *Triodia* spp.
3.	15%	**Stony plains** - gently undulating stony or gritty surfaced plains extending for up to 1 km below units 1 and 2, surface mantles vary from very few to abundant pebbles of granitic material and quartz.	Red shallow sands (423) and red loamy earths (544).	Hummock grassland of *Triodia pungens* (soft spinifex) or *Triodia wiseana* (hard spinifex) with very scattered acacia shrubs (PSSG, PHSG). Less frequently acacia shrublands with soft spinifex understorey (PSSG).
4.	5%	**Narrow drainage floors and channels** - almost level floors <50 m wide in narrow valleys in upper parts becoming up to 300 m wide further downstream; channels up to 100 m wide with banks to 4 m.	Red shallow sands (423) and shallow river bed soils (705) in channels.	Small floors have hummock grasslands of soft or hard spinifex with scattered shrubs (ASSG, AHSG). Larger floors with channels support moderately close to close tall shrublands/woodlands with *Acacia, Eucalyptus* and *Melaleuca* spp. with hummock or tussock grasses (DAHW, DESG, DEGW).
5.	<1%	**Drainage foci** - isolated foci up to 200 m in extent at base of, and receiving run-on from, bare domes or hills (unit 1).	Red shallow sands (423).	Close tall shrublands of *Acacia tumida* (pindan wattle) or other acacias with variable mid and low shrubs and tussock grasses (DEAW).

GREGORY LAND SYSTEM (113 km^2, 0.06% of the survey area)

(after Payne and Tille 1992)

Linear dunes and restricted sandplains supporting shrubby hard spinifex (and occasionally soft spinifex) grasslands.

Land type: 11

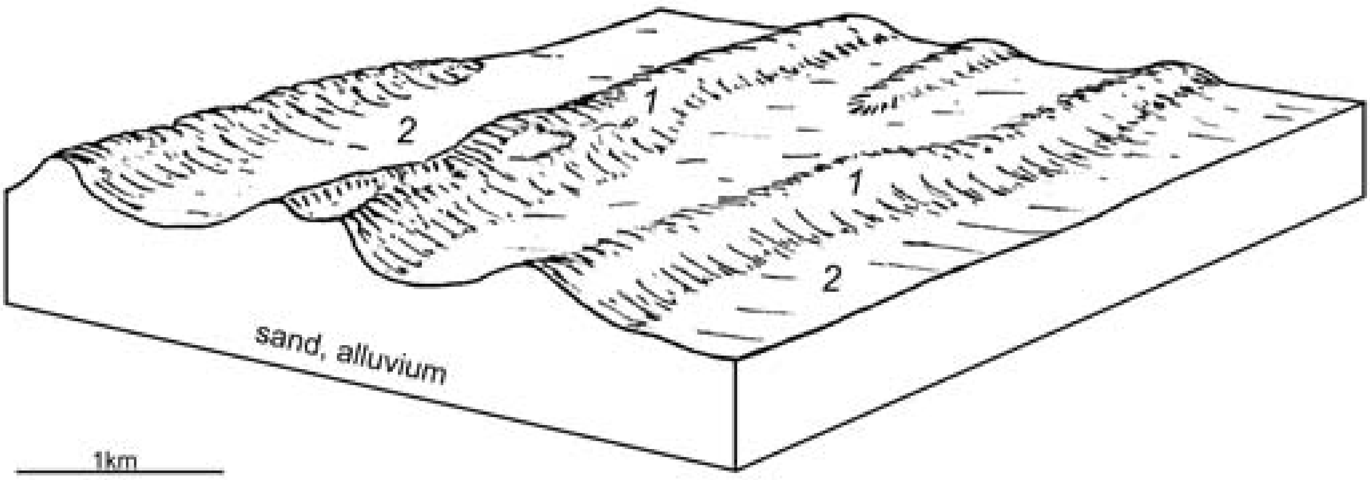
Geology: Quaternary eolian sand.

Geomorphology: Depositional surfaces; linear red sand dunes up to 12 m high with sandy swales and restricted sandplains. No organised drainage.

Land management: Hard spinifex vegetation is not preferred by livestock but soft spinifex is moderately preferred for a few years following burning. The system is prone to fires on a fairly regular basis. The system is generally not susceptible to significant degradation of vegetation, however, there is some risk of erosion following burning or other disturbance, particularly on dune crests and flanks.

Traverse condition summary: (4 assessments)
Vegetation - very good 25%, good 25%, fair 50%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Linear dune	-	2
2.	Swale and sandplain	4	-
	Total	4	2

Gregory land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	60%	**Linear dunes** - dunes up to 4 km long and up to 12 m high, gently to moderately inclined side slopes, dune crests with moundy, loose surfaces.	Red deep sands (445).	Hummock grasslands of *Triodia pungens, T. schinzii* (soft spinifex) or *T.* spp. (hard spinifex) with numerous shrubs or scattered to moderately close shrublands with *Acacia stellaticeps* (poverty bush), *A. trachycarpa* and other acacias with spinifex understorey (SSSG, SHSG).
2.	40%	**Swales and sandplains** - swales and sandplains with concave gently inclined marginal slopes near dunes becoming level elsewhere, up to 2 km in extent between dunes.	Red deep sands (445) with minor red sandy earths (463) within swales.	Hummock grasslands of *Triodia* spp. (soft and hard spinifex) with numerous shrubs including *Acacia ancistrocarpa* (shiny leaf wattle), *A. bivenosa* (two vein wattle), *A. acradenia, A. stellaticeps* and occasional eucalypt trees (SSSG, SHSG).

HOOLEY LAND SYSTEM (590 km^2, 0.3% of the survey area)

Alluvial clay plains supporting a mosaic of snakewood shrublands and tussock grasslands.

Land type: 15

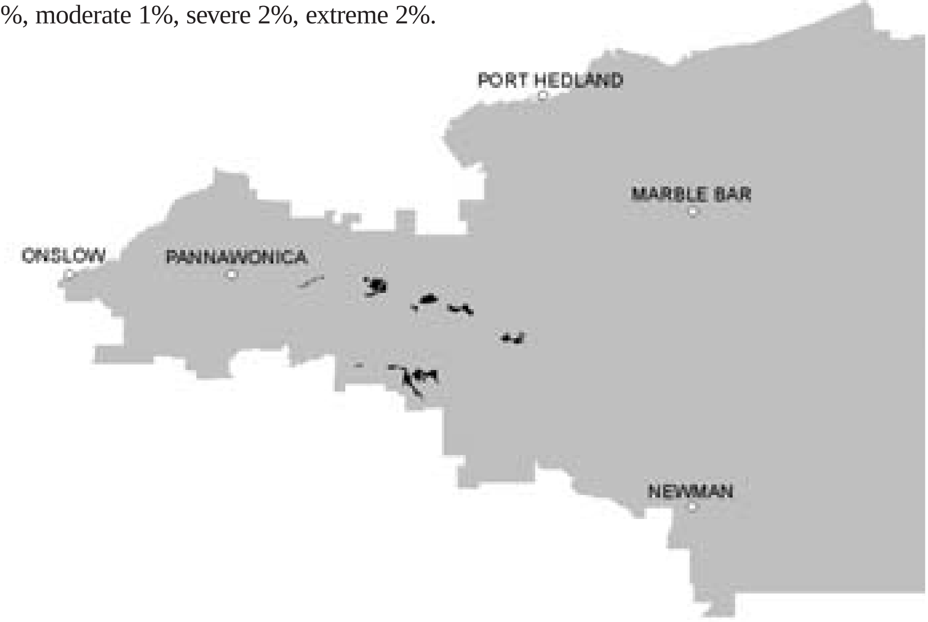
Geology: Quaternary alluvium.

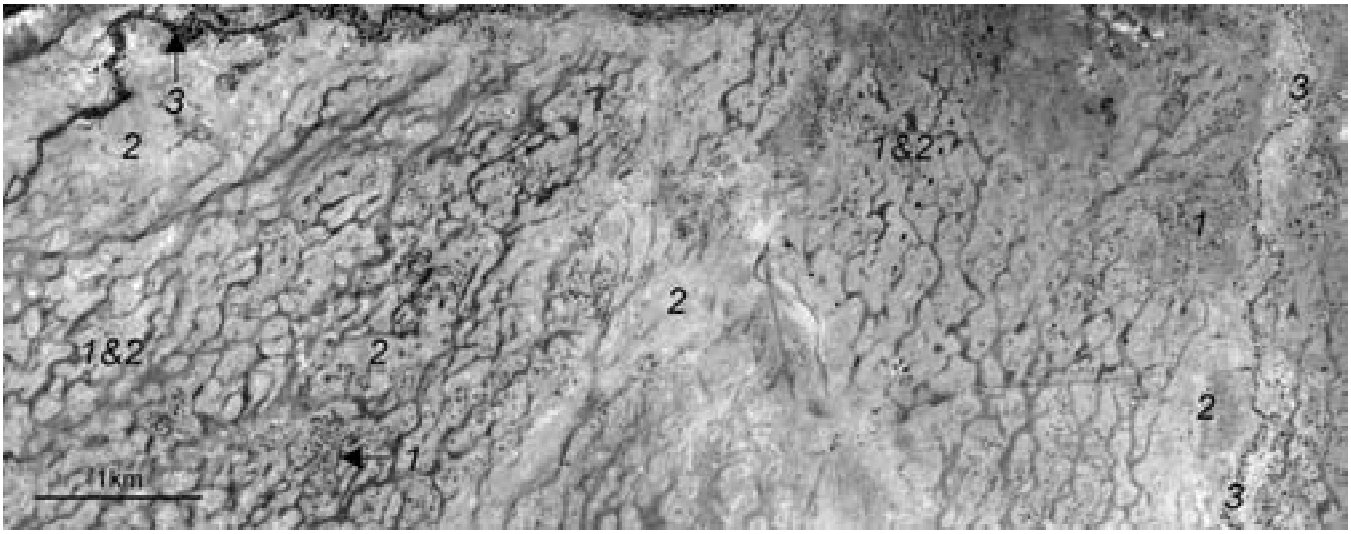
Geomorphology: Depositional surfaces; level plains of clayey and stony alluvium as a mosaic of surfaces with gilgai microrelief, sometimes stony, and non-gilgaied surfaces with abundant stony mantles; mostly sluggish internal drainage but occasional drainage tracts with major through going channels.

Land management: Tussock grasslands and snakewood shrub communities are favoured by grazing animals and are prone to degradation (especially the snakewood communities) if overgrazed. Those parts of the system not protected by a stony surface mantle are moderately susceptible to soil erosion.

Traverse condition summary: (121 assessments)
Vegetation - very good 21%, good 20%, fair 26%, poor 21%, very poor 12%.
Soil erosion - nil 91%, slight 1%, minor 3%, moderate 1%, severe 2%, extreme 2%.

Area mapped as sde: 963 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Stony plain	47	4
2.	Gilgai plain	55	4
3.	Drainage tract	17	1
	Other	2	-
	Total	121	9

Hooley land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	40%	**Stony plains** - very gently inclined plains extending for up to 1 km or as patches 10-300 m in extent as a mosaic with gilgai plains (unit 2); surface mantles of abundant to very abundant ironstone and other pebbles.	Deep red/brown non-cracking clays (622) and red loamy earths (544) with self-mulching cracking clays (602).	Hummock grasslands of *Triodia pungens* (soft spinifex) and *T.* sp. (hard spinifex) with isolated shrubs (PSSG, PHSG) or scattered tall shrublands of *Acacia xiphophylla* (snakewood) with sparse tussock grasses (SSTS, PSCS).
2.	50%	**Gilgai plains** - level plains with gilgai microrelief occurring as areas up to 1.5 km in extent or as patches 10-300 m in extent as a tight mosaic with stony plains (unit 1); surface mantles vary from very few to abundant ironstone pebbles.	Self-mulching cracking clays (602).	Mainly tussock grasslands predominantly with *Eragrostis xerophila* (Roebourne Plains grass) but also *Chrysopogon fallax* (ribbon grass) and *Astrebla pectinata* (barley Mitchell grass) (ARPG, APXG, APMG). Also scattered tall shrublands/woodlands of *Acacia aneura* (mulga) or *A. xiphophylla* with sparse tussock grasses (GMGW, SSTS).
3.	10%	**Drainage tracts** - nearly level tracts with clay soils, sometimes gilgaied, and variable surface mantles of ironstone pebbles, subject to occasional flooding by overbank flow from central channels up to 50 m wide and incised to 3-4 m.	Deep red/brown non-cracking clays (622) with self-mulching cracking clays (602).	Tussock grasslands of *Eragrostis xerophila* (ARPG) or tall moderately close shrublands/woodlands with *Acacia aneura* (mulga), *A. xiphophylla, A. coriaceae* (river jam), *Eucalyptus victrix* (coolibah) and tussock grasses (DEGW).

HORSEFLAT LAND SYSTEM (1,261 km^2, 0.7% of the survey area)

(modified from Payne and Tille 1992)

Gilgaied clay plains supporting tussock grasslands and minor grassy snakewood shrublands.

Land type: 14

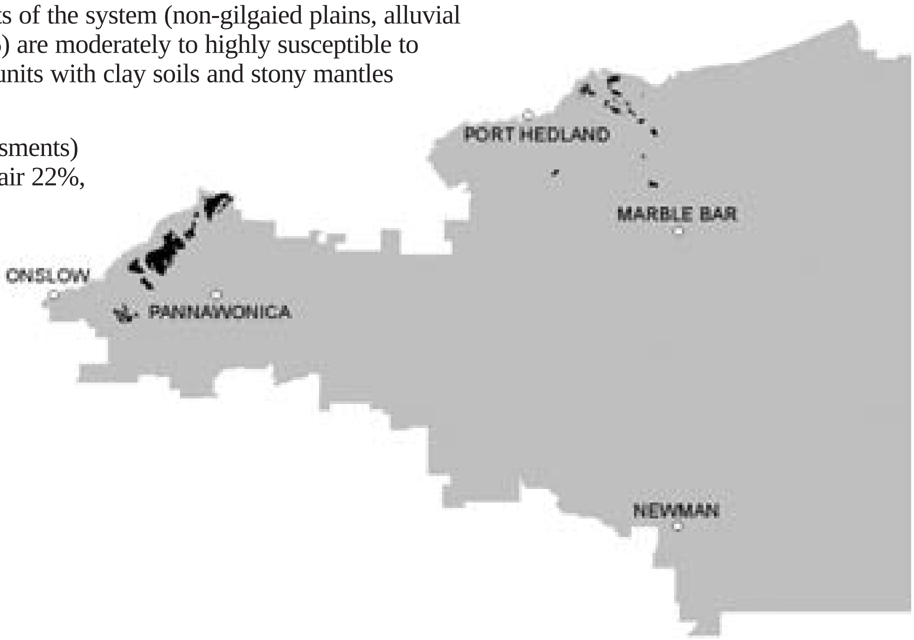
Geology: Quaternary alluvium.

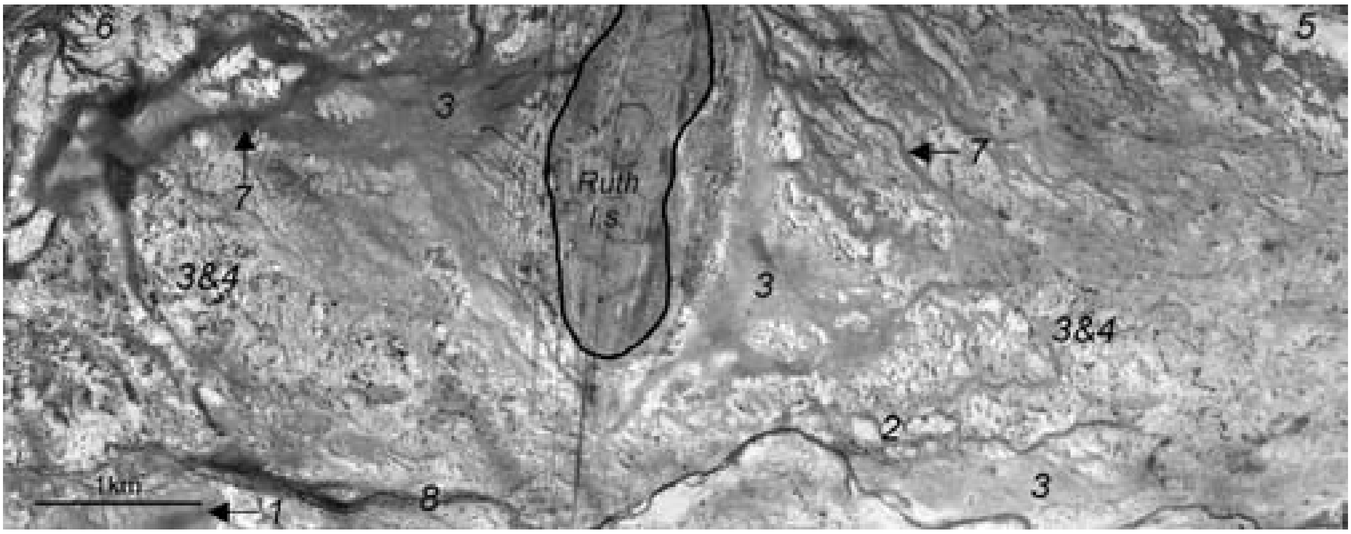
Geomorphology: Depositional surfaces; gilgaied and non-gilgaied clay plains, stony plains, narrow linear drainage depressions and dissected slopes marginal to the River land system; mostly internally drained, some through going trunk drainage channels.

Land management: Tussock grass vegetation is moderately attractive to grazing animals and is prone to decline if overgrazed. Parts of some units of the system (non-gilgaied plains, alluvial plains and dissected slopes, units 4, 5 and 6) are moderately to highly susceptible to erosion if vegetation is depleted, other flat units with clay soils and stony mantles are inherently resistant.

Traverse condition summary: (248 assessments)
Vegetation - very good 17%, good 30%, fair 22%, poor 23%, very poor 8%.
Soil erosion - nil 82%, slight 5%, minor 2%, moderate 5%, severe 3%, extreme 3%.

Area mapped as sde: 1,389 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Stony rise and low hill	2	1
2.	Calcrete plain	6	1
3.	Gilgaied plain	119	2
4.	Non gilgaied, sometimes stony plain	75	3
5.	Alluvial plain	33	1
6.	Dissected slope	-	-
7.	Drainage depression	12	1
8.	Channel and minor river terrace	1	1
	Total	248	10

Horseflat land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	<1%	**Stony rises and low hills** - isolated stony rises or low hills extending up to 700 m with surface mantles of abundant ironstone or basalt pebbles and cobbles; relief up to 20 m.	Stony soils (203) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana, T. brizoides* (hard spinifex) with isolated shrubs (HSPG).
2.	2%	**Calcrete plains** - very gently inclined plains restricted to 300-400 m in extent with mantles of many to abundant calcrete pebbles.	Calcareous shallow loams (544).	Hummock grasslands of *T. wiseana* with isolated shrubs (CASG).
3.	52%	**Gilgaied plains** - level plains extending for up to 3 km or as a tight mosaic (10-200 m in diameter) with similarly sized non-gilgaied plains (unit 4) or they may be linearly arranged; gilgai microrelief; surface mantles vary from nil to abundant pebbles of ironstrone, basalt and other rocks.	Self-mulching cracking clays (602).	Mostly tussock grasslands dominated by *Eragrostis xerophila* (Roebourne Plains grass) (ARPG) but also other grasses such as *Chrysopogon fallax* (ribbon grass) and *Eriachne benthamii* (swamp grass) (APRG, APSG). Occasional patches of very scattered to scattered mid height shrublands of *Acacia xiphophylla* (snakewood) with tussock grasses (SSTS).
4.	30%	**Non gilgaied, sometimes stony plains** - almost level plains extending up to 2 km but more usually as much smaller patches between gilgaied areas (unit 3), marginally higher than unit 3, surface mantles vary from nil to abundant pebbles and cobbles of ironstone, basalt and other rocks.	Deep red/brown non-cracking clays (622).	Very scattered to scattered tall and mid height shrublands of *Acacia xiphophylla* with tussock grasses mostly *Eragrostis xerophila* (SSTS). Also patchy tussock and annual grasslands (PMOG) and hummock grasslands of *Triodia wiseana, T. longiceps* (hard spinifex) (PHSG).
5.	10%	**Alluvial plains** - level plains 1-2 km in extent often adjacent to dissected slopes (unit 6) or as slightly lower inclusions in gilgaied plains (unit 3); no surface mantles, subject to occasional flooding.	Deep red/brown non-cracking clays (622) with some self-mulching cracking clays (602).	Tussock grasslands with *Eragrostis xerophila, Eriachne benthamii, Chrysopogon fallax, Cenchrus ciliaris* (buffel grass) (APXG, ARPG); also tussock grasslands with shrub *Atriplex bunburyana* (silver saltbush) (PCGS). Occasionally *Triodia* spp. (spinifex) hummock grasslands.
6.	1%	**Dissected slopes** - short (generally <400 m wide) very gently inclined slopes flanking River land system, gilgaied plains (unit 3) and alluvial plains (unit 5), moundy surfaces with rills and gullies incised 1-2 m; gullies may be active or stabilised by stony mantle and vegetation.	Deep red/brown non-cracking clays (622) with some red deep loamy duplex soils (506).	Very scattered tall and mid height shrublands of *A. xiphophylla* with patchy tussock grasses (SSTS). Also very sparse tussock grasslands and annual grasslands/herbfields.
7.	4%	**Drainage depressions** - generally narrow (20-200 m wide, occasionally much larger) linear drainage zones running through and marginally lower than units 3 and 4; mostly unchannelled.	Deep red/brown non-cracking clays (622) and red loamy earths (544).	Dense tussock grasslands including *Eriachne benthamii, Chrysopogon fallax* with occasional eucalypt trees and shrubs such as *Acacia farnesiana* (mimosa bush) (APXG, APRG, DEGW).
8.	<1%	**Channels and minor river terraces** - channels up to 50 m wide, banks and narrow river terraces.	River bed soils (705).	Fringing woodlands with *Eucalyptus camaldulensis* (river red gum), *E. victrix* (coolibah) and *Acacia coriaceae* (river jam) and grasses *Cenchrus ciliaris, Chrysopogon fallax, Triodia pungens* (soft spinifex) (DEGW).

HOUNDSTOOTH LAND SYSTEM (427 km^2, 0.2% of the survey area)

Rough shale hills, stony plains and broad drainage floors supporting hard spinifex grasslands and sparse shrubs.

Land type: 1

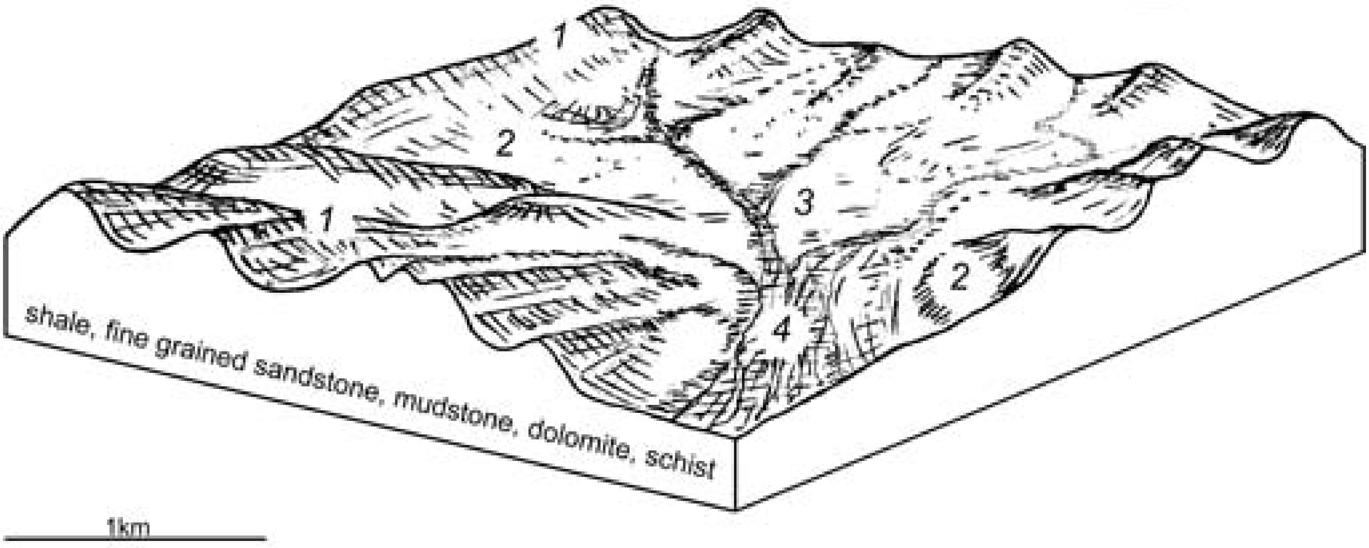
Geology: Lower Proterozoic shale, fine-grained sandstone, mudstone, dolomite and schist, minor Quaternary alluvium.

Geomorphology: Erosional surfaces; ridges and hills of steeply dipping maroon shale or other sedimentary rocks with stony footslopes and lower plains; moderately spaced tributary drainage patterns in hills becoming sub-parallel on stony footslopes thence spreading broadly onto lower plains or draining into broad flow zones with or without braided channels. Relief usually less than 30 m.

Land management: Hard spinifex vegetation is not preferred by livestock; soft spinifex and sparse tussock grasses in drainage zones are moderately preferred and can become degraded. Drainage zones (unit 4) are slightly susceptible to accelerated erosion; the rest of the system is not susceptible.

Traverse condition summary: (46 assessments)
Vegetation - very good 86%, good 7%, fair 7%.
Soil erosion - nil 98%, slight 2%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Shale hill and ridge	5	2
2.	Lower footslope	9	-
3.	Stony plain	19	1
4.	Flow zone	12	-
	Other	1	-
	Total	46	3

Houndstooth land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	60%	**Shale hills and ridges** - rough crests and gently inclined to steep hill slopes, mantles of abundant tabular shale fragments and steeply dipping shale outcrop; relief up to 30 m.	Stony soils (203), shallow red/brown non-cracking clays (622) and red shallow sandy duplex soils (406).	Hummock grasslands of *Triodia wiseana, T. brizoides* (hard spinifex) with isolated shrubs (HSPG). Less frequently *T. pungens* (soft spinifex) (HSPG).
2.	20%	**Lower footslopes** - very gently inclined concave stopes up to 500 m in extent with mantles of abundant quartz pebbles, dissected to shale at 0.5 m by narrow creeklines.	Shallow red/brown non-cracking clays (622) and red shallow sandy duplex soils (406).	As for unit 1 (HSPG).
3.	10%	**Stony plains** - level plains up to 500 m in extent marginal to and receiving run-off from lower footslopes; surface mantles of abundant to very abundant quartz pebbles and cobbles.	Red shallow loams (522).	Hummock grasslands predominantly *Triodia wiseana* (hard spinifex) with isolated shrubs (PHSG). Occasionally *T. pungens* (soft spinifex) (PSSG).
4.	10%	**Flow zones** - nearly level drainage zones up to 600 m wide and 4 km long, flat or guttered surfaces receiving run-off from other units; unchannelled or with braided channels up to 20 m wide and incised up to 1.5 m.	Red loamy earths (544) and red/brown non-cracking clays (622).	Very scattered to scattered tall shrublands of *Acacia* spp. and occasional eucalypt trees with patchy tussock grasses such as *Chrysopogon fallax* (ribbon grass) or hummock grass *Triodia pungens* (DEGW, ASSG).

JAMINDIE LAND SYSTEM (2,074 km^2, 1.1% of the survey area)

(modified from Wilcox and McKinnon 1972)

Stony hardpan plains and rises supporting groved mulga shrublands, occasionally with spinifex understorey.

Land type: 12

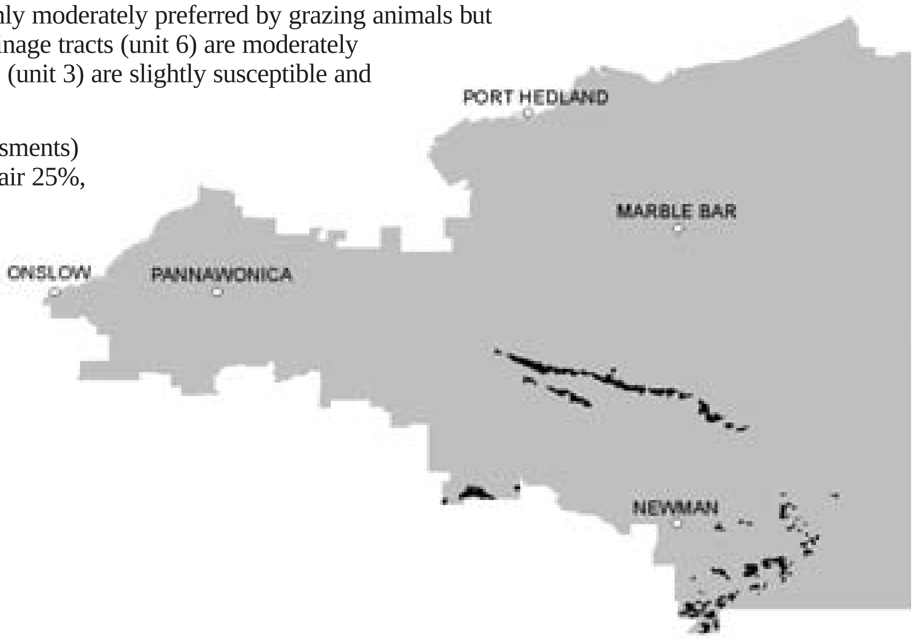
Geology: Partly cemented Quaternary colluvium, alluvium and laterite; minor sedimentary rocks of Proterozoic age.

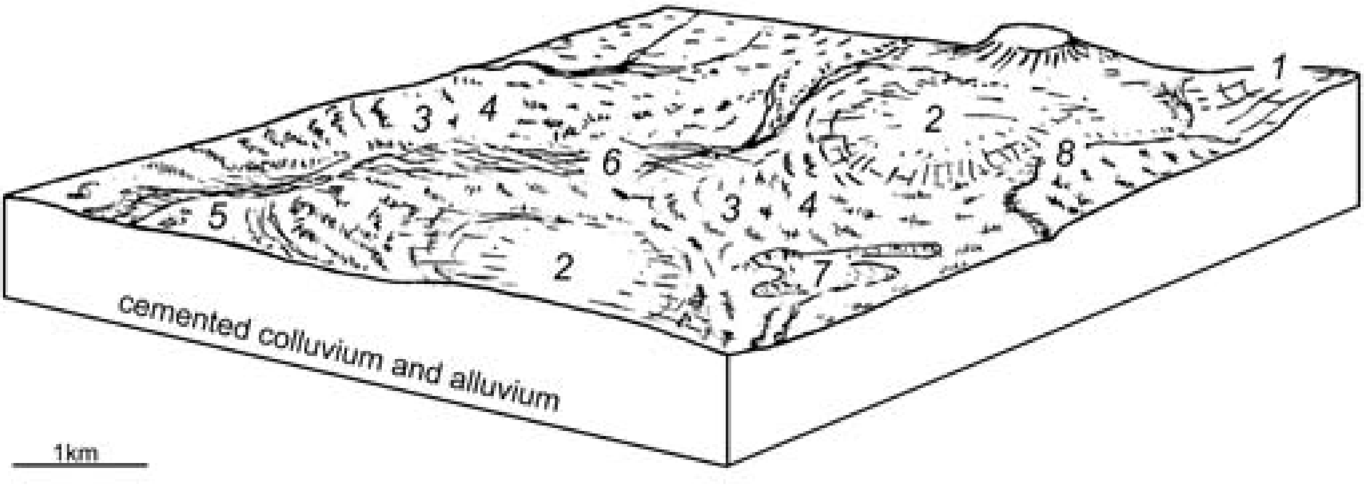
Geomorphology: Depositional surfaces; non-saline plains with hardpan at shallow depth and groved vegetation, stony upper plains and low rises on hardpan or rock, very widely spaced tributary drainage tracts and channels; minor stony gilgai plains, sandy banks and low ridges and hills. Relief up to 30 m.

Land management: Most vegetation is only moderately preferred by grazing animals but can become degraded by overgrazing. Drainage tracts (unit 6) are moderately susceptible to erosion, some hardpan plains (unit 3) are slightly susceptible and other parts are inherently resistant.

Traverse condition summary: (221 assessments)
Vegetation - very good 22%, good 26%, fair 25%, poor 15%, very poor 12%.
Soil erosion - nil 93%, slight 2%, minor 3%, moderate 1%, severe 1%.

Area mapped as sde: 1,927 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low ridge and hill	6	3
2.	Stony upper plain and low rise	51	3
3.	Hardpan plain	79	2
4.	Grove	59	-
5.	Gilgai plain	1	1
6.	Drainage tract	14	-
7.	Sandy bank	10	-
8.	Channel and bank	1	-
	Total	221	9*

* Seven of these sites described from field work done in 1990 as part of an assessment of the impact of Ophthalmia Dam on the flood plains of the Fortescue River (see Payne and Mitchell 1992).

Jamindie land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	5%	**Low ridges and hills** - ridges and hills up to 25 m high and 1.5 km long, gently inclined footslopes with mantles of abundant pebbles and cobbles and some rock outcrop.	Stony soils (203).	Hummock grasslands of *Triodia* spp. (hard spinifex) with very scattered *Acacia* spp. shrubs and occasional eucalypt trees (HSPG, HESG).
2.	20%	**Stony upper plains and low rises** - gently undulating plains up to 3 km in extent, up to 20 m above lowest units; surface mantles of many to very abundant pebbles and cobbles of ironstone and other rocks.	Stony soils (203) and red shallow loams (522).	Shrubby hummock grasslands of *Triodia* spp. (hard spinifex) (PHSG) or scattered to moderately close tall shrublands with *Acacia xiphophylla* (snakewood), *A. aneura* (mulga) with shrub understoreys (PSCS, PSMS) or *Triodia* spp. (hard and soft spinifex) understorey (PMSS).
3.	50%	**Hardpan plains** - almost level plains up to 8 km in extent by 4-5 km wide between shallow drainage tracts (unit 6); surface mantles of many to very abundant pebbles of ironstone and chert, subject to sheet overland flow.	Red-brown hardpan shallow loams (523).	Very scattered tall shrublands of *Acacia aneura* and other acacias with sparse *Eremophila* and *Ptilotus* spp. low shrubs (HPMS, PSMS). Occasionally *Triodia pungens* (soft spinifex) in ground layer.
4.	15%	**Groves** - accurate drainage foci, up to 400 m long and 20 m wide but commonly much less, on hardpan plains (unit 3), arranged with long axes at right angles to direction of sheet overland flow.	Red loamy earths (544).	Close tall shrublands/woodlands of *A. aneura* with numerous *Eremophila, Ptilotus* and *Sida* spp. mid and low shrubs and sparse tussock grasses (GMUW, GMGW). Less frequently *Triodia pungens* in ground layer (DAHW).
5.	2%	**Gilgai plains** - level plains less than 1 km in extent associated with drainage tracts (unit 6) or as isolated areas within unit 3; gilgai microrelief.	Self-mulching cracking clays (602).	Very scattered tall shrublands of *Acacia* spp. with variable low shrubs and sparse tussock grasses (ARPG).
6.	5%	**Drainage tracts** - nearly level tracts associated with hardpan plains (unit 3), receiving more concentrated through flow and usually 300-400 m wide but up to 1 km, channelled or unchannelled; hardpan exposed in parts, variable pebbly mantles.	Red-brown hardpan shallow loams (523) and minor red loamy earths (544).	Scattered tall shrublands of *A. aneura* and other acacias and understorey of low shrubs and sparse tussock or hummock grasses (DEGW, DAHW).
7.	2%	**Sandy banks** - banks up to 0.5 m high, mostly less than 100 m long and 10 to 20 m wide, on unit 3; loose hummocky surfaces.	Red deep sands (445).	Shrublands with *A. aneura* and other acacias with *Eremophila* and *Senna* spp. low shrubs and *Triodia* spp. (hard and soft spinifex) ground layer (PMSS).
8.	1%	**Channels and banks** - channels 5-50 m wide, finely incised 1-2 m in hardpan on broad plains, up to 5 m in lower parts.	River bed soils (705).	Scattered to moderately close tall shrublands/woodlands with *A. aneura* and other acacias and tussock grasses (DEGW).

JIGALONG LAND SYSTEM (713 km^2, 0.4% of the survey area)

(modified from Payne and Mitchell 1992)

Alluvial plains and flood plains supporting grassy shrublands and woodlands and halophytic shrublands.

Land type: 17

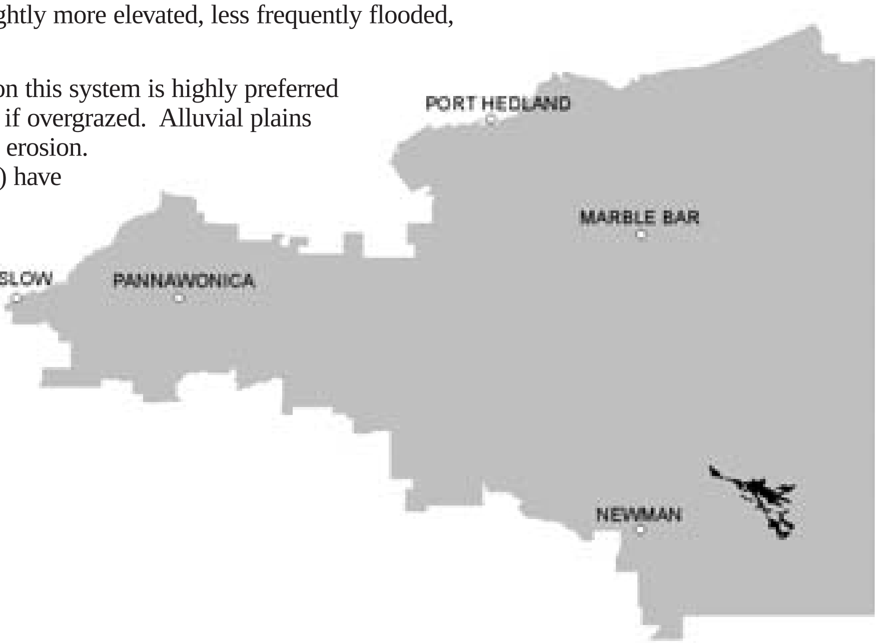
Geology: Quaternary alluvium and colluvium.

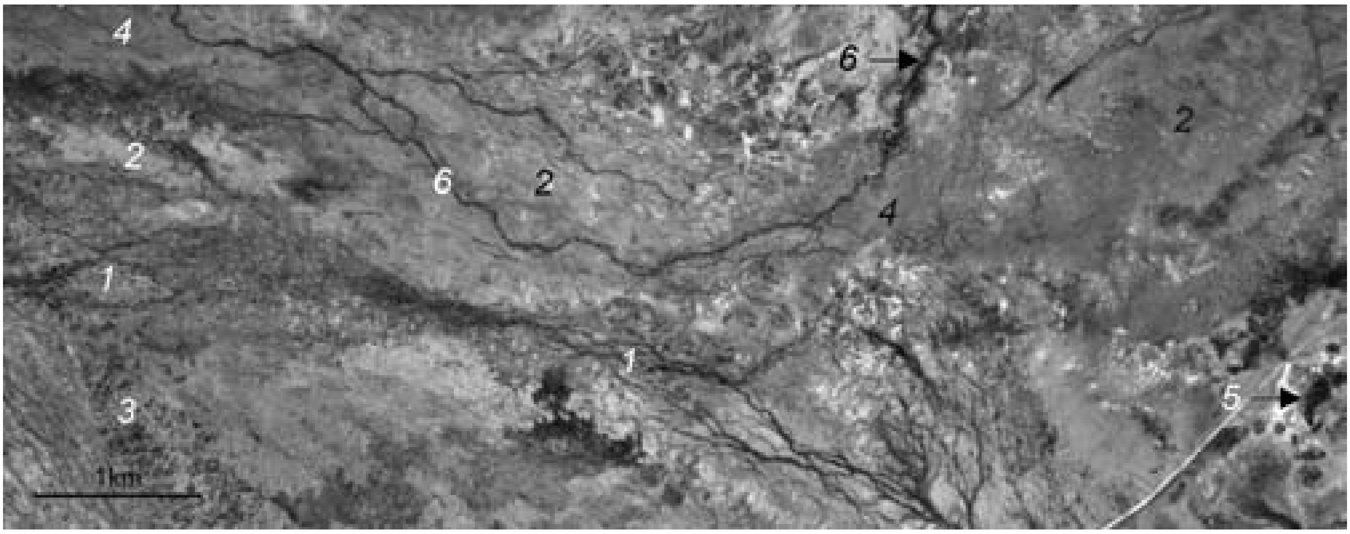
Geomorphology: Depositional surfaces; flood plains and alluvial plains subject to fairly regular flooding from central anastomosing channels and creeklines, also slightly more elevated, less frequently flooded, gravelly plains and minor gilgai plains.

Land management: Much of the vegetation on this system is highly preferred by grazing animals and is liable to degradation if overgrazed. Alluvial plains (unit 2) are moderately to highly susceptible to erosion. Gravelly plains and gilgai plains (units 3 and 4) have low to moderate susceptibility to erosion.

Traverse condition summary:
(90 assessments)
Vegetation - good 9%, fair 19%, poor 42%, very poor 30%.
Soil erosion - nil 69%, slight 3%, minor 12%, moderate 8%, severe 7%, extreme 1%.

Area mapped as sde: 995 ha





No.	Unit name	Traverse recordings	Inventory sites
1.	Flood plain and channelled tract	16	-
2.	Alluvial plain	48	4
3.	Gravelly plain	7	1
4.	Gilgai plain	9	1
5.	Drainage focus	5	1
6.	Major and minor channel	2	-
	Other	3	-
	Total	90	7*

* These sites described from fieldwork done in 1990 as part of an assessment of the impact of Ophthalmia Dam on the flood plains of the Fortescue River (see Payne and Mitchell 1992).

Jigalong land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	20%	**Flood plains and channelled tracts** - level, fairly regularly flooded plains and tracts, mostly <500 m wide, flanking major channels, frequently with braided minor channels and gutters.	Deep red/brown non-cracking clays (622).	Scattered to moderately close mixed height shrublands with *Acacia aneura* (mulga), *A. citrinoviridis* (black mulga), *Eremophila* spp., *Maireana pyramidata* (sago bush), *M. aphylla* (spiny bluebush), *Atriplex bunburyana* (silver salt bush) and tussock grasses *Chrysopogon fallax* (ribbon grass), *Eragrostis xerophila* (Roebourne Plains grass) (PMCS, PXHS).
2.	54%	**Alluvial plains** - almost level plains up to 5 km in extent, subject to periodic flooding and overland sheet flow; surfaces often scalded, hummocked and rilled, mantles of variable density ironstone gravel.	Red deep sandy duplex (405), red deep loamy duplex (506) and red/brown non-cracking clays (622).	Patchy, very scattered to scattered mixed height shrublands dominated by *Acacia victoriae* (prickly acacia) or *A. aneura* with halophytic and non-halophytic low shrubs *Maireana, Atriplex, Eremophila, Senna* spp. and sparse tussock grasses or *Triodia longiceps* (hard spinifex) (PXHS, PCGS, HPMS, PMGS, AHSG).
3.	10%	**Gravelly plains** - gently inclined plains on outer margins of system, slightly elevated above and not flooded as frequently as units 1 and 2; surfaces may be moundy with mantles of abundant to very abundant ironstone grit, gravel and cobbles.	Red-brown hardpan shallow loams (523) and red shallow loams (522).	Very scattered to scattered tall and low shrublands with *Acacia aneura* and *Eremophila* and *Senna* spp. (LHAS, SAES).
4.	10%	**Gilgai plains** - level plains up to 1 km in extent with weakly gilgaied microrelief and mantles of variable density ironstone gravel.	Self-mulching cracking clays (602).	Patchy tussock grasslands of *Eragrostis xerophila* with very scattered *Senna* and *Eremophila* spp. shrubs (ARPG, PMOG).
5.	3%	**Drainage foci** - discrete drainage foci, groves and pans mostly <250 m in extent (occasionally larger) within unit 2, occasionally with weakly gilgaied microrelief.	Deep red/brown non-cracking clays (622) with some self-mulching cracking clays (602).	Small foci may have grassy or bare central areas ringed by *A. aneura* and other shrubs, larger foci support moderately close tall shrublands with *A. aneura, Senna, Eremophila* and *Rhagodia* spp. and tussock grasses including *Chrysopogon fallax* and *Eriachne* spp. (GMGW).
6.	3%	**Major and minor channels** - meandering and anastomosing channels up to 100 m wide with associated narrow river terraces, levees and banks to 4 m high.	River bed soils (705).	Close fringing woodlands and tall shrublands often dominated by *Acacia citrinoviridis*. Also *A. coriacea* (river jam), *Eucalyptus camaldulensis* (river red gum), *E. victrix* (coolibah) and tussock grasses (DEAW).

JURRAWARRINA LAND SYSTEM (664 km^2, 0.4% of the survey area)

Hardpan plains and alluvial tracts supporting mulga shrublands with tussock and spinifex grasses.

Land type: 12

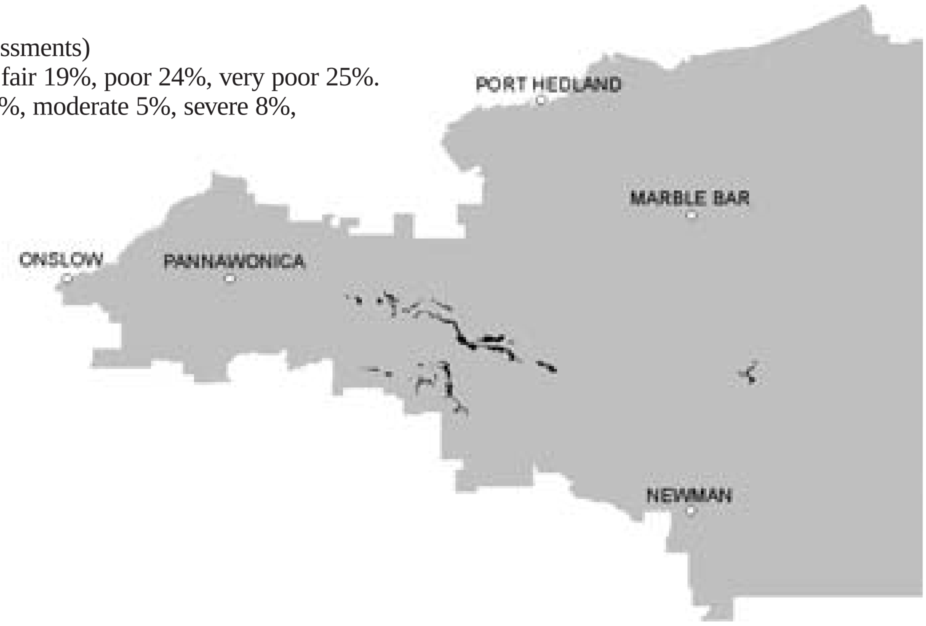
Geology: Quaternary alluvium and colluvium.

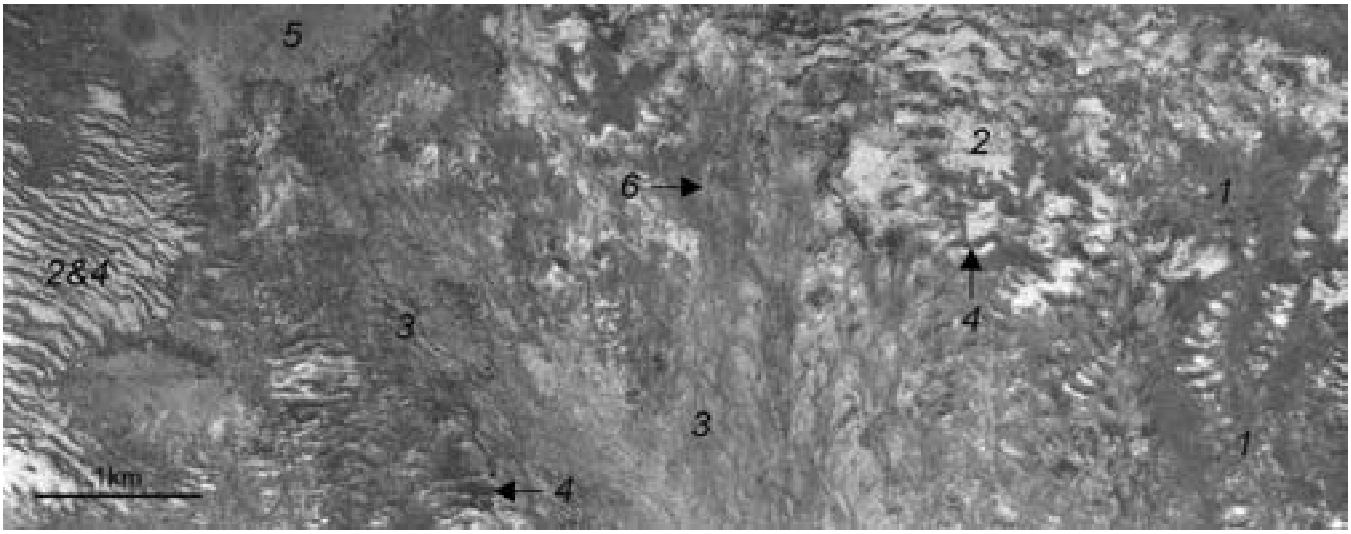
Geomorphology: Depositional surfaces; plains receiving overland sheet flow and with prominent drainage foci (groves) arranged as right angles to direction of flow, broad drainage tracts receiving more concentrated flow, with or without defined channels and with prominent gilgaied drainage foci; minor plains with clay soils and gilgai microrelief, also occasional through going creek channels.

Land management: Much of the vegetation on this system is highly preferred by grazing animals and is prone to degradation if overgrazed. Some hardpan washplains, drainage tracts and groves (units 2, 3 and 4) are moderately susceptible to erosion.

Traverse condition summary: (117 assessments)
Vegetation - very good 14%, good 18%, fair 19%, poor 24%, very poor 25%.
Soil erosion - nil 70%, slight 3%, minor 8%, moderate 5%, severe 8%, extreme 6%.

Area mapped as sde: 3,350 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Stony plain	36	-
2.	Hardpan plain	31	1
3.	Drainage tract	15	3
4.	Grove and drainage focus	26	1
5.	Gilgai plain	6	1
6.	Channel	1	-
	Other	2	-
	Total	117	6

Jurrawarrina land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	20%	**Stony plains** - very gently inclined plains up to 1 km in extent on outer margins of system; surface mantles of abundant pebbles and cobbles of ironstone, chert and quartz.	Red shallow sandy duplex soils (406).	Very scattered tall shrublands of *Acacia aneura* (mulga) and/or *A. xiphophylla* (snakewood) with *Triodia pungens* (soft spinifex) ground layer, less frequently with hard spinifex (PMSS, PSSG).
2.	32%	**Hardpan plains** - level plains receiving overland sheet flow from unit 1 and adjacent land systems, surface mantle varies from very few to abundant ironstone pebbles.	Red-brown hardpan shallow loams (523) and red loamy earths (544).	Very scattered to scattered tall shrublands of *A. aneura* with sparse *Eremophila* and *Ptilotus* spp. low shrubs (PSMS, HPMS). Also scattered tall shrublands of *A. xiphophylla* and sparse tussock grasses (SSTS).
3.	20%	**Drainage tracts** - level, channelled or unchannelled tracts and alluvial plains with clayey soils, up to about 750 m wide, receiving more concentrated through flow, usually without surface mantles, sometimes with gilgai microrelief.	Red loamy earths (544).	Scattered to moderately close tall shublands/woodlands of *A. aneura* and other acacias with tussock grasses (DEGW). Less frequently with *Triodia pungens* ground layer (DAHW).
4.	22%	**Groves and drainage foci** - foci as bands up to 400 m long by 30 m wide (but usually much smaller) arranged with long axes at right angles to direction of sheet flow on stony and hardpan plains (units 1 and 2), also less uniformly shaped foci and depressions 30-300 m in extent on hardpan plains and drainage tracts (units 2 and 3); both frequently with gilgai micro relief.	Deep red/brown non-cracking clays (622) and self-mulching cracking clays (602).	Close tall shrublands/woodlands of *A. aneura* with very scattered low shrubs and grasses such as *Chrysopogon fallax* (ribbon grass) and *T. pungens* (GMGW).
5.	5%	**Gilgai plains** - level plains up to 500 m in extent with gilgai microrelief, surface mantles vary from few to many pebbles of ironstone.	Self-mulching cracking clays (602) and some red/brown non-cracking clay (622).	Tussock grasslands of *Eragrostis xerophila* (Roebourne Plains grass), *Chrysopogon fallax, Astrebla* spp. (Mitchell grass) with isolated or very scattered shrubs (APXG).
6.	1%	**Channels** - channels up to 50 m wide with banks up to 4 m high.	River bed soils (705).	Moderately close fringing tall shrublands/woodlands with *A. aneura*, other acacias and eucalypts with tussock grass ground layer (DEGW).

KANJENJIE LAND SYSTEM (152 km^2, 0.1% of the survey area)

Stony clay plains supporting snakewood shrublands with tussock grasses.

Land type: 10

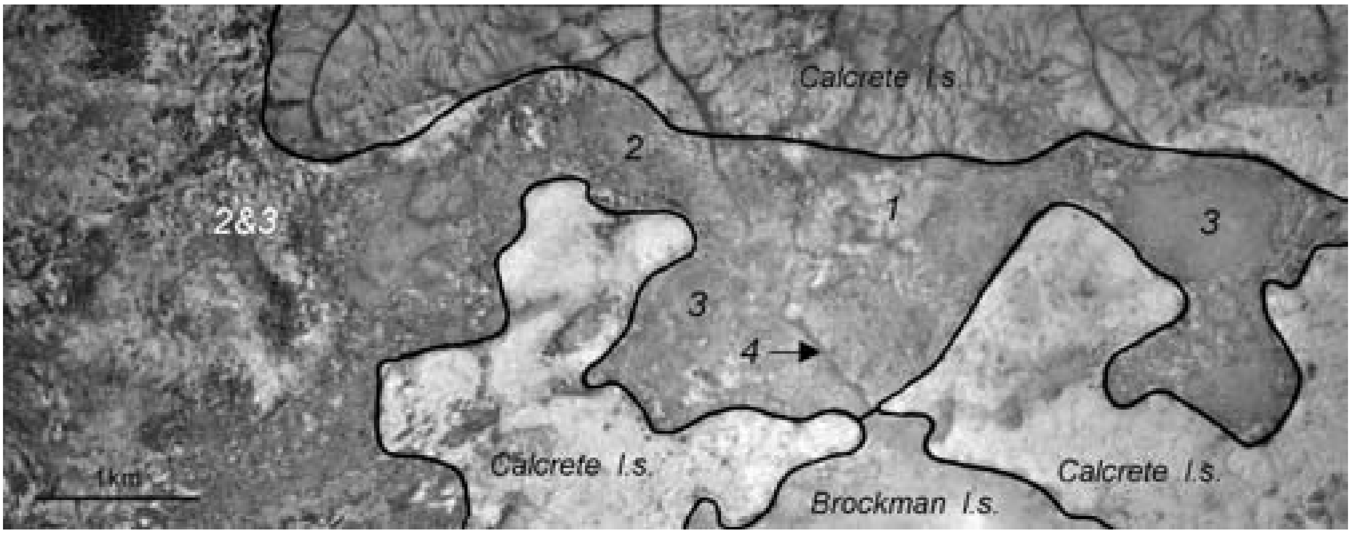
Geology: Quaternary alluvium and eluvium, minor calcrete.

Geomorphology: Depositional surfaces; stony plains with clay soils and a mosaic of gilgaied and non-gilgaied surfaces, minor calcrete platforms slightly raised above surrounding plains, internal drainage with rare channelled drainage tracts.

Land management: Most of the vegetation on this system is highly preferred by grazing animals and tussock grasses can become depleted if overgrazed. The system is inherently resistant to erosion.

Traverse condition summary: (31 assessments)
Vegetation - very good 43%, good 35%, fair 16%, poor 6%,
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Calcrete platform	5	-
2.	Stony plain	12	1
3.	Stony gilgai plain	11	4
4.	Drainage tract	2	-
	Other	1	-
	Total	31	5

Kanjenjie land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	10%	**Calcrete platforms** - level plains up to 500 m in extent raised 1-2 m above surrounding plains, surface mantles of abundant to very abundant pebbles and cobbles of calcrete.	Calcareous shallow loams (521).	Hummock grasslands of *Triodia wiseana* (limestone spinifex) with very scattered to scattered shrubs including *Acacia bivenosa*, (two vein wattle) and *A. xiphophylla* (snakewood) (CASG).
2.	40%	**Stony plains** - level or very gently inclined plains up to 3 km in extent or as a much smaller mosaic with stony gilgai plains (unit 3), surface mantles of common to abundant pebbles and cobbles of calcrete.	Calcareous loamy earths (542), deep red/brown non-cracking clays (622) and self-mulching cracking clays (602).	Scattered tall shrublands dominated by *A. xiphophylla*, numerous other shrubs and tussock grasses *Astrebla pectinata* (barley Mitchell grass), *Chrysopogon fallax* (ribbon grass), *Eragrostis xerophila* (Roebourne Plains grass), or hummock grass *Triodia wiseana* (SSTS, ASHS).
3.	45%	**Stony gilgai plains** - level plains up to 4 km in extent or as a smaller mosaic with stony plains (unit 2), surface mantles vary from few to abundant pebbles of calcrete and/or ironstone.	Self-mulching cracking clays (602).	Scattered to moderately close tall shrublands dominated by *A. xiphophylla*, numerous other shrubs and tussock grasses *Astrebla* spp., *Chrysopogon fallax*, *Eragrostis xerophila* (SSTS).
4.	5%	**Drainage tracts** - occasional level tracts up to 300 m wide with sluggish, poorly defined, grassy channels up to 50 m wide.	Deep red/brown non-cracking clays (622).	As for unit 3 (SSTS).

KUMINA LAND SYSTEM (151 km^2, 0.1% of the survey area)

Duricrust plains and plateau remnants supporting hard spinifex grasslands.

Land type: 3

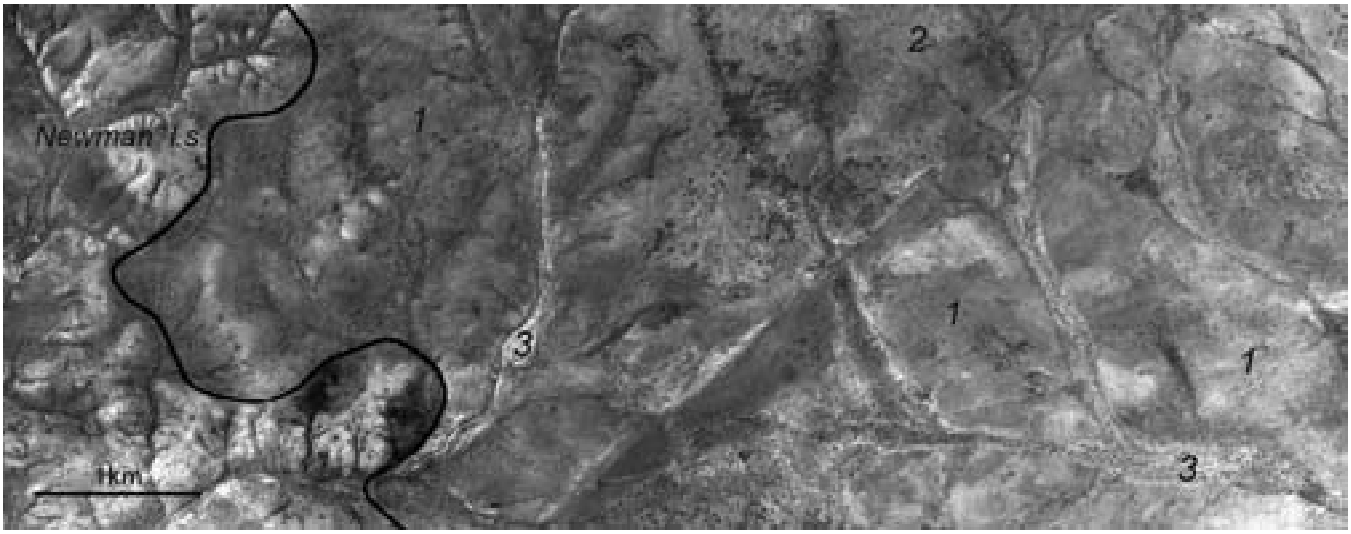
Geology: Partly consolidated Quaternary colluvium, Tertiary laterite, including surficial haematite-goethite deposits, and indurated duricrust.

Geomorphology: Level to gently undulating plateaux remnants and stony uplands with widely spaced tributary drainage tracts which may be channelled or unchannelled. Relief up to 15 m.

Land management: Hard spinifex grasslands dominate this system and are not preferred by livestock or prone to degradation. The system is inherently resistant to erosion because of its very stony nature.

Traverse condition summary: (3 assessments)
Vegetation - very good 100%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Stony plain	3	2
2.	Low rise	-	-
3.	Drainage tract	-	-
	Total	3	2

Kumina land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	90%	**Stony plains** - level to gently undulating upland plains extending for up to 6 km but usually smaller; surface mantles of abundant to very abundant pebbles and cobbles of ironstone.	Red loamy earths (544).	Shrubby hummock grasslands with *Triodia wiseana, T. angusta, Plectrachne* sp. (hard spinifex) with scattered *Acacia atkinsiana, A. ancistrocarpa* (shiny leaf wattle) and other acacias and low shrubs, occasional small eucalypt trees (PHSG).
2.	5%	**Low rises** - rounded rises up to 500 m in extent with gently inclined slopes and relief to 10 m; surface mantles of abundant to very abundant pebbles and cobbles of ironstone, also ironstone rock outcrop.	Red shallow loams (522).	As for unit 1 (PHSG).
3.	5%	**Drainage tracts** - tributary drainage tracts as shallow depressions with or without channels within stony plains (unit 1).	Red loamy earths (544).	Scattered to moderately close tall shrublands with *Acacia aneura* (mulga), other acacias and occasional eucalypt trees, *Triodia* spp. hummock grass ground layer (DAHW).

LATERITE LAND SYSTEM (355 km^2, 0.2% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Laterite mesas and gravelly rises and plains supporting mulga shrublands.

Land type: 4

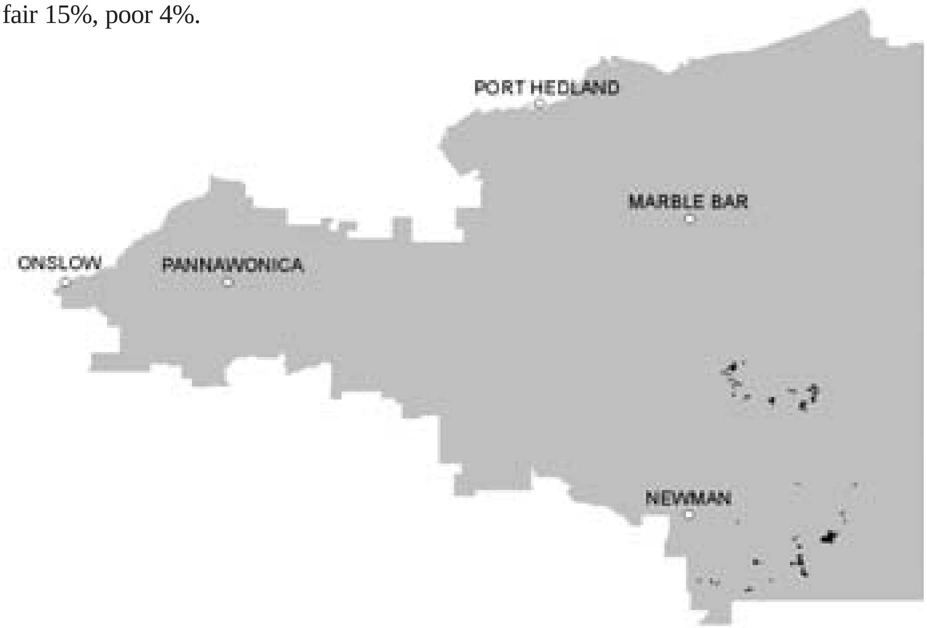
Geology: Tertiary laterite, limonite and colluvium overlying weathered sedimentary rocks of Lower Proterozoic age.

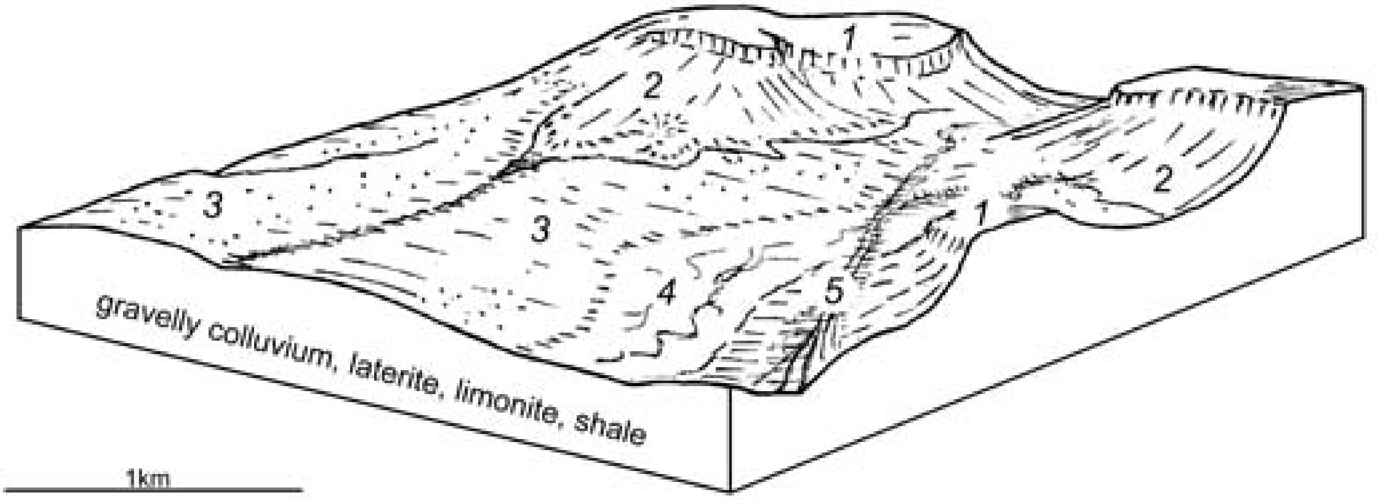
Geomorphology: Erosional surfaces; formed by dissection of lateritised parts of the old Tertiary plateau; low lateritised mesas and residuals with short vertical breakaway faces overlying pallid zone of weathered bedrock, gravelly footslopes and lower plains frequently saline; drainage tracts and floors with sluggish drainage or sub-parallel braided creeks. Relief up to 20 m.

Land management: Most vegetation on the system is only moderately preferred by grazing animals; minor areas of tussock grasslands on drainage tracts (unit 4) and low halophytic shrublands on some gravelly plains (unit 3) are more highly preferred. Most units are inherently stable but some erosion can occur on unit 4 and vegetation deterioration on units 3 and 4.

Traverse condition summary: (27 assessments)
Vegetation - very good 55%, good 26%, fair 15%, poor 4%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Mesa and low hill	5	1
2.	Mesa footslope	1	1
3.	Gravelly plain	17	2
4.	Sluggish drainage tract	3	1
5.	Drainage floor with braided creekline	1	-
	Total	27	5

Laterite land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	30%	**Mesas and low hills** - lateritised residuals up to 2 km long and 200 m wide, up to 20 m high; nearly level mesa tops or rounded crests, vertical breakaway faces up to 3-4 m; surface mantles of very abundant laterite, ironstone or shaly gravels.	Stony soils (203) and red shallow sands (423).	Hummock grasslands of *Triodia* spp. (hard spinifex) with isolated shrubs (PHSG). Less frequently tall shrublands of *Acacia aneura* (mulga) with other acacias, *Senna* and *Eremophila* spp. (SAES).
2.	15%	**Mesa footslopes** - very gently to gently inclined slopes extending up to 300 m downslope between shallow, sub-parallel drainage lines; mantles of very abundant lateritic or ironstone pebbles.	Red shallow sands (423) or red shallow loams (522).	Very scattered to scattered tall or mid height shrublands with *Acacia aneura, Senna* spp., *Eremophila cuneifolia* (royal poverty bush) and other *Eremophila* spp. (SAES).
3.	35%	**Gravelly plains** - level to very gently inclined plains and interfluves up to 2 km in extent, separated by narrow drainage lines; mantles of many to very abundant ironstone gravels.	Shallow gravel soils (304).	Scattered mixed height shrublands dominated by *Acacia aneura*, other acacias, *Senna, Eremophila* and *Ptilotus* spp. (HPMS, SAES). Occasionally shrubby hummock grasslands *Triodia* spp. (hard spinifex) (PHSG). Also more saline sites with patchy halophytic low shrublands with *Maireana* and *Frankenia* spp. and *Acacia victoriae* (prickly acacia) (PXHS).
4.	10%	**Sluggish drainage tracts** - level tracts up to 500 m wide and 3 km long with sluggish internal drainage lines, sometimes with gilgai microrelief; variable density surface mantles of ironstone gravels.	Deep red/brown non-cracking clays (622) and self-mulching cracking clays (602).	Tussock grasslands with patchy *Eragrostis xerophila* (Roebourne Plains grass), *E. setifolia* (neverfail) (ARPG). Also patchy low shrublands with *Eremophila lachnocalyx, Acacia victoriae, Maireana, Atriplex* and *Halosarcia* spp. (PXHS).
5.	10%	**Drainage floors with braided creeklines** - almost level floors up to 200 m wide and 2 km long with numerous braided flowlines with minor incision.	Deep red/brown non-cracking clays (622) with channels of river bed soils (705).	Moderately close tall shrublands/woodlands of *Acacia aneura* and other acacias with numerous low shrubs (DEAW).

LIME LAND SYSTEM (50 km^2, 0.03% of the survey area)

Calcareous plains supporting soft and hard spinifex grasslands and melaleuca shrublands.

Land type: 18

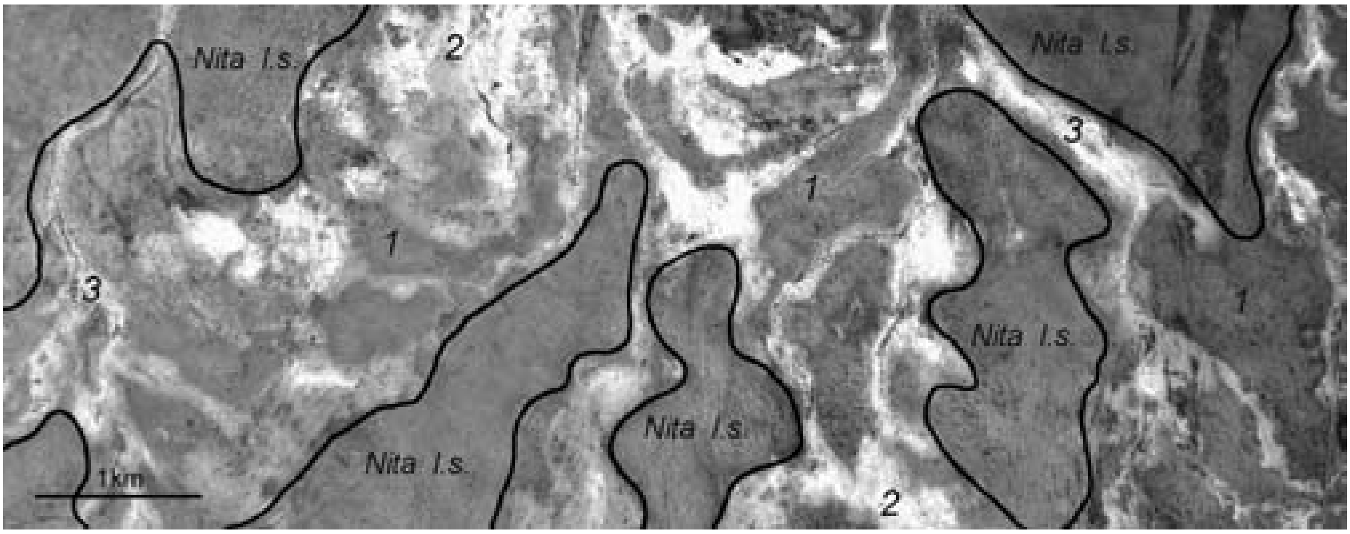
Geology: Quaternary sandy limestone, minor eolian sand and alluvium.

Geomorphology: Depositional surfaces; level to gently undulating calcareous plains and sandy sheets (marginal to adjacent sandplain systems) and low lying drainage tracts with weakly saline alluvium.

Land management: The spinifex vegetation on this system is not highly preferred by livestock but can provide some useful forage after fires. Wind erosion may occur after fire but stabilisation is usually rapid following rain and consequent regeneration of vegetation.

Traverse condition summary: (5 assessments)
Vegetation - good 40%, fair 60%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Sand sheet	3	2
2.	Calcareous plain	1	-
3.	Drainage floor	1	1
	Total	5	3

Lime land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	50%	**Sand sheets** - level to gently undulating sand sheets and sandy banks up to 1.5 km in extent, elevated up to 2 m above other units.	Red deep sands (445).	Hummock grasslands of *Triodia epactia* (soft spinifex) with very scattered to moderately close low or mid height shrubs such as *Acacia stellaticeps* (poverty bush) and *Melaleuca* spp. (SSSG).
2.	30%	**Calcareous plains** - level plains up to 1 km in extent, surface mantles of few to many calcrete pebbles.	Calcareous loamy earths (542) and calcareous shallow loams (522).	Hummock grasslands of *Triodia secunda* (hard spinifex) with isolated or very scattered shrubs *Pluchea* and *Melaleuca* spp. (CASG).
3.	20%	**Drainage floors** - level floors 100-300m wide as linear or more sinuous corridors through units 1 and 2, usually unchannelled in upper parts but with minor channels downstream; occasional small bare claypans or densely vegetated drainage foci.	Red deep sandy duplex soils (405).	Hummock grasslands of *Triodia secunda* (AHSG) or scattered to moderately close *Melaleuca* spp. shrublands with halophytic undershrubs and patchy spinifex. Some drainage foci have close tall shrublands of *Melaleuca* spp. (DMES).

LITTLE SANDY LAND SYSTEM (13,283 km^2, 7.3% of the survey area)

Sandplains with linear and reticulate dunes supporting shrubby hard and soft spinifex grasslands.

Land type: 11

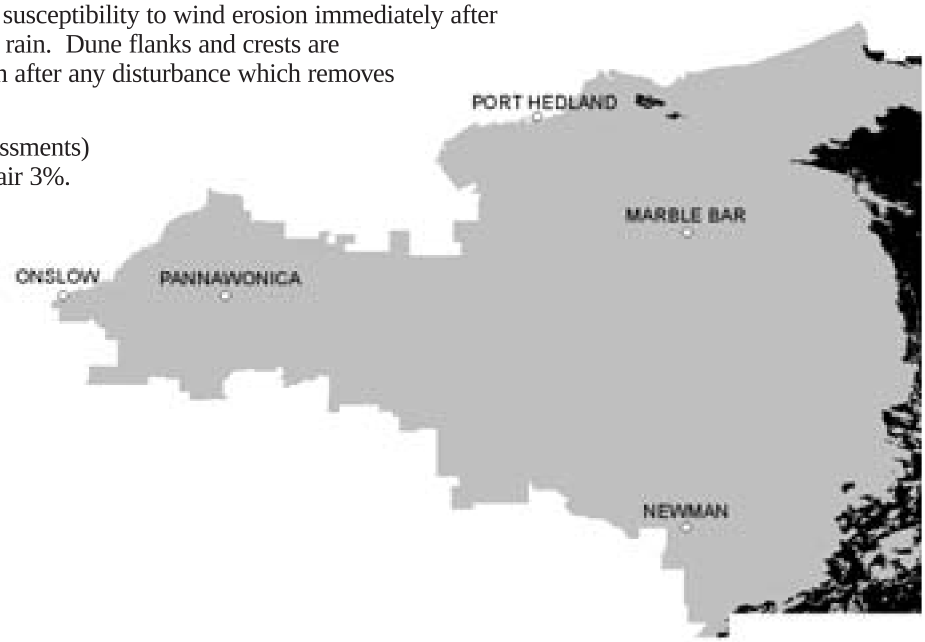
Geology: Quaternary eolian sand.

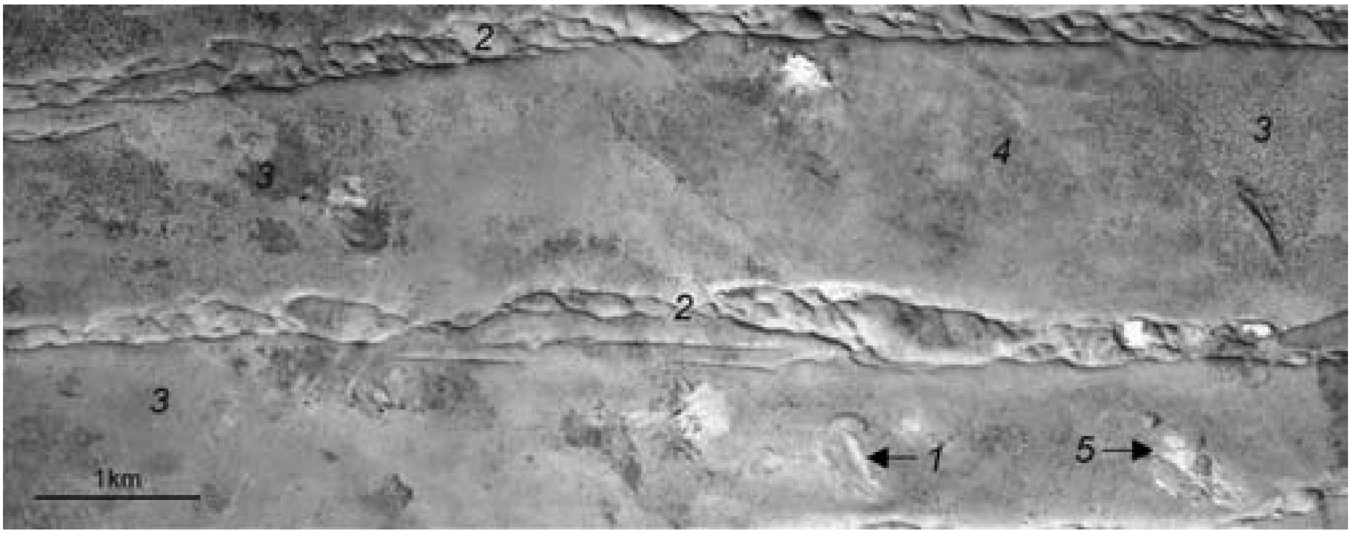
Geomorphology: Depositional surfaces; sandplains and dune fields formed by wind action; linear and reticulate dunes trending generally west-north west to east-south east, sandplains and swales as corridors between dunes, minor gravelly plains and plains with thin sand cover over calcrete and isolated low hills; no organised drainage features but some low lying tracts receiving through flow. Dune relief is up to 30 m.

Land management: Fires occur fairly regularly in spinifex vegetation; dunes (unit 2) and sandplains and swales (unit 3) show some susceptibility to wind erosion immediately after burning but rapid stabilisation occurs after rain. Dune flanks and crests are moderately to highly susceptible to erosion after any disturbance which removes vegetation.

Traverse condition summary: (173 assessments)
Vegetation - very good 94%, good 3%, fair 3%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low hill	-	1
2.	Linear sand dune	6	3
3.	Sandplain and swale	142	4
4.	Gravelly plain	12	-
5.	Plain with thin sand cover over calcrete	5	-
6.	Drainage tract	8	-
7.	Drainage focus	-	1
	Total	173	9

Little Sandy land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	<1%	**Low hills** - isolated hills with gently inclined to steep slopes, up to 500 m in extent and 50 m relief, occurring within unit 3; surface mantles of abundant cobbles, stones and boulders of granitic or sedimentary rocks and outcrop.	Red shallow sands (423).	Patchy hummock grasses *Triodia pungens* (soft spinifex) or *T.* spp. (hard spinifex) with very scattered shrubs (HSPG)
2.	8%	**Linear sand dunes** - linear and reticulate dunes extending for up to at least 40 km with moderately inclined slopes, lose, uneven crest surfaces; relief up to 30 m.	Red deep sands (445).	Hummock grasslands with *Triodia schinzii, T. melvillei* (soft or hard spinifex) with scattered shrubs including *Grevillea* and *Acacia* spp., occasional trees of *Corymbia chippendalei* (sand dune bloodwood) (SSSG, SHSG).
3.	78%	**Sandplains and swales** - level plains extending for up to 5 km or as corridors 0.5-2 km wide between dunes.	Red deep sands (445) with some red sandy earths (463) in swales.	Hummock grasslands with *Triodia basedowii, T.* sp. (hard spinifex) with very scattered to scattered shrubs and trees *Grevillea, Acacia* spp., *Allocasuarina decaisneana* (desert oak) and many other species (SHSG). Less frequently *Triodia schinzii* (soft spinifex) understorey (SSSG).
4.	8%	**Gravelly plains** - level to gently undulating plains extending for up to 2 km, sandy surfaces with mantles of common to abundant ironstone gravels.	Shallow gravel soils (304).	Hummock grasslands of *Triodia lanigera* and other *T.* spp. (hard spinifex) with very scattered shrubs (PHSG).
5.	3%	**Plains with thin sand cover over calcrete** - level plains up to 1.5 km in extent occurring within sandplains and swales (unit 3).	Red shallow sands on calcrete (423).	Shrubby hummock grasslands with *Triodia wiseana* (spinifex) (CASG).
6.	1%	**Drainage tracts** - level tracts up to 500 m wide occurring as low areas within sandplains and swales (unit 3) and receiving occasional through flow, usually unchannelled.	Red deep sands (445) and some sandy red earths (463).	Scattered to moderately close shrublands of *Melaleuca* spp. with patchy *Triodia* spp. understorey (DMES).
7.	<1%	**Drainage foci** - isolated swampy depressions up to 1 km in extent.	Deep red/brown non-cracking clays (622).	Scattered woodlands of *Eucalyptus victrix* (coolibah) and very sparse tussock grasses (DEAW).

LITTORAL LAND SYSTEM (1,577 km^2, 0.9% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Bare coastal mudflats with mangroves on seaward fringes, samphire flats, sandy islands, coastal dunes and beaches.

Land type: 19

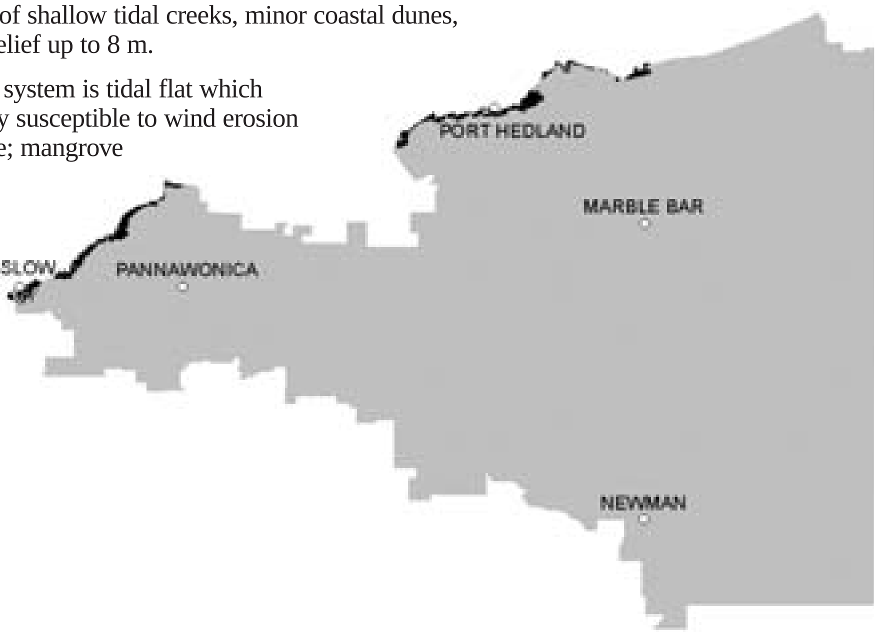
Geology: Quaternary mudflat deposits, clay, salt and sand; eolian sand.

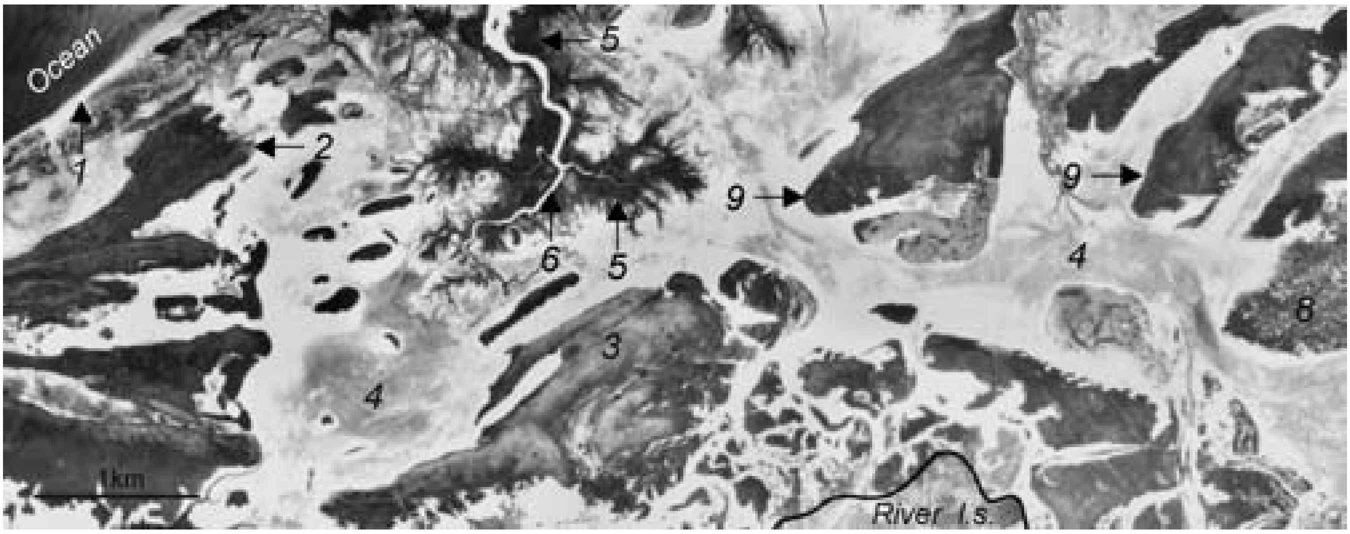
Geomorphology: Depositional surfaces; saline coastal flats; estuarine and littoral surfaces with extensive bare saline tidal flats subject to infrequent tidal inundation, slightly higher samphire flats and alluvial plains, mangrove seaward fringes with dense branching patterns of shallow tidal creeks, minor coastal dunes, limestone ridges, sandy plains and beaches. Relief up to 8 m.

Land management: About 70 per cent of the system is tidal flat which supports no vegetation, coastal dunes are highly susceptible to wind erosion if plant cover is lost by fire or other disturbance; mangrove communities are significant habitats.

Traverse condition summary:
(49 assessments)
Vegetation - very good 59%, good 31%, fair 10%.
Soil erosion - nil 96%, slight 2%, minor 2%.

Area mapped as sde: 260 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Beach	-	-
2.	Coastal dune	-	1
3.	Limestone ridge	2	1
4.	Tidal flat	-	2
5.	Mangrove outer margin	-	1
6.	Tidal channel	-	-
7.	Samphire flat	24	1
8.	Alluvial plain	12	2
9.	Sandy plain and island	11	2
	Total	49	10

Littoral land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	<1%	**Beaches** - shelly beaches up to 100 m wide above high water mark, often backed by narrow foredunes or flanked by mangroves.	Calcareous deep sands (442).	No vegetation.
2.	3%	**Coastal dunes** - beach foredunes and hind dunes with gently to moderately inclined slopes, moundy surfaces, relief to about 8 m.	Calcareous deep sands (442).	Hummock grasslands with *Triodia pungens* or *T. epactia* (soft spinifex) and scattered shrubs such as *Acacia coriacea, Aerva javanica* (kapok bush), *Threlkeldia diffusa* (CDSG).
3.	<1%	**Limestone ridges** - linear ridges up to 100 m wide and several kilometres long, gently inclined slopes, mantles of limestone pebbles and cobbles and minor sinkholes and pits.	Red shallow sands (423).	Grasslands often mixed *Triodia pungens* and *Cenchrus ciliaris* (buffel grass) with isolated shrubs.
4.	70%	**Tidal flats** - level plains up to 5-6 km in extent; bare, often salt encrusted surfaces subject to inundation by peak tides.	Tidal soils (104).	Mostly no vegetation. Occasional patches of very scattered low shrublands of *Halosarcia* spp. (samphire).
5.	5%	**Mangrove outer margins** - up to 1 km wide flanking tidal creeks and in the tidal zone abutting adjacent mudflats and beaches.	Tidal soils (104).	Close to closed mangrove woodlands with *Avicennia marina* and *Rhizophora stylosa*.
6.	4%	**Tidal channels** - channels 20-200 m wide meandering through other units of the system, bare mud surfaces at low tides.	Tidal soils (104).	Narrow fringing communities of mangroves and samphire.
7.	10%	**Samphire flats** - level plains slightly raised above adjacent bare tidal flats, up to 2 km long and 500 m wide, occasionally inundated by peak tides.	Red/brown non-cracking clays (622) mixed with tidal soils (104).	Scattered to moderately close low shrublands or grassy shrublands of *Halosarcia* spp. (samphire), *Sporobolus virginicus* (salt water couch) (PSPS).
8.	2%	**Alluvial plains** - level plains up to 1.5 km in extent on landward margin of system, not subject to tidal inundation.	Red deep sandy duplex soils (405).	Tussock grasslands of *Cenchrus ciliaris* (APBG) or mixed perennial grasses such as *Chrysopogon fallax* (ribbon grass), *Eragrostis xerophila* (Roebourne Plains grass) and *Sporobolus virginicus*, (APXG); also *Triodia pungens* (soft spinifex).
9.	5%	**Sandy plains and islands** - level plains raised 2-3 m above other units and extending for up to 2 km, also as discrete oval or circular islands on tidal flats (unit 4).	Red deep sands (445).	Hummock grasslands of *Triodia pungens, T. epactia* (soft spinifex) with isolated shrubs (SSSG); less frequently with *T.* spp. (hard spinifex) (SHSG).

LOCHINVAR LAND SYSTEM (287 km^2, 0.2% of the survey area)

(provisional description only)

Stony plains and occasional sand dunes supporting hard spinifex (and occasionally soft spinifex) grasslands.

Land type: 8

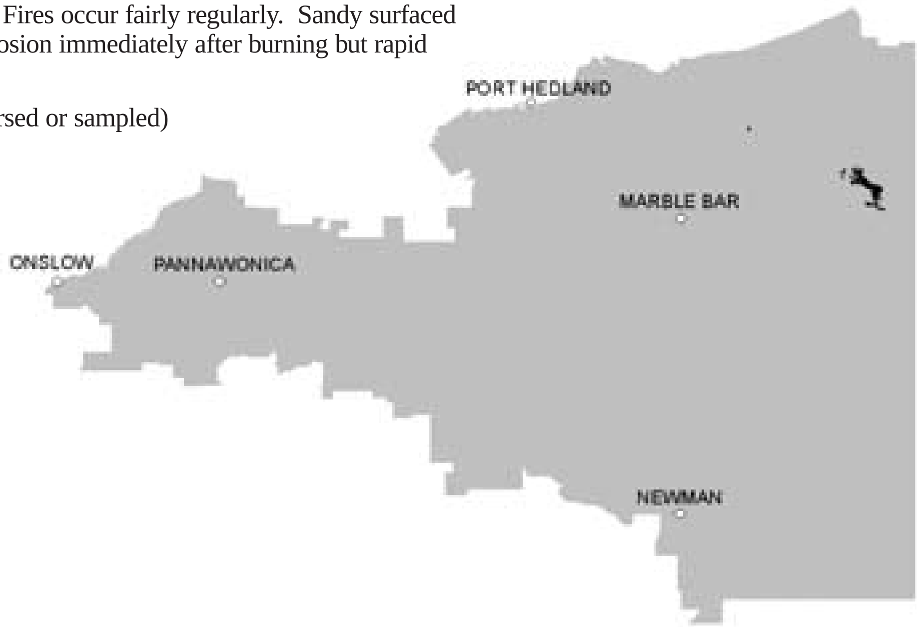
Geology: Granophyre, felsic and intermediate lavas and minor sedimentary rocks of Proterozoic age; Quaternary colluvium and minor eolian sand.

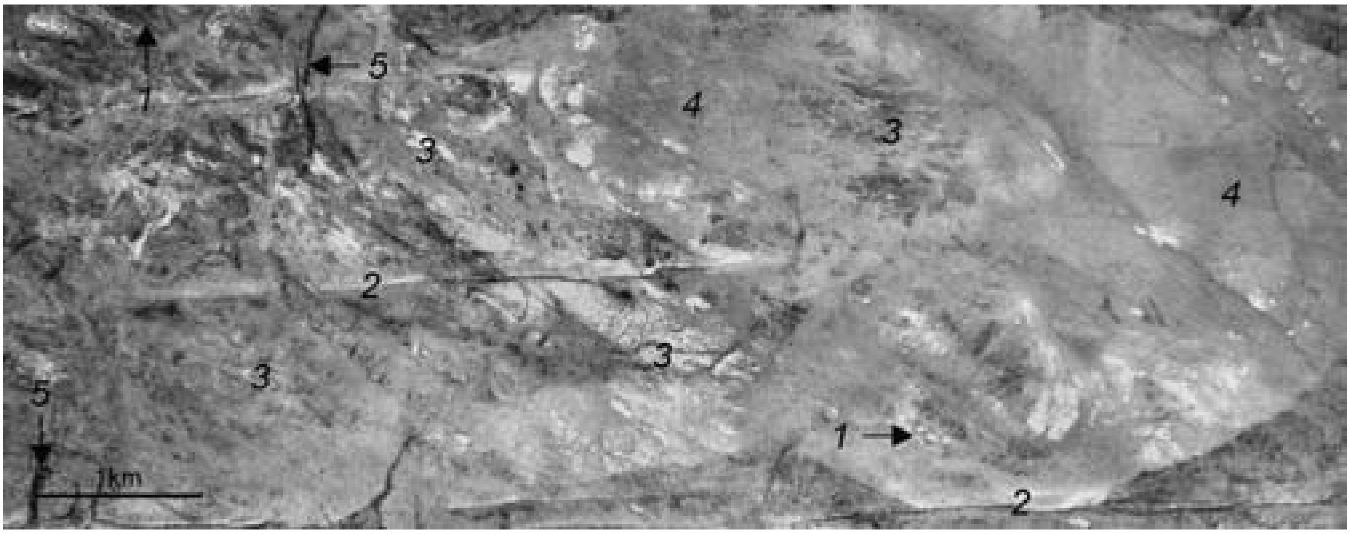
Geomorphology: Erosional surfaces; level to gently undulating stony plains, pediments and plains with thin sand cover, isolated low hills, ridges and linear sand dunes; few organised drainage features other than rare, interrupted, narrow, usually unchannelled floors. Relief up to 30 m.

Land management: Hard spinifex hummock grasslands are not preferred by livestock and are not prone to grazing induced degradation. Fires occur fairly regularly. Sandy surfaced plains show some susceptibility to wind erosion immediately after burning but rapid stabilisation occurs after rain.

Traverse condition summary: (not traversed or sampled)
Vegetation - no records
Soil erosion - no records

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low hill and ridge	-	-
2.	Linear sand dune	-	-
3.	Stony plain	-	-
4.	Plain with thin sand cover	-	-
5.	Drainage floor	-	-
	Total	-	-

Lochinvar land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	5%	**Low hills and ridges** - isolated hills and ridges with gently inclined to steep slopes, up to 2 km in extent and 30 m relief; surface mantles of abundant cobbles and stones and rock outcrop.	Stony soils (203) with some red shallow sands (423) and red shallow loams (522).	Patchy hummock grasses *Triodia pungens, T.* spp. (soft or hard spinifex) with very scattered shrubs (HSPG).
2.	3%	**Linear sand dunes** - longitudinal dunes extending for up to 7 km with moderately inclined slopes, lose, uneven crest surfaces; relief up to 20 m.	Red deep sands (445).	Hummock grasslands of *Triodia* spp. (soft or hard spinifex) with scattered shrubs including *Grevillea* and *Acacia* spp., occasional trees of *Corymbia chippendalei* (sand dune bloodwood) (SSSG, SHSG).
3.	70%	**Stony plains** - level to gently undulating plains extending for up to 10 km, surface mantles of abundant pebbles and cobbles and rock outcrop.	Red loamy earths (544).	Hummock grasslands of *Triodia* spp. (predominantly hard spinifex) with very scattered shrubs (PHSG).
4.	20%	**Plains with thin sand cover** - level plains extending for up to 2.5 km, sandy surfaces overlying rock at shallow depth.	Red shallow sands (423).	Hummock grasslands of *Triodia* spp. (predominantly hard spinifex) with very scattered to scattered shrubs (PHSG).
5.	2%	**Drainage floors** - narrow (<250 m wide) diffuse, interrupted tracts, usually unchannelled.	Red sandy earths (463) and red loamy earths (544).	Hummock grasslands of *Triodia pungens* (ASSG).

MACROY LAND SYSTEM (13,095 km^2, 7.2% of the survey area)

(modified from Payne and Tille 1992)

Stony plains and occasional tor fields based on granite supporting hard and soft spinifex grasslands.

Land type: 8

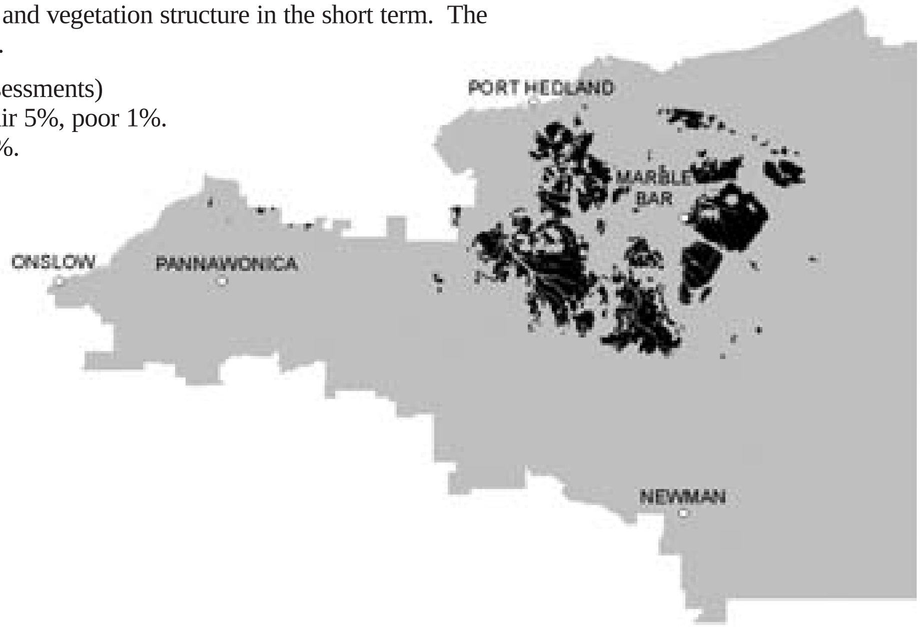
Geology: Archaean granite and granodiorite; Quaternary eluvium, colluvium and minor alluvium.

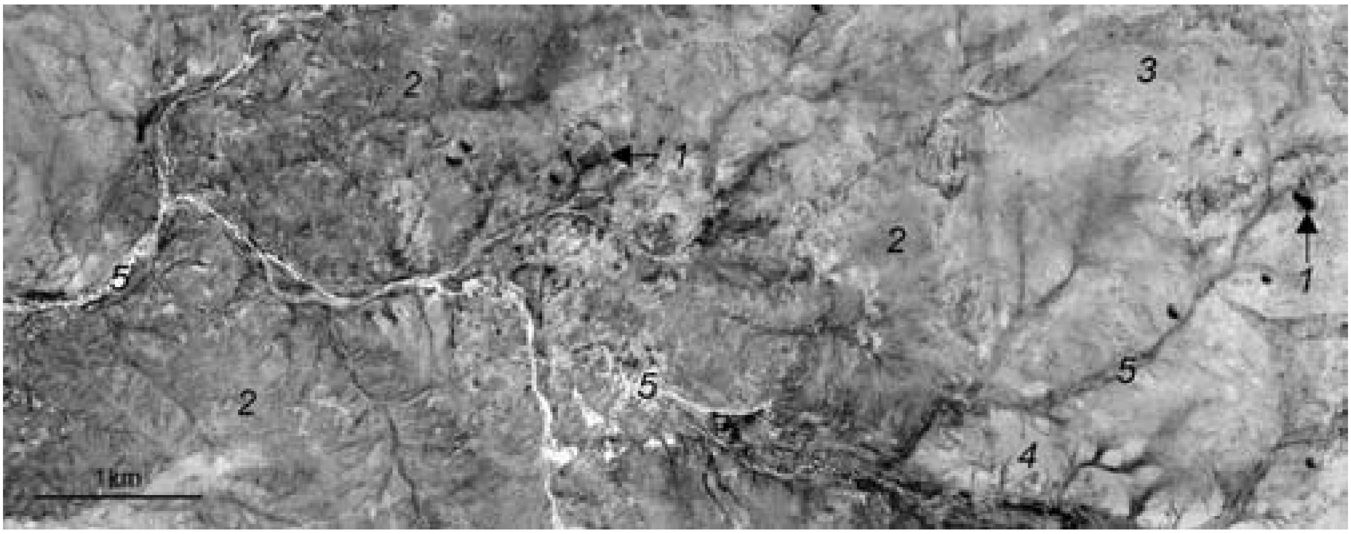
Geomorphology: Erosional surfaces; gently undulating stony plains and interfluves with quartz surface mantles, sandy surfaced plains, minor calcrete plains, closely spaced tributary drainage lines in upper parts of system becoming much wider downslope; minor granite hills, tor fields and quartz ridges. Relief is up to 25 m.

Land management: Mature spinifex vegetation is not preferred by grazing animals but younger stands after burning are moderately preferred. Vegetation is generally not prone to grazing induced changes but fairly regular fires change botanical composition and vegetation structure in the short term. The system has low or very low erosion hazard.

Traverse condition summary: (1,502 assessments)
Vegetation - very good 85%, good 9%, fair 5%, poor 1%.
Soil erosion - nil 98%, slight 1%, minor 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low hill or ridge	19	3
2.	Stony plain and interfluve	905	25
3.	Sandy plain	326	8
4.	Calcrete plain	65	2
5.	Drainage floor and channel	187	23
	Total	1,502	61

Macroy land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	5%	**Low hills and ridges** - isolated hills and tor heaps up to 500 m in extent or ridges up to several kilometres long, moderately inclined to very steep slopes, surface mantles of abundant to very abundant cobbles, stones and boulders of granite, quartz and other rocks; relief up to 25 m.	Stony soils (203) and red shallow loams (522).	Patchy hummock grasses *Triodia pungens* (soft spinifex) or *T.* spp. (hard spinifex) with isolated or very scattered shrubs (HSPG).
2.	70%	**Stony plains and interfluves** - level to gently undulating plains and interfluves extending up to 4 km between drainage lines in lower parts but much narrower between small drainage lines in upper parts; surface mantles of few to very abundant grit and pebbles of quartz and granite, occasional outcrops of granite.	Red shallow sands (423), red sandy earths (463), red shallow sandy duplex soils (406) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana, T. lanigera* (hard spinifex) or *T. pungens* (soft spinifex) in about equal proportions; isolated to scattered *Acacia inaequilatera* (kanji) and other *Acacia* spp. shrubs (PHSG, PSSG).
3.	10%	**Sandy plains** - level sandy surfaced plains extending up to 2 km as inclusions within unit 2, surface mantles absent or as few pebbles of quartz.	Red deep sandy duplex (405), red shallow sandy duplex (406), red sandy earths (463) and red deep sand (445).	Hummock grasslands of *Triodia pungens, T. lanigera* (soft or hard spinifex) with very scattered to scattered shrubs *Acacia inaequilatera, A. stellaticeps* (poverty bush) (PSSG, PHSG).
4.	3%	**Calcrete plains** - level plains restricted to 300-400 m in extent associated with lower parts of unit 2 or unit 5, sometimes raised 3-4 m above surrounding plains, surface mantles of common to many pebbles of calcrete and quartz, also calcrete outcrop.	Calcareous shallow loams (521) and red deep sandy duplex soils (405).	Hummock grasslands of *Triodia wiseana* or *T. plurinervata* (hard spinifex) with isolated *Acacia* spp. shrubs or *Corymbia hamersleyana* (Hamersley bloodwood) trees (CASG).
5.	12%	**Drainage floors and channels** - level to very gently inclined linear drainage tracts up to 500 m wide as slight depressions within unit 2 becoming much narrower, more incised and dendritic in upper parts of unit 2; unchannelled or with channels to 100 m wide.	Red sandy earths (463), red deep sands (445), red deep sandy duplex soils (405) and red loamy earths (544). Channels of river bed soils (705).	Hummock grasslands of *Triodia* spp. (hard or soft spinifex) with isolated to scattered *Acacia* spp. shrubs and occasional eucalypt trees (AHSG, ASSG, DAHW). Also tussock grasslands or shrublands/woodlands with tussock grass understorey with *Chrysopogon fallax* (ribbon grass), occasionally *Cenchrus ciliaris* (buffel grass) (DEGW). Channels have fringing grassy woodlands with *Eucalyptus camaldulensis* (river red gum) and *Acacia coriacea* (river jam).

MALLINA LAND SYSTEM (2,557 km^2, 1.4% of the survey area)

(modified from Payne and Tille 1992)

Sandy surfaced alluvial plains supporting soft spinifex (and occasionally hard spinifex) grasslands.

Land type: 13

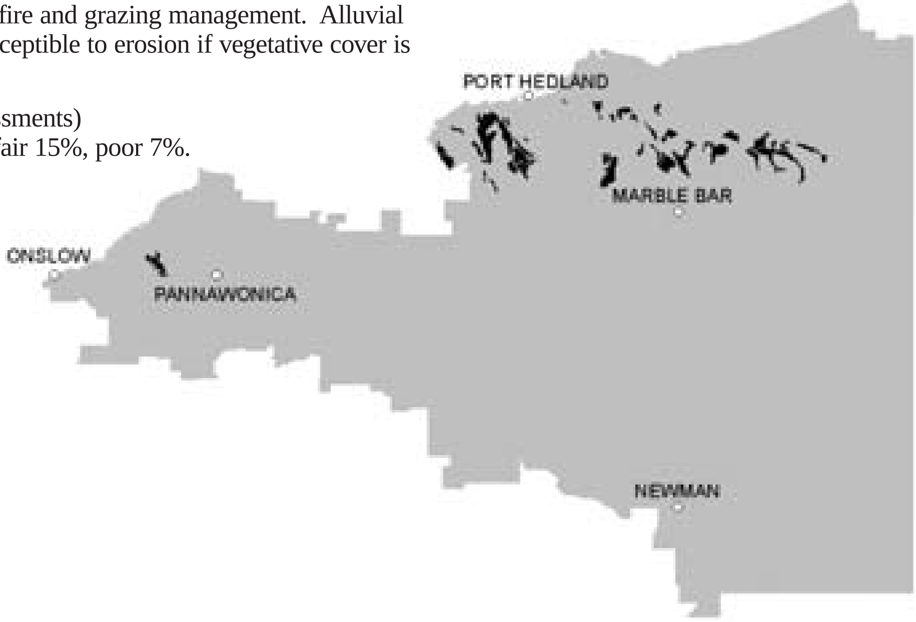
Geology: Quaternary alluvium and eluvium.

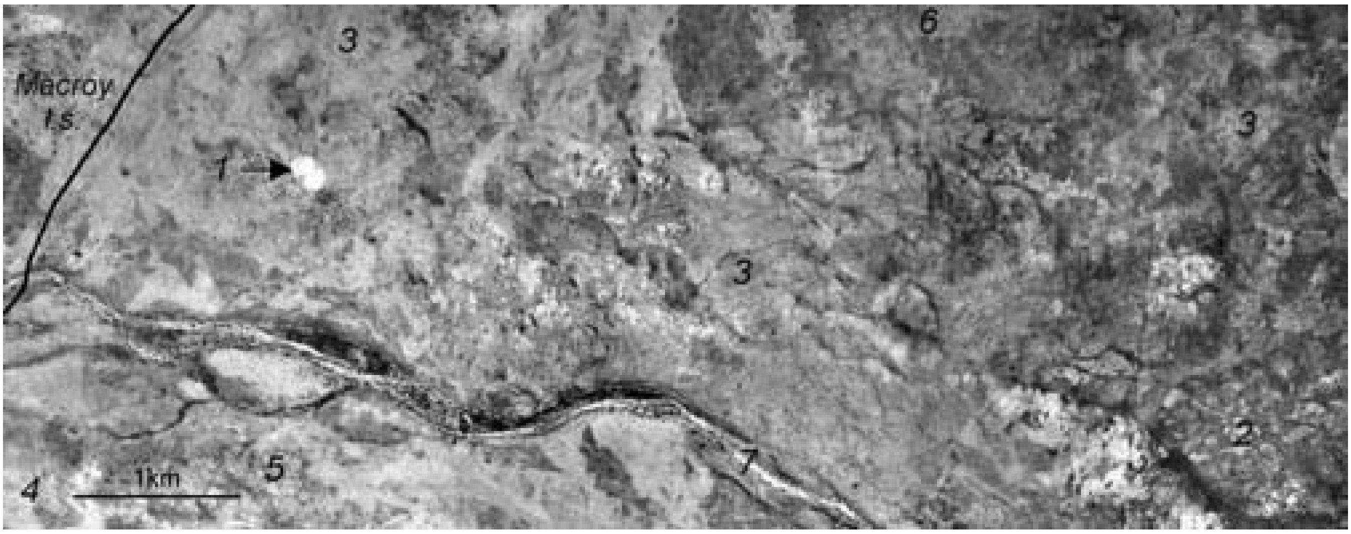
Geomorphology: Depositional surfaces; level sandy surfaced plains on alluvium with occasional patches of small claypans, minor clay plains with gilgai microrelief, minor stony plains and occasional isolated low hills; drainage patterns restricted to rare, non tributary through channels with narrow terraces.

Land management: Soft spinifex vegetation is moderately preferred by grazing animals if kept in immature condition by appropriate fire and grazing management. Alluvial plains (unit 3) are moderately to highly susceptible to erosion if vegetative cover is seriously depleted.

Traverse condition summary: (423 assessments)
Vegetation - very good 42%, good 36%, fair 15%, poor 7%.
Soil erosion - nil 87%, slight 6%, minor 4%, moderate 3%.

Area mapped as sde: 83 ha





No.	Unit name	Traverse recordings	Inventory sites
1.	Stony rise and low hill	1	-
2.	Calcrete plain	3	1
3.	Sandy surfaced alluvial plain with occasional claypan	279	13
4.	Gilgai plain	7	-
5.	Stony plain	48	2
6.	Sandplain	63	2
7.	Drainage tract, river terrace, bank and channel	21	4
	Other	1	-
	Total	423	22

Mallina land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	<1%	**Stony rises and low hills** - occasional isolated stony rises or low hills up to 400 m in extent, abundant stony surface mantles and rock outcrop; relief up to 20 m.	Stony soils (203) and red shallow loams (522).	Sparse hard spinifex hummock grasslands with isolated shrubs (HSPG).
2.	1%	**Calcrete plains** - level plains or low platforms up to 500 m in extent and raised up to 4-5 m above surrounding plains, surface mantles of abundant calcrete gravel.	Calcareous shallow loams (521).	Hummock grasslands of *Triodia wiseana, T. plurinervata* (hard spinifex) with isolated shrubs, less frequently with *Triodia pungens* (soft spinifex) (CASG).
3.	75%	**Sandy surfaced alluvial plains with occasional claypans** - level plains extending up to 5 km or more and frequently flanking major rivers and creeklines, occasional patches of small claypans; subject to occasional over-bank flooding; surface mantles absent to few (occasionally many) pebbles of quartz.	Red sandy earths (463), red deep sandy duplex soils (405), red loamy earths (544) and red/brown non-cracking clays (622).	Hummock grasslands predominantly (80%) of *Triodia pungens* (soft spinifex) with isolated (occasionally very scattered to scattered) shrubs such as *Acacia inaequilatera* (kanji), *A. ancistrocarpa* (shiny leaf wattle), *A. stellaticeps* (poverty bush) (ASSG, PSSG). Less frequently (20%) hummock grasslands of *Triodia longiceps, T. secunda* (hard spinifex) (AHSG, PHSG).
4.	1%	**Gilgal plains** - level plains as inclusions 20-200 m in extent (occasionally up to 500 m) within unit 3, weakly gilgaied microrelief, surface mantles absent to common.	Self-mulching cracking clays (602) and red/brown non-cracking clays (622).	Tussock grasslands dominated by *Eragrostis xerophila* (Roebourne Plains grass), also *Eriachne benthamii* (swamp grass) and *Chrysopogon fallax* (ribbon grass) (ARPG).
5.	10%	**Stony plains** - level plains as inclusions within unit 3, may be slightly higher than and shed water onto unit 3; surface mantles of many to abundant pebbles of quartz.	Red loamy earths (544) and red sandy earths (463).	Hummock grasslands of *Triodia pungens* or *T. wiseana* (soft or hard spinifex) with isolated shrubs (PSSG, PHSG).
6.	10%	**Sandplains** - level to gently undulating sand sheets up to 1.5 km in extent, moundy surfaces.	Red sandy earths (463).	Hummock grasslands of *Triodia pungens* (soft spinifex) or scattered to moderately close *Acacia* spp. shrublands with prominent ground layer of spinifex or *Eragrostis eriopoda* (woolly butt) (SSSG).
7.	2%	**Drainage tracts, river terraces, banks and channels** - tracts up to 500 m wide receiving through flow; may be unchannelled or with creeklines and channels up to 100 m wide.	Red sandy earths (463) with minor loamy red earths (544) and channels with river bed soils (705).	Hummock grasslands of *Triodia pungens* with very scattered shrubs (ASSG). Scattered to moderately close *Acacia* spp. tall shrublands/woodlands with understoreys of spinifex and/or tussock grasses *Chrysopogon fallax* (ribbon grass), *Cenchrus ciliaris* (buffel grass) (DAHW, DEGW). Also fringing grassy woodlands of *Eucalyptus camaldulensis* (river red gum), *E. victrix* (coolibah) along channels.

MANNERIE LAND SYSTEM (190 km^2, 0.1% of the survey area)

(modified from Cotching unpublished)

Seepage areas on inland margins of paleo-tidal plains supporting melaleuca thickets and halophytic shrublands.

Land type: 16

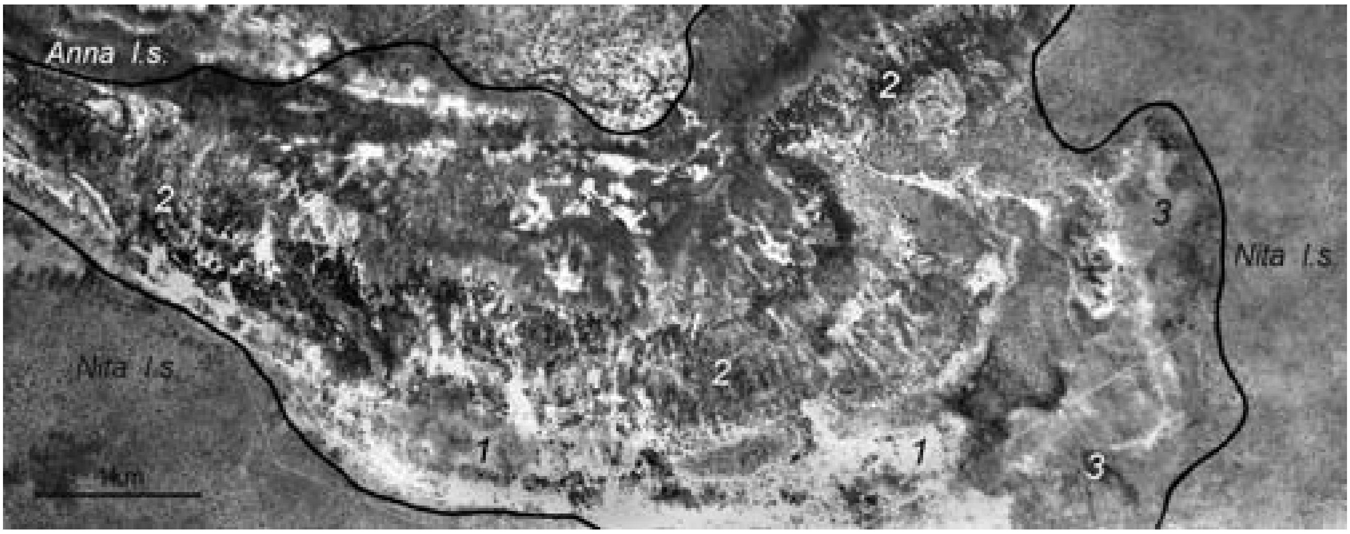
Geology: Quaternary supratidal mudflat deposits; clay, silt and sand.

Geomorphology: Depositional surfaces; level plains with seepage areas and swamps on saline alluvium, minor sandy banks; no organised drainage features.

Land management: The system is subject to inundation and supports very dense shrublands making access difficult.

Traverse condition summary: (35 assessments)
Vegetation - very good 31%, good 38%, fair 14%, poor 17%.
Soil erosion - nil 97%, moderate 3%.

Area mapped as sde: Nil



No.	Unit name	Traverse recordings	Inventory sites
1.	Saline plain	14	1
2.	Seepage zone and swamp	9	2
3.	Sand sheet and bank	11	1
	Other	1	-
	Total	35	4

Mannerie land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	25%	**Saline plains** - level plains up to 3 km in extent or as smaller patches within seepage zones (unit 2), surfaces often with saline or carbonate encrustations.	Grey calcareous loamy earths (542).	Scattered to moderately close low or mid height shrublands of *Halosarcia* spp. (samphire), *Frankenia* spp. (frankenia), *Trianthema turgidifolia* with occasional taller shrubs *Acacia ampliceps* (black wattle), *Melaleuca lasiandra* and grass *Sporobolus virginicus* (salt water couch) (PSPS). Occasionally mixed grasslands (APXG)
2.	60%	**Seepage zones and swamps** - level tracts up to 6 km in extent, subject to inundation and with water table very close to surface.	Grey calcareous shallow loams (542) and grey deep loamy duplex soils (509).	Moderately close to closed tall shrublands or low woodlands of *Melaleuca lasiandra* or *Acacia ampliceps*, understoreys absent or very sparse, occasional patches of grass *Sporobolus virginicus* (DMES).
3.	15%	**Sand sheets and banks** - level plains and sandy banks as patches up to 1 km in extent or as plains up to 500 m wide on outer landward margins of the system, hummocky surfaces elevated up to 1 m above saline plains and seepage zones (units 1 and 2).	Red deep sands (445) with some red sandy earths (463).	Scattered to moderately close shrublands of *Acacia* and *Melaleuca* spp., other shrubs and prominent ground layer of *Triodia pungens* (soft spinifex) (SSSG) and occasionally *Cenchrus ciliaris* (buffel grass) (APBG).

MARANDOO LAND SYSTEM (459 km^2, 0.3% of the survey area)

Basalt hills and restricted stony plains supporting grassy mulga shrublands.

Land type: 2

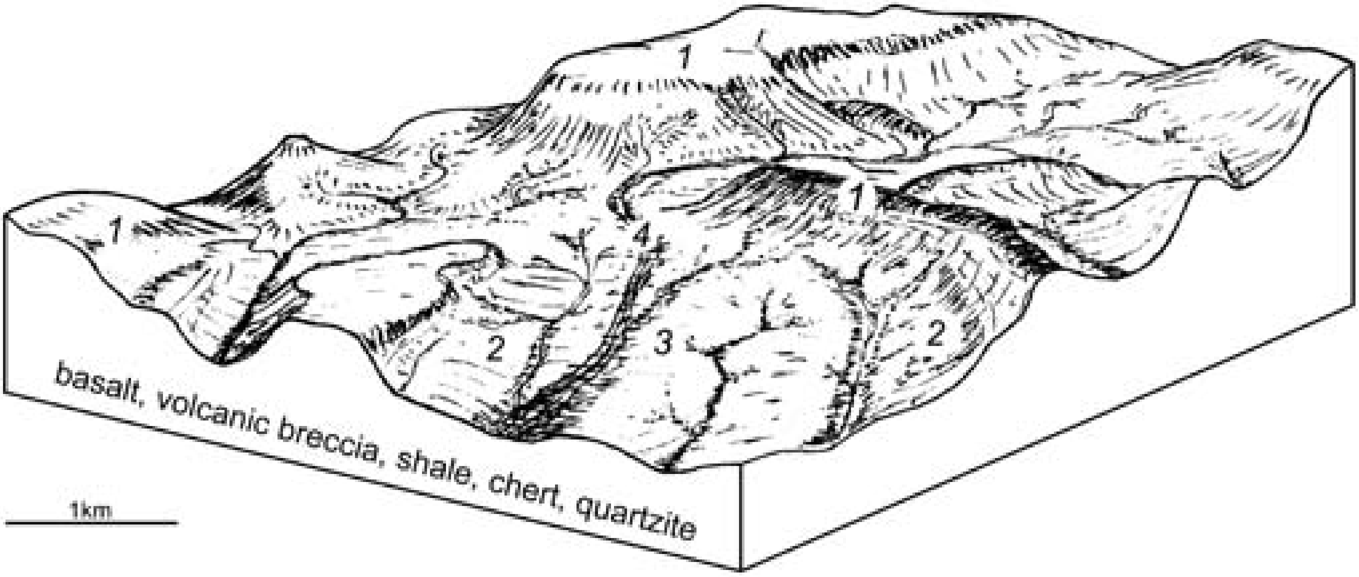
Geology: Proterozoic basalt, volcanic breccia, shale, chert, mudstone and quartzite.

Geomorphology: Erosional surfaces; hills and ridges with steep stony upper slopes, more gently inclined lower slopes and stony interfluves, widely spaced tributary drainage floors and channels. Relief is up to 300 m.

Land management: Mulga shrublands with understorey grasses and shrubs are moderately attractive to grazing animals although more rugged parts are poorly accessible. These shrublands are probably subject to less frequent burning than mulga shrublands with spinifex understoreys.

Traverse condition summary: (8 assessments)
Vegetation - good 50%, fair 50%.
Soil erosion - nil 100%

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Hill, ridge and upper slope	1	1
2.	Lower footslope	4	1
3.	Stony lower plain	-	1
4.	Drainage floor and channel	3	1
	Total	8	4

Marandoo land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	50%	**Hills, ridges and upper slopes** - rounded hill crests and ridge summits with moderately inclined to steep upper slopes, surface mantles of very abundant pebbles, cobbles and stones of basalt and other rocks, also rock outcrop; relief up to 250 m.	Stony soils (203) and red shallow loams (522).	Scattered tall shrublands of *Acacia aneura* (mulga) with numerous low shrubs including *Eremophila* and *Senna* spp. with sparse tussock grasses *Themeda triandra* (kangaroo grass), *Chrysopogon fallax* (ribbon grass) (HMGS). Less frequently mulga and *Triodia* spp. (hard spinifex) (HSPG).
2.	30%	**Lower footslopes** - very gently inclined to gently inclined slopes, surface mantles of very abundant pebbles and cobbles of basalt and other rocks.	Red shallow sandy duplex soils (406) and red shallow loams (522).	Scattered to moderately close tall shrublands of *Acacia aneura*, numerous low shrubs and sparse tussock grasses as for unit 1 (HMGS).
3.	10%	**Stony lower plains** - gently undulating plains and interfluves extending for up to 2 km below units 1 and 2, mantles of abundant pebbles of basalt.	Red loamy earths (544).	Very scattered to scattered tall shrublands of *A. aneura* with *Senna* spp. low shrubs and patchy tussock grasses.
4.	10%	**Drainage floors and channels** - narrow (<250 m wide) dendritic drainage floors with channels incised in valleys amongst hills and ridges (unit 1) becoming wider and more widely spaced downstream; channels up to 50 m wide.	Red loamy earth (544). Channels with river bed soils (705).	Moderately close woodlands of *A. aneura* with patchy tussock grasses. Also grassy eucalypt woodlands along creeks (DEGW).

MARILLANA LAND SYSTEM (419 km^2, 0.2% of the survey area)

Gravelly plains with large drainage foci and unchannelled drainage tracts supporting snakewood shrublands and grassy mulga shrublands.

Land type: 15

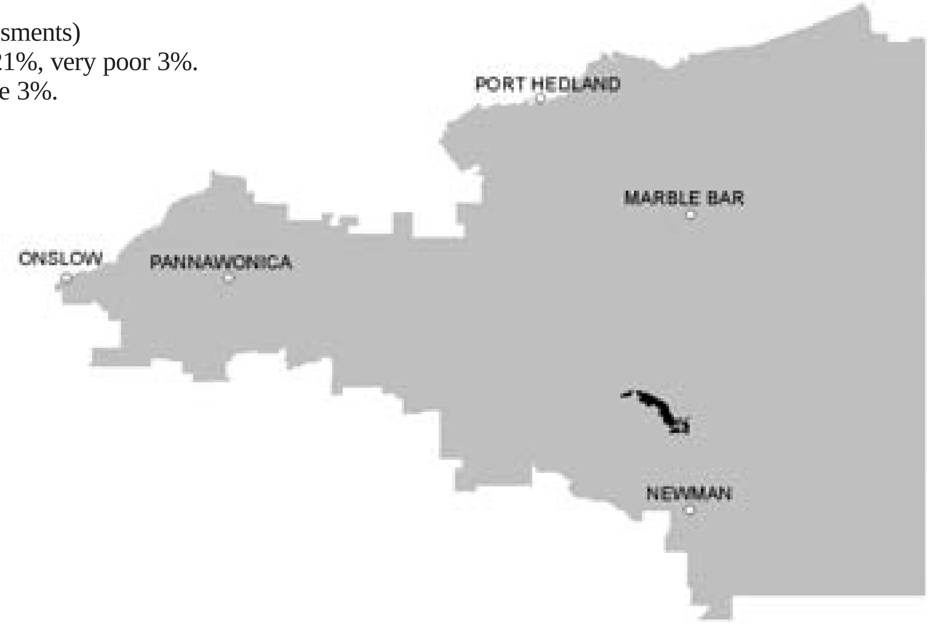
Geology: Quaternary alluvium.

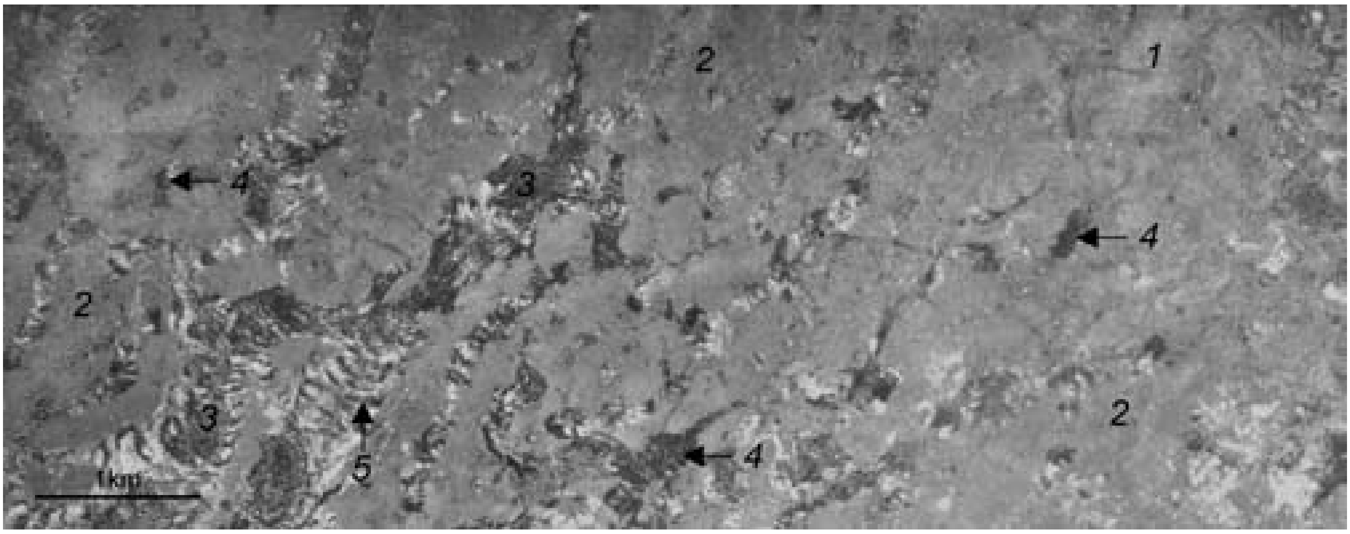
Geomorphology: Depositional surfaces; level plains with dense surface mantles of ironstone gravel, subject to sheet flow; broad, usually unchannelled drainage tracts receiving more concentrated through flow, drainage foci and groves with clay soils; no channelled drainage patterns.

Land management: The system supports low shrubs and grasses which are highly preferred by grazing animals and is susceptible to degradation if grazing pressure is excessive.

Traverse condition summary: (33 assessments)
Vegetation - good 40%, fair 36%, poor 21%, very poor 3%.
Soil erosion - nil 94%, severe 3%, extreme 3%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Calcrete platform	2	-
2.	Gravelly plain	18	1
3.	Drainage tract	7	2
4.	Drainage foci	5	-
5.	Grove	1	-
	Total	33	3

Marillana land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Calcrete platforms** - level plains up to 300 m in extent and raised up to 1 m above adjacent surfaces (units 2 and 3).	Calcareous shallow loams (521).	Hummock grassland of *Triodia wiseana* (hard spinifex) with very scattered to scattered *Acacia* and *Senna* spp. shrubs (CASG).
2.	64%	**Gravelly plains** - level plains up to 3 km in extent, surface mantles of abundant to very abundant ironstone gravel; subject to sheet flow.	Red deep loamy duplex soils (506) and deep red/brown non-cracking clays (622).	Very scattered to scattered and somewhat clumpy tall shrublands of *Acacia xiphophylla* (snakewood) with undershrubs of *Maireana pyramidata* (sago bush), *M. triptera* (three winged bluebush), *M. georgei* (golden bluebush) and *Atriplex bunburyana* (silver saltbush) (PSCS).
3.	22%	**Drainage tracts** - almost level tracts as corridors up to 1 km wide through gravelly plains (unit 2) and receiving run-off from unit 2, gilgai microrelief is common; usually unchannelled but occasionally with gutters and small channels.	Red loamy earths (544) and self-mulching cracking clays (602) with minor red sandy earths (463).	Scattered to close tall shrublands or woodlands of *Acacia aneura* with numerous undershrubs and patchy tussock grasses such as *Eragrostis setifolia* (neverfail) and *Chrysopogon fallax* (ribbon grass) (DEGW, GMUW).
4.	12%	**Drainage foci** - level foci as shallow, circular or irregularly shaped depressions up to 1 km in extent, receiving run-on from adjacent plains and drainage tracts (units 2 and 3); gilgai microrelief.	Self-mulching cracking clays (602) and deep red/brown non-cracking clays (622).	Close to closed tall shrublands or woodlands of *Acacia aneura* with numerous undershrubs and tussock grasses such as *Chrysopogon fallax* (DEGW, GMGW).
5.	1%	**Groves** - arcuate foci up to 500 m long by 50 m wide arranged on gravelly plains and drainage tracts (units 2 and 3) with long axes at right angles to direction of sheet flow, receiving run-off from adjacent surfaces.	Deep red/brown non-cracking clays (622) or red loamy earths (544).	As for unit 4 (GMGW).

MARSH LAND SYSTEM (977 km^2, 0.5% of the survey area)

(modified from Payne and Mitchell 1992)

Lakebeds and flood plains subject to regular inundation, supporting samphire shrublands, salt water couch grasslands and halophytic shrublands.

Land type: 20

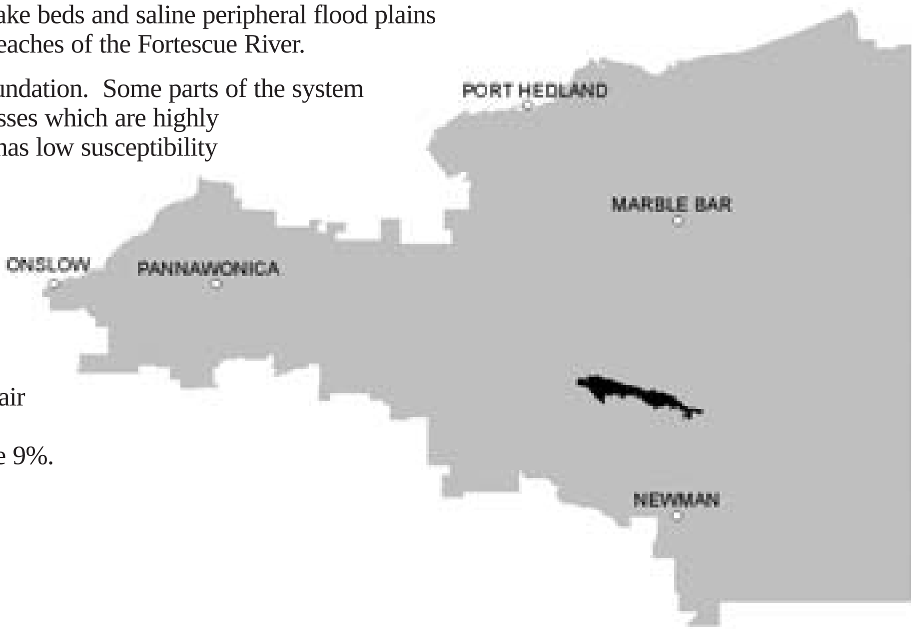
Geology: Quaternary alluvium and lacustrine deposits.

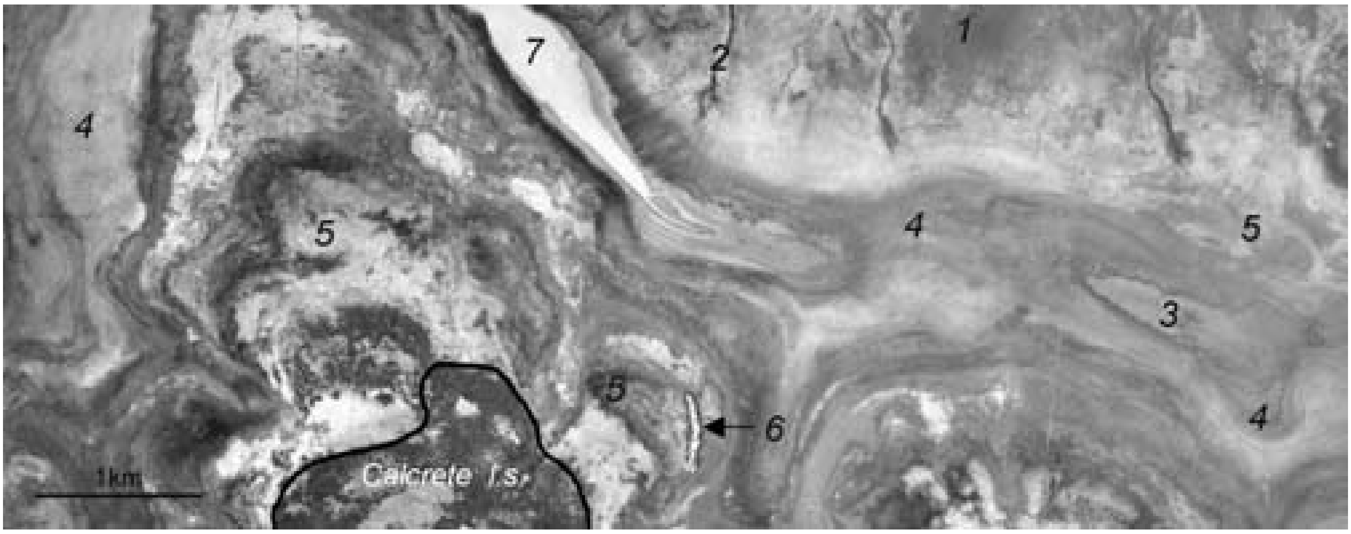
Geomorphology: Depositional surfaces; lake beds and saline peripheral flood plains forming a termination basin for the upper reaches of the Fortescue River.

Land management: Subject to regular inundation. Some parts of the system support chenopod shrubs and perennial grasses which are highly preferred by grazing animals. The system has low susceptibility to degradation and erosion except for some alluvial fans and drainage floors (unit 2) and some outer margins of flood plains (unit 4) which are moderately susceptible.

Traverse condition summary:
(23 assessments)
Vegetation - very good 43%, good 22%, fair 26%, poor 9%.
Soil erosion - nil 82%, minor 9%, moderate 9%.

Area mapped as sde: 415 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Stony plain	4	1
2.	Alluvial fan and drainage floor	2	-
3.	Gilgai plain	1	-
4.	Flood plain	7	4
5.	Saline flood plain and lake bed	8	2
6.	Kopi bank	-	-
7.	Channel and water hole	-	-
	Other	1	-
	Total	23	7*

* Four of these sites described from field work done in 1990 as part of an assessment of the impact of Ophthalmia Dam on the flood plains of the Fortescue River (see Payne and Mitchell 1992).

Marsh land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	1%	**Stony plains** - level or gently inclined plains on outer margins of system and slightly elevated above other units, often with mantles of abundant angular pebbles and rocks.	Deep red/brown non-cracking clays (622).	Very scattered low shrublands of *Halosarcia* spp. (samphire), *Eremophila* sp., *Frankenia* sp. (frankenia) and *Atriplex bunburyana* (silver saltbush) (PXHS). Also very scattered mid height shrublands with *Acacia xiphophylla* (snakewood) (PSCS).
2.	2%	**Alluvial fans and drainage floors** - outwash fans and drainage floors up to 2 km in extent where creeklines enter outer margins of system, often with braided channels, gutters and rills.	Red loamy earths (544) and deep red/brown non-cracking clays (622).	Scattered to close tall shrublands with *Acacia coriacea* (river jam), *A. farnesiana* (mimosa bush), *A. sclerosperma* (limestone wattle) with halophytic undershrubs *Atriplex* and *Maireana* spp. and grasses such as *Cenchrus ciliaris* (buffel grass) (PCGS).
3.	1%	**Gilgai plains** - level clay plains up to 1 km in extent with gilgai microrelief.	Self-mulching cracking clays (602).	Very scattered low shrublands of *Atriplex bunburyana, A. amnicola* (river saltbush) (PXHS). Also occasional thickets of *Melaleuca* sp. shrubs (DMES).
4.	45%	**Flood plains** - level plains extending to 4-5 km, subject to periodic inundation.	Deep red/brown non-cracking clays (622).	Shrubby grasslands of *Sporobolus virginicus* (salt water couch) in patches or as more or less continuous swards with *Muellerolimon salicorniaceum* (false lignum) and *Muehlenbeckia florulenta* (lignum) (SPSG). Also scattered to moderately close grassy low shrublands with *Atriplex bunburyana* (PCGS).
5.	50%	**Saline flood plains and lakebeds** - level saline plains and lake beds up to 5-6 km in extent, subject to regular inundation.	Deep red/brown non-cracking clays (622) with high alkalinity and high gypsum content.	Very scattered to moderately close low shrublands of *Halosarcia* spp. (samphire) often with distinct zonation of species (PSPS). Also some extensive areas with no perennial vegetation.
6.	<1%	**Kopi banks** - not sampled.		Not sampled.
7.	<1%	**Channels and water holes** - Intermittent channels up to 100 m wide usually with bare clayey surfaces; very occasional large waterholes up to 300 m wide and 3 km long.		Fringing tall shrublands with *Acacia ampliceps* (black wattle), *A. farnesiana* and scattered trees. *Eucalyptus camaldulensis* (river red gum), *E. victrix* (coolibah) around water holes.

McKAY LAND SYSTEM (4,202 km^2, 2.3% of the survey area)

Hills, ridges, plateaux remnants and breakaways of meta sedimentary and sedimentary rocks supporting hard spinifex grasslands.

Land type: 1

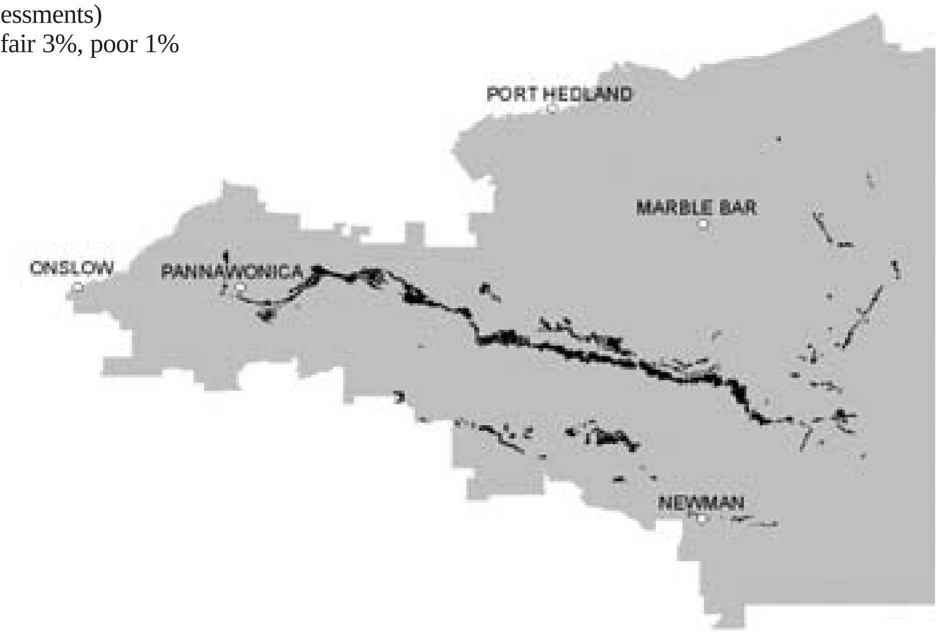
Geology: Lower Proterozoic shale, chert, mudstone, sandstone and dolomite.

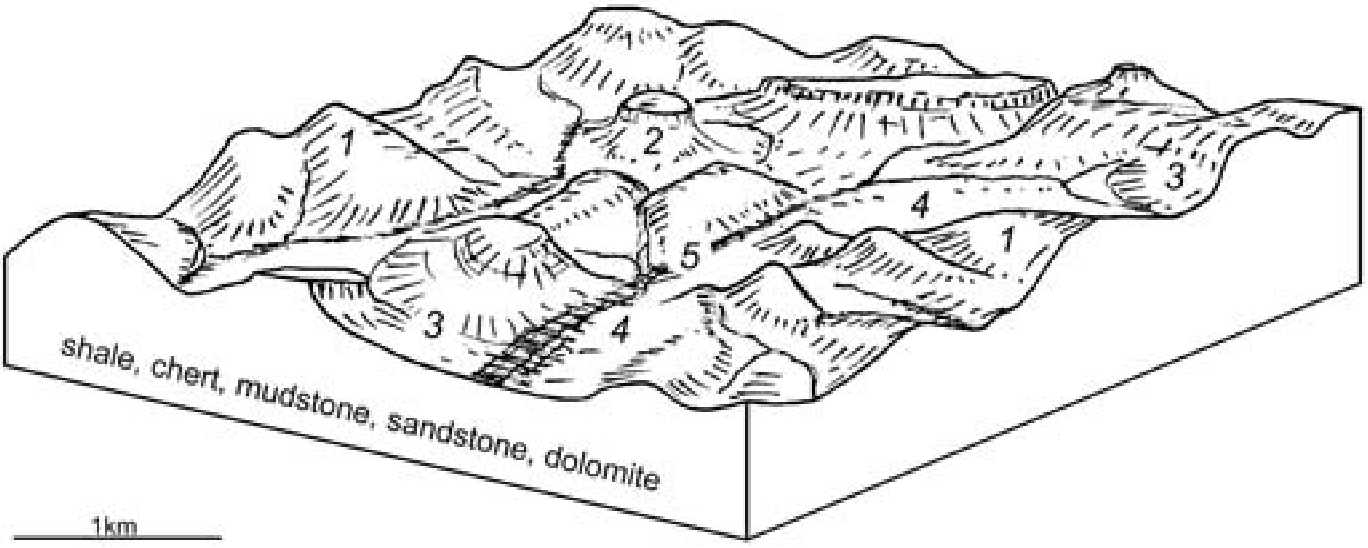
Geomorphology: Erosional surfaces; hill tracts, ridges, plateaux remnants and breakaways with steep upper slopes and more gently inclined lower footslopes, restricted stony plains and interfluves; moderately spaced tributary drainage patterns incised in narrow valleys in upper parts becoming broader and more widely spaced downstream. Relief up to 100 m.

Land management: This system supports predominantly hard spinifex vegetation and is not preferred by livestock. Some areas are poorly accessible and the system is not prone to degradation or soil erosion.

Traverse condition summary: (132 assessments)
Vegetation - very good 88%, good 8%, fair 3%, poor 1%
Soil erosion - nil 99%, slight 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Hill, ridge and plateau remnant	20	3
2.	Breakaway	-	1
3.	Lower footslope	28	1
4.	Stony plain	67	2
5.	Drainage floor	15	-
	Other	2	-
	Total	132	7

McKay land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	60%	**Hills, ridges and plateaux remnants** - rounded hill and ridge crests, level to gently inclined plateaux surfaces, moderately inclined to very steep upper slopes; surface mantles of very abundant pebbles, cobbles and stones of shale, chert, ironstone, sandstone or dolomite, also rock outcrop; relief up to 100 m.	Stony soils (203).	Hummock grasslands of *Triodia lanigera, T. wiseana* (hard spinifex) with isolated to scattered *Acacia* spp. shrubs or *Eucalyptus leucophloia* (snappy gum) trees (HSPG, HESG).
2.	2%	**Breakaways** - indurated mesa caps of ironstone or laterite with vertical breakaway faces up to 15 m high over weathered parent rock and with short, moderately inclined to steep slopes below; mantles of very abundant ironstone gravels and other rocks.	Stony soils (203).	Very scattered to scattered shrublands with *Acacia aneura* (mulga) or other acacias and *Triodia* spp. (spinifex) understorey. Also *Triodia* spp. hummock grasslands (HSPG).
3.	10%	**Lower footslopes** - very gently inclined slopes extending for up to 500 m below unit 1, mantles of very abundant pebbles of mixed lithology.	Red shallow loams (522).	Hummock grasslands of *Triodia* spp. (hard spinifex) with isolated to scattered *Acacia* spp. shrubs or *Eucalyptus leucophloia* trees (PHSG, HESG). Less frequently with *Triodia pungens* (soft spinifex (PSSG).
4.	20%	**Stony plains** - level to undulating plains and interfluves extending for up to 2 km below units 1, 2 and 3; mantles of abundant to very abundant pebbles of chert, shale, dolomite and other rocks.	Red deep loamy duplex soils (506) with minor red shallow loams (522) and red shallow sandy duplex soils (406).	Hummock grasslands of *Triodia wiseana, T.* spp. (hard spinifex) with isolated to very scattered *Acacia* spp. shrubs and occasional eucalypt trees (PHSG). Occasionally hummock grasslands of *Triodia pungens* (soft spinifex) (PSSG).
5.	8%	**Drainage floors** - dendritic floors less than 100 m wide with channels incised in narrow valleys in upper parts of system becoming broader (up to 250 m wide) with channels up to 50 m wide further downstream.	Red loamy earths (544) with river bed soils (705) in channels.	Scattered tall shrublands/woodlands with *Acacia* and *Eucalyptus* spp. and hummock grass *Triodia* spp. understorey (DAHW, DESG).

MOSQUITO LAND SYSTEM (1,840 km^2, 1.0% of the survey area)

Stony plains and prominent ridges of schist and other metamorphic rocks supporting hard spinifex grasslands.

Land type: 6

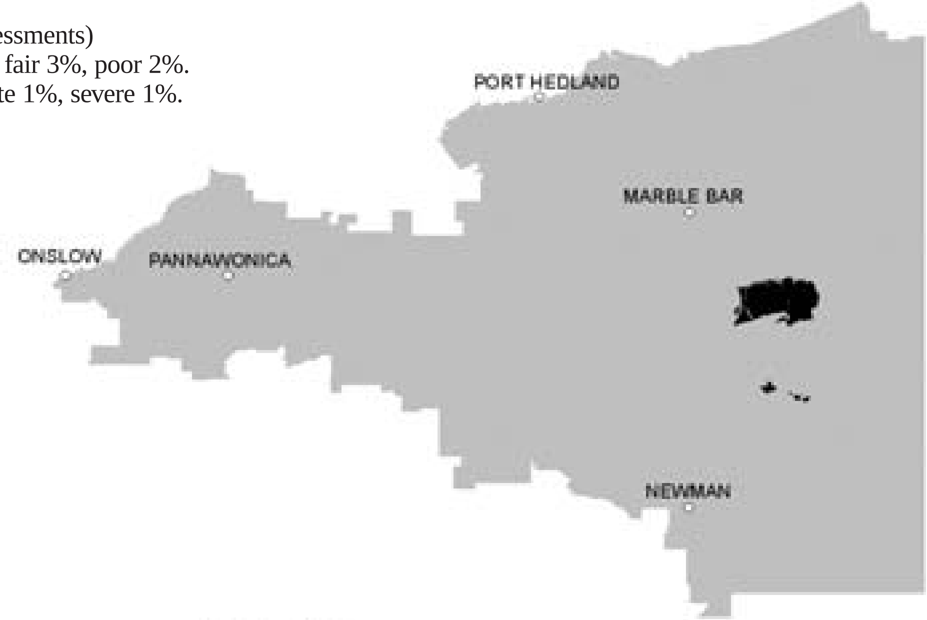
Geology: Archaean schist, greywacke, gabbro and minor conglomerate.

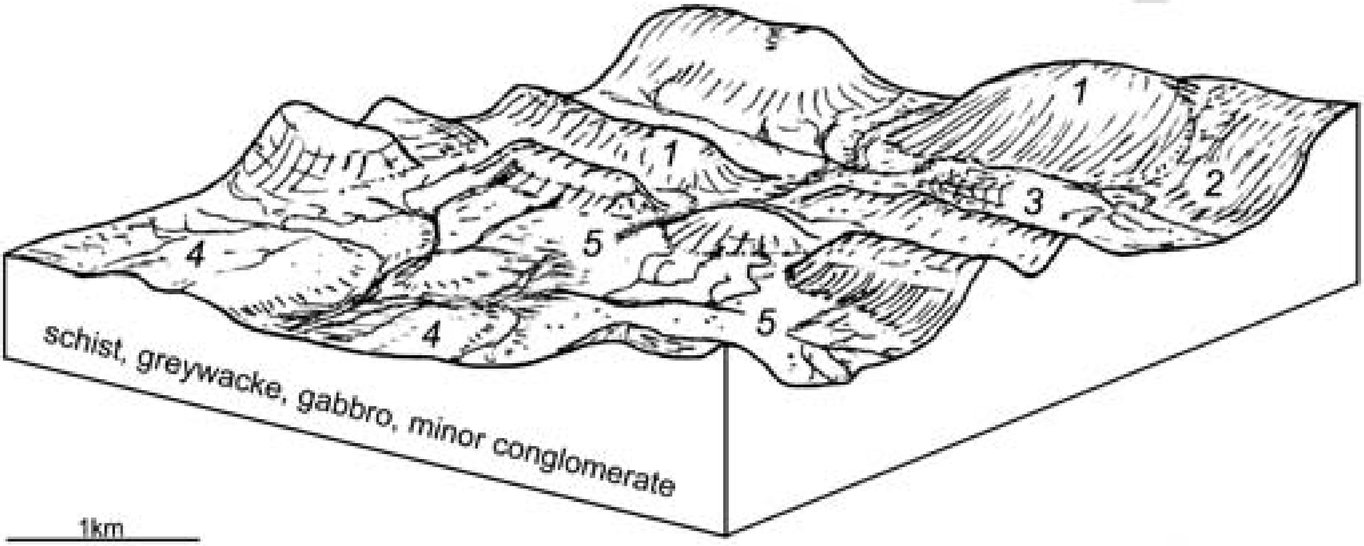
Geomorphology: Erosional surfaces; stony plains and pediments with prominent ridges and hills with steep upper slopes and short more gently inclined footslopes, moderately spaced tributary flow lines and channels. Relief up to 100 m.

Land management: Past and present mining activity on the system has resulted in localised disturbance and degradation. Much of the system supports hard spinifex vegetation which is little grazed by livestock. However, vegetation on stony saline plains (unit 4) includes chenopod low shrubs which are preferred and are prone to decline if management is inappropriate. Most of the system has low susceptibility to erosion except for some drainage floors (unit 5) which are moderately susceptible if vegetative cover is lost.

Traverse condition summary: (153 assessments)
Vegetation - very good 77%, good 18%, fair 3%, poor 2%.
Soil erosion - nil 97%, slight 1%, moderate 1%, severe 1%.

Area mapped as sde: 156 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Ridge and hill	12	1
2.	Lower footslope	15	-
3.	Stony plain	40	2
4.	Stony saline plain	58	3
5.	Drainage line and channel	27	2
	Other	1	-
	Total	153	8

Mosquito land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	40%	**Ridges and hills** - ridges and hill tracts with narrow rounded summits and moderately inclined to steep upper slopes, surface mantles of very abundant platy pebbles, cobbles and stones of schist and greywacke, also rock outcrop; relief up to 100 m.	Stony soils (203) with red shallow loams (522).	Hummock grasslands of *Triodia wiseana* (hard spinifex) with isolated shrubs such as *Acacia aphanoclada* (HSPG).
2.	10%	**Lower footslopes** - very gently to gently inclined slopes extending up to 200 m below hills, surface mantles of abundant to very abundant pebbles and cobbles of schist and other rocks.	Red shallow loams (522).	Hummock grasslands of *Triodia wiseana* with isolated shrubs (PHSG).
3.	15%	**Stony plains** - gently undulating to undulating plains and interfluves between frequent small drainage lines usually <500 m apart, surface mantles of abundant or very abundant quartz pebbles.	Red shallow loams (522).	Patchy hummock grasslands of *Triodia wiseana, T. longiceps* (hard spinifex) with isolated or very scattered shrubs such as *Acacia trachycarpa, A. synchronicia* (PHSG).
4.	25%	**Stony saline plains** - undulating plains and interfluves between frequent small drainage lines usually <500 m apart; surface mantles abundant to very abundant quartz pebbles.	Shallow red/brown non-cracking clays (622) and red shallow loams (522).	Patchy hummock grasslands of *T. longiceps* with isolated to scattered shrubs *Acacia, Senna* and *Maireana* spp. (SSCG).
5.	10%	**Drainage lines and channels** - narrow (20-100 m wide) drainage floors and small channels finely dendritic in upper parts becoming broader (up to 500 m) downstream, channels to 50 m wide.	Shallow red/brown non-cracking clays (622) and red shallow loams (522). Channels with river bed soils (705).	Scattered to close tall shrublands/woodlands with *Acacia* spp., *Eucalyptus victrix* (coolibah), *E. camaldulensis* (river red gum) with hummock grass *Triodia* spp. or tussock grass including *Cenchrus ciliaris* (buffel grass) understorey (DAHW, DESG, DEGW). Also hummock grasslands of *Triodia* spp. (hard or soft spinifex) (AHSG, ASSG).

NANUTARRA LAND SYSTEM (697 km², 0.4% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Low mesas and hills of sedimentary rocks supporting soft and hard spinifex grasslands.

Land type: 3

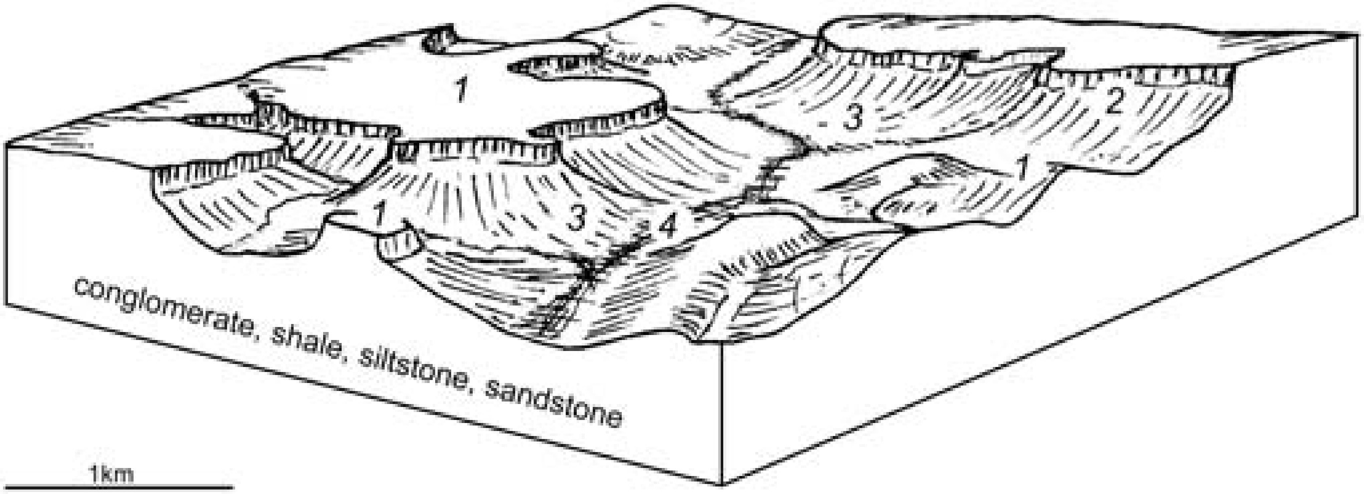
Geology: Cretaceous conglomerate, shale, siltstone and sandstone.

Geomorphology: Erosional surfaces; formed by partial dissection of an old plateau of marine sediments - low plateaux, dissected plateaux, mesas, buttes and low hills with rounded crests, short stony footslopes with parallel and radial drainage patterns, narrow dendritic drainage zones and creeklines between dissected plateaux and mesas. Relief up to 40 m.

Land management: Hard spinifex is not preferred by livestock but young soft spinifex is moderately preferred. The system is subject to fairly regular burning which has short-term effects on vegetation composition. The system is generally not prone to degradation or erosion.

Traverse condition summary: (5 assessments)
Vegetation - very good 80%, poor 20%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Low plateau, mesa, butte and hill	-	1
2.	Upper footslope	-	2
3.	Lower footslope	5	-
4.	Narrow drainage zone	-	-
	Total	5	3

Nanutarra land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	60%	**Low plateaux, mesas, buttes and hills** - level plateaux and mesa tops up to 2 km in extent but mostly much less, also low hills with rounded crests, surface mantles of very abundant pebbles and cobbles of ironstone; relief up to 30 m.	Stony soils (203).	Hummock grasslands of *Triodia pungens* (soft spinifex) with isolated *Acacia* and *Senna* spp. shrubs (HSPG).
2.	10%	**Upper footslopes** - concave, steep to very steep slopes with short, near vertical breakaway faces at top, mantles of abundant pebbles and cobbles of conglomerate, shale and other rocks.	Stony soils (203) and some red shallow loams (522).	Hummock grasslands of *Triodia wiseana* (hard spinifex) with very scattered to scattered *Acacia* spp. shrubs (HSPG). Less frequently hummock grasslands of *T. pungens*.
3.	25%	**Lower footslopes** - concave, gently inclined lower slopes up to 300 m long, mantles of abundant pebbles and cobbles of conglomerate, shale and other rocks.	Red shallow loams (522) and some red deep sandy duplex (405) soils.	Hummock grasslands of *Triodia* spp. (hard and soft spinifex) with very scattered *Acacia* and *Eremophila* spp. shrubs (PHSG, PSSG). Also scattered tall shrublands of *Acacia xiphophylla* (snakewood) with hummock grass understorey (ASHS).
4.	5%	**Narrow drainage zones** - very gently inclined drainage zones up to 200 m wide, unchannelled or with minor channels incised up to 1 m.	Red loamy earths (544). Channels with river bed soils (705).	Scattered shrublands of *Acacia xiphophylla* and other acacias with sparse low shrubs and *Triodia lanigera* understorey (ASHS).

NARBUNG LAND SYSTEM (159 km^2, 0.1% of the survey area)

Alluvial washplains with prominent internal drainage foci supporting snakewood and mulga shrublands with halophytic low shrubs.

Land type: 15

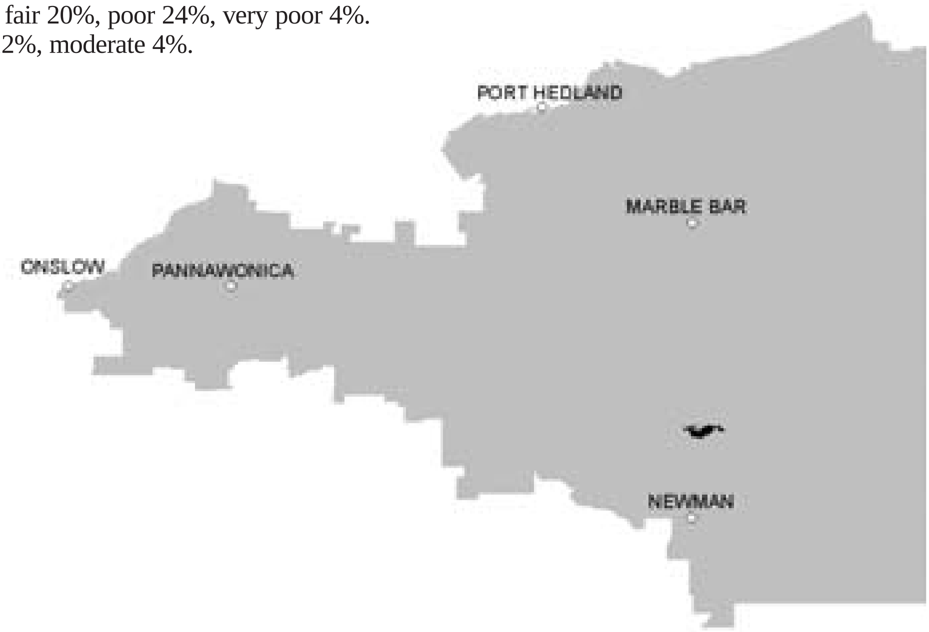
Geology: Quaternary alluvium.

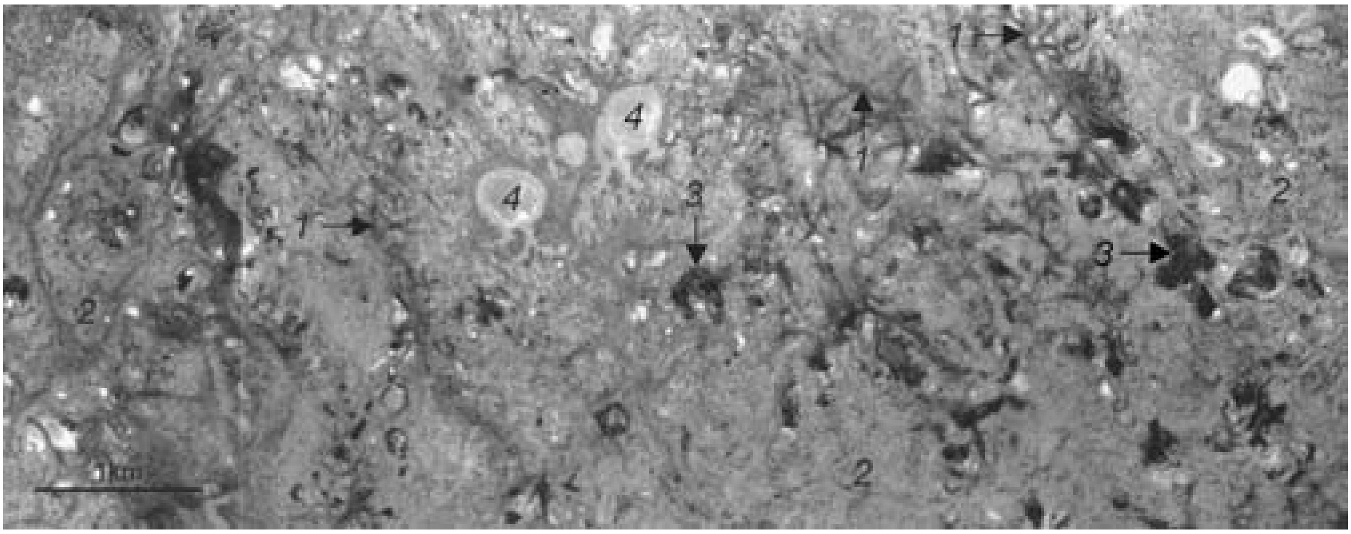
Geomorphology: Depositional surfaces; almost level alluvial plains receiving overland sheet flow, minor sand patches and sandy banks; no defined channelled drainage features but internal drainage zones with prominent drainage foci, groves and small claypans.

Land management: Parts of the system support vegetation which is highly preferred by grazing animals and prone to degradation if overgrazed. Alluvial plains (unit 2) are moderately susceptible to erosion.

Traverse condition summary: (25 assessments)
Vegetation - very good 24%, good 28%, fair 20%, poor 24%, very poor 4%.
Soil erosion - nil 76%, slight 8%, minor 12%, moderate 4%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Sandplain and sandy bank	2	-
2.	Alluvial plain	22	2
3.	Drainage focus	1	-
4.	Claypan	-	-
	Total	25	2

Narbung land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	8%	**Sandplains and sandy banks** - level plains up to 400 m in extent and sinuous sandy banks up to 2 km long by 100 m wide, somewhat moundy surfaces raised up to 1.5 m above surrounding alluvial plains (unit 2).	Sandplains of red sandy earths (463) and sandy banks of red deep sand (445).	Shrubby hummock grasslands of *Triodia pungens* (soft spinifex) with scattered shrubs *Acacia aneura* (mulga), other acacias and *Senna* spp. (SSSG, SBAS).
2.	87%	**Alluvial plains** - level plains up to 6 km in extent, uneven surfaces occasionally with mantles of few pebbles; subject to sheet flow.	Red deep sandy duplex (405) and red shallow sandy duplex soils (406).	Very scattered to scattered mixed height shrublands with *Acacia xiphophylla* (snakewood), *A. victoriae* (prickly acacia), *A. aneura, Senna* spp., *Maireana* spp. (blue bushes), *Enchylaena tomentosa* (ruby saltbush) and *Eremophila* spp. (PSCS).
3.	4%	**Drainage foci** - circular, oval or irregularly shaped foci and groves up to 500 m in extent receiving run-on from adjacent plains (unit 2).	Deep red/brown non-cracking clays (622) and red deep sandy duplex soils (405).	Moderately close to closed tall shrublands/woodlands with *Acacia aneura, A. xiphophylla*, numerous undershrubs and patchy tussock grasses (GMGW).
4.	1%	**Claypans** - circular pans and depressions 50-500 m in diameter.	Deep red/brown non-cracking clays (622).	No vegetation.

NEWMAN LAND SYSTEM (14,580 km^2, 8.0% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands.

Land type: 1

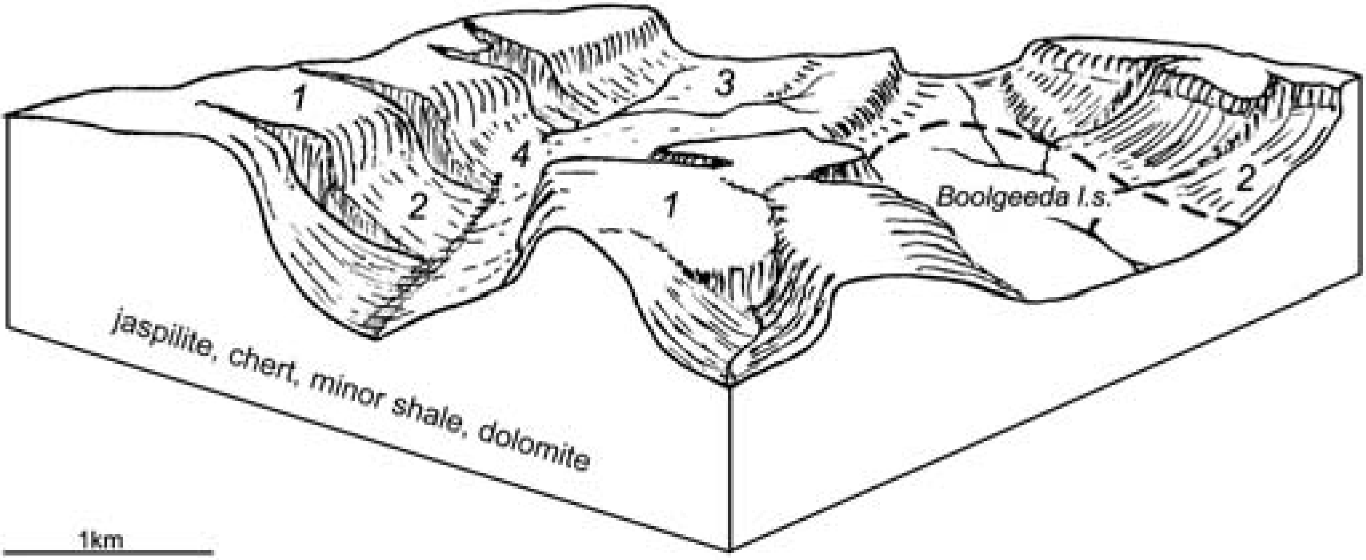
Geology: Lower Proterozoic jaspilite, chert, siltstone, shale, dolomite and minor acid volcanics.

Geomorphology: Erosional surfaces; plateaux and mountains - extensive high plateaux, mountains and strike ridges with vertical escarpments and steep scree slopes and more gently inclined lower slopes; moderately spaced dendritic and rectangular tributary drainage patterns of narrow valleys and gorges with narrow drainage floors and channels. Relief up to 450 m.

Land management: Much of the system is inaccessible or poorly accessible and is unsuitable for pastoral purposes. The system contains iron ore deposits which are currently being mined and deposits which are likely to be mined in the future. Spinifex is the dominant vegetation and the system is burnt fairly frequently.

Traverse condition summary: (228 assessments)
Vegetation - very good 91%, good 7%, fair 1%, poor 1%.
Soil erosion - nil 99%, minor 0.5%, moderate 0.5%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Plateau, ridge, mountain and hill	31	10
2.	Lower slope	74	2
3.	Stony plain	57	1
4.	Narrow drainage floor with channel	58	1
	Other	8	-
	Total	228	14

Newman land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	70%	**Plateaux, ridges, mountains and hills** - mountain tracts, plateaux and strike ridges, relief up to 400 m; level or rounded plateaux summits and mountain crests, ridges and indented escarpments with vertical upper cliff faces and moderately inclined to very steep upper scree slopes; surface mantles of abundant to very abundant pebbles, cobbles and stones of ironstone, jaspilite, chert and other rocks. Also outcrop of parent rock.	Stony soils (203), red shallow loams (522) and some red shallow sands (423).	Hummock grasslands of *Triodia wiseana, T. brizoides, T. plurinervata* (hard spinifex) with very scattered to scattered shrubs and trees including *Acacia* and *Senna* spp., *Grevillea wickhamii* (Wickham's grevillea), *Eucalyptus leucophloia* (snappy gum) and other eucalypts (HESG, HSPG). Occasionally hummock grass is *Triodia biflora* (soft spinifex).
2.	20%	**Lower slopes** - gently inclined concave slopes mostly less than 400 m in extent with mantles of very abundant pebbles and cobbles of ironstone and other rocks.	Stony soils (203) on upper margins with red loamy earths (544) on lower margins.	Similar to unit 1 (HESG, PHSG).
3.	5%	**Stony plains** - gently undulating lower plains and interfluves up to 500 m in extent with mantles of abundant to very abundant pebbles of ironstone.	Stony soils (203), red shallow loams (522) with some red loamy earths (544).	Hummock grasslands of *Triodia wiseana, T.* spp. (hard spinifex) with isolated to very scattered shrubs of *Acacia* and *Senna* spp. and occasional eucalypt trees (PHSG). Occasionally hummock grasslands of *Triodia pungens* (soft spinifex) (PSSG).
4.	5%	**Narrow drainage floors with channels** - almost level floors up to 400 m wide but usually much less in valleys, mantles of abundant pebbles of ironstone and other rocks; channels up to 200 m wide with cobble bedloads.	Red shallow loams (522), red loamy earths (544). Channels with river bed soils (705).	Smaller floors support hummock grassland of *Triodia pungens* with very scattered shrubs (ASSG). Larger floors and channels support tall shrublands/woodlands of *Acacia* spp. and *Eucalyptus victrix* (coolibah) with tussock grass or hummock grass understoreys (DEGW, DAHW, DESG).

NIRRAN LAND SYSTEM (163 km², 0.1% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Undulating stony plains and hills supporting hard spinifex grasslands and mulga shrublands with soft spinifex.

Land type: 6

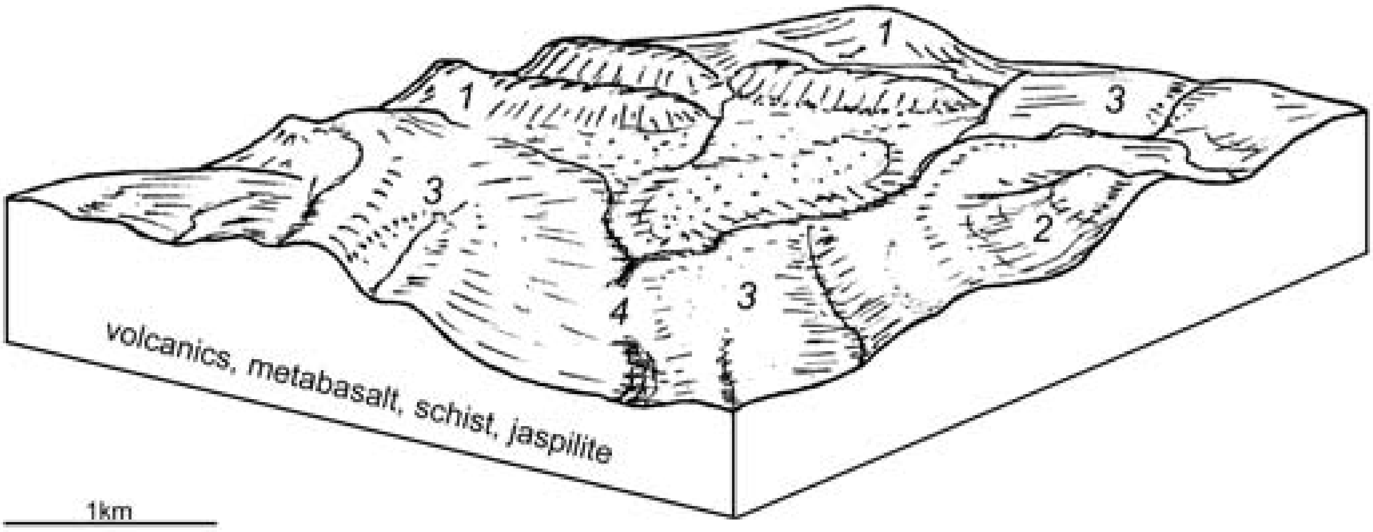
Geology: Archaean volcanics, metabasalt, schist and jaspilite.

Geomorphology: Erosional surfaces; undulating stony plains and interfluves, low ridges and hills, moderately to widely spaced tributary drainage patterns incised between interfluves and low hills with narrow drainage floors and channels. Relief up to 60 m but usually much less.

Land management: Much of the system supports spinifex vegetation which is not highly preferred by livestock. However, the snakewood-chenopod communities are preferred and are prone to degradation if grazing pressure is excessive. Generally the system has low susceptibility to erosion.

Traverse condition summary: (29 assessments)
Vegetation - very good 94%, good 3%, fair 3%.
Soil erosion - nil 86%, slight 7%, minor 7%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Low ridge and rounded hill	-	-
2.	Hill footslope	7	-
3.	Stony plain	17	-
4.	Narrow drainage floor and creekline	5	1
	Total	29	1

Nirran land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	15%	**Low ridges and rounded hills** - ridges and hills with gently rounded crests and moderately inclined upper slopes, surface mantles of abundant pebbles and cobbles; also rock outcrop. Relief up to 50 m.	Red shallow loams (522).	Mostly hummock grasslands of *Triodia* spp. (hard and soft spinifex) with very scattered shrubs *Acacia aneura* (mulga) other acacias and *Senna* spp. (HSPG).
2.	10%	**Hill footslopes** - very gently inclined to gently inclined short slopes up to 200 m in extent, surface mantles of abundant pebbles.	Red shallow loams (522) and red loamy earths (544).	Mostly hummock grasslands of *Triodia* spp. (hard and soft spinifex) with very scattered shrubs *Acacia aneura* (mulga) other acacias and *Senna* spp. (HSPG). Also scattered *A. aneura* tall shrublands with mixed low shrubs (PMSS).
3.	67%	**Stony plains** - gently undulating to undulating stony plains, interfluves and low rises up to 1.5 km in extent between drainage lines, abundant surface mantles of pebbles.	Red loamy earths (544).	Hummock grasslands of *Triodia* spp. (hard and soft spinifex) with very scattered to scattered shrubs including *Acacia aneura* (PHSG, PMSS). Also tall shrublands of *Acacia xiphophylla* (snakewood), *A. aneura* with *Senna* and *Eremophila* spp. and chenopod low shrubs (PSCS).
4.	8%	**Narrow drainage floors and creeklines** - floors up to 150 m wide with central channels or small creeklines incised between interfluves and on hillslopes.	Red loamy earths (544). Channels with river bed soils (705).	Moderately close tall shrublands/woodlands with *Acacia citrinoviridis* (black mulga), *A. aneura* and tussock grasses such as *Cenchrus ciliaris* (buffel grass) (DEGW).

NITA LAND SYSTEM (11,250 km^2, 6.2% of the survey area)

(modified from Cotching unpublished)

Sandplains supporting shrubby soft spinifex grasslands with occasional trees.

Land type: 11

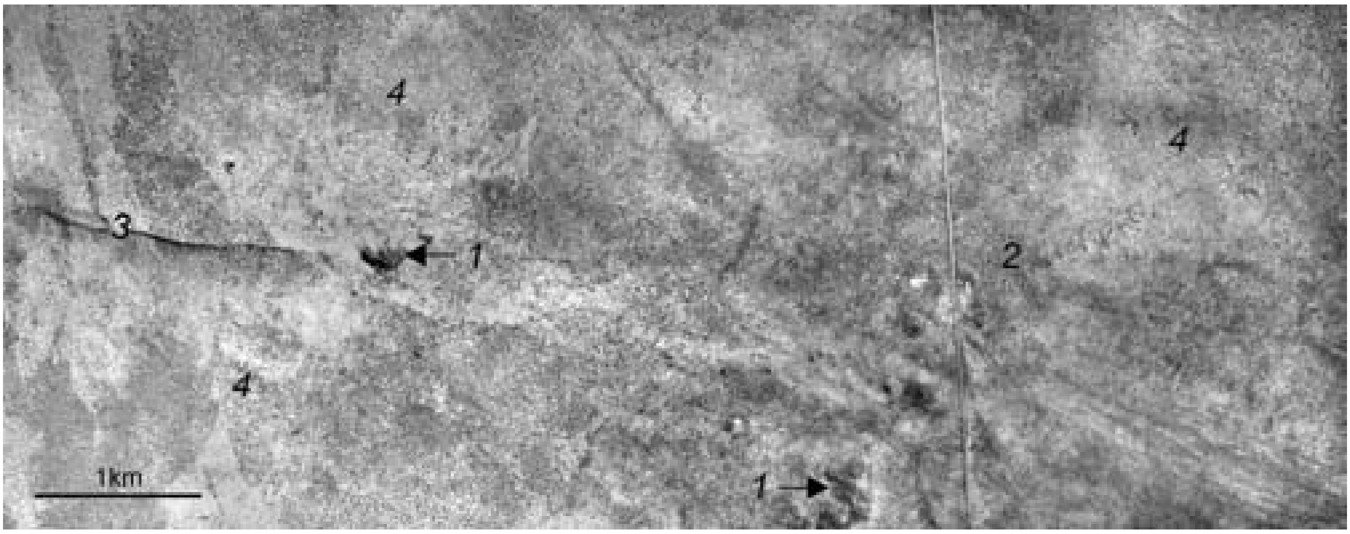
Geology: Quaternary eolian sand.

Geomorphology: Depositional surfaces; level eolian sandplains and occasional linear dunes, isolated low hills and occasional stony or gravelly rises; no organised drainage features. Relief up to 15 m.

Land management: Spinifex hummock grasslands on this system are subject to frequent fires which induce short-term changes in botanical composition and structure. Wind erosion may occur after fire, however stabilisation is usually rapid following rain and consequent regeneration of vegetation. Young soft spinifex (2 or 3 years after fire) is moderately preferred by grazing animals but mature stands are unattractive.

Traverse condition summary: (300 assessments)
Vegetation - very good 82%, good 7%, fair 8%, poor 3%.
Soil erosion - nil 100%

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Low hill	-	-
2.	Stony or gravelly plain	6	1
3.	Dune	5	-
4.	Sandplain	283	8
	Other	6	1
	Total	300	10

Nita land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	<1%	**Low hills** - occasional isolated low hills of sandstone or ferruginised sandstone up to 500 m in extent, surface mantles of abundant pebbles, cobbles and stones. Relief up to 15 m.	Red shallow sands (423) and stony soils (203).	Hummock grasslands of *Triodia* spp. (hard or soft spinifex) (HSPG).
2.	2%	**Stony or gravelly plains** - level or very gently inclined plains up to 1 km in extent, surface mantles of many to abundant pebbles and cobbles of sandstone or ferruginised sandstone or lateritic gravels.	Red shallow sands (423) and shallow gravel soils (304).	Hummock grasslands of *Triodia epactia* or *T. pungens* (soft spinifex) with isolated shrubs (PSSG).
3.	1%	**Dunes** - linear and occasionally reticulate sand dunes up to 3 km long with gently to moderately inclined slopes, uneven hummocky crest surfaces; relief up to 8 m.	Red deep sands (445).	Hummock grasslands of *Triodia epactia* or *T. pungens* with scattered mixed shrubs (SSSG).
4.	96%	**Sandplains** - level sand sheets extending for many kilometres.	Red deep sands (445).	Scattered to moderately close shrublands with acacias including *Acacia ancistrocarpa* (shiny leaf wattle), *A. stellaticeps* (poverty bush), *A. eriopoda* (Broome wattle), *A. monticola*, occasional trees such as *Bauhinia cunninghamii* (bauhinia), *Corymbia zygophylla* (Broome bloodwood) with prominent hummock grass *Triodia epactia, T. schinzii, T. pungens* (soft spinifex) ground layer (SSSG). Also hummock grasslands of *T. epactia, T. schinzii*, and *T. pungens* with isolated or very scattered shrubs (SSSG). Sandplains near the westward margin of the system (adjacent to Mannerie and Anna land systems) often support shrubby tussock grasslands of *Cenchrus ciliaris* (buffel grass).

NOOINGNIN LAND SYSTEM (898 km^2, 0.5% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Hardpan plains with very large groves supporting mulga shrublands.

Land type: 12

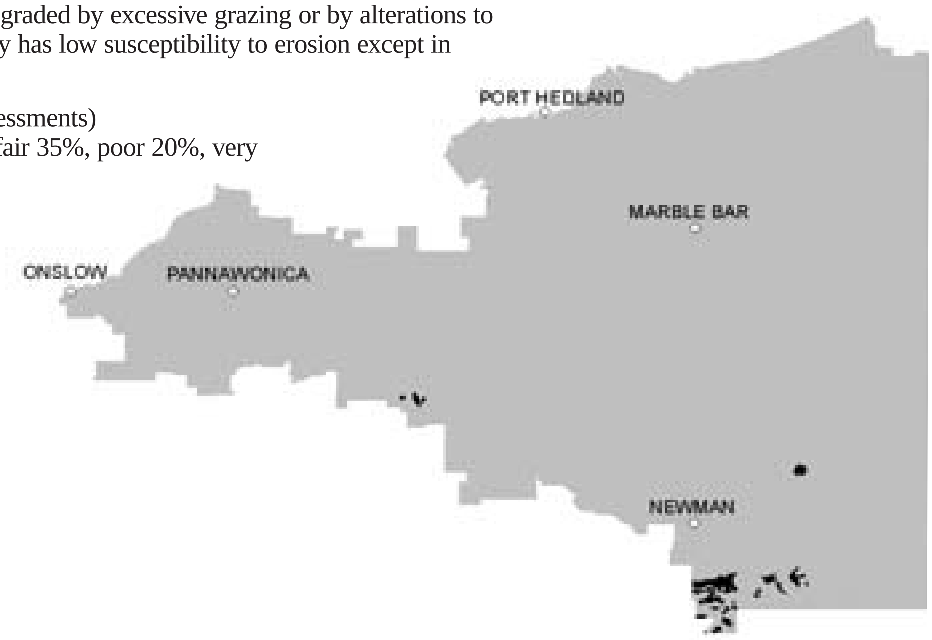
Geology: Tertiary cemented colluvium and alluvium.

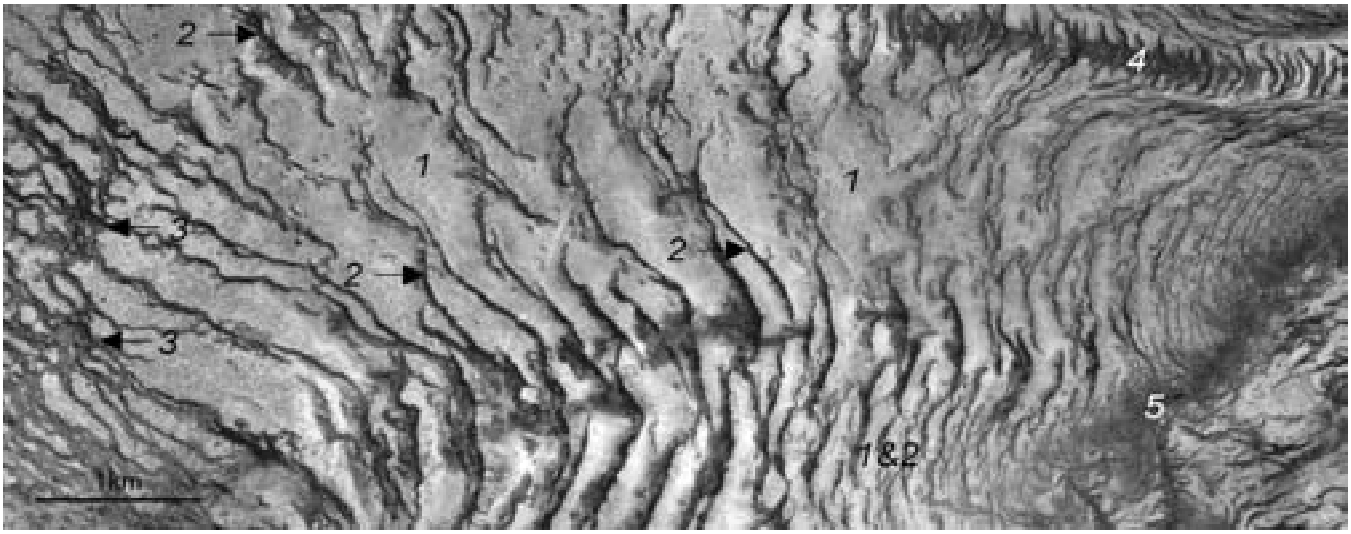
Geomorphology: Depositional surfaces; level non-saline hardpan washplains subject to sheet flow and with very large groves and low sandy banks; plains and narrow drainage zones receiving more concentrated sheet flow; very minor plains on saline alluvium and internal drainage flats. Relief less than 5 m.

Land management: Vegetation on the system includes shrubs and grasses which are preferred by livestock, and may decline markedly if grazing pressure is excessive. Any disturbance, such as inappropriately located or constructed tracks and roads, that restricts, diverts or concentrates surface water sheet flows will often adversely effect vegetation on this system. Although generally stable, groves (unit 2) can be degraded by excessive grazing or by alterations to surface water flows. The system generally has low susceptibility to erosion except in extreme cases of vegetation loss.

Traverse condition summary: (115 assessments)
Vegetation - very good 6%, good 29%, fair 35%, poor 20%, very poor 10%.
Soil erosion - nil 98%, minor 1%, moderate 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Hardpan plain	89	-
2.	Grove	10	-
3.	Sandy bank	11	-
4.	Plain receiving concentrated sheet flow	-	-
5.	Narrow drainage zone	5	-
	Total	115	-

Nooingnin land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	68%	**Hardpan plains** - level plains up to 8 km in extent, subject to sheet flow, occasionally with surface mantles of quartz pebbles or ironstone gravel.	Red-brown hardpan shallow loams (523).	Very scattered tall shrublands of *Acacia aneura* (mulga) and other *Acacia* spp. with sparse low shrubs *Eremophila* spp., *Ptilotus obovatus* (cotton bush) (HPMS, PSMS).
2.	10%	**Groves** - bands of dense vegetation on hardpan plains (unit 1), mostly 0.5-1 km long but up to 5 km long and 40 m wide arranged in parallel bands transverse to direction of sheet flow.	Red loamy earths (544).	Close to closed woodlands or tall shrublands of *Acacia aneura* and other *Acacia* spp., dense low shrubs *Eremophila forrestii* (Wilcox bush) *Ptilotus obovatus, Sida* spp. (GMUW, GMGW).
3.	10%	**Sandy banks** - banks up to 0.5 m high and 100 m wide, linear or reticulate up to 2 km long, hummocky surfaces with grit veneers.	Red deep sands (445) and red sandy earths (463).	Tall shrublands of *A. aneura* and other acacias, numerous low shrubs especially *Eremophila* spp. with perennial grasses *Monachather paradoxa* (broad-leaved wanderrie) *Eragrostis eriopoda* (woolly butt) (WABS) or *Triodia* spp. (hard spinifex) (SBAS).
4.	10%	**Plains receiving concentrated sheet flow** - level plains up to 1.5 m wide and extending up to 3 km downslope.	Red-brown hardpan shallow loams (523).	Low sparse shrublands of *Eremophila spathulata* (grey poverty bush) with occasional *Acacia tetragonophylla* (curara) and *A. aneura* (PSMS).
5.	2%	**Narrow drainage zones** - level, low zones within unit 1, up to 400 m wide and 6 km long, unchannelled or with shallow gutters.	Red-brown hardpan shallow loams (523), red shallow loams (522) and red loamy earths (544).	Close low woodlands of *A. aneura* and other *Acacia* spp., numerous low shrubs, sparse perennial grasses such as *Chrysopogon fallax* (ribbon grass) (DEAW, DEGW).

OAKOVER LAND SYSTEM (1,529 km^2, 0.8% of the survey area)

Breakaways, mesas, plateaux and stony plains of calcrete supporting hard spinifex grasslands.

Land type: 3

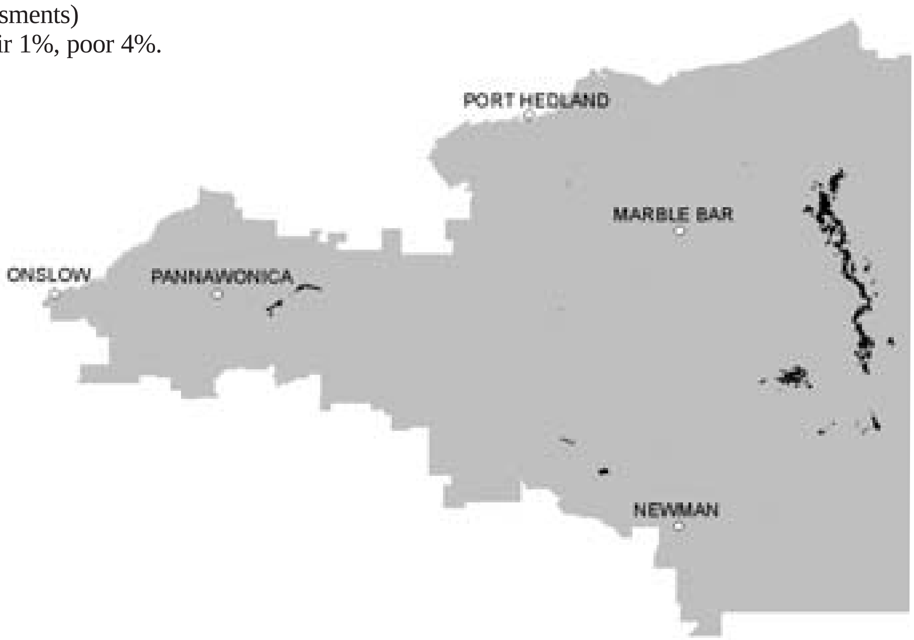
Geology: Tertiary silicified calcrete and calcareous sandstone, Quaternary colluvium and alluvium.

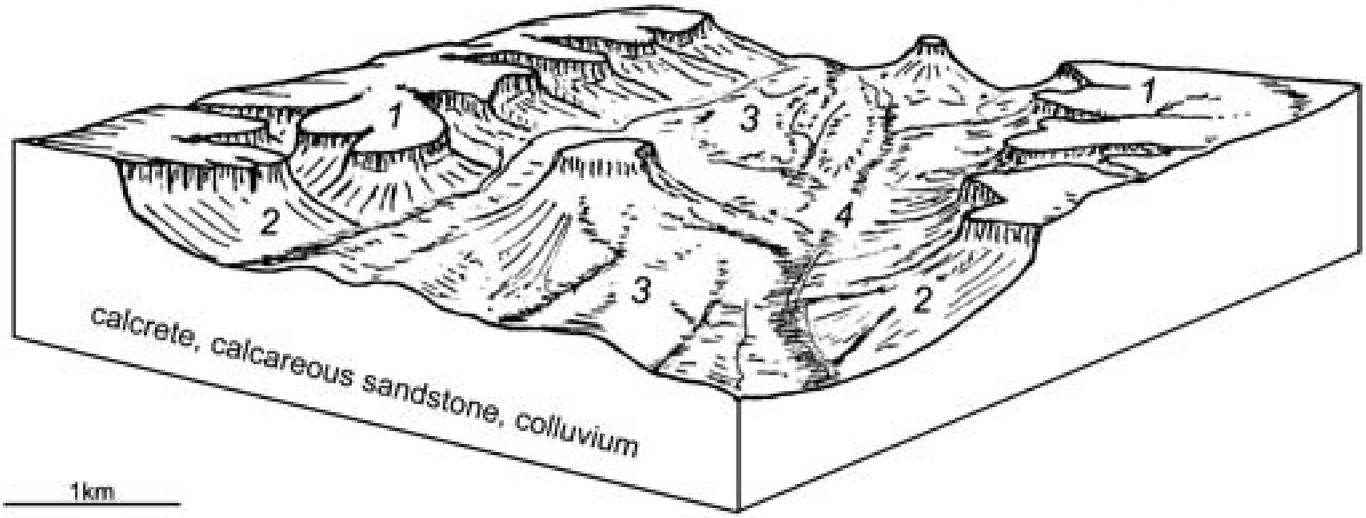
Geomorphology: Depositional surfaces; mesas, buttes and plateaux remnants with very steep breakaway faces of silicified or calcreted duricrust, more gently inclined lower footslopes and calcareous lower plains; closely spaced tributary drainage lines in upper parts becoming moderately spaced downstream with narrow, through going drainage floors and minor channels. Relief up to 60 m.

Land management: The hard spinifex grasslands on this system are not preferred by livestock. They are subject to occasional burning but perhaps not as regularly as other spinifex communities due to the somewhat patchy nature of the stands. The system is not generally prone to degradation or susceptible to soil erosion.

Traverse condition summary: (120 assessments)
Vegetation - very good 89%, good 6%, fair 1%, poor 4%.
Soil erosion - nil 99%, minor 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Plateau and mesa top with breakaway	28	2
2.	Footslope	16	2
3.	Calcareous plain	62	5
4.	Drainage line	11	1
	Other	3	-
	Total	120	10

Oakover land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	40%	**Plateaux and mesa tops with breakaways** - level or very gently inclined plateaux surfaces with highly dissected margins, almost vertical breakaway escarpments of duricrust (to 10 m) and steep upper slopes, surface mantles of abundant angular pebbles and cobbles of calcrete, also calcrete outcrop. Overall relief above drainage lines is up to 60 m.	Calcareous shallow loams (521) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana* (hard spinifex) with scattered shrubs *Acacia, Senna, Corchorus* spp. (CASG).
2.	20%	**Footslopes** - very gently inclined to moderately inclined slopes up to 1 km in extent below unit 1, surface mantles of abundant angular pebbles of calcrete.	Calcareous shallow loams (521).	Hummock grasslands of *Triodia wiseana* with isolated to very scattered shrubs such as *Acacia bivenosa* (two vein wattle) and *Senna* spp. (CASG, PHSG).
3.	30%	**Calcareous plains** - level to gently undulating plains, interfluves and low rises up to 2.5 km in extent, surface mantles of few to abundant pebbles of calcrete.	Calcareous shallow loams (521) with some shallow red/brown non-cracking clay (622). Some calcareous loamy earths (542).	Hummock grasslands of *Triodia wiseana* with isolated shrubs *Acacia bivenosa*, other acacias and *Senna* spp. (CASG, PHSG).
4.	10%	**Drainage lines** - narrow (20-100 m wide), usually unchannelled drainage tracts in upper parts of system becoming more defined downslope as drainage floors up to 300 m wide with channels.	Red deep loamy duplex soils (506) and channels with river bed soils (705).	Small drainage lines support hummock grasslands of *Triodia pungens* (soft spinifex) or *T. wiseana* with isolated or very scattered shrubs (ASSG, AHSG). Larger floors with channels support acacia or eucalypt tall shrublands/woodlands with hummock grass or tussock grass understoreys (DAHW, DESG, DEGW).

ONSLOW LAND SYSTEM (424 km^2, 0.2% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Sandplains, dunes and clay plains supporting soft spinifex grasslands and minor tussock grasslands.

Land type: 19

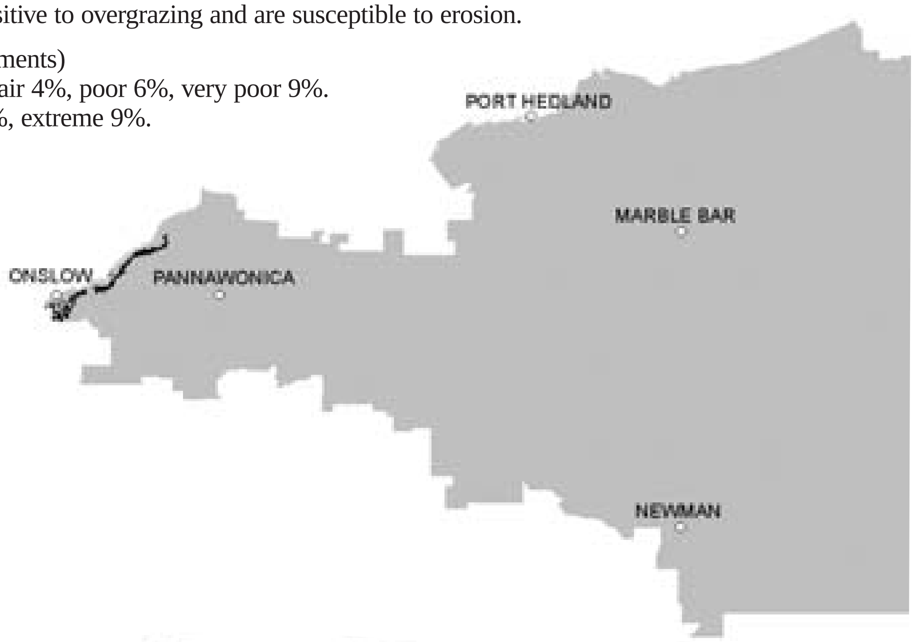
Geology: Quaternary quartz sand, silt, clay and gravel.

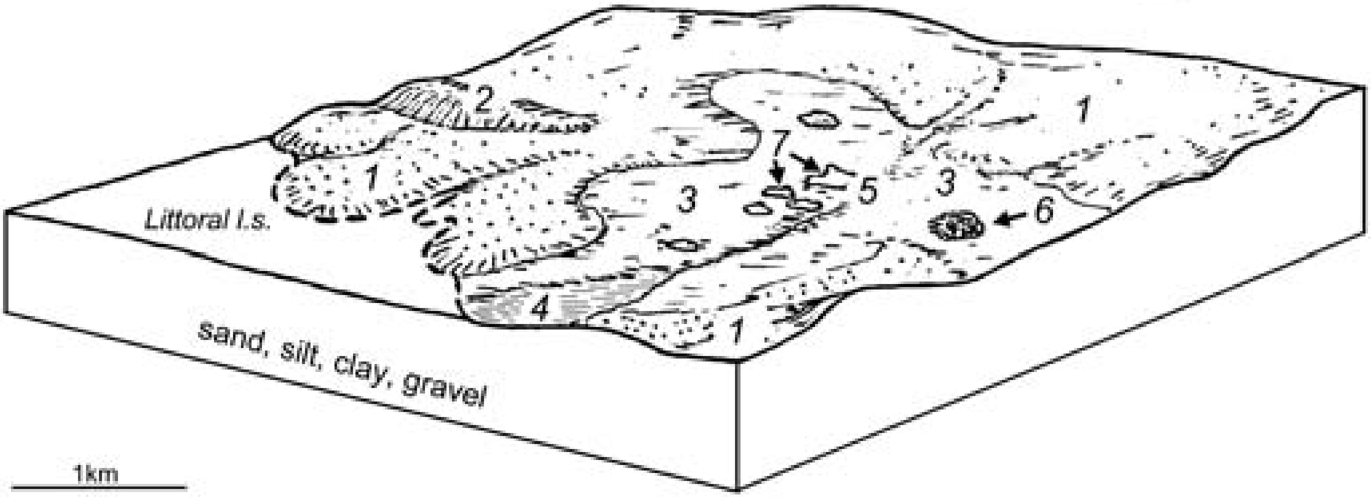
Geomorphology: Depositional surfaces; sandy plains formed by eolian and fluvial processes - gently undulating sandplains with intervening non-saline clay plains subject to sheet flow, narrow drainage zones receiving more concentrated flow, minor depressions subject to inundation; coastal fringes of low sandplain, interspersed with slightly lower saline samphire flats; also minor claypans, coastal dunes and beaches. Relief up to 20 m.

Land management: Young soft spinifex and associated tussock grasses are moderately preferred by grazing animals. The sandy units of the system are susceptible to wind erosion when bared by overgrazing or fire, but revegetate rapidly after rain. Clay plains with tussock grasses (unit 3) are sensitive to overgrazing and are susceptible to erosion.

Traverse condition summary: (47 assessments)
Vegetation - very good 60%, good 21%, fair 4%, poor 6%, very poor 9%.
Soil erosion - nil 87%, slight 2%, minor 2%, extreme 9%.

Area mapped as sde: 772 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Sandplain	15	2
2.	Dune	8	2
3.	Clay plain	15	1
4.	Saline flat	6	1
5.	Narrow drainage floor	3	-
6.	Depression	-	-
7.	Claypan	-	-
	Total	47	6

Onslow land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	40%	**Sandplains** - gently undulating sandplains up to 3 km in extent, hummocky surfaces.	Red deep sands (445) and red sandy earths (463).	Hummock grasslands of *Triodia pungens* (soft spinifex) with isolated *Acacia* spp. shrubs (SSSG). Also patches of *Cenchrus ciliaris* (buffel grass) (APBG).
2.	5%	**Dunes** - linear dunes up to 1 km long and 10 m high with gently to moderately inclined slopes, hummocky crests with loose surfaces.	Calcareous deep sands (442).	Hummock grasslands of *Triodia pungens* with isolated to very scattered shrubs such as *Crotalaria cunninghamii* (green bird flower) (SSSG). Patches of *Cenchrus ciliaris*.
3.	35%	**Clay plains** - level plains up to 2.5 km in extent between sandplains (unit 1), subject to sheet flow, often with scalded surfaces and claypans (unit 7) near coast.	Deep red/brown non-cracking clays (622).	Hummock grasslands of *Triodia longiceps* (AHSG). Patchy tussock grasslands with *Eragrostis xerophila* (Roebourne Plains grass) with sparse chenopod shrubs including *Atriplex* spp. (saltbush) (PCGS, ARPG). Patchy *Sporobolus virginicus* (salt water couch) grasslands with *Halosarcia* spp. low shrubs (SPSG, PSPS).
4.	12%	**Saline flats** - level saline plains marginal to adjacent Littoral land system or between sandplains, up to 1 km in extent.	Red deep loamy duplex soils (506) and deep red/brown non-cracking clays (622).	Very scattered to scattered low shrublands of *Halosarcia* spp. (samphire) and/or *Frankenia* spp. (frankenia) with variable amounts of *Sporobolus virginicus* grass (PSPS, SPSG). Some highly saline parts (extensions of tidal flats) with no vegetation.
5.	5%	**Narrow drainage floors** - up to 200 m wide, sinuous tracts receiving concentrated flow, may be unchannelled or with scour lines and minor channels.	Red loamy earths (544).	Tussock grasslands or grassy woodlands with *Sporobolus virginicus, Eragrostis xerophila, Chrysopogon fallax* (ribbon grass), *Eulalia aurea* (silky browntop) and *Eucalyptus victrix* (coolibah) trees (APXG, DEGW).
6.	1%	**Depressions** - circular or oval drainage foci to 400 m in diameter, up to 2 m below surrounding surfaces.	Deep red/brown clays non-cracking (622).	Variable tussock grasslands, mostly *Sporobolus virginicus* and *Eriachne benthamii* (swamp grass) with fringing margins of *Eucalyptus victrix* trees.
7.	2%	**Claypans** - bare, sealed surfaces with short marginal slopes up to 3 m high to surrounding plains; circular, oval or irregularly shaped, mostly less than 50 m in extent but occasionally up to 600 m; mostly found on clay plains (unit 3) less frequently on sandplains (unit 1).	Deep red/brown non-cracking clays (622).	No vegetation.

PARABURDOO LAND SYSTEM (565 km^2, 0.3% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Basalt derived stony gilgai plains and stony plains supporting snakewood and mulga shrublands with spinifex and tussock grasses.

Land type: 10

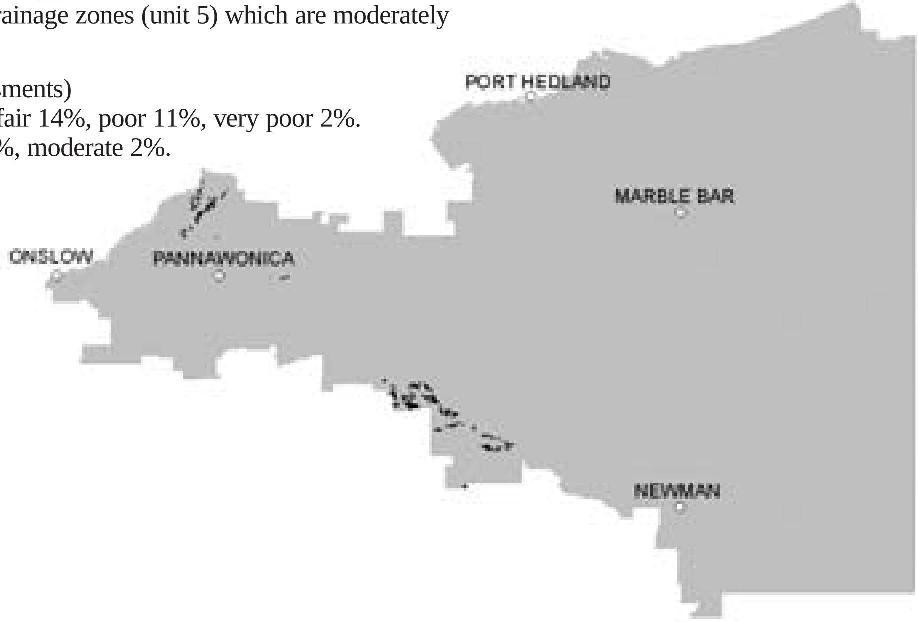
Geology: Quaternary colluvium and alluvium derived mainly from basalt.

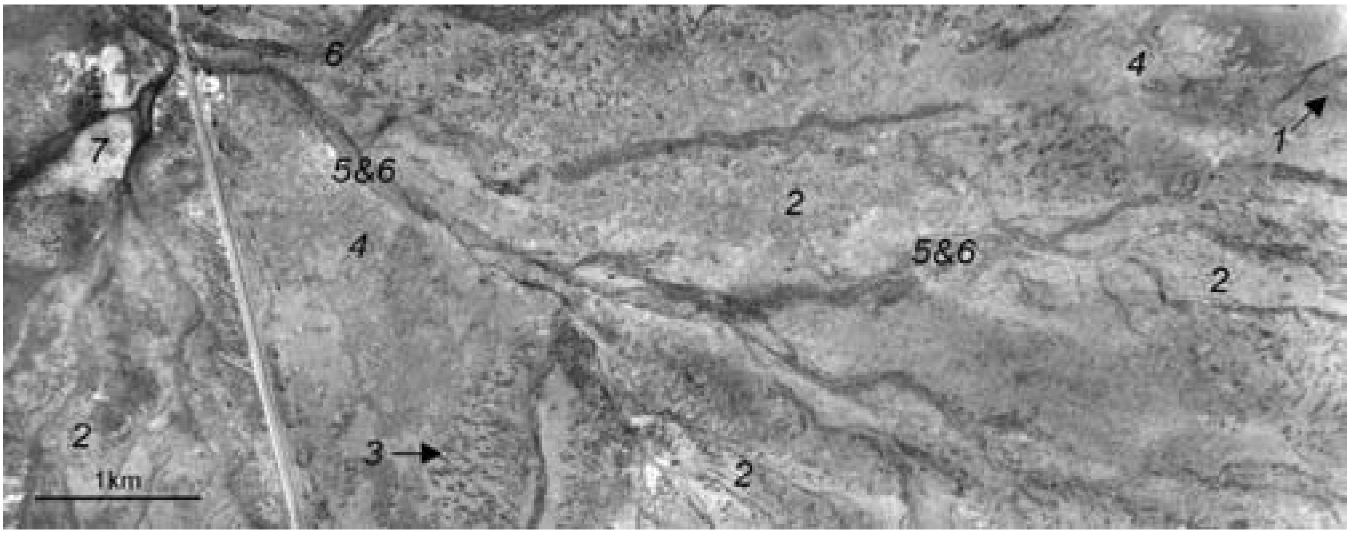
Geomorphology: Mostly depositional surfaces; isolated low basalt hills, stony upper interfluves and plains with small groves, stony plains with gilgai microrelief; moderately spaced patterns of sub-parallel tributary drainage extending downslope into broad zones with braided drainage and major trunk channels. Relief mostly less than 8 m but isolated hills up to 25 m.

Land management: Snakewood communities include many low shrubs and perennial grasses which are preferred by grazing animals and are prone to degradation if grazing pressure is excessive. Much of the system is inherently resistant to erosion except for drainage zones (unit 5) which are moderately susceptible.

Traverse condition summary: (84 assessments)
Vegetation - very good 49%, good 24%, fair 14%, poor 11%, very poor 2%.
Soil erosion - nil 95%, slight 1%, minor 2%, moderate 2%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low basalt hill and ridge	1	-
2.	Upper interfluve and slope	51	1
3.	Grove	3	1
4.	Gilgai plain	14	-
5.	Drainage zone	11	-
6.	Braided creekline and channel	3	-
7.	Calcrete platform	1	-
	Total	84	2

Paraburdoo land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	2%	**Low basalt hills and ridges** - up to 1 km long with rounded crests up to 25 m high, gently to moderately inclined footslopes, surface mantles of abundant to very abundant pebbles and cobbles of basalt and rock outcrops of basalt.	Stony soils (203).	Low shrublands with *Corchorus walcottii* (grey corchorus), *Ptilotus obovatus* (cotton bush), *Senna* spp. (cassias), and sparse overstorey of *Acacia* spp.. Also hummock grasslands of *Triodia wiseana* (hard spinifex) and very scattered shrubs (HSPG).
2.	50%	**Upper interfluves and slopes** - gently undulating surfaces below adjacent hill land systems, dissected to 3 m by sub-parallel drainage lines to form interfluves and plains 100-500 m wide extending for up to 3 km downslope, surface mantles of very abundant pebbles and cobbles of basalt and quartz.	Shallow red/brown non-cracking clays (622) and red shallow loams (522).	Scattered tall shrublands of *Acacia aneura* (mulga) or *A. xiphophylla* (snakewood) with numerous low shrubs including *Senna* spp. and *Maireana* spp. (bluebushes) (PMCS, PSCS). Also hummock grasslands of *Triodia wiseana* with very scattered acacia shrubs (PHSG).
3.	2%	**Groves** - level drainage foci mostly 20-40 m in extent (occasionally larger) on unit 2, often with gilgai microrelief and surface mantles of many basalt pebbles.	Red deep loamy duplex soils (506) and self-mulching cracking clays (602).	Moderately close to close tall shrublands/woodlands of *Acacia aneura* with sparse undershrubs and tussock grasses such as *Chrysopogon fallax* (ribbon grass) (GMGW).
4.	30%	**Gilgai plains** - level clay plains up to 3 km in extent with gilgai microrelief and surface mantles of few to abundant pebbles of basalt.	Deep red/brown non-cracking clays (622) and self-mulching cracking clays (602).	Tussock grasslands with *Eragrostis xerophila* (Roebourne Plains grass) and other perennial grasses and isolated or very scattered shrubs (ARPG, APXG) or scattered tall shrublands of *Acacia xiphophylla* with tussock grass understorey (SSTS).
5.	12%	**Drainage zones** - almost level drainage zones up to 500 m wide and many kilometres long, sometimes unchannelled but central parts often with braided channels or major channels of trunk drainage (unit 6), gilgai microrelief common.	Deep red/brown non-cracking clays (622) and red loamy earths (544).	Scattered tall shrublands with *Acacia aneura, A. xiphophylla, A. victoriae* (prickly acacia) with variable understoreys including *Senna* and *Maireana* spp. with tussock and/or hummock grasses (PMCS, DEGW, DAHW). Also hummock grasslands of *Triodia* spp. (hard and soft spinifex) with very scattered shrubs (AHSG, ASSG).
6.	3%	**Braided creeklines and channels** - minor channels and runnels up to 10 m wide and 1.5 m deep, separated by narrow, flood banks of mixed alluvium; major channels up to 50 m wide and 5 m deep.	River bed soils (705).	Moderately close tall shrublands/woodlands of *Acacia citrinoviridis* (black mulga) and other *Acacia* spp., *E. camaldulensis* (river red gum) with variable low shrubs and tussock grasses (DEGW).
7.	1%	**Calcrete platforms** - level plains mostly less than 500 m in extent, raised up to 0.5 m above surrounding surfaces, surface mantles of calcrete pebbles.	Calcareous shallow loams (521).	Hummock grasslands of *Triodia wiseana* with very scattered shrubs (CASG) or shrublands of *Senna* and *Acacia* spp. (CACS).

PARADISE LAND SYSTEM (1,479 km^2, 0.8% of the survey area)

Alluvial plains supporting soft spinifex grasslands and tussock grasslands.

Land type: 13

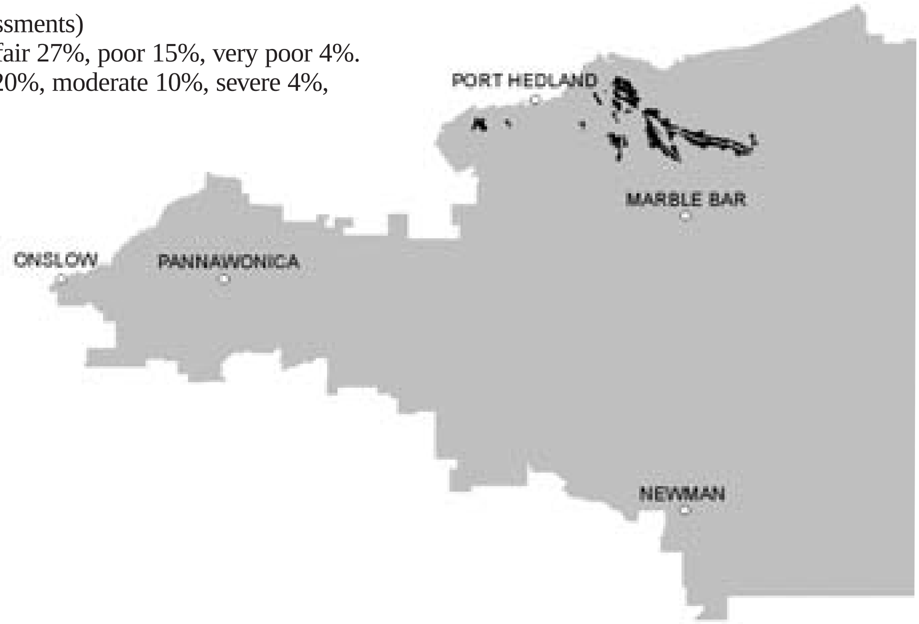
Geology: Quaternary alluvium.

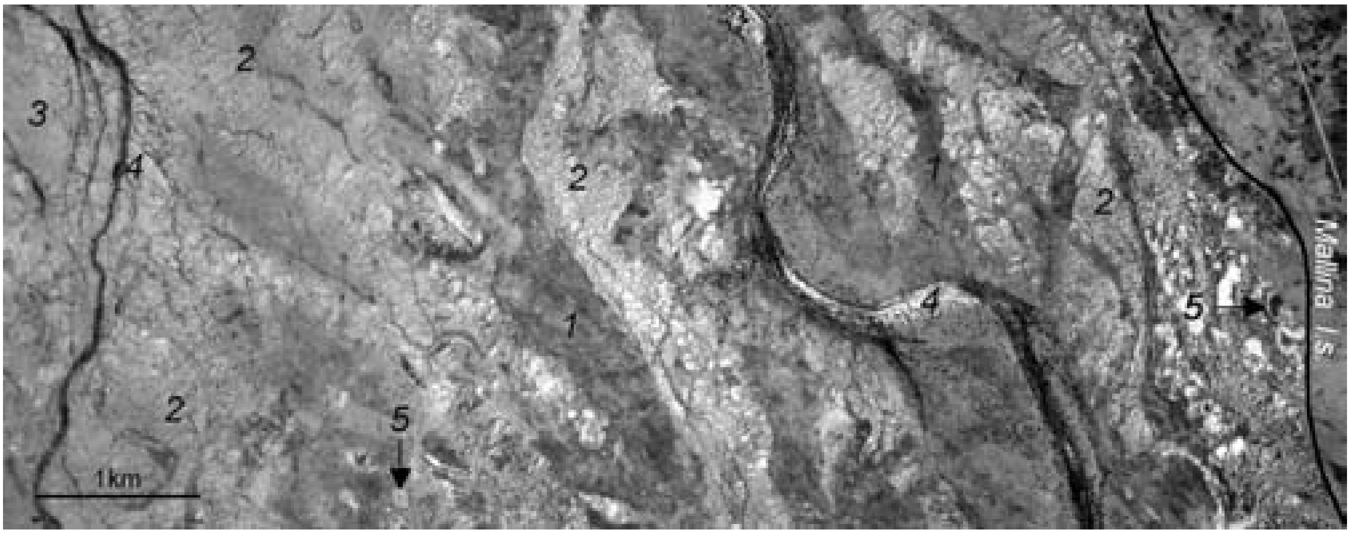
Geomorphology: Depositional surfaces; plains (weakly saline in parts) with numerous small scalds and claypans on reworked old alluvium, subject to flooding; also tracts receiving more concentrated through flow with sluggish channels and minor clay plains with gilgai microrelief.

Land management: The system is prone to periodic flooding. Much of the vegetation on the system is favoured by grazing animals and is prone to degradation if overgrazed. Loamy plains and alluvial plains (units 1 and 2) are highly susceptible to water and wind erosion if the vegetative cover is depleted.

Traverse condition summary: (225 assessments)
Vegetation - very good 23%, good 31%, fair 27%, poor 15%, very poor 4%.
Soil erosion - nil 53%, slight 12%, minor 20%, moderate 10%, severe 4%, extreme 1%.

Area mapped as sde: 4,351 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Loamy plain	18	4
2.	Alluvial plain	163	10
3.	Gilgai plain	10	-
4.	Tract receiving more concentrated flow	32	3
5.	Claypan	-	1
	Other	2	-
	Total	225	18

Paradise land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	6%	**Loamy plains** - level plains up to 1 km in extent or as somewhat sinuous tracts up to 500 m wide and 3 km long, slightly elevated (1-2 m) above surrounding alluvial plains (unit 2).	Red sandy earths (463).	Hummock grasslands of *Triodia pungens* (soft spinifex) with isolated to scattered *Acacia* spp. shrubs (PSSG, ASSG). *Cenchrus ciliaris* (buffel grass) has colonised some areas.
2.	75%	**Alluvial plains** - level plains extending up to 5 km or more, subject to flooding, often with scalded hummocky surfaces and numerous small claypans, surface mantles absent or few to common (patchy) pebbles of ironstone, quartz and other rocks.	Red deep sandy duplex (405), red deep loamy duplex (506), red loamy earths (544) and deep red/brown non-cracking clays (622).	Patchy hummock grasslands of *Triodia pungens* (soft spinifex) or *T. secunda* (hard spinifex) or patchy tussock grasslands of *Eragrostis xerophila* (Roebourne Plains grass) (ASSG, AHSG, ARPG).
3.	4%	**Gilgai plains** - level clay plains up to 1 km in extent with gilgai microrelief, surface mantles mostly absent or few.	Deep red/brown non-cracking clays (622) and self-mulching cracking clays (602).	Tussock grasslands with *Eragrostis xerophila* and *Eriachne benthamii* (swamp grass) (ARPG).
4.	14%	**Tracts receiving more concentrated flow** - level tracts up to 500 m wide receiving more concentrated through flow than surrounding alluvial plains (unit 2); unchannelled or with anastomosing or meandering channels 10-100 m wide and incised up to 4 m.	Deep red/brown non-cracking clays (622), red deep sandy duplex (405), red deep loamy duplex (506), red loamy earths (544). Channels with red deep sands (445) or river bed soils (705).	Variable dense tussock grasslands or grassy woodlands with *Cenchrus ciliaris*, *Chrysopogon fallax* (ribbon grass), *Eulalia aurea* (silky browntop), *Eriachne benthamii* with isolated to scattered *Eucalyptus* and *Acacia* spp. trees (APBG, APXG, DEGW). Also hummock grasslands of *Triodia pungens* (ASSG) or *T. pungens* with scattered eucalypts or acacia trees (DAHW).
5.	1%	**Claypans** - level, round, oval or irregularly shaped pans occurring on alluvial plains (unit 2), 25-250 m in extent; bare surfaces surrounded by banks up to 2 m high.	Deep red/brown non-cracking clays (622).	Mostly no vegetation except for banks at edges of pans which support *Triodia pungens* and sometimes *Cenchrus ciliaris*.

PATERSON LAND SYSTEM (818 km^2, 0.5% of the survey area)

Stony and sandy plains with isolated low hills of sandstone or conglomerate supporting hard spinifex (and occasionally soft spinifex) grasslands and minor tussock grasslands.

Land type: 8

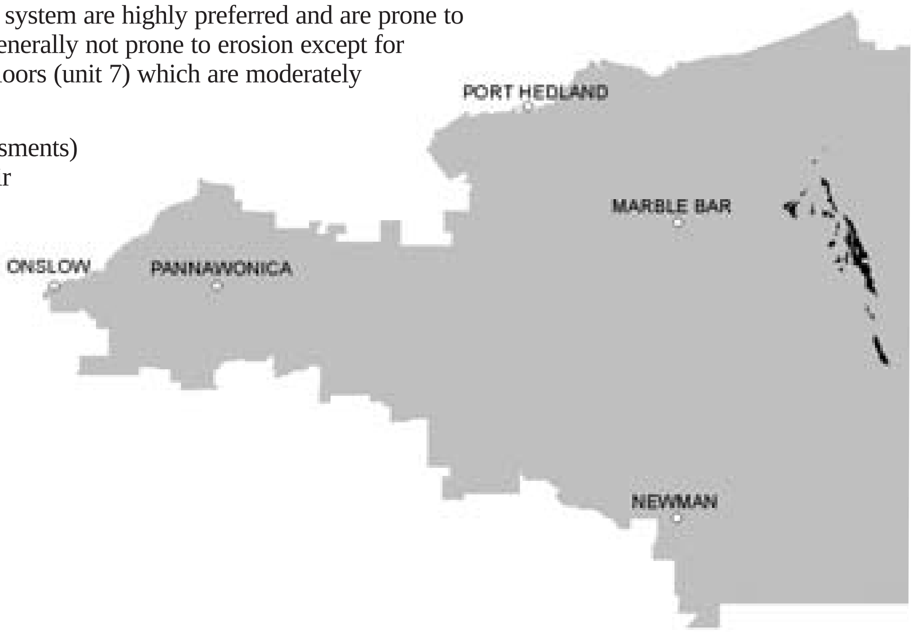
Geology: Quaternary sandy and gravelly eluvium, colluvium and minor alluvium; Permian sandstone and conglomerate.

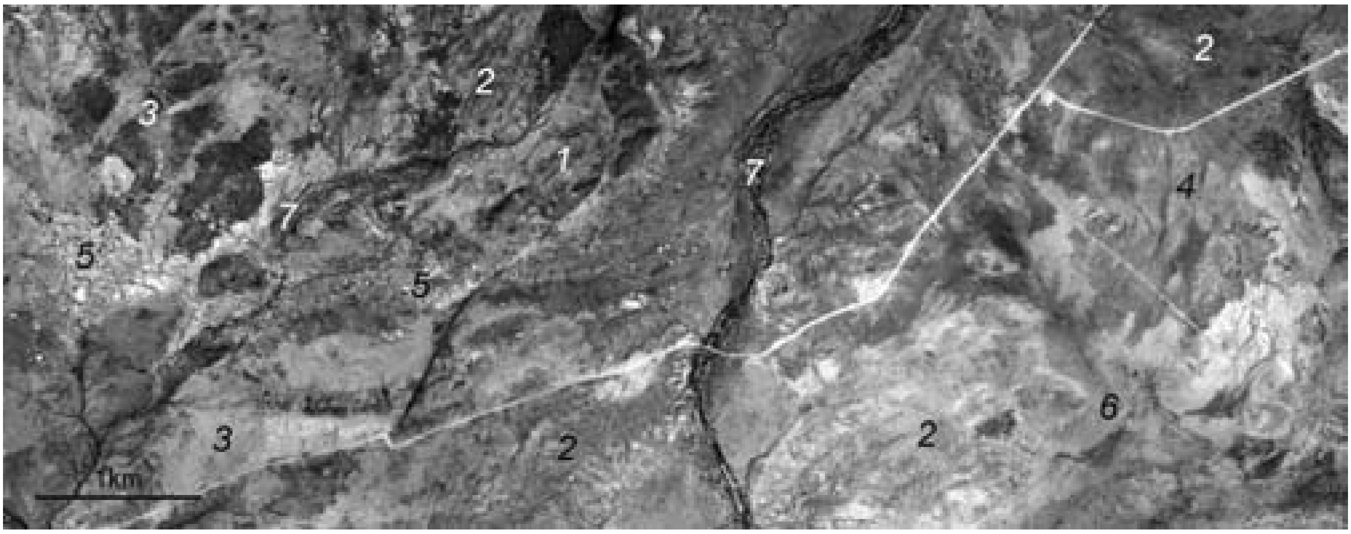
Geomorphology: Mainly erosional surfaces; isolated low hills and mesas, extensive gently undulating stony plains, pediments and rises, sandy surfaced plains formed in situ over sandstone or conglomerate, minor alluvial plains; moderately to very widely spaced tributary drainage floors with or without channels. Isolated hills with relief up to 60 m and relief of plains usually less than 20 m.

Land management: Hard spinifex vegetation is not preferred by livestock but young soft spinifex is moderately preferred. Minor tussock grasslands on the system are highly preferred and are prone to degradation if overgrazed. The system is generally not prone to erosion except for alluvial plains (unit 5) and some drainage floors (unit 7) which are moderately susceptible if vegetative cover is depleted.

Traverse condition summary: (133 assessments)
Vegetation - very good 78%, good 6%, fair 8%, poor 6%, very poor 2%.
Soil erosion - nil 92%, slight 1%, minor 4%, moderate 2%, severe 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low hill and mesa	1	2
2.	Stony plain and low rise	66	3
3.	Sandy plain	16	5
4.	Calcareous plain	13	1
5.	Alluvial plain	17	1
6.	Gilgai plain	4	-
7.	Drainage floor	16	3
	Total	133	15

Paterson land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	2%	**Low hills and mesas** - hills, mesas, buttes and ridges up to 500 m in extent with gently inclined to steep footslopes and mantles of very abundant pebbles and cobbles of conglomerate and sandstone, also rock outcrop; relief up to 60 m but usually much less.	Stony soils (203) and red shallow loams (522).	Hummock grasslands of *Triodia brizoides* and other *T.* spp. (hard spinifex) with isolated to very scattered shrubs (HSPG).
2.	55%	**Stony plains and low rises** - gently undulating to undulating plains, low rounded rises and interfluves extending for 0.5-2 km between drainage lines; surface mantles of many to very abundant pebbles and cobbles of mixed lithology.	Red shallow loams (522), red shallow sands (423), calcareous shallow loams (521) and some red sandy earths (463).	Hummock grasslands of *Triodia wiseana* and other *T*. spp. (hard spinifex) with isolated to very scattered shrubs (PHSG). Occasionally hummock grasslands of *Triodia pungens* (soft spinifex) (PSSG).
3.	15%	**Sandy plains** - level plains with thin sand cover extending for up to 1.5 km.	Red sandy earths (463), red deep sandy duplex soils (405) and red loamy earths (544).	Hummock grasslands of *Triodia plurinervata* and other *T*. spp. (hard spinifex) or, less frequently, *Triodia pungens* (soft spinifex) with isolated to very scattered shrubs (PHSG, PSSG).
4.	9%	**Calcareous plains** - gently undulating plains with surface mantles of abundant calcrete pebbles and cobbles, also calcrete outcrop.	Calcareous shallow loams (521).	Hummock grasslands of *Triodia wiseana* (hard spinifex) with very scattered to scattered diverse shrubs (CASG).
5.	6%	**Alluvial plains** - level plains up to 2 km in extent usually flanking drainage lines (unit 7), with or without patchy surface mantles of pebbles and cobbles, some surfaces are scalded and moundy.	Red sandy earths (463) and some red loamy earths (544).	Tussock grasslands of *Eragrostis xerophila* (Roebourne Plains grass) or *Cenchrus ciliaris* (buffel grass) (ARPG, APBG). Also hummock grasslands of *Triodia pungens* (soft spinifex) with very scattered shrubs (ASSG).
6.	3%	**Gilgai plains** - level plains up to 1.5 km in extent, weakly gilgaied microrelief with or without surface mantles of pebbles and cobbles.	Deep red/brown non-cracking clays (622).	Tussock grasslands of *Eragrostis xerophila* (ARPG).
7.	10%	**Drainage floors** - almost level floors between other units of the system, narrow (50-250 m), with or without channels in upper parts becoming wider (up to 500 m) downslope with channels up to 50 m wide.	Red deep sands (445) in narrow zones, red loamy earths (544) downslope. Channels with river bed soils (705).	Hummock grasslands of *Triodia pungens* and very scattered *Acacia* spp. and other shrubs (ASSG). Occasionally tussock grasslands of C*enchrus ciliaris* (APBG). Tall shrublands/woodlands of *Acacia* spp. with soft spinifex understorey (DAHW) or tussock grasses (DEGW). Channels with grassy *Eucalyptus* and *Melaleuca* spp. fringing woodlands (GMEW).

PEEDAMULLA LAND SYSTEM (587 km^2, 0.3% of the survey area)

Gravelly plains supporting hard spinifex grasslands and minor snakewood shrublands.

Land type: 8

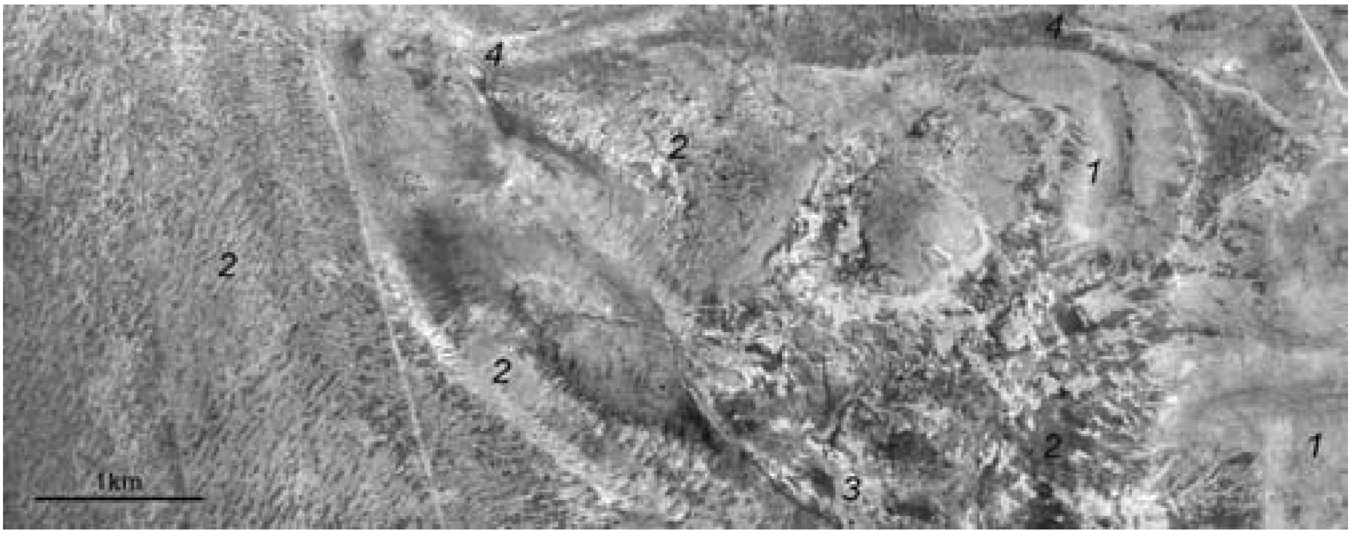
Geology: Quaternary eluvium, alluvium and minor colluvium; minor Cretaceous shale, siltstone, sandstone and conglomerate.

Geomorphology: Depositional surfaces; occasional low rises and low hills above extensive, level to gently undulating gravelly plains receiving sheet flow, minor stony clay plains with gilgai microrelief, sparse shallow tributary drainage floors with or without channels. Relief up to 15 m.

Land management: Hard spinifex vegetation is not preferred by livestock but young soft spinifex is moderately preferred. The tussock grasslands and grassy snakewood shrub communities on the system are subject to preferential grazing and are prone to degradation.

Traverse condition summary: (64 assessments)
Vegetation - very good 70%, good 8%, fair 6%, poor 14%, very poor 2%.
Soil erosion - nil 95%, slight 2%, minor 3%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Rise and low hill	4	-
2.	Gravelly plain	48	9
3.	Stony gilgai plain	7	-
4.	Drainage floor	5	2
	Total	64	11

Peedamulla land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	8%	**Rises and low hills** - rounded rises up to 1 km in extent with very gently inclined slopes and surface mantles of very abundant ironstone gravel, also ferruginised rock outcrop; relief up to 10 m above surrounding plains.	Stony soils (203) and shallow gravel soils (304).	Hummock grasslands of *Triodia wiseana, T. lanigera* (hard spinifex) with isolated to very scattered acacia shrubs (PHSG).
2.	82%	**Gravelly plains** - level to gently undulating plains up to 8 km in extent, surface mantles of abundant to very abundant fine and medium ironstone gravels.	Stony (203) and shallow gravel soils (304). Red shallow loams (522), red sandy earths (463), red loamy earths (544), red deep loamy duplex soils (506) and deep red/brown non-cracking clays (622).	Hummock grasslands of *Triodia wiseana, T. lanigera* with isolated to scattered shrubs including *Acacia atkinsiana*, other acacias and *Grevillea wickhamii* (Wickham's grevillea) (PHSG). Occasionally hummock grasslands of *Triodia pungens* (soft spinifex) with shrubs (PSSG). Also mid height shrublands of *Acacia xiphophylla* (snakewood) with *Triodia* spp. (hard and soft spinifex) understorey (ASHS).
3.	2%	**Stony gilgai plains** - level plains up to 750 m in extent, gilgai microrelief with surface mantles of ironstone gravels.	Deep red/brown non-cracking clays (622) with some self-mulching cracking clays (602).	Tussock grasslands of *Eragrostis xerophila* (Roebourne Plains grass) and other perennial grasses (ARPG, APXG) or shrublands of *Acacia xiphophylla* with patchy tussock grass understorey (SSTS).
4.	8%	**Drainage floors** - almost level floors up to 750 m wide, and several km long, surface mantles of variably abundant fine gravel and grit of ironstone; unchannelled or occasionally with gutters and small channels.	Red loamy earths (544) with minor river bed soils (705).	Scattered to close tall shrublands or low woodlands of acacias and eucalypts with *Triodia pungens* or tussock grass understorey (DAHW, DESG, DEGW).

PINDERING LAND SYSTEM (351 km^2, 0.2% of the survey area)

Gravelly hardpan plains supporting groved mulga shrublands with hard and soft spinifex.

Land type: 12

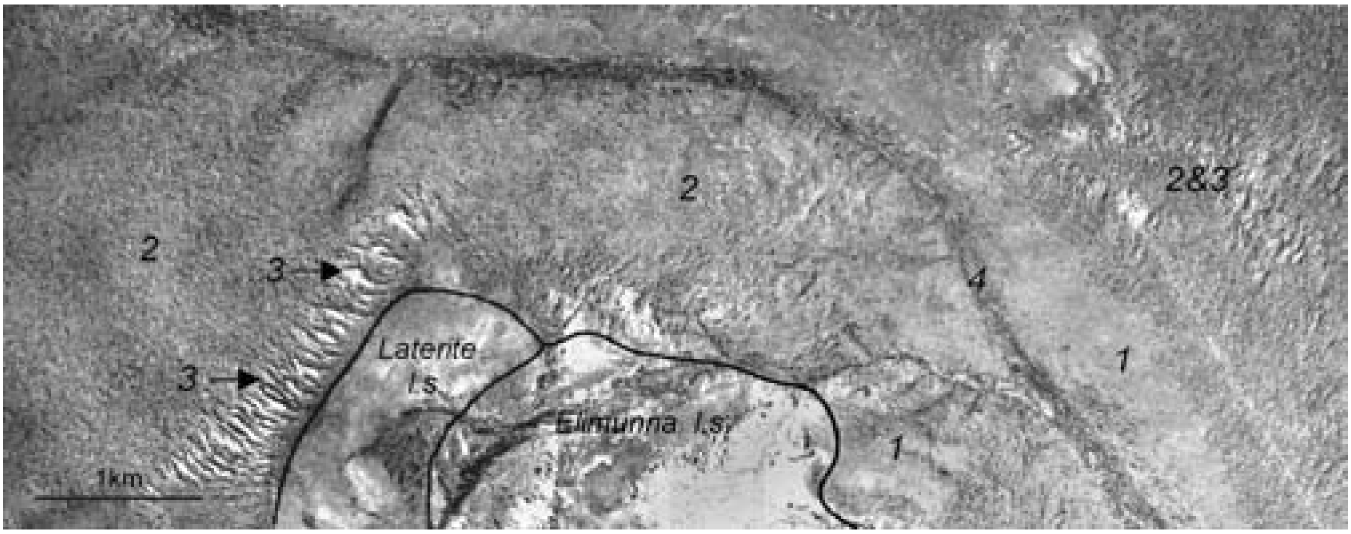
Geology: Tertiary and Quaternary colluvium - partly consolidated and consolidated valley fill deposits, minor alluvium.

Geomorphology: Depositional surfaces; level to gently undulating stony plains and gravelly plains on hardpan, receiving sheet flow; numerous small linear or arcuate drainage foci (groves) arranged at right angles to direction of sheet flow, rare tributary drainage tracts with minor channels. Relief up to 10 m.

Land management: Spinifex vegetation on the system is mostly unattractive to livestock except for a year or two following fire. Some palatable shrubs can decline under excessive grazing pressure. The system is not susceptible to erosion.

Traverse condition summary: (61 assessments)
Vegetation - very good 49%, good 38%, fair 8%, poor 5%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Stony plain	19	1
2.	Gravelly hardpan plain	27	3
3.	Grove	5	2
4.	Drainage tract	7	-
	Other	3	-
	Total	61	6

Pindering land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	22%	**Stony plains** - almost level plains up to 1.5 km in extent and slightly more elevated than adjacent plains (unit 2); surface mantles of abundant to very abundant gravels predominantly of ironstone.	Red shallow loams (522).	Hummock grasslands of *Triodia* spp. (hard and soft spinifex) with isolated shrubs (PHSG, PSSG) or very scattered to scattered tall shrublands of *Acacia aneura* (mulga) with *Triodia* spp. understorey (PMSS).
2.	60%	**Gravelly hardpan plains** - level plains with hardpan or gravel at shallow depth, extending for up to 4 km, receiving sheet flow from unit 1 and from higher adjacent systems; surface mantles of few to abundant ironstone gravel.	Red shallow loams (522), red shallow sandy duplex soils (406) and red loamy earths (544).	Scattered to moderately close tall shrublands of *Acacia aneura* with other acacias and sparse low shrubs and *Triodia lanigera, T. pungens* (hard and soft spinifex) (PMSS).
3.	8%	**Groves** - linear or arcuate drainage foci up to 400 m long by 30 m wide but commonly much smaller, arranged with long axes at right angles to direction of sheet flow, surface mantles absent or few.	Red loamy earths (544) and some red shallow loams (522).	Close tall shrublands or woodlands of *Acacia aneura, A. catenulata* with *Eremophila, Sida* spp. and other low shrubs and patchy tussock grasses or *Triodia pungens* (GMUW).
4.	10%	**Drainage tracts** - drainage corridors up to 500 m wide with surface mantles of variably abundant ironstone gravels; shallow gutters and channels up to 20 m wide.	Red loamy earths (544). Channels with river bed soils (705).	Scattered to moderately close tall shrublands/ woodlands of *Acacia aneura* with sparse low shrubs and hummock and tussock grasses (DAHW, DEGW).

PLATFORM LAND SYSTEM (1,570 km², 0.9% of the survey area)

(after Payne, Mitchell and Holman 1988)

Dissected slopes and raised plains supporting hard spinifex grasslands.

Land type: 5

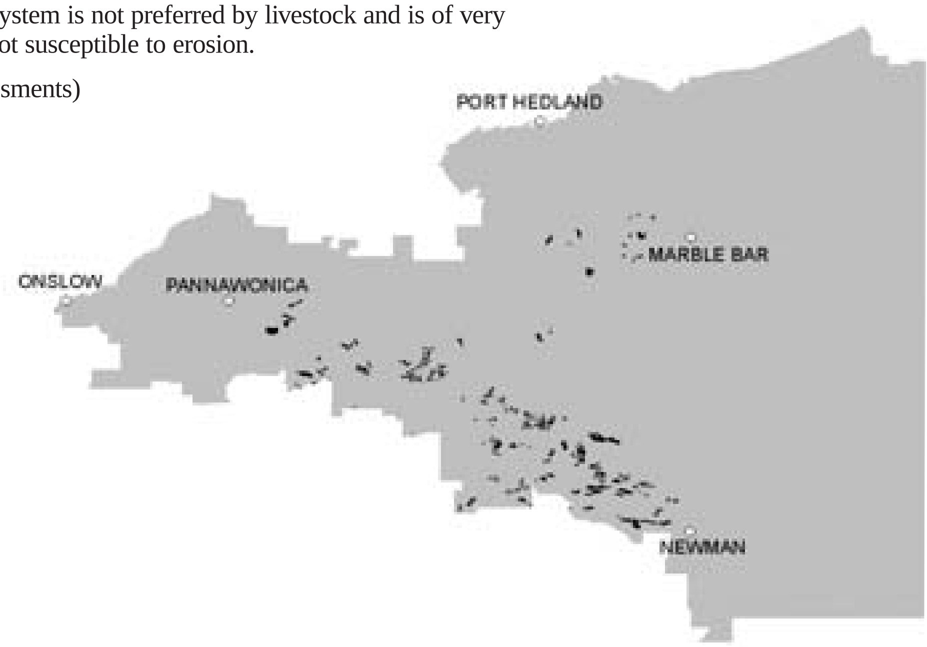
Geology: Partly consolidated Tertiary colluvium.

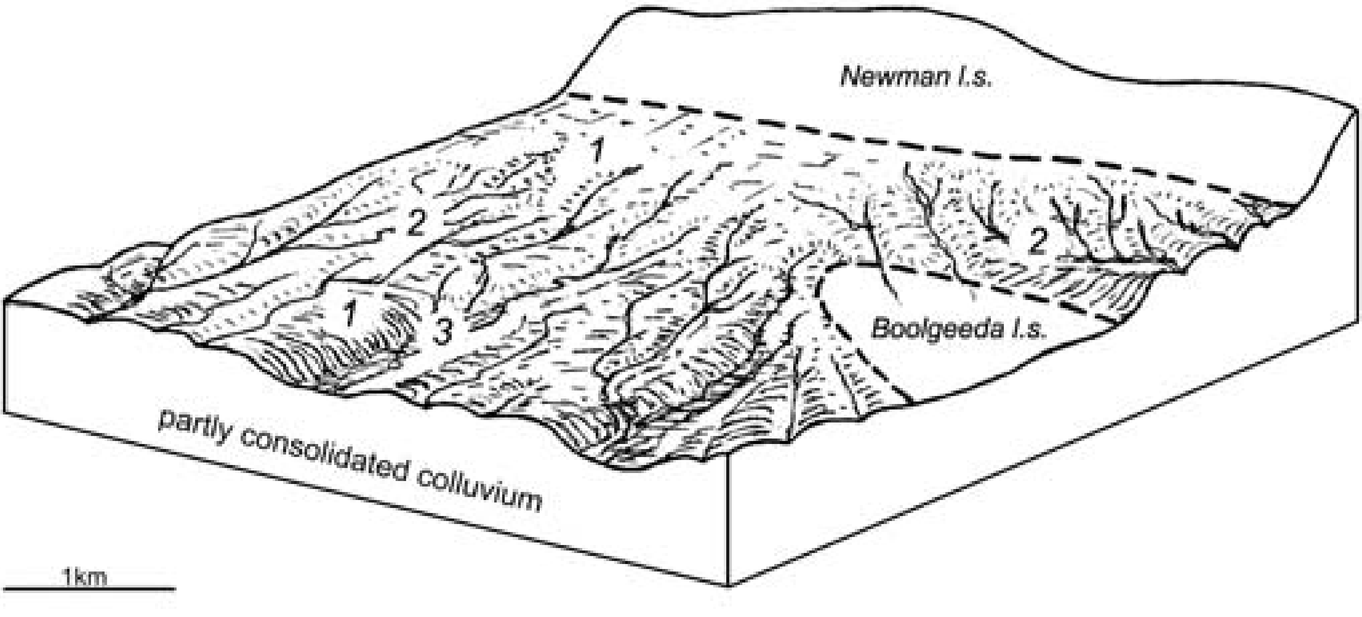
Geomorphology: Erosional surfaces formed by partial dissection of the old Tertiary surface; very gently inclined upper plains with extensive marginal dissection zones with gently inclined to steep slopes, closely spaced dendritic or sub-parallel drainage patterns with narrow floors in upper parts, floors incised up to 30 m with steep stable marginal slopes and becoming wider downslope.

Land management: Vegetation on this system is not preferred by livestock and is of very little use for pastoralism. The system is not susceptible to erosion.

Traverse condition summary: (95 assessments)
Vegetation - very good 97%, good 3%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Stony upper plain	44	1
2.	Dissected slope	34	2
3.	Drainage floor	17	5
	Other	-	1
	Total	95	9

Platform land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	25%	**Stony upper plains** - very gently inclined upper surfaces occurring mostly as raised, narrow interfluves 50-200 m wide and 0.5-1 km long inter-digitated between dendritic or sub-parallel incised drainage, also as broader plains; surface mantles of very abundant pebbles and cobbles of ironstone and other rocks.	Red shallow loams (522) and stony soils (203).	Hummock grasslands of *Triodia wiseana* and other *Triodia* spp. (hard spinifex) with isolated to very scattered *Acacia* spp. shrubs (PHSG).
2.	60%	**Dissected slopes** - gently inclined to moderately inclined convex and concave stable slopes with narrow creeklines incised up to 30 m below unit 1; surface mantles of very abundant pebbles and cobbles.	Red shallow loams (522) and red loamy earths (544).	Hummock grasslands of *Triodia wiseana, T. plurinervata* (hard spinifex) with isolated to very scattered *Acacia* spp. shrubs or *Eucalyptus leucophloia* (snappy gum) (PHSG, HESG).
3.	15%	**Drainage floors** - almost level floors 20-50 m wide and 3-4 km long, few to very abundant surface mantles of pebbles; unchannelled or with braided channels incised in central areas with bedloads of pebbles, cobbles and stones of jaspilite and other rocks.	Red loamy earths (544) and minor red shallow sandy duplex soils (406). Channels with river bed soils (705).	Scattered to close tall shrublands/woodlands with *Acacia citrinoviridis* (black mulga), *A. tumida* (pindan wattle) and other acacias, occasional eucalypt trees, numerous low shrubs including *Senna* spp. (cassias), *Ptilotus obovatus* (cotton bush), *Corchorus walcottii* (grey corchorus) and *Triodia pungens* (soft spinifex) (DAHW).

PRAIRIE LAND SYSTEM (1,221 km^2, 0.7% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Gently undulating stony plains and granite hills supporting acacia-eremophila-cassia shrublands and minor soft spinifex grasslands.

Land type: 7

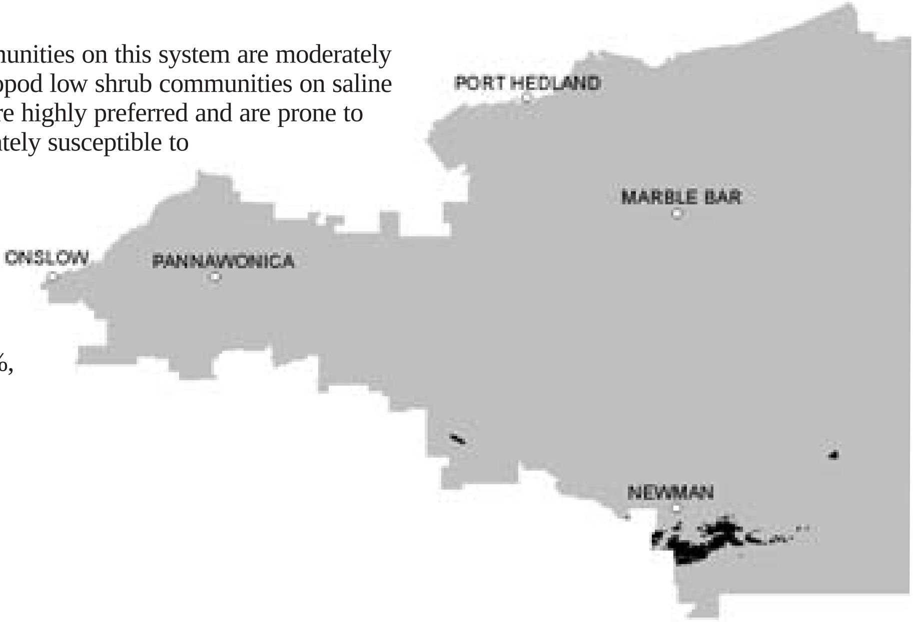
Geology: Archaean granitoid rocks, metagranite to metagranodiorite with amphibolite and metadolerite intrusions.

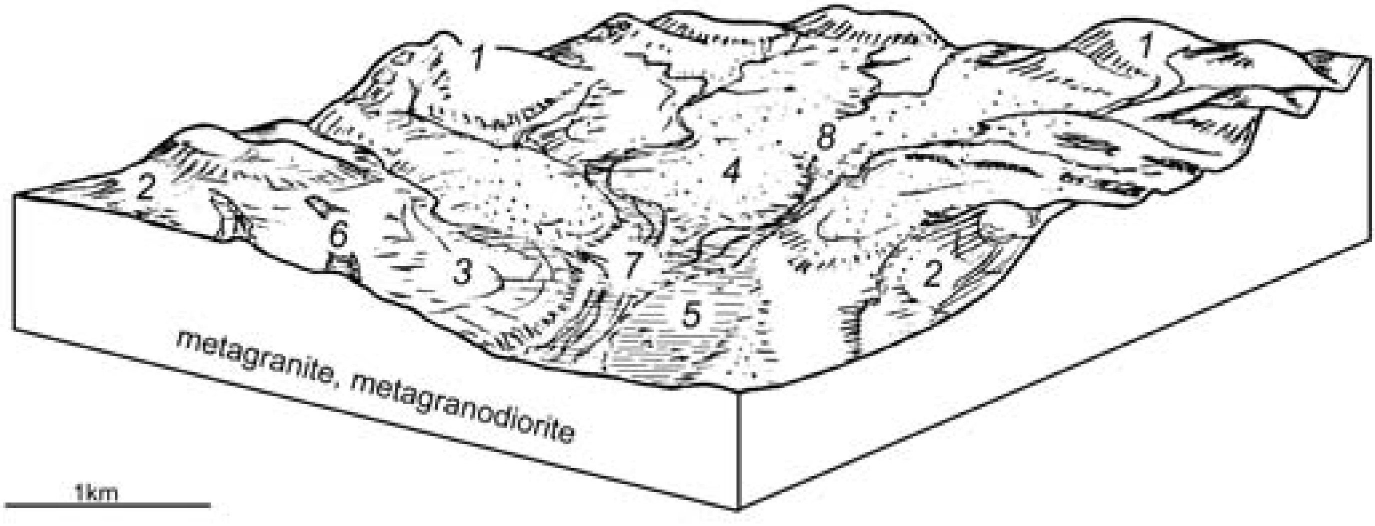
Geomorphology: Erosional surfaces; low hills with rounded, boulder strewn crests and steep benched upper slopes, short gentle lower slopes; extensive gently undulating lower plains and interfluves sometimes showing striking patterns of narrow dolerite dykes trending north, north-east and north-west; moderately dense patterns of finely branching tributary drainage with narrow sandy floors and braided channels becoming sub-parallel with major channels in lower parts.
Relief up to 50 m.

Land management: The vegetation communities on this system are moderately to highly preferred by livestock. The chenopod low shrub communities on saline plains and drainage floors (units 5 and 7) are highly preferred and are prone to degradation. Units 5 and 7 are also moderately susceptible to accelerated erosion.

Traverse condition summary:
(83 assessments)
Vegetation - very good 8%, good 27%, fair 46%, poor 18%, very poor 1%.
Soil erosion - nil 89%, slight 4%, minor 5%, moderate 1%, severe 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Hill	2	1
2.	Lower footslope	3	-
3.	Stony plain and interfluve	18	1
4.	Gritty surfaced plain and interfluve	31	1
5.	Saline plain	16	-
6.	Dolerite ridge	-	-
7.	Sandy drainage floor	11	1
8.	Creekline and channel	2	-
	Total	83	4

Prairie land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	26%	**Hills** - low hills with rounded and boulder strewn crests and moderately inclined benched upper slopes, mantles of variably abundant pebbles, cobbles and stones of granite and outcrops of granite; relief up to 50 m.	Stony soils (203).	Shrublands or shrubby hummock grasslands with *Acacia aneura* (mulga), *A. rhodophloia* (miniritchie), *A. maitlandii, Senna* and *Eremophila* spp. and *Triodia pungens* (soft spinifex) (SAES, HSPG)
2.	12%	**Lower footslopes** - very gently inclined to gently inclined slopes mostly less than 200 m long, surface mantles of abundant pebbles and cobbles of granite.	Red shallow sands (423).	As for unit 1. (SAES, HSPG)
3.	15%	**Stony plains and interfluves** - gently undulating to undulating plains and interfluves up to 500 m wide between drainages dissected to 10 m with local gently inclined slopes, surface mantles of many to abundant pebbles, cobbles and stones of granite and quartz.	Red shallow sands (423) and red shallow sandy duplex soils (406).	Scattered tall or mid height shrubland with *Acacia aneura, A. rhodophloia* and other acacias, *Senna artemisioides* subsp. *helmsii* (crinkled cassia), other *Senna* spp. and *Eremophila* spp. (SAES, PAGS)
4.	25%	**Gritty surfaced plains and interfluves** - gently undulating plains and interfluves up to 1 km wide between drainages, loamy and gritty surfaces with mantles of few to many small pebbles of quartz.	Red-brown hardpan shallow loams (523) and red shallow sands (423).	Very scattered to scattered tall shrublands with *Acacia aneura*, and other *Acacia, Senna* and *Eremophila* spp. (PAGS). Occasionally shrubby hummock grasslands of *Triodia* spp. (soft or hard spinifex) (PHSG, PMSS)
5.	8%	**Saline plains** - almost level plains up to 500 m in extent with pebbly surface mantles.	Red deep sandy duplex soils (405).	Very scattered to scattered low or mid height shrublands of *Halosarcia* spp. (samphire), *Frankenia* spp. (frankenia), *Maireana* spp. (bluebush) and *Acacia* spp. (PXHS)
6.	2%	**Dolerite ridges** - low (up to 5 m high) ridges up to 50 m wide usually 100-500 m long but occasionally several kilometres, gently inclined slopes and mantles of pebbles and cobbles of dolerite.	Red shallow sands (423).	Low shrublands of *Senna artemisioides* subsp. *helmsii*, *Corchorus walcottii* (grey corchorus) and acacias. (PAGS)
7.	8%	**Sandy drainage floors** - almost level floors up to 300 m wide, loose surfaces and gravelly patches.	Red deep sands (445).	Scattered tall shrublands/woodlands with various *Acacia* spp., occasional eucalypt trees, variable low shrubs including *Senna, Corchorus* and *Maireana* spp. and patchy hummock or tussock grasses. (DAHW, PMCS).
8.	4%	**Creeklines and channels** - braided channels up to 10 m wide incised up to 1 m, sandy banks between channels; major channels up to 80 m wide.	River bed soils (705).	Close fringing low woodlands or tall shrublands with *Eucalyptus victrix* (coolibah), *Acacia* spp. and tussock grasses. (DEGW).

PULLGARAH LAND SYSTEM (563 km^2, 0.3% of the survey area)

Alluvial plains supporting tussock grasslands and soft spinifex grasslands.

Land type: 14

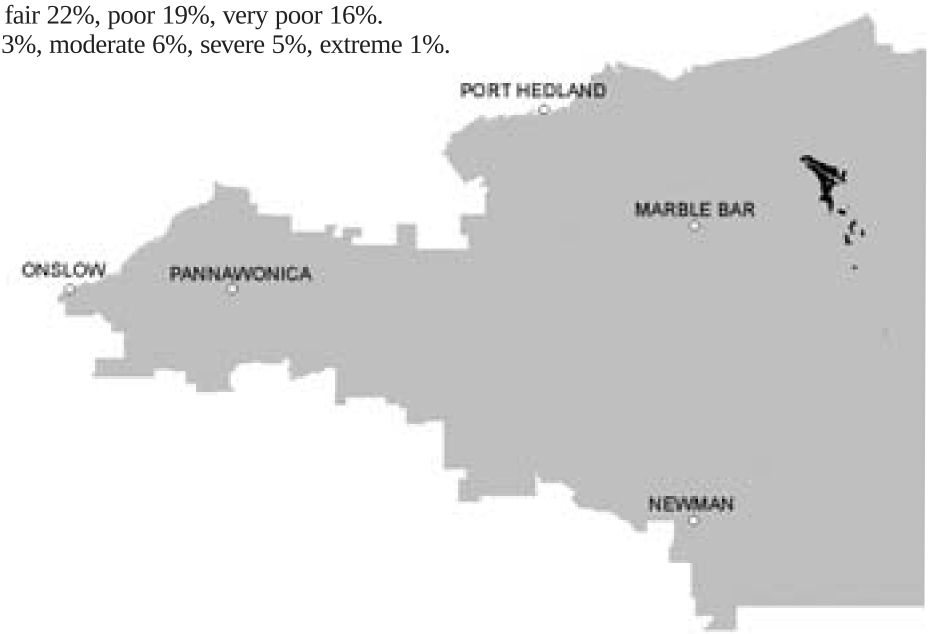
Geology: Quaternary alluvium and minor colluvium - sand, silt, clay and gravel.

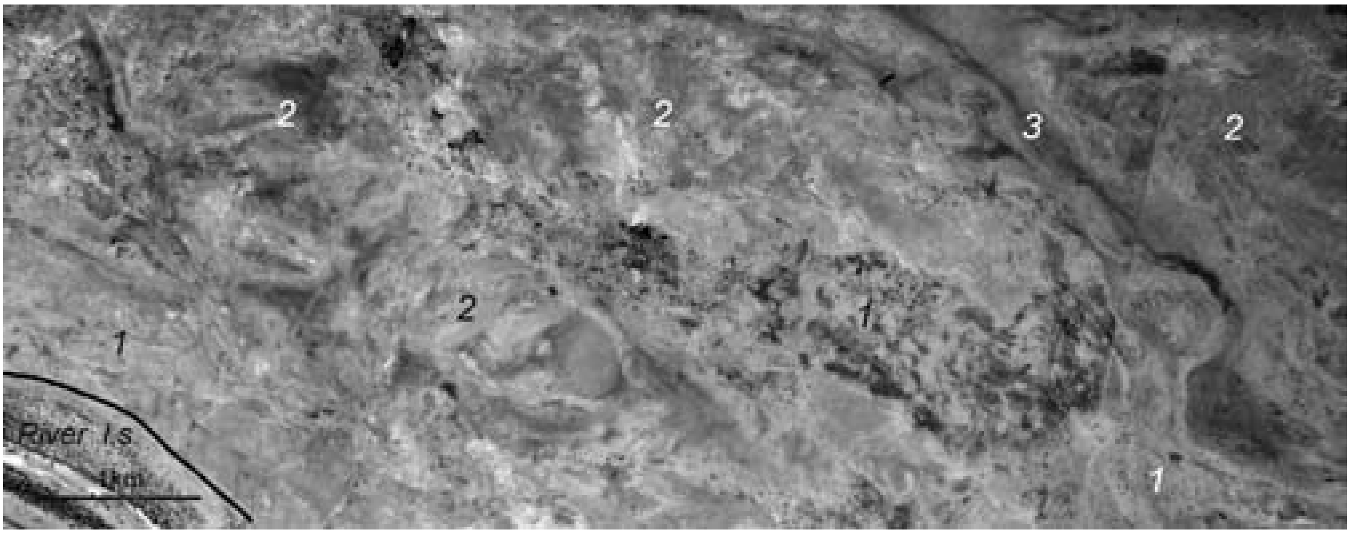
Geomorphology: Depositional surfaces; level alluvial plains occasionally subject to overbank flooding and plains with clay soils and gilgai microrelief; organised drainage features are rare but occasional drainage tracts receiving more concentrated flow with shallow, meandering channels.

Land management: Vegetation on this system is preferred or highly preferred by livestock and is prone to degradation if grazing pressure is excessive. Alluvial plains (unit 1) are moderately to highly susceptible to accelerated erosion. Gilgai plains (unit 2) are inherently more resistant but are slightly to moderately susceptible if vegetative cover is severely depleted.

Traverse condition summary: (93 assessments)
Vegetation - very good 15%, good 28%, fair 22%, poor 19%, very poor 16%.
Soil erosion - nil 67%, slight 8%, minor 13%, moderate 6%, severe 5%, extreme 1%.

Area mapped as sde: 240 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Alluvial plain	46	7
2.	Gilgai plain	45	6
3.	Drainage tract	1	-
	Other	1	-
	Total	93	13

Pullgarah land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	48%	**Alluvial plains** - level to very gently inclined plains up to 4-5 km in extent subject to occasional overbank flooding from adjacent River land system. Surface mantles absent or patchy as few to abundant pebbles of mixed lithology.	Red loamy earths (544) with minor deep red/brown non-cracking clays (622).	Patchy hummock grasslands of *Triodia pungens* (soft spinifex) with isolated to very scattered shrubs such as *Acacia farnesiana* (mimosa bush), *A. glaucocaesia* and *A. synchronicia* (ASSG). Occasionally patchy tussock grasslands with *Eragrostis xerophila* (Roebourne Plains grass) or *Cenchrus ciliaris* (buffel grass) (ARPG, APBG).
2.	50%	**Gilgai plains** - level plains extending for up to about 5 km or as smaller mosaics with stony non-gilgaied surfaces (unit 3); gilgai microrelief, surface mantles absent or as very few to many pebbles of quartz, ironstone or mixed lithology.	Self-mulching cracking clays (602).	Tussock grasslands of *Eragrostis xerophila, Eriachne benthamii* (swamp grass) and *Astrebla* spp. (Mitchell grass). Shrubs absent or isolated to very scattered low shrubs such as *Senna artemisioides* subsp. *oligophylla* (blood bush) (ARPG, APMG).
3.	2%	**Drainage tracts** - linear tracts up to 500 m wide receiving more concentrated through flow than adjacent plans; unchannelled or with shallow, meandering channels.	Deep red/brown non-cracking clays (622) and red loamy earths (544).	Tussock grasslands of *Eragrostis xerophila, Eriachne benthamii, Chrysopogon fallax* (ribbon grass) with occasional shrubs such as *Acacia farnesiana* and *A. victoriae* (prickly acacia) (APXG, DEGW).

PYRAMID LAND SYSTEM (142 km^2, 0.1% of the survey area)

(after Payne and Tille 1992)

Stony gilgai plains supporting hard spinifex grasslands and minor tussock grasslands.

Land type: 8

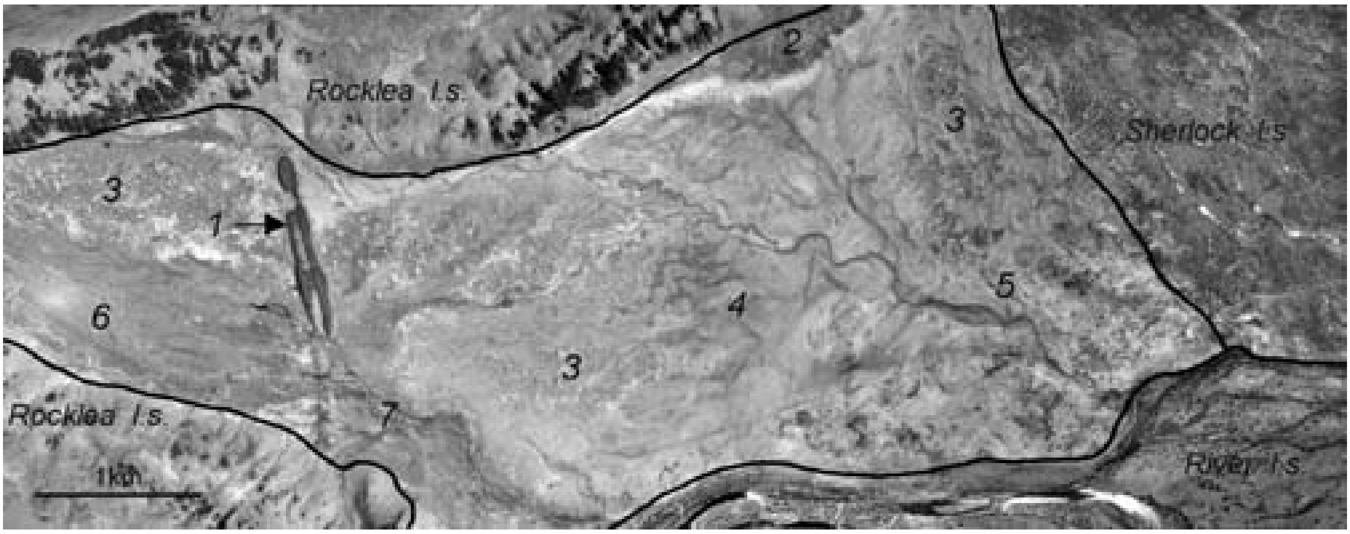
Geology: Quaternary alluvium and eluvium.

Geomorphology: Depositional surfaces; level, slightly elevated stony plains with a mosaic of gilgai and non-gilgai surfaces, low stony rises and occasional hills and minor calcreted plains. Sparse patterns of tributary and through going trunk drainage.

Land management: The system predominantly supports hard spinifex vegetation which is not preferred by grazing animals. Minor areas of tussock grasses are more preferred and are liable to preferential overuse and degradation. The system has a low erosion risk.

Traverse condition summary: (3 assessments)
Vegetation - very good 100%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Low hill and ridge	-	-
2.	Low stony crest and upper plain	-	-
3.	Stony plain with gilgai and non-gilgai surfaces	2	2
4.	Gilgai plain	-	-
5.	Calcreted lower plain	-	-
6.	Stony clay plain	-	-
7.	Narrow drainage floor and channel	-	-
	Other	1	-
	Total	3	2

Pyramid land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	2%	**Low hills and ridges** - occasional isolated basalt hills and ridges up to 500 m in extent, mantles of very abundant pebbles, cobbles and stones of basalt, also basalt outcrop; relief up to 20 m.	Stony soils (203) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana* (hard spinifex) with isolated shrubs (HSPG).
2.	5%	**Low stony crests and upper plains** - rounded stony crests and gently inclined upper plains, elevated up to 5 m above unit 3, mantles of many to very abundant pebbles, cobbles and stones of basalt.	Shallow red loams (522) and shallow red/brown non-cracking clays (622).	Patchy hummock grasslands of *Triodia wiseana* with occasional tussock grasses *Eragrostis xerophila* (Roebourne Plains grass), very few shrubs (PHSG).
3.	80%	**Stony plains with gilgai and non-gilgai surfaces** - level plains extending up to 4 km between drainage lines; unit is a mosaic of non-gilgai surfaces 10-200 m in extent and slightly lower gilgaied areas of similar dimensions; both parts have surface mantles of abundant or very abundant pebbles and cobbles of basalt.	Self-mulching cracking clays (602) and deep red/brown non-cracking clays (622).	Patchy hummock grasslands of *Triodia wiseana* with patches of tussock grass *Eragrostis xerophila* and isolated shrubs such as *Acacia xiphophylla* (snakewood) and *Senna artemisioides* subsp. *oligophylla* (blood bush) (PHSG, ARPG).
4.	2%	**Gilgai plains** - level plains 200 m to 1 km in extent with little surface mantle and gilgai microrelief.	Self-mulching cracking clays (602).	Tussock grasslands of *Eragrostis xerophila* and annual grasslands/herbfields (ARPG).
5.	5%	**Calcreted lower plains** - level lower plains associated with drainage lines, up to 500 m in extent, surface mantle of many to very abundant calcrete gravels.	Shallow calcareous loams (521).	Hummock grasslands of *Triodia wiseana* or tall or mid height shrublands of *Acacia xiphophylla* with sparse spinifex understorey (CASG, ASHS).
6.	3%	**Stony clay plains** - level plains fringing drainage floors, up to 500 m in extent, surface mantle of abundant basalt pebbles.	Deep red/brown non-cracking clays (622).	Herbfields or annual grasslands with occasional *Acacia xiphophylla* shrubs and hummocks of *T. wiseana* (ASHS).
7.	3%	**Narrow drainage floors and channels** - drainage floors, minor river terraces and banks up to 100 m wide flanking channels and creeklines up to 50 m wide.	Red loamy earths (544). Channels with river bed soils (705).	Open woodlands of *Eucalyptus victrix* (coolibah) and fringing woodlands of *E. camaldulensis* (river red gum) with acacia shrubs and hummock and tussock grasses such as *Triodia pungens* and *Chrysopogon fallax* (ribbon grass) (DESG, DEGW).

RIVER LAND SYSTEM (4,088 km^2, 2.3% of the survey area)

(modified from Payne and Tille 1992)

Active flood plains and major rivers supporting grassy eucalypt woodlands, tussock grasslands and soft spinifex grasslands.

Land type: 17

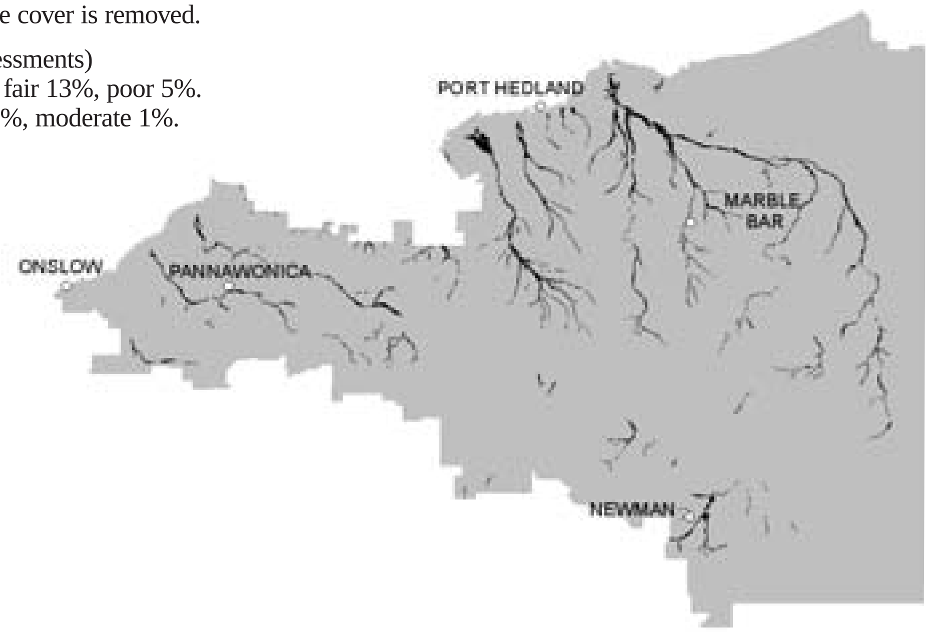
Geology: Quaternary alluvium.

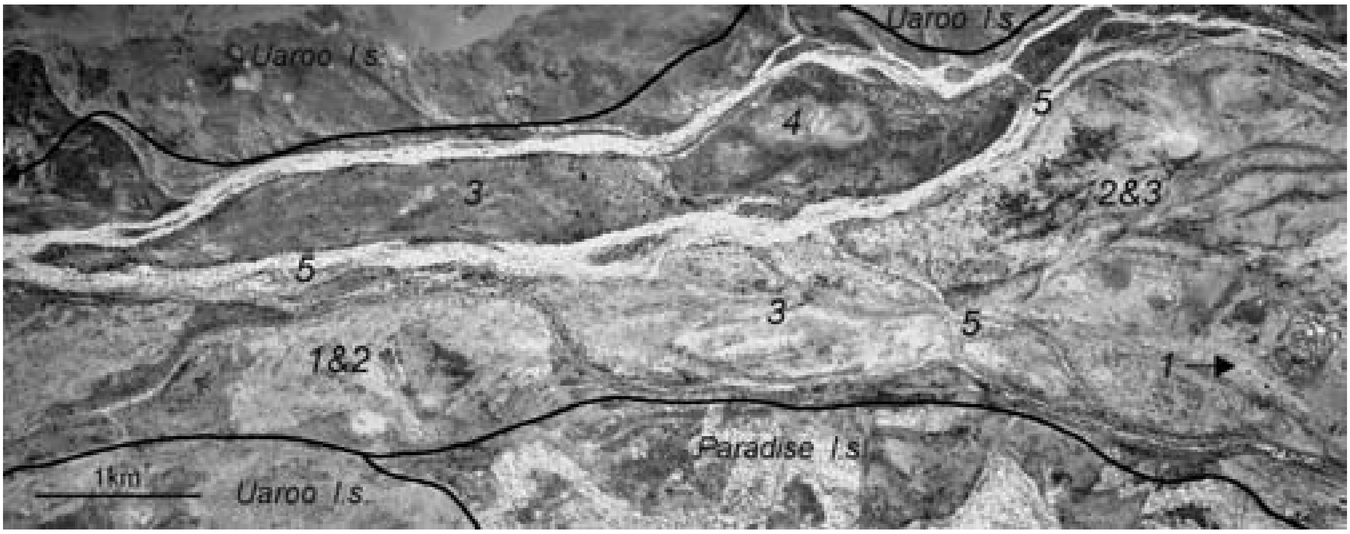
Geomorphology: Flood plains and river terraces subject to fairly regular overbank flooding from major channels and watercourses, sandy banks and poorly defined levees and cobble plains. Banks, levees and slightly higher upper terraces receive less regular flooding than lower terraces and flood plains.

Land management: Buffel grass and soft spinifex on this system are highly and moderately preferred respectively by livestock. The system is largely stabilised by buffel and spinifex and accelerated erosion is uncommon. However, susceptibility to erosion is high or very high if vegetative cover is removed.

Traverse condition summary: (401 assessments)
Vegetation - very good 56%, good 26%, fair 13%, poor 5%.
Soil erosion - nil 94%, slight 3%, minor 2%, moderate 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Sandy levee and sand sheet	101	9
2.	Upper terrace	20	1
3.	Flood plain and lower terrace	176	6
4.	Stony plain	68	4
5.	Minor and major channel	28	6
	Other	8	-
	Total	401	26

River land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	15%	**Sandy levees and sand sheets** - narrow (generally <300 m wide), ill-defined sandy levees flanking units 2 and 5 and raised up to 5 m (occasionally higher) above unit 3; also as broader sandy sheets, moundy surfaces.	Mostly red deep sands (445) with red sandy earths (463), red loamy earths (544) and some river bed soils (705).	Hummock grasslands of *Triodia pungens* (soft spinifex) with very scattered to moderately close shrubs such as *Acacia trachycarpa* (miniritchie) and *A. inaequilatera* (kanji) (ASSG, PSSG). Tussock grasslands of *Cenchrus ciliaris* (buffel grass), *Eragrostis eriopoda* (woolly butt) with very scattered to scattered acacia shrubs and trees (APBG) or open eucalypt woodlands with grass understorey of *C. ciliaris* (AEBW, DEGW).
2.	5%	**Upper terraces** - level, upper terraces marginally higher (1-2 m) than unit 3, up to 500 m wide, surface mantle absent or few to many water worn pebbles; subject to occasional flooding.	Red deep sands (445).	Hummock grasslands of *Triodia* spp. (hard spinifex) or *T. pungens* (soft spinifex) frequently with no shrubs, occasionally isolated to very scattered *Acacia* spp. shrubs and trees such as *Hakea suberea* (corkwood) (PHSG, PSSG).
3.	50%	**Flood plains and lower terraces** - level flood plains and terraces flanking single and multiple channels of the major rivers, commonly 300-800 m wide but up to 2 km in lower reaches, often with moundy surfaces; subject to fairly regular flooding.	Deep red/brown non-cracking clays (622) and red loamy earths (544).	Tussock grasslands of *Cenchrus ciliaris* (buffel grass) or hummock grasslands mainly of *Triodia pungens* (soft spinifex) (APBG, ASSG, AHSG). Also scattered to moderately close *Eucalyptus victrix* (coolibah) or acacia woodlands/tall shrublands with prominent tussock grass understorey of *C. ciliaris, Chrysopogon fallax* (ribbon grass), *Eulalia aurea* (silky brown top) and others (AEBW, DEGW) or hummock grass understorey of *Triodia pungens* (DESG, DAHW).
4.	10%	**Stony plains** - level to very gently inclined plains up to 500 m in extent with surface mantles of common to very abundant pebbles and water worn cobbles; some are active flood areas over old cobble beds between minor and major channels, others are raised above general flood levels.	Red shallow loams (522) and red shallow sands (423).	Hummock grasslands of *Triodia* spp. (soft and hard spinifex) with very scattered to scattered acacia shrubs (PSSG, PHSG). Also woodlands/tall shrublands with *Eucalyptus victrix, Acacia* spp. and tussock and hummock grasses (DEGW).
5.	20%	**Minor and major channels** - channels 30-1,000 m wide between sandy banks 1-10 m above channel beds, bedloads of sand, gravel, pebbles and stones.	River bed soils (705).	Channels - no vegetation. Banks - close or closed fringing woodlands with *Eucalyptus camaldulensis* (river red gum), *E. victrix, Melaleuca argentea* (cadjeput), *M. glomerata, Sesbania formosa* (white dragon tree), *Acacia coriacea* (river jam) with understorey of sedges and grasses including *Cyprus vaginatus, Cenchrus ciliaris* and *Triodia pungens* (GMEW, AEBW).

ROBE LAND SYSTEM (865 km^2, 0.5% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Low limonite mesas and buttes supporting soft spinifex (and occasionally hard spinifex) grasslands.

Land type: 3

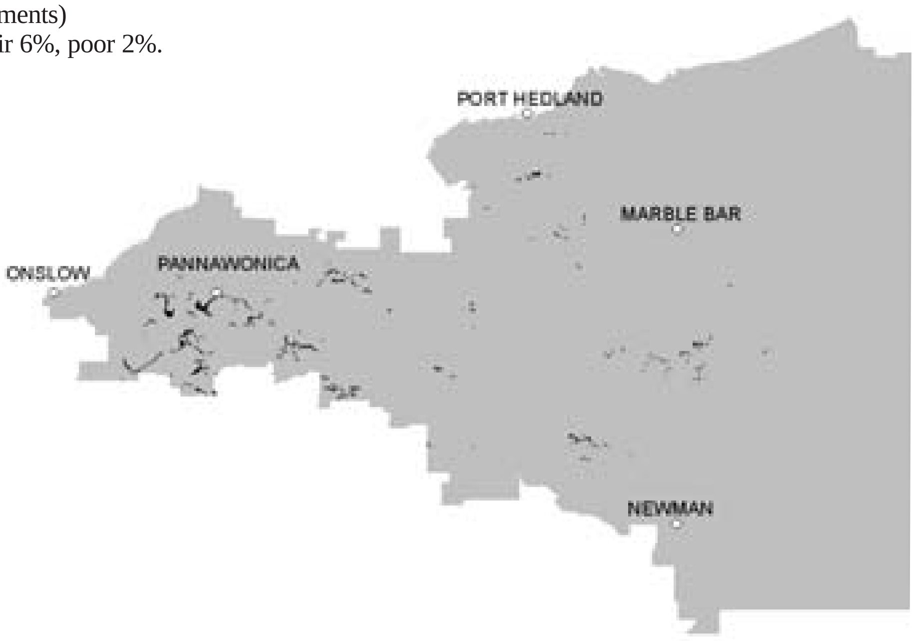
Geology: Tertiary pisolitic limonite and laterite (Robe pisolite).

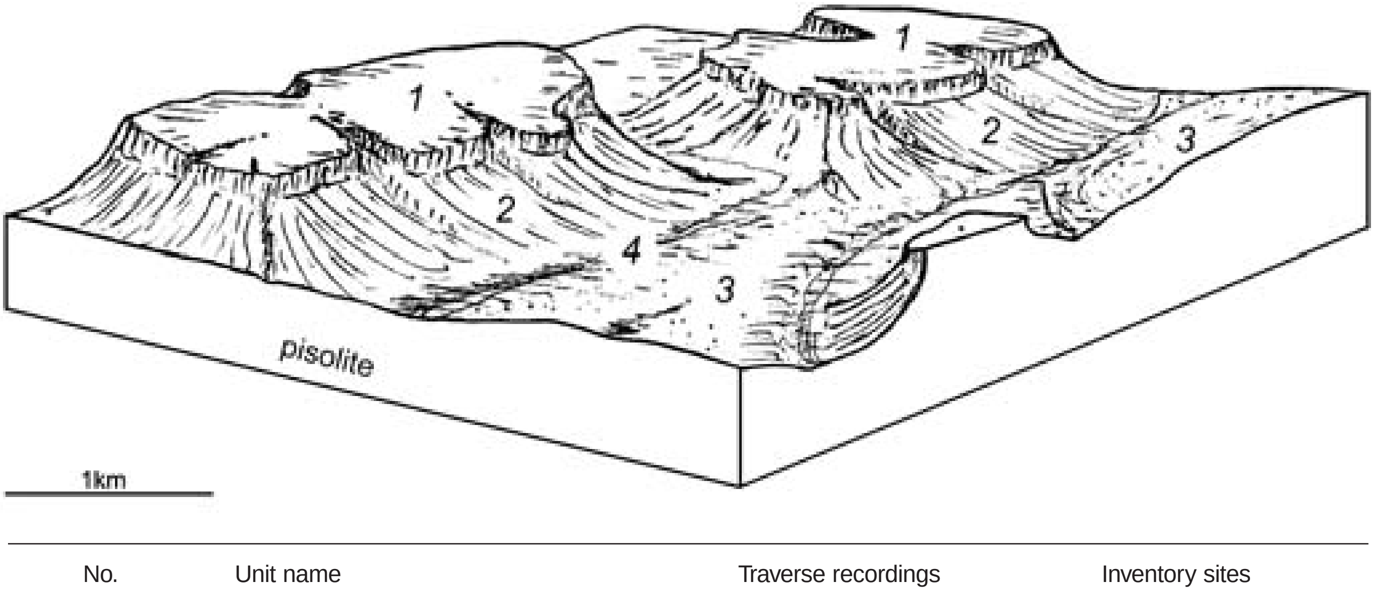
Geomorphology: Erosional surfaces; formed by partial dissection of old Tertiary surfaces, dissected plateaux and long lines of low mesas along present and past river valleys, indented near vertical breakaway faces and steep slopes with limonite outcrop and pisolitic gravelly mantles, restricted gravelly lower slopes and closely to moderately spaced narrow tributary drainage floors. Relief up to 50 m.

Land management: Soft spinifex vegetation on this system is moderately preferred by grazing animals if kept in young condition by burning. Hard spinifex vegetation is not preferred. The system contains iron deposits which are currently being mined or which may be mined in the future. The system is not generally susceptible to vegetation degradation or erosion.

Traverse condition summary: (98 assessments)
Vegetation - very good 86%, good 6%, fair 6%, poor 2%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low plateau, mesa and butte	3	4
2.	Lower slope	26	3
3.	Gravelly plain	55	3
4.	Drainage floor and channel	14	-
	Total	98	10

Robe land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	60%	**Low plateaux, mesas and buttes** - up to 50 m high above surrounding plains in lines up to 20 km or more in length; level to very gently inclined crests, near vertical breakaway faces up to 10 m high, moderately inclined to steep upper slopes; surface mantles of abundant to very abundant pisolitic limonite gravels and outcrops of limonite.	Stony soils (203) and shallow gravel soils (304).	Hummock grasslands of *Triodia pungens* (soft spinifex) with isolated to scattered *Acacia* and *Senna* spp. shrubs and occasional *Eucalyptus leucophloia* (snappy gum) trees (HSPG).
2.	20%	**Lower slopes** - very gently inclined to gently inclined slopes rarely extending more than 300 m down slope, surface mantles of very abundant pisolitic limonite gravels.	Red shallow loams (522) and minor calcareous shallow loams (521).	Hummock grasslands of *Triodia wiseana, T. longiceps* (hard spinifex) with isolated to very scattered *Acacia* and *Senna* spp. shrubs, (PHSG). Occasionally hummock grasslands of *Triodia pungens* (soft spinifex) (PSSG).
3.	15%	**Gravelly plains** - level to gently undulating plains extending for up to 1 km, surface mantles of many to very abundant limonitic and other gravels.	Red loamy earths (544).	As for unit 2 (PHSG, less frequently PSSG).
4.	5%	**Drainage floors and channels** - almost level floors up to 300 m wide, shallow central flow lines with little incision; also major channels up to 40 m wide.	Red loamy earths (544). Channels with river bed soils (705).	Hummock grasslands of *Triodia pungens* with very scattered to moderately close *Acacia* spp. shrubs (ASSG). Also moderately close eucalypt or acacia woodlands/tall shrublands with *T. pungens* understorey (DESG, DAHW).

ROBERTSON LAND SYSTEM (2,714 km², 1.5% of the survey area)

Hills and ranges of sedimentary rocks supporting hard spinifex grasslands.

Land type: 1

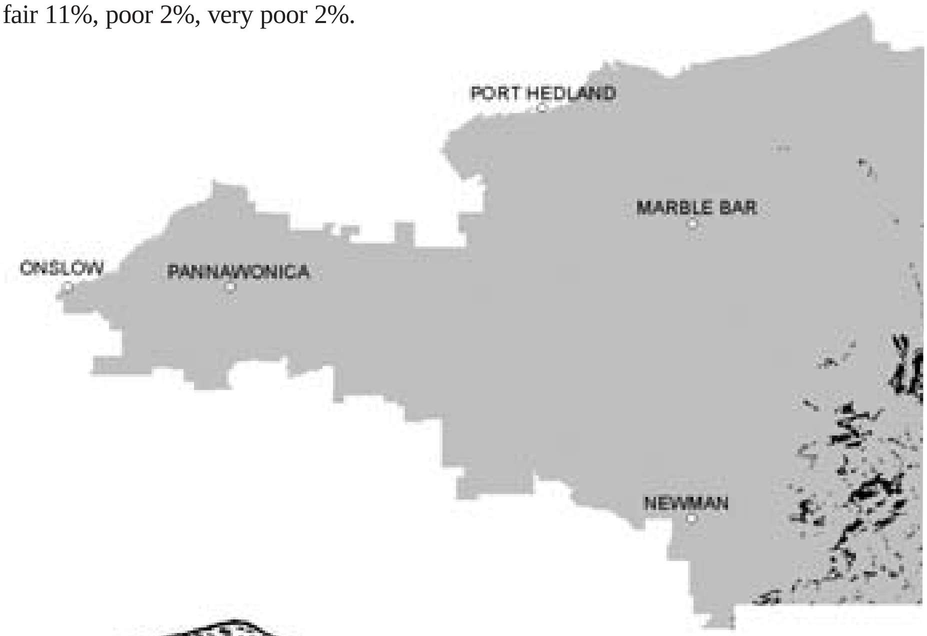
Geology: Proterozoic shale, siltstone, sandstone, dolomite and minor conglomerate.

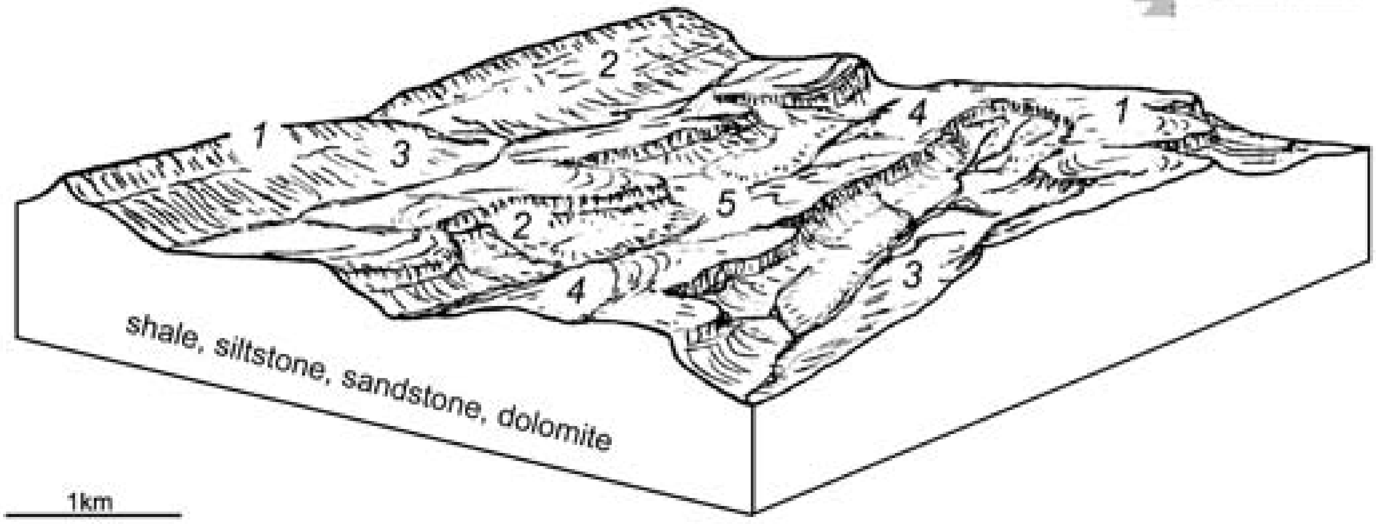
Geomorphology: Erosional surfaces; hills, ranges, ridges and plateaux with rounded or gently inclined boulder strewn crests, steep rocky upper slopes and more gently inclined very stony lower slopes, restricted stony plains; widely spaced tributary drainage patterns as narrow creeklines in valleys in upper parts becoming broader drainage floors with larger channels further downslope. Relief up to 80 m.

Land management: Hard spinifex vegetation on the system is not preferred by livestock. Some parts of the system are rugged and poorly accessible. The system is subject to fairly frequent fires but is not generally prone to vegetation decline or erosion.

Traverse condition summary: (44 assessments)
Vegetation - very good 58%, good 27%, fair 11%, poor 2%, very poor 2%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Hill crest and plateau surface	-	1
2.	Upper hillslope	3	2
3.	Lower footslope	7	-
4.	Stony plain and low rise	26	5
5.	Narrow drainage floor and creekline	6	-
	Other	2	-
	Total	44	8

Robertson land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	20%	**Hill crests and plateaux surfaces** - rounded, very gently inclined or undulating crests extending for several kilometres, surface mantles of abundant to very abundant angular pebbles, cobbles, stones and boulders of sedimentary rocks, also much rock outcrop. Relief up to 80m.	Stony soils (203) and red shallow sands (423) and red shallow loams (522).	Patchy hummock grasslands of *Triodia lanigera, T.* sp. (hard spinifex) with isolated to very scattered low and mid height shrubs (HSPG). Occasionally *Triodia pungens* (soft spinifex) (HSPG).
2.	25%	**Upper hillslopes** - moderately inclined to steep upper hillslopes and occasional near vertical cliff faces (to 15 m) below crests, surface mantles of very abundant pebbles, cobbles and stones of sandstone or other sedimentary rocks, frequent rock outcrop.	Stony soils (203) and red shallow sands (423).	Hummock grasslands of *Triodia lanigera* or *T. pungens* (hard or soft spinifex) with isolated to scattered shrubs such as *Acacia hilliana, A. stellaticeps* (poverty bush) and *Senna glutinosa* (HSPG).
3.	30%	**Lower footslopes** - very gently to gently inclined slopes, surface mantles of abundant to very abundant pebbles and cobbles of sandstone or other sedimentary rocks.	Stony soils (203) and red shallow sands (423).	Hummock grasslands of *Triodia* spp. (hard spinifex) with isolated to scattered *Acacia* and *Senna* spp. shrubs (HSPG).
4.	20%	**Stony plains and low rises** - gently undulating to undulating plains and low rises up to 1 km in extent, surface mantles of abundant to very abundant pebbles and cobbles of sandstone, shale, dolomite and other rocks.	Red shallow loams (522) and shallow red/brown non-cracking clays (622).	Very scattered to scattered low shrublands of *Eremophila, Senna* and *Acacia* spp. (PAGS). Also hummock grasslands of *Triodia wiseana, T. plurinervata*, or *T. longiceps* (hard spinifex) with very scattered to scattered *Acacia* and *Senna* spp. shrubs (PHSG).
5.	5%	**Narrow drainage floors and creeklines** - small drainage lines (10-20 m wide) in upper parts becoming broader floors to 300 m wide with channels to 50 m wide further downslope.	Red loamy earths (544). Channels with river bed soils (705).	Hummock grasslands of *Triodia pungens* with scattered *Acacia* spp. shrubs (ASSG). Moderately close tall shrublands/low woodlands of *Acacia* spp. with patchy tussock grass or hummock grass *T. pungens* understorey (DEGW, DAHW).

ROCKLEA LAND SYSTEM (22,993 km^2, 12.7% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Basalt hills, plateaux, lower slopes and minor stony plains supporting hard spinifex (and occasionally soft spinifex) grasslands.

Land type: 1

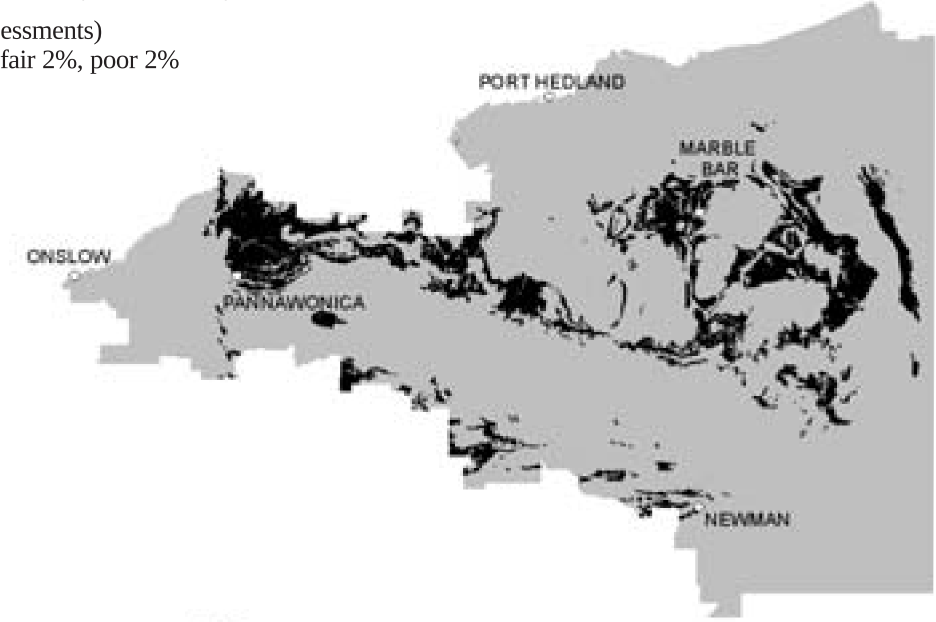
Geology: Archaean basalt, Lower Proterozoic basalt, dolerite, tuff and agglomerate, minor shale and jaspilite.

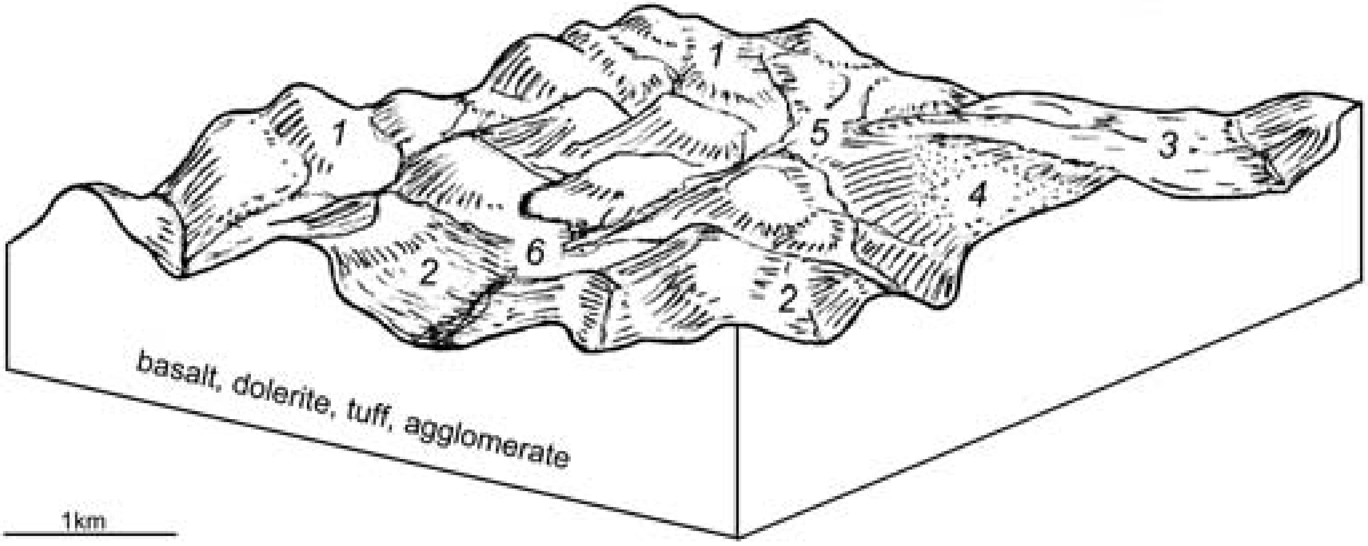
Geomorphology: Erosional surfaces; hills, ridges and plateaux remnants on basalt with steep stony slopes, restricted lower slopes, stony interfluves and minor gilgai plains; moderately spaced tributary drainage patterns of small channels in shallow valleys in upper parts becoming broader floors and channels downslope. Relief up to 110 m.

Land management: Spinifex hummock grasslands are poorly accessible and are generally not preferred by livestock. The system is subject to fairly regular burning. The system has very low erosion hazard.

Traverse condition summary: (880 assessments)
Vegetation - very good 89%, good 7%, fair 2%, poor 2%
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Hill, ridge, plateau and upper slope	80	8
2.	Lower slope	195	2
3.	Stony plain and interfluve	422	9
4.	Gilgai plain	7	-
5.	Upper drainage line	53	3
6.	Drainage floor and channel	115	4
	Other	8	1
	Total	880	27

Rocklea land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	65%	**Hills, ridges, plateaux and upper slopes** - rounded, very gently inclined or undulating crests and plateaux surfaces with moderately inclined to very steep, sometimes benched, upper slopes; surface mantles of very abundant cobbles and pebbles mostly of basalt, also much outcrop of basalt; relief up to 110 m.	Stony soils (203), red shallow loams (522) and calcareous shallow loams (521).	Hummock grasslands of *Triodia wiseana, T.* spp. (hard spinifex) or, less frequently, of *T. pungens* (soft spinifex) with isolated to very scattered shrubs such as *Acacia inaequilatera* (kanji) and *Senna* spp. (HSPG).
2.	15%	**Lower slopes** - very gently inclined to gently inclined slopes extending up to 1 km downslope from hills (unit 1), surface mantles of abundant to very abundant pebbles and cobbles mostly of basalt, also outcrop of basalt.	Red shallow loams (522) and red shallow sandy duplex soils (406).	As for unit 1 (HSPG).
3.	10%	**Stony plains and interfluves** - gently undulating to undulating plains, interfluves and low rises up to 1.5 km in extent, surface mantles of abundant to very abundant pebbles and cobbles of basalt and occasionally shale and other rocks.	Calcareous shallow loams (521), red sandy earths (463) and shallow red/brown non-cracking clays (622).	Hummock grasslands of *Triodia wiseana* or, less frequently, *T. pungens* with isolated to very scattered shrubs such as *Acacia inaequilatera* (PHSG, PSSG). Occasionally grassy shrublands with *Acacia, Senna* and *Eremophila* spp. (PAGS, SAES).
4.	1%	**Gilgai plains** - level plains up to 500 m in extent with gilgai microrelief and variably abundant surface mantles of basalt pebbles and cobbles.	Self-mulching cracking clays (602).	Tussock grasslands with *Astrebla pectinata* (barley Mitchell grass), *Eragrostis xerophila* (Roebourne Plains grass) and other perennial grasses (BUTG).
5.	4%	**Upper drainage lines** - narrow headwater valleys with branching drainage tracts mostly <200 m wide, unchannelled or with central channels up to 10 m wide.	Red shallow sands (423) and calcareous shallow loams (521). Channels with river bed soils (705).	Hummock grasslands of *Triodia wiseana* or *T. pungens* with very scattered to scattered acacia shrubs and occasional *Corymbia hamersleyana* (Hamersley bloodwood) trees (AHSG, ASSG, DAHW).
6.	5%	**Drainage floors and channels** - almost level floors rarely more than 400 m wide, central tracts with braided channels and stony banks; major trunk channels up to 50 m wide.	Red loamy earths (544) with red shallow sandy duplex soils (406) and red/brown non-cracking clays (622).	Scattered to moderately close tall shrublands or woodlands of *Acacia* and *Eucalyptus* spp. with numerous undershrubs and hummock grass understoreys (DAHW, DESG) or tussock grass understoreys (DEGW).

ROEBUCK LAND SYSTEM (31 km^2, 0.02% of the survey area)

(modified from Speck at al. 1964)

Saline coastal plains supporting salt water couch grasslands, samphire shrublands and mangroves.

Land type: 19

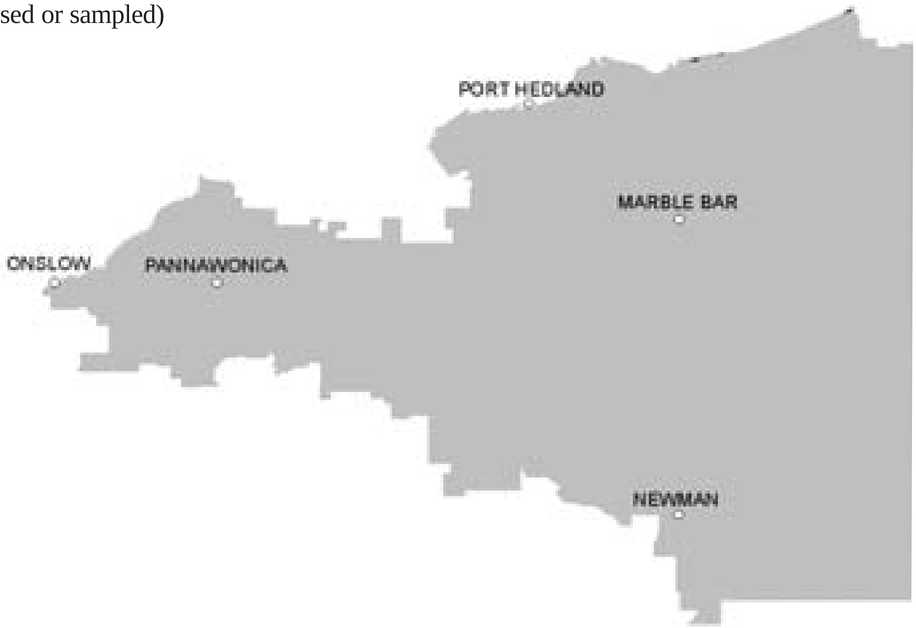
Geology: Quaternary supratidal mudflat deposits; clay, silt and sand.

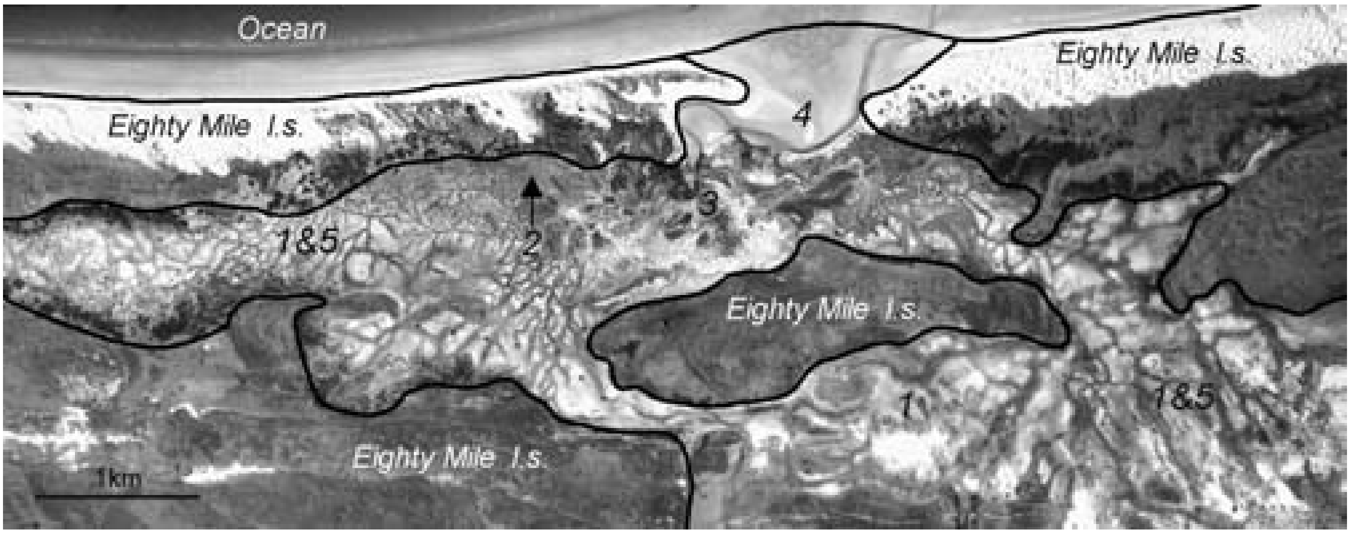
Geomorphology: Depositional surfaces; estuarine and littoral flats comprising grassy plains above high tides, traversed by a close network of channels; samphire flats and mangrove fringes along the seaward margins.

Land management: Salt water couch grasslands are highly preferred by grazing animals and can become degraded if overgrazed. The system is generally not prone to erosion.

Traverse condition summary: (not traversed or sampled)
Vegetation - no records
Soil erosion - no records

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Coastal plain	-	-
2.	Samphire flat and mudflat	-	-
3.	Lower margins	-	-
4.	Outer flat	-	-
5.	Channel	-	-
	Total	-	-

Roebuck land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	60%	**Coastal plains** - level plains up to 4 km in extent.	Calcareous deep sands (442).	Grasslands of *Sporobolus virginicus* (salt water couch) (SPSG).
2.	15%	**Samphire flats and mudflats** - level, highly saline plains up to 500 m in extent between plains (unit 1) and lower margins (unit 3). Subject to occasional tidal inundation.	Deep red/brown non-cracking clays (622), grey non-cracking clays (621) and calcareous loamy earths (542).	Very scattered to scattered low shrublands of *Halosarcia* spp. (samphire) (PSPS). Some mudflats with no vegetation.
3.	5%	**Lower margins** - very gently sloping seaward margins to samphire flats and mudflats (unit 2), up to 200 m in extent. Subject to tidal inundation.	Tidal soils (104).	Mangrove communities.
4.	5%	**Outer flats** - level flats up to 500 m wide, in shallow water or exposed at high tide.	Tidal soils (104).	Mangrove communities or no vegetation.
5.	15%	**Channels** - reticulated channels on unit 1 up to 30 m wide and 1 m deep but without sharp incision.	Deep red/brown non-cracking clays (622), grey non-cracking clays (621) and calcareous loamy earths (542).	Grasslands with *Sporobolus virginicus, Dichanthium* sp., *Eulalia aurea* (silky brown top) and *Eriachne benthamii* (swamp grass) (APXG, SPSG).

RUTH LAND SYSTEM (346 km², 0.2% of the survey area)

(modified from Payne and Tille 1992)

Hills and ridges of volcanic and other rocks supporting hard spinifex (occasionally soft spinifex) grasslands.

Land type: 1

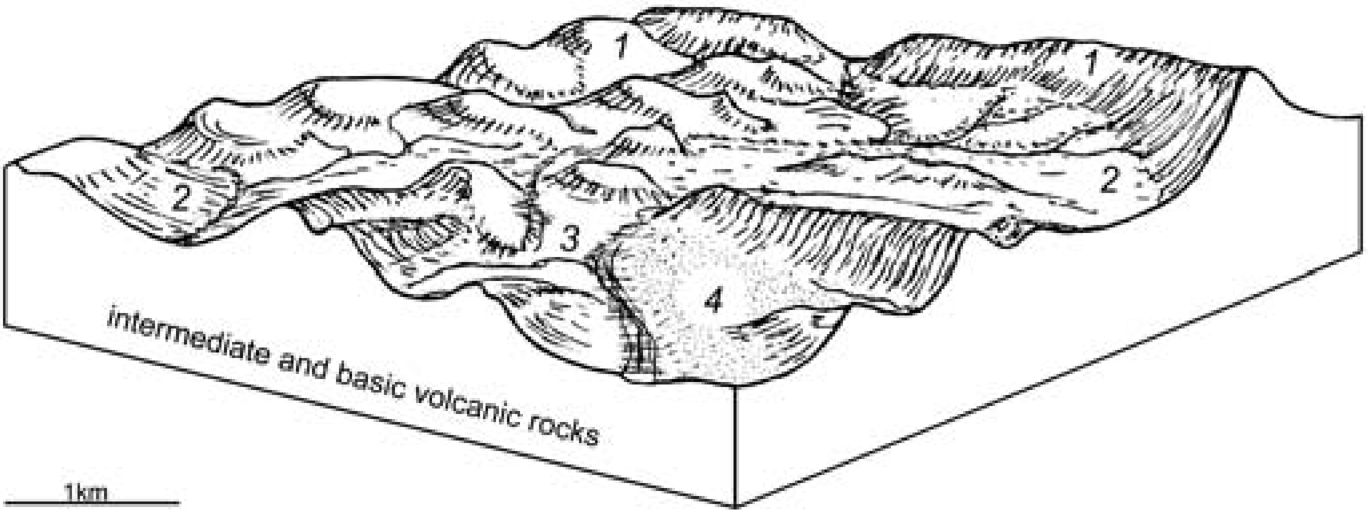
Geology: Archaean and Proterozoic intermediate and basic volcanic rocks; also quartz, minor chert, jaspilite, shale and siltstone.

Geomorphology: Erosional surfaces; rounded hills and ridges with restricted lower slopes and stony interfluves, moderately to widely spaced drainage patterns. Relief up to 90 m.

Land management: Predominantly hard spinifex vegetation which is not preferred by livestock. Some soft spinifex which is moderately attractive for a few years following fire. The system is prone to fairly regular burning but is not susceptible to erosion.

Traverse condition summary: (18 assessments)
Vegetation - very good 72%, good 11%, fair 11%, poor 6%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Hill, ridge and upper slope	2	2
2.	Lower slope and stony plain	7	-
3.	Narrow drainage floor, creekline and channel	1	-
4.	Sandplain	8	-
	Total	18	2

Ruth land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	75%	**Hills, ridges and upper slopes** - hills and ridges with rounded and undulating crests and summits, moderately inclined to steep convex and concave upper slopes, surface mantles of abundant pebbles and cobbles of volcanic rocks, shale or chert, also outcrop of parent rock. Relief up to 80 m but usually much less.	Stony soils (203) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana* or *T.* spp. (hard spinifex) or *T. pungens* (soft spinifex) with isolated shrubs such as *Acacia inaequilatera* (kanji), *A. pyrifolia* (fire wattle), *A. orthocarpa* (HSPG).
2.	15%	**Lower slopes and stony plains** - very gently inclined to gently inclined lower footslopes and restricted stony plains extending for up to 500 m below hills and ridges (unit 1), surface mantles of abundant pebbles and cobbles of volcanic rocks, shale or chert.	Red shallow loams (522).	Hummock grasslands of *Triodia wiseana, T.* spp. or *T. pungens* with isolated to very scattered *Acacia* and *Senna* spp. shrubs (PHSG, PSSG).
3.	5%	**Narrow drainage floors, creeklines and channels** - very small drainage floors (generally <100 m wide) with creeklines and channels in valleys between hills and footslopes; channels incised in bedrock with bedloads of gravel, pebbles and cobbles.	Red shallow loams (522). Channels with river bed soils (705).	Hummock grasslands of *Triodia* spp. (hard and soft spinifex) with scattered to moderately close *Acacia, Senna* and *Indigofera* spp. shrubs and occasional eucalypt trees (DAHW).
4.	5%	**Sandplains** - restricted patches of sandplain up to 200 m in extent between hills (unit 1) or on stony plains (unit 2).	Red deep sands (445) and red sandy earths (463).	Hummock grasslands of *Triodia* spp. (hard and soft spinifex) with isolated to scattered *Acacia* spp. shrubs (SHSG, SSSG).

SATIRIST LAND SYSTEM (377 km^2, 0.2% of the survey area)

(modified from Payne and Tille 1992)

Stony plains and low rises supporting hard spinifex grasslands, and gilgai plains supporting tussock grasslands.

Land type: 8

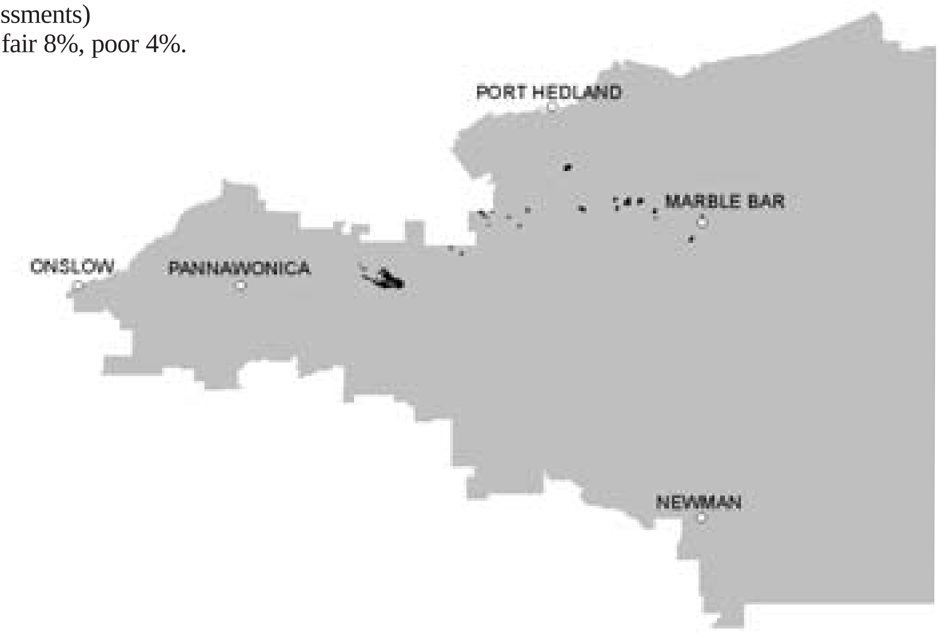
Geology: Quaternary alluvium and colluvium; clay, gravel and pebble deposits, minor Lower Proterozoic or Archaean chert, quartzite, shale and agglomerate.

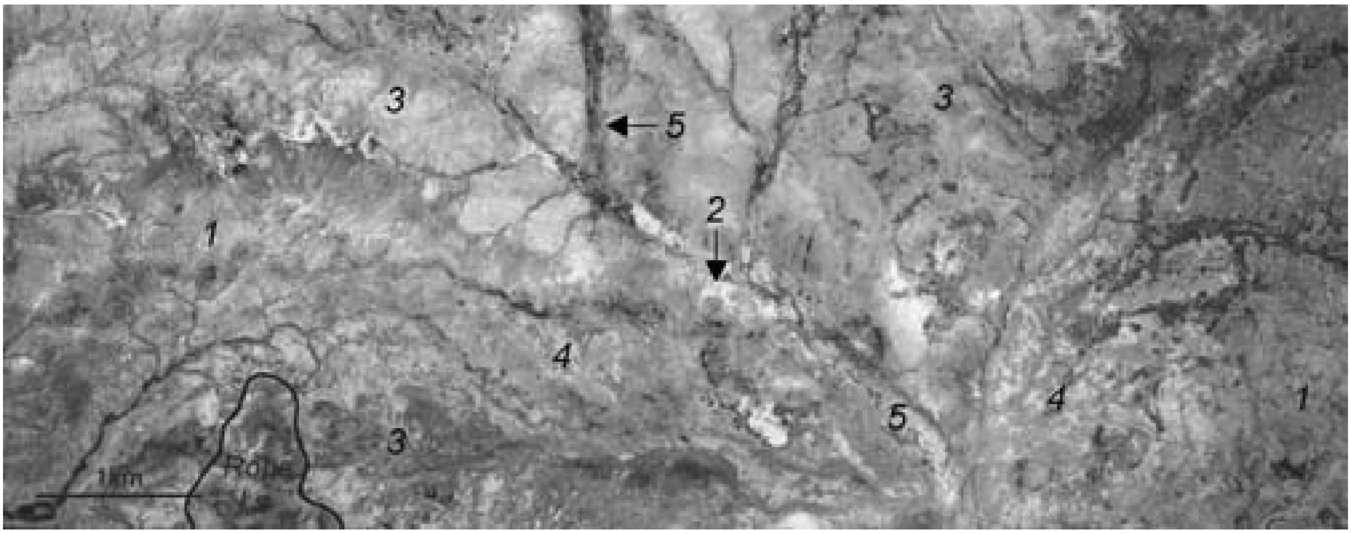
Geomorphology: Mainly depositional surfaces; level to very gently inclined stony plains, plains with gilgai microrelief, low stony rises and drainage flats; sparse tributary drainage patterns with minor channels. Relief up to 10 m.

Land management: The predominantly hard spinifex vegetation on the system is not preferred by livestock. Minor areas of tussock grasslands are preferentially grazed and are prone to degradation. The system is generally not susceptible to erosion.

Traverse condition summary: (53 assessments)
Vegetation - very good 82%, good 6%, fair 8%, poor 4%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low rise and upper plain	11	-
2.	Calcrete plain	2	-
3.	Stony plain	29	2
4.	Gilgai plain	4	3
5.	Drainage tract and minor channel	5	1
	Other	2	-
	Total	53	6

Satirist land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	20%	**Low rises and upper plains** - gently undulating low rises, upper plains and interfluves extending up to 1 km and elevated up to 8 m above other units, mantles of abundant pebbles and cobbles of mixed lithology.	Red shallow loams (522).	Hummock grasslands of *Triodia wiseana* and other *Triodia* spp. (hard spinifex) with isolated shrubs such as *Acacia bivenosa* (two vein wattle), *A. pyrifolia* (fire wattle) (PHSG).
2.	5%	**Calcrete plains** - level plains 200-300 m in extent raised up to 3 m above units 3 and 4, gently rounded margins, surface mantles of abundant calcrete gravel, also calcrete outcrop.	Calcareous shallow loams (521).	Hummock grasslands of *Triodia wiseana* (hard spinifex) with very scattered trees and shrubs (CASG).
3.	55%	**Stony plains** - level plains extending for up to 2 km, mostly non-gilgaied surfaces, but with some patches (10-30 m in extent) with gilgai microrelief; surface mantles of many to abundant pebbles and cobbles of mixed lithology.	Deep red/brown non-cracking clays (622) with red loamy earths (544) and calcareous loamy earths (542).	Hummock grasslands of *Triodia longiceps, T. wiseana* (hard spinifex), less frequently *T. pungens* (soft spinifex) with isolated shrubs on non-gilgaied surfaces (PHSG, PSSG). Tussock grasslands of *Eragrostis xerophila* (Roebourne Plains grass) with isolated shrubs on gilgaied areas (ARPG).
4.	15%	**Gilgai plains** - level plains up to 500 m in extent with gilgai microrelief, surface mantles of few to abundant ironstone and other pebbles.	Self-mulching cracking clays (602).	Tussock grasslands of *Eragrostis xerophila, Eriachne benthamii* (swamp grass) and other perennial grasses with isolated to very scattered shrubs such as *Acacia farnesiana* (mimosa bush), *A. victoriae* (prickly acacia) and *Senna artemisioides* subsp. *oligophylla* (blood bush) (ARPG, APXG).
5.	5%	**Drainage tracts and minor channels** - narrow up to 200 m wide drainage tracts through unit 1, 2 and 3 with minor channels.	Red loamy earths (544). Channels with river bed soils (705).	Hummock grasslands of *Triodia pungens* with scattered *Acacia* spp. shrubs and eucalypt trees (DAHW). Also tall shrublands of *Acacia xiphophylla* (snakewood) with patchy spinifex understorey (ASHS). Larger channels may have fringing grassy woodlands with *Eucalyptus victrix* (coolibah).

SHERLOCK LAND SYSTEM (192 km^2, 0.1% of the survey area)

(modified from Payne and Tille 1992)

Stony alluvial plains supporting snakewood shrublands with patchy tussock grasses and spinifex grasslands.

Land type: 15

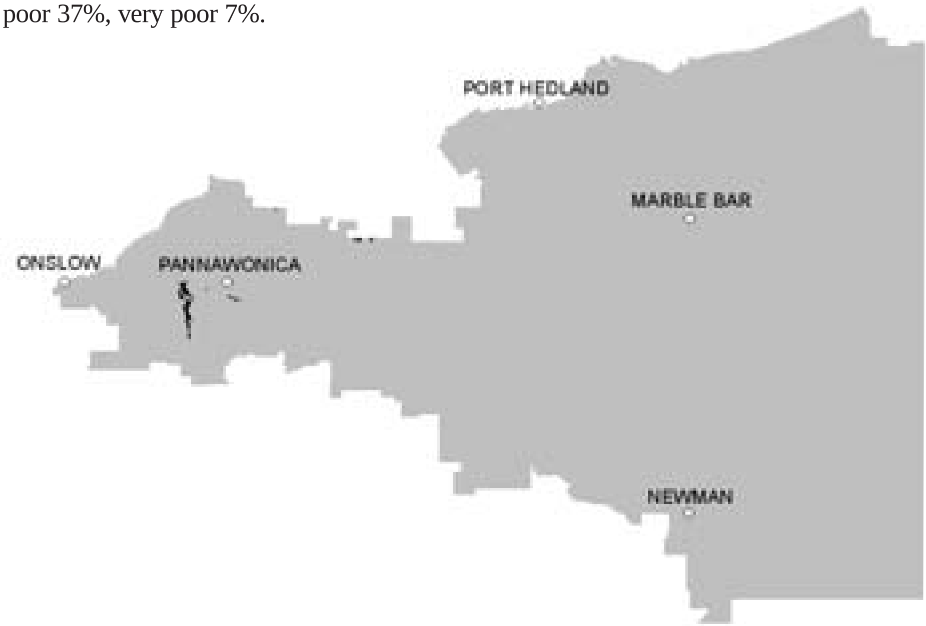
Geology: Quaternary alluvium.

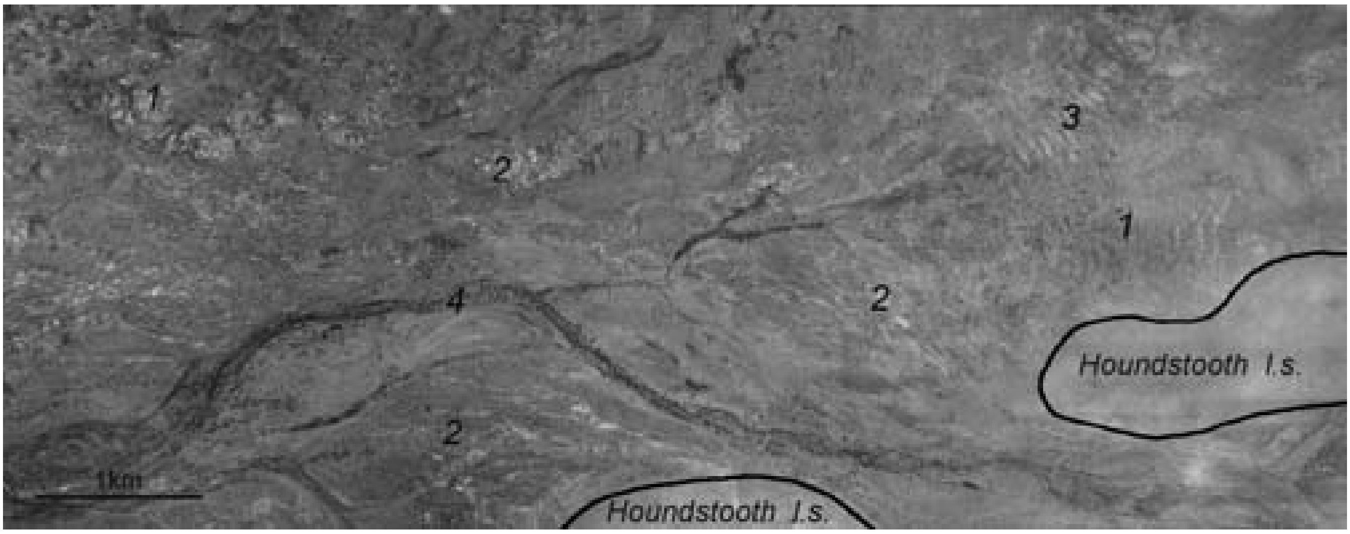
Geomorphology: Depositional surfaces; level stony alluvial plains with some gilgai development; very rare, mainly non-tributary, through going drainage lines and channels.

Land management: The snakewood communities and tussock grasslands on this system include low shrubs and perennial grasses which are highly preferred by grazing animals and are prone to degradation if overgrazed. The system is generally not susceptible to erosion.

Traverse condition summary: (27 assessments)
Vegetation - very good 41%, good 15%, poor 37%, very poor 7%.
Soil erosion - nil 96%, minor 4%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Stony plain with spinifex	8	1
2.	Stony alluvial plain with snakewood	15	2
3.	Gilgai plain	2	-
4.	Drainage line	2	-
	Total	27	3

Sherlock land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	30%	**Stony plains with spinifex** - very gently inclined plains slightly higher than unit 2, surface mantles of abundant pebbles and cobbles, occasional patches 5-50 m in extent with gilgai microrelief.	Deep red/brown non-cracking clays (622) and minor self-mulching cracking clays (602).	Hummock grasslands of *Triodia wiseana* (hard spinifex) with isolated or very scattered shrubs (PHSG). Minor gilgai areas support annual grasslands or herbfields with very scattered tussocks of *Eragrostis xerophila* (Roebourne Plains grass).
2.	55%	**Stony alluvial plains with snakewood** - level plains with surface mantles of abundant to very abundant ironstone pebbles and patches 5-50 m in extent with gilgai microrelief between larger areas with non-gilgaied surfaces.	Deep red/brown non-cracking clays (622) with self-mulching cracking clays (602) and minor red deep sandy duplex soils (405).	Mid height or tall shrublands of *Acacia xiphophylla* (snakewood) with understoreys of low shrubs such as *Enchylaena tomentosa* (ruby saltbush) and *Senna artemisioides* subsp. *hamersleyensis* (creeping cassia), and tussock grasses *Eragrostis xerophila* and *Enteropogon acicularis* (windmill grass) or hummock grass *Triodia pungens* (soft spinifex) (PSCS, ASHS, SSTS). Also, hummock grasslands of T*riodia pungens* with isolated to scattered *Acacia* spp. shrubs (ASSG).
3.	10%	**Gilgai plains** - level plains 100-400 m in extent, slightly lower than unit 2, gilgai microrelief with surface mantles of few to abundant pebbles.	Self-mulching cracking clays (602).	Tussock grasslands of *Eragrostis xerophila* and *Eriachne benthamii* (swamp grass) (ARPG) or shrublands of *Acacia xiphophylla* with tussock grass understorey (SSTS).
4.	5%	**Drainage lines** - linear drainage zones up to 400 m wide a few metres lower than and running through units 2 and 3, with or without channels.	Deep red/brown non-cracking clays (622).	Hummock grasslands of *Triodia pungens* with very scattered shrubs and trees (ASSG). Also scattered to moderately close tall shrublands/woodlands with species such as *Acacia trachycarpa* (miniritchie), *A. pyrifolia* (fire wattle), *Eucalyptus victrix* (coolibah) and *Hakea suberea* (corkwood) with *Triodia pungens* understorey (DESG).

SPEARHOLE LAND SYSTEM (1,270 km^2, 0.7% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Gently undulating hardpan plains supporting groved mulga shrublands and hard spinifex.

Land type: 12

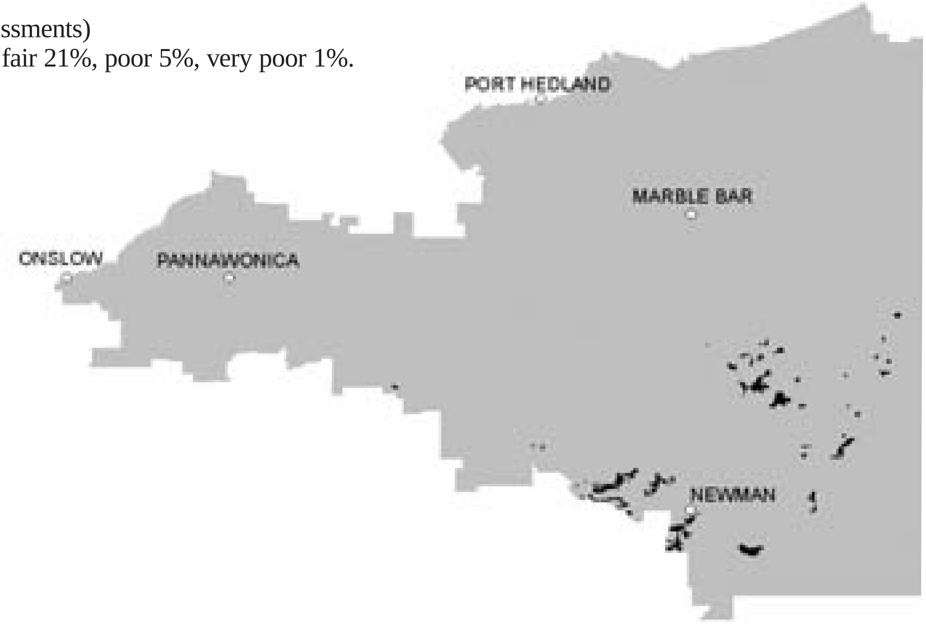
Geology: Partially cemented Quaternary alluvium and colluvium.

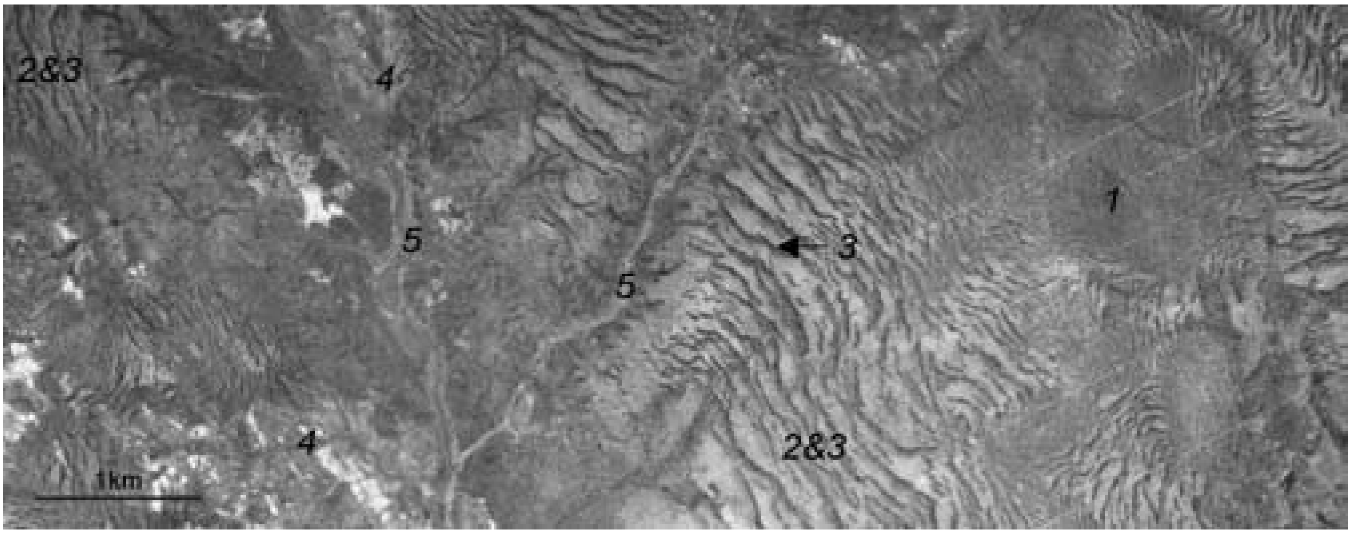
Geomorphology: Depositional surfaces; gently undulating non-saline plains with hardpan at shallow depth and groved vegetation, sparse patterns of tributary drainage with restricted areas of shallow valleys and finely dissected slopes. Relief up to 35 m.

Land management: Spinifex vegetation on the system is mostly unattractive to grazing animals except for a year or two following fire. However, some palatable shrub components of the vegetation will decline if grazing pressure is excessive. The system is not prone to erosion.

Traverse condition summary: (107 assessments)
Vegetation - very good 37%, good 36%, fair 21%, poor 5%, very poor 1%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low rise	24	-
2.	Gravelly hardpan plain	64	3
3.	Grove	7	-
4.	Dissected slope	3	-
5.	Drainage zone and channel	5	-
	Other	4	-
	Total	107	3

Spearhole land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	15%	**Low rises** - gently rounded crests with very gently inclined slopes, extending up to 1 km and mostly up to 15 m relief above general level of surrounding plains, surface mantles of abundant ironstone gravel.	Red loamy earths (544) and red-brown hardpan shallow loams (523).	Very scattered to scattered tall shrublands with *Acacia aneura* (mulga), *A. pruinocarpa* (gidgee) and other acacias with sparse low shrubs *Eremophila* and *Ptilotus* spp. with or without *Triodia* spp. (hard spinifex) ground layer (PMSS, SAES).
2.	55%	**Gravelly hardpan plains** - level or gently undulating plains or intergrove areas up to 6 km or more in extent with surface mantles of abundant ironstone gravel subject to sheet flow.	Red-brown hardpan shallow loams (523), red loamy earths (544) and some red sandy earths (463).	Very scattered to moderately close tall shrublands of *Acacia aneura, A. catenulata* with *Eremophila* and *Ptilotus* spp. low shrubs with or without a prominent ground layer of *Triodia* spp. (hard spinifex) (PMSS, PHSG, HPMS). Also hummock grasslands of *Triodia* spp. (hard spinifex) with few shrubs (PHSG).
3.	15%	**Groves** - groves or arcuate bands up to 1.5 km long by 100 m wide (though commonly much smaller) arranged on hardpan plains (unit 2) with long axes at right angles to direction of sheet flow.	Red loamy earths (544) and red-brown hardpan loams (523).	Close woodlands/tall shrublands with *Acacia aneura, A. catenulata* and other acacias with numerous low shrubs of *Eremophila, Ptilotus, Sida* spp. and occasionally perennial grasses (GMUW, GMGW).
4.	10%	**Dissected slopes** - adjacent to hardpan plains (unit 2) and extending up to 1 km downslope to drainage lines or as stripped margins to other land systems, often intensely dissected up to 20 m to give a series of spur slopes and interfluves with gently inclined slopes.	Red shallow loams (522) and red-brown hardpan shallow loams (523).	Hummock grasslands of *Triodia wiseana* (hard spinifex) with very scattered *Acacia* spp. shrubs and occasional trees such as *Eucalyptus socialis, Corymbia hamersleyana* (Hamersley bloodwood) (PHSG).
5.	5%	**Drainage zones and channels** - drainage zones 10-40 m wide in upper parts becoming wider downslope, channels incised 1-2 m in hardpan or centrally positioned in shallow valleys incised up to 20 m with flanking slopes of unit 4.	Red loamy earths (544) or red sandy earths (463). Channels with river bed soils (705).	Scattered to moderately close woodlands or tall shrublands with eucalypts and acacias, low shrubs and prominent ground storey of *Triodia* spp. (hard spinifex) or tussock grasses (DAHW, DEGW).

STUART LAND SYSTEM (1,794 km^2, 1.0% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Gently undulating stony plains supporting hard and soft spinifex grasslands and snakewood shrublands.

Land type: 8

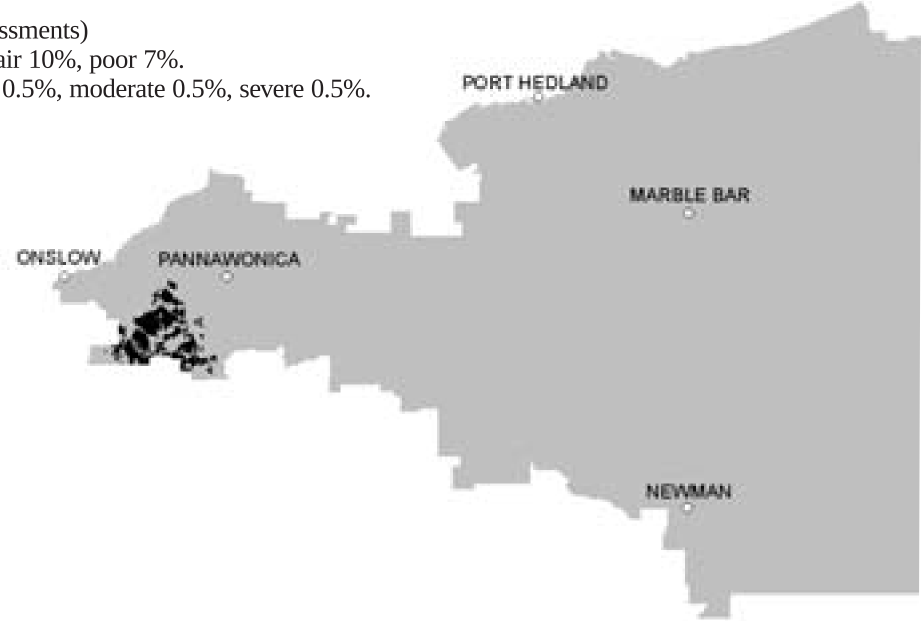
Geology: Lower Proterozoic schist, gneiss, sandstone, shale and minor volcanics. Quaternary colluvium and alluvium.

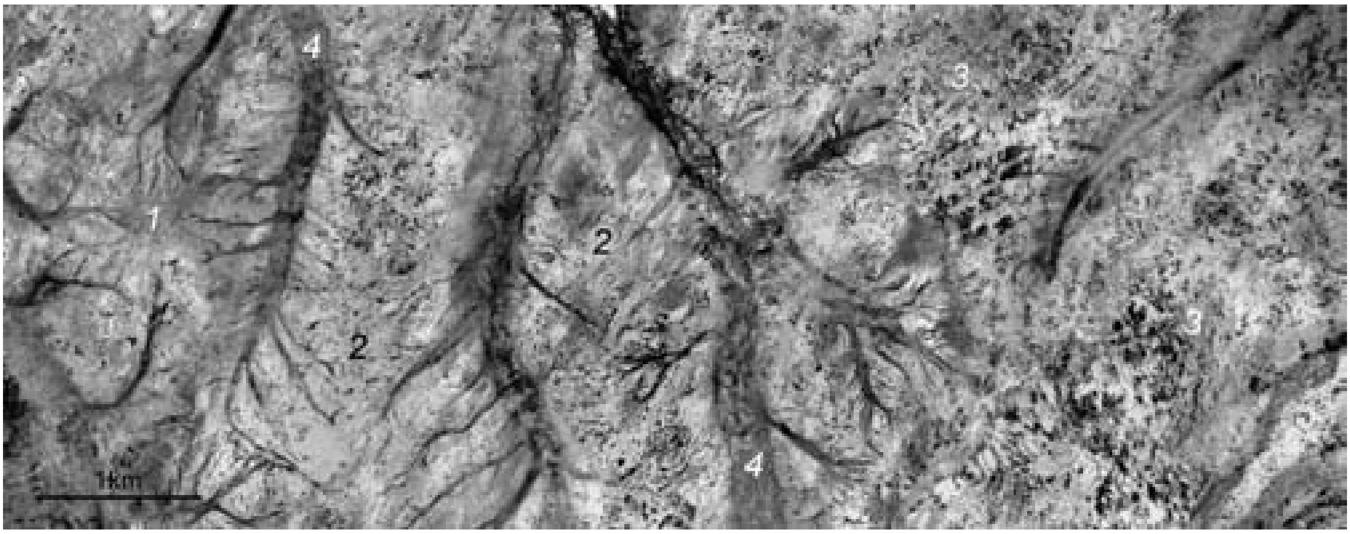
Geomorphology: Mainly erosional surfaces; minor hills, gently undulating stony plains and broad lower plains; moderately spaced tributary drainage tracts in upper parts becoming sparse and much broader downslope, may be channelled or unchannelled. Relief up to 25 m.

Land management: Hard spinifex vegetation on this system is not preferred by grazing animals; soft spinifex is moderately preferred when in young condition. Some low shrubs in the snakewood communities are highly preferred and the community is prone to degrade if overgrazed. The system is generally resistant to erosion except for some lower plains and drainage tracts (units 3 and 4) which are slightly to moderately susceptible.

Traverse condition summary: (211 assessments)
Vegetation - very good 74%, good 9%, fair 10%, poor 7%.
Soil erosion - nil 98%, slight 0.5%, minor 0.5%, moderate 0.5%, severe 0.5%.

Area mapped as sde: 100 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low hill	8	1
2.	Stony plain	100	2
3.	Lower plain	69	4
4.	Drainage tract	34	3
	Total	211	10

Stuart land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	3%	**Low hills** - isolated hill tracts up to 1.5 km in extent with gently inclined convex slopes, surface mantles of abundant to very abundant pebbles and cobbles of mixed lithology and outcrop of parent rock; relief up to 20 m.	Stony soils (203) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana* (hard spinifex) with isolated or very scattered shrubs such as *Acacia atkinsiana, A. bivenosa* (two vein wattle) (HSPG).
2.	42%	**Stony plains** - gently undulating plains and rises extending up to 5 km, surface mantles of abundant to very abundant pebbles of quartz and other rocks; relief up to 10 m.	Red shallow loams (522), shallow red/brown non-cracking clays (622), red loamy earths (544) and minor calcareous shallow loams (521).	Hummock grasslands of *Triodia wiseana, T. lanigera, T. brizoides* (hard spinifex) with isolated to scattered *Acacia* spp. and other shrubs (PHSG). Less frequently *Triodia pungens* (soft spinifex) (PSSG).
3.	40%	**Lower plains** - level plains usually 1.5-2 km in extent but up to 5 km, patchy surface mantles of few to very abundant pebbles of quartz and other rocks.	Red deep loamy duplex soils (506) and deep red/brown non-cracking clays (622).	Very scattered to scattered tall shrublands of *Acacia xiphophylla* (snakewood) with numerous low shrubs including *Enchylaena tomentosa* (ruby saltbush), *Maireana* and *Senna* spp. and hummock grasses *Triodia longiceps* (hard spinifex) or *T. pungens* (soft spinifex) (PSCS, ASHS). Also hummock grasslands of *T. longiceps* or *T. pungens* with very few shrubs (PHSG, PSSG).
4.	15%	**Drainage tracts** - almost level through flow tracts, with or without channels, within units 2 and 3, extending many km downslope; up to 1 km wide in lower parts, narrower and branching in upper parts.	Red loamy earths (544) and deep red/brown non-cracking clays (622).	Hummock grasslands of *Triodia pungens* with scattered shrubs such as *Acacia bivenosa* and *A. victoriae* (prickly acacia) (ASSG). Also moderately close woodlands/tall shrublands with eucalypts, and acacias and tussock grass such as *Chrysopogon fallax* (ribbon grass) understorey (DEGW).

SYLVANIA LAND SYSTEM (1,077 km^2, 0.6% of the survey area)

Gritty surfaced plains and low rises on granite supporting acacia-eremophila-cassia shrublands.

Land type: 10

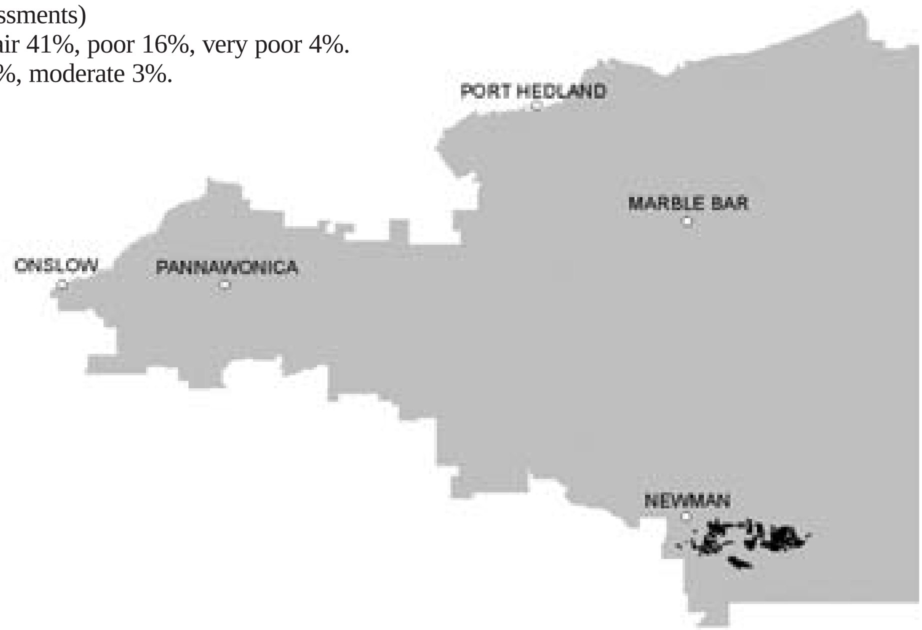
Geology: Archaean granitoid rocks, metagranite to metagranodiorite; Quaternary colluvium and alluvium.

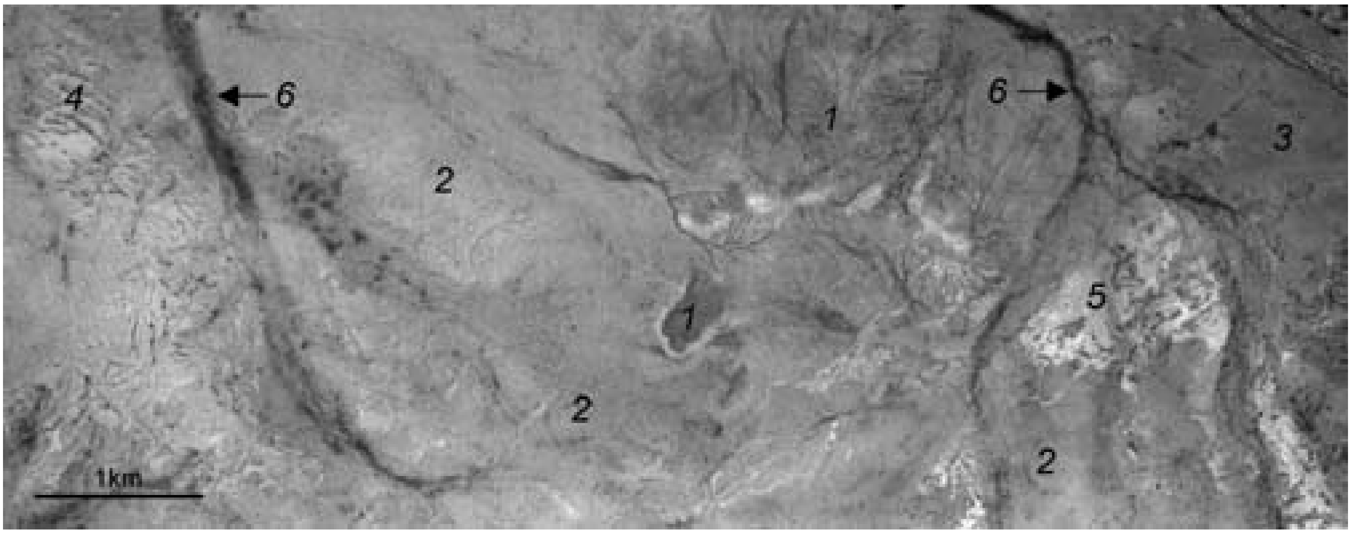
Geomorphology: Mainly erosional surfaces; level to gently undulating gritty surfaced and stony plains, low rises and occasional granitic tor heaps, sandy plains, hardpan wash plains and minor stony plains with saline soils; widely spaced tributary drainage floors with or without channels. Relief up to 20 m but usually much less.

Land management: Vegetation communities on this system include low shrubs and tussock grasses which are moderately to highly preferred by grazing animals and are prone to degradation if overgrazed. Drainage floors and some saline plains and sandy plains (units 6, 5 and 3) have slight to moderate susceptibility to erosion. Other units are generally not susceptible.

Traverse condition summary: (111 assessments)
Vegetation - very good 3%, good 36%, fair 41%, poor 16%, very poor 4%.
Soil erosion - nil 91%, slight 1%, minor 5%, moderate 3%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low rise and tor	2	-
2.	Gritty surfaced plain	54	3
3.	Sandy plain	11	1
4.	Hardpan plain and small grove	23	-
5.	Saline stony plain	8	1
6.	Drainage tract	13	2
	Total	111	7

Sylvania land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	5%	**Low rises and tors** - gently undulating rises extending for up to 1 km and occasional tor heaps of granite with relief to 20 m; surface mantles of abundant quartz and granite pebbles and cobbles and outcrop of granite.	Stony soils (203), red shallow sands (423) and some bare rock.	As for unit 2 (PAGS, SAES).
2.	50%	**Gritty surfaced plains** - level to gently undulating plains extending for up to 2.5 km; surface mantles vary from very few to very abundant veneers of quartz grit or quartz and granitic pebbles and cobbles; occasional outcrops of granite.	Red shallow sands (423).	Very scattered to scattered mixed height shrublands with *Acacia aneura* (mulga), *A. rhodophloia* (miniritchie) and other acacias, *Senna* spp. (cassias), *Eremophila fraseri* (turpentine bush), *E. cuneifolia* (royal poverty bush) other eremophilas and annual grasses (PAGS, SAES).
3.	10%	**Sandy plains** - level sandy surfaced plains extending for up to 1.5 km.	Red deep sands (445).	Tall very scattered shrublands of *Acacia aneura* and other acacias with *Triodia* spp. (hard spinifex) understorey (PMSS). Less frequently very scattered mixed height shrublands with *Acacia*, and *Eremophila* spp. and scattered tussock grasses (PAGS).
4.	18%	**Hardpan plains and small groves** - level plains up to 1.5 km in extent, surface mantles vary from absent to abundant pebbles of quartz and other rocks; occasional small groves (up to 200 m long by 30 m wide) on plains and receiving run-on from plains.	Red-brown hardpan shallow loams (523) and red loamy earths (544).	Scattered tall shrublands predominantly of *Acacia aneura* with sparse undershrubs including *Eremophila forrestii* (Wilcox bush), other eremophilas and *Senna* and *Ptilotus* spp. (HPMS). Groves support close tall shrublands or woodlands of similar composition (GMUW).
5.	7%	**Saline stony plains** - level plains up to 1 km in extent often adjacent to drainage tracts (unit 6) or as inclusions in other units; surface mantles of common to abundant pebbles of quartz.	Red shallow sandy duplex (406), red shallow loams (522) and red deep loamy duplex soils (506).	Patchy low shrublands with isolated to scattered low shrubs *Senna* and *Eremophila* spp., *Maireana pyramidata* (sago bush), *Enchylaena tomentosa* (ruby saltbush) with patchy tussock grasses such as *Eragrostis xerophila* (Roebourne Plains grass) and a few tall acacias (PXHS).
6.	10%	**Drainage tracts** - level drainage floors usually less than 400 m wide, unchannelled or with channels with minor incision into hardpan or granitic material.	Red sandy earths (463) and red loamy earths (544).	Moderately close tall shrublands of *Acacia aneura* and other acacias with sparse low shrubs and tussock grasses such as *Chrysopogon fallax* (ribbon grass) and occasionally *Cenchrus ciliaris* (buffel grass) (DEGW).

TABLE LAND SYSTEM (77 km^2, 0.04% of the survey area)

(after Payne, Mitchell and Holman 1988)

Low calcrete plateaux, mesas and lower plains supporting mulga and cassia shrublands and minor spinifex grasslands.

Land type: 4

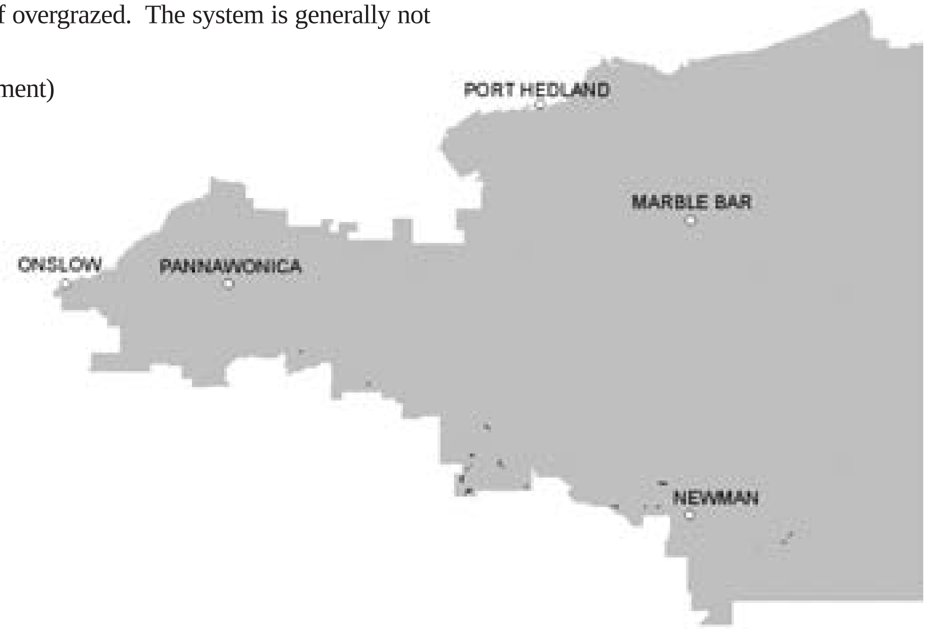
Geology: Tertiary calcrete valley fill deposits.

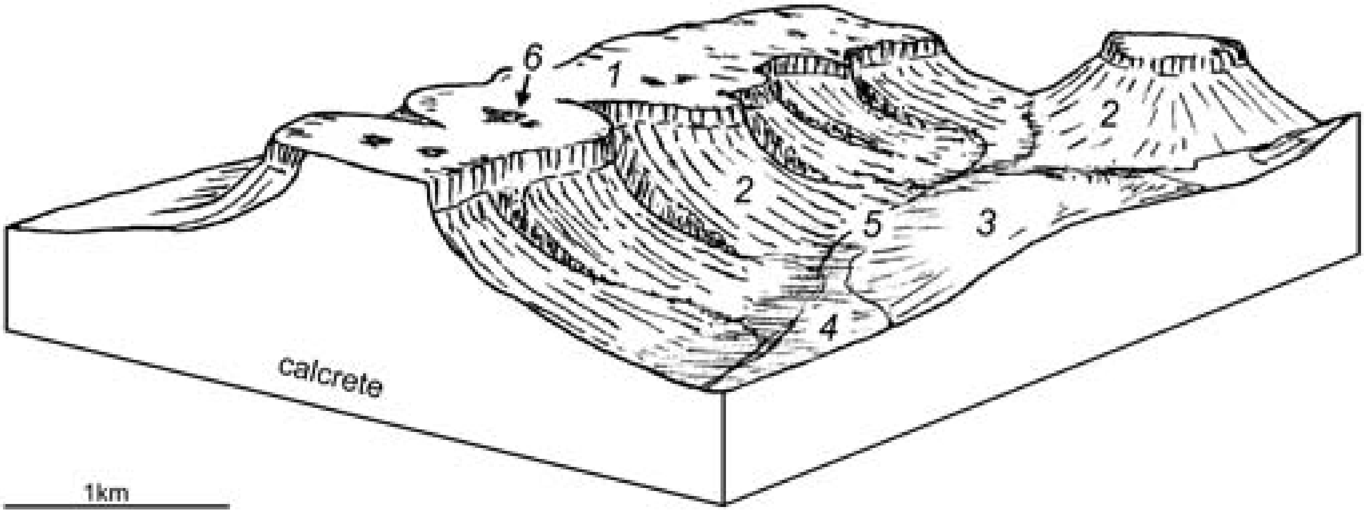
Geomorphology: Erosional surfaces formed by dissection of the old Tertiary surface; low dissected plateaux with tops up to several kilometres in extent and with numerous small drainage foci; isolated mesas, buttes and low hills with vertical breakaway faces and short lower slopes, restricted lower calcareous plains; moderately to widely spaced tributary and non tributary drainage floors and channels. Relief up to 60 m.

Land management: Vegetation on the system includes low shrubs which are moderately preferred by grazing animals and are prone to decline if overgrazed. The system is generally not susceptible to erosion.

Traverse condition summary: (1 assessment)
Vegetation - very good 100%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Calcrete mesa, low plateau and hill	-	-
2.	Footslope	1	-
3.	Lower plain	-	-
4.	Drainage floor	-	-
5.	Channel and creekline	-	-
6.	Drainage focus	-	-
	Total	1	-

Table land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	50%	**Calcrete mesas, low plateaux and hills** - up to 60 m high but mostly much less, level plateaux tops up to 3 km in extent; surface mantles of sparse calcrete fragments.	Calcareous shallow loams (521).	Very scattered to scattered tall shrublands of *Acacia aneura* (mulga) and other *Acacia* spp. with low shrubs *Senna artemisioides* subsp. *oligophylla* (blood bush) and *Ptilotus obovatus* (cotton bush) (CACS). Also *Triodia wiseana* (hard spinifex) hummock grasslands (CASG).
2.	25%	**Footslopes** - gently inclined to very steep concave slopes often with short vertical breakaway faces at top; up to 500 m long and dissected up to 3 m into narrow spurs; mantles of dense calcrete fragments.	Red shallow loams (522).	Very scattered shrublands with *Acacia xiphophylla* (snakewood), *Senna* and *Eremophila* spp. and *Ptilotus obovatus*. Also *Triodia wiseana* hummock grasslands (CACS, CASG).
3.	15%	**Lower plains** - downslope from units 1 and 2, level to very gently inclined plains and interfluves up to 1.5 km in extent between narrow flow lines and small creeks incised up to 1 m; variable mantles of calcrete fragments.	Red loamy earths (544), red deep sands (445) and some red sandy earths (463).	Very scattered to scattered tall shrublands of *Acacia aneura* and other *Acacia* spp., with *Senna artemisioides* subsp. *oligophylla, Eremophila* spp. and *Ptilotus obovatus* (CACS).
4.	5%	**Drainage floors** - level to very gently inclined floors mostly 100-200 m wide but up to 500 m, between low calcrete plateaux (unit 1) or on unit 3, central areas with channels.	Red loamy earths (544) and some self-mulching cracking clays (602).	Scattered tall shrublands of *Acacia aneura* and other *Acacia* spp. with numerous low shrubs *Senna* spp., *Rhagodia eremaea* (tall saltbush), *Ptilotus obovatus* (DEAW).
5.	4%	**Channels and creeklines** - 5-20 m wide incised 0.5-2 m, occasional wider major river channels.	River bed soils (705).	Close fringing tall shrublands/woodlands of *Acacia aneura* and other *Acacia* spp., numerous low shrubs and patchy grasses (DEAW, DEGW).
6.	1%	**Drainage foci** - on unit 1 about 0.5 m below adjacent surfaces, oval or elongated 30-300 m in extent, mantles of variably abundant calcrete fragments.	Self-mulching cracking clays (602).	Scattered tall shrublands of *Acacia aneura* with prominent low shrubs mostly *Senna artemisioides* subsp. *oligophylla* and tussock grasses such as *Eragrostis xerophila* (Roebourne Plains grass) and *Eriachne flaccida* (claypan grass) (DEGW).

TALAWANA LAND SYSTEM (161 km^2, 0.1% of the survey area)

Alluvial plains and claypans supporting grassy halophytic shrublands.

Land type: 16

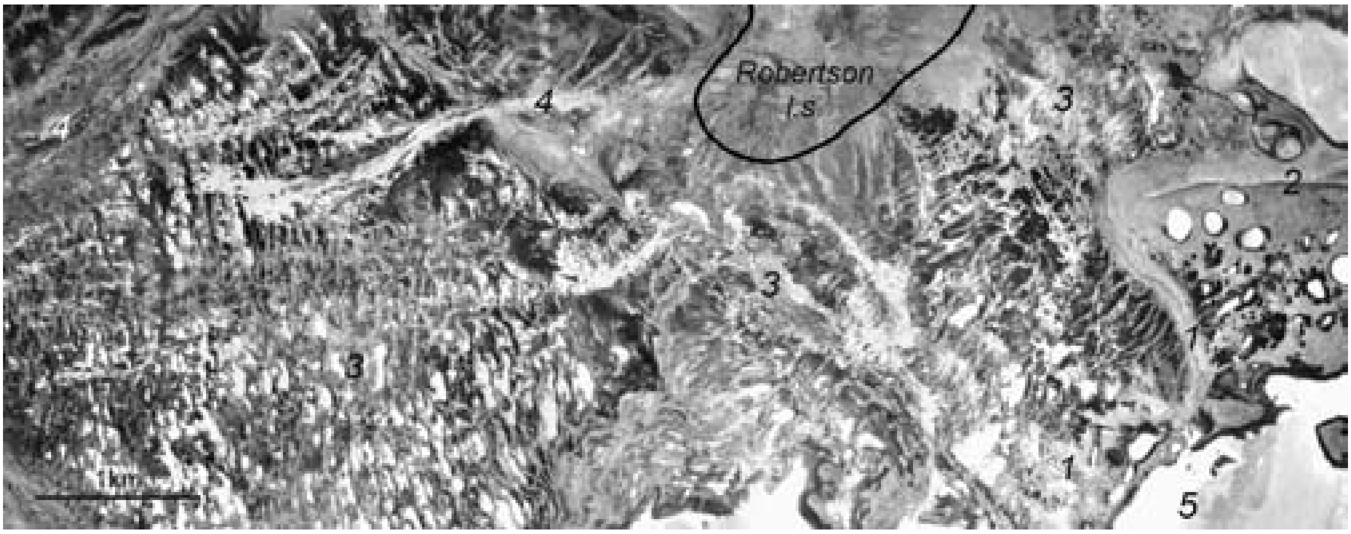
Geology: Quaternary mixed lacustrine and eolian deposits; clay, silt and sand.

Geomorphology: Depositional surfaces; level plains and broad drainage tracts of alluvium subject to sheet water flow, prominent bare claypans and drainage foci holding water for short periods after flooding; sandy banks and sand sheets of mixed eolian and fluvial origin, occasional large sand dunes, widely spaced to sparse drainage tracts with distributary patterns of gutters and small channels.

Land management: Alluvial plains and drainage tracts (units 3 and 4) support shrubs and tussock grasses which are highly preferred by livestock and other animals and are prone to degradation and soil erosion.

Traverse condition summary: (3 assessments)
Vegetation - fair 33%, very poor 67%.
Soil erosion - minor 33%, severe 67%.

Area mapped as sde: 239 ha.



No.	Unit name	Traverse recordings	Inventory sites
1.	Sandy bank and sand sheet	-	1
2.	Sand dune	-	-
3.	Alluvial plain	2	1
4.	Drainage tract	1	1
5.	Claypan, lakebed and swamp	-	-
	Total	3	3

Talawana land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	4%	**Sandy banks and sand sheets** - linear and reticulate sandy banks up to 750 m long and 150 m wide raised up to 1 m above surrounding alluvial plains (unit 3) or fringing claypans (unit 5); also sand sheet patches up to 1 km in extent.	Red deep sands (445).	Scattered grassy shrublands with *Acacia aneura* (mulga), *Senna* and *Eremophila* spp. and tussock grasses such as *Eragrostis eriopoda* (woolly butt) (SBAS).
2.	1%	**Sand dunes** - occasional linear red sand dunes up to 2 km long and 8 m high with moderately inclined slopes and hummocky crest surfaces.	Red deep sands (445).	Hummock grasslands of *Triodia schinzii, T. melvillei* (soft and hard spinifex) with scattered *Acacia* and *Grevillea* spp. shrubs and occasional *Corymbia chippendalei* (sand dune bloodwood) trees SSSG, SHSG).
3.	80%	**Alluvial plains** - level plains up to 3 km in extent, subject to sheet flow, moundy surfaces with surface mantles of many to abundant ironstone gravels interspersed with patches without mantles or with few ironstone gravels.	Red shallow sandy duplex soils (406).	Very scattered to scattered mid height shrublands with *Acacia victoriae* (prickly acacia), other acacias, *Eremophila* spp., *Maireana aphylla* (spiny bluebush) and patchy tussock grasses *Eragrostis xerophila* (Roebourne Plains grass) (PCGS).
4.	10%	**Drainage tracts** - tracts up to 750 m wide receiving more concentrated through flow than adjacent alluvial plains (unit 3) surfaces with or without gravel mantles and with gutters, rills and small channels.	Red deep loamy duplex soils (506).	Scattered low shrublands with *Maireana aphylla* and patchy *Acacia aneura, A. victoriae, A. tetragonophylla* (curara) and sparse tussock grasses *Eragrostis xerophila* (PCGS).
5.	5%	**Claypans, lakebeds and swamps** - level pans and drainage foci circular or oval in shape and up to 2.5 km in extent but usually much less; mostly bare crusted surfaces occasionally with mantles of few to common pebbles and cobbles.	Deep red/brown non-cracking clays (622).	Mostly no vegetation. Some lakes fringed by grassy woodlands of *Eucalyptus victrix* (coolibah) or *Acacia aneura* and tussock grasses such as *Eragrostis setifolia* (neverfail) and *Leptochloa fusca*.

TALGA LAND SYSTEM (2,124 km^2, 1.2% of the survey area)

Hills and ridges of greenstone and chert and stony plains supporting hard and soft spinifex grasslands.

Land type: 1

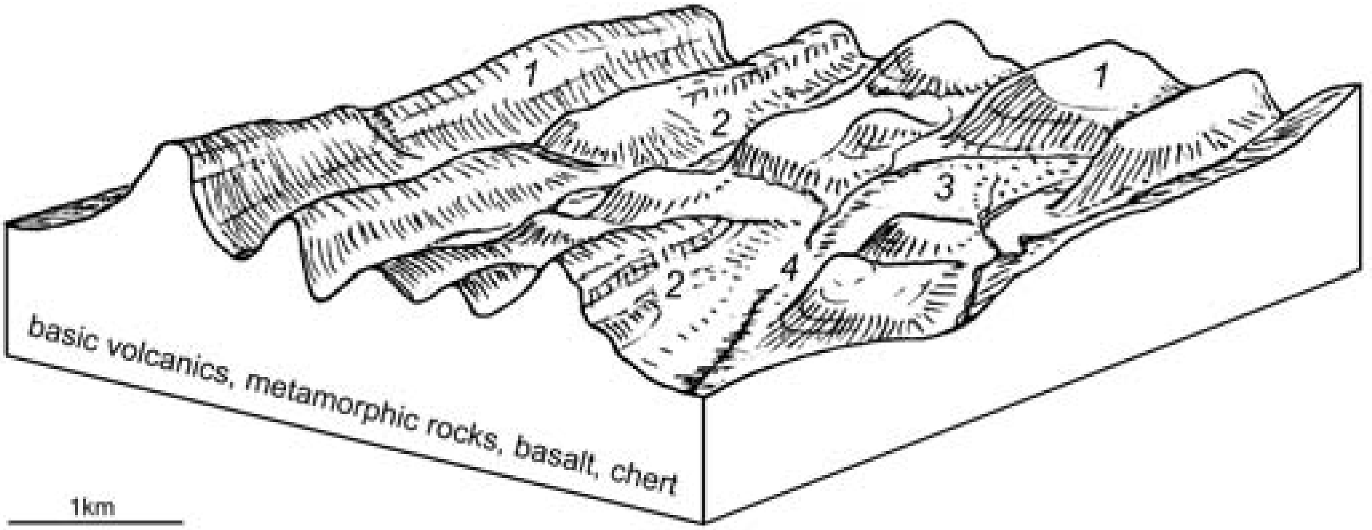
Geology: Archaean basic volcanics, ultramafic rocks and other metamorphics, basalt, andesite, shale, slate, chert and Quaternary colluvium.

Geomorphology: Erosional surfaces; hill tracts and ridges on basalt, greenstones, schist, other metamorphics and chert with rocky rounded crests and ridge tops extending for many kilometres; very steep upper slopes, more gently inclined lower footslopes, restricted lower stony plains and interfluves; moderately spaced tributary and strike aligned drainage floors and channels. Relief is up to about 100 m.

Land management: Much of the system is poorly accessible. Hard spinifex vegetation is not preferred by grazing animals but soft spinifex is moderately preferred for a few years following fire. The system is prospective and localised areas have been disturbed by exploration and mining activity. The system is not susceptible to erosion.

Traverse condition summary: (144 assessments)
Vegetation - very good 93%, good 4%, fair 3%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Hill and ridge	17	5
2.	Lower footslope	35	2
3.	Stony plain	66	4
4.	Drainage floor and channel	26	3
	Total	144	14

Talga land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	50%	**Hills and ridges** - hills and strike ridges with rounded rocky crests and ridge tops extending for many kilometres; moderately inclined to very steep, sometimes benched, upper slopes; surface mantles of abundant pebbles and cobbles of metamorphic rocks and basalt, outcrops of parent rock. Relief up to 90 m.	Stony soils (203) and some calcareous shallow loams (521).	Hummock grasslands of *Triodia wiseana, T. lanigera, T.* spp., (hard spinifex) or, less frequently, *Triodia pungens* (soft spinifex) with isolated to scattered shrubs such as *Acacia inaequilatera* (kanji), *A. orthocarpa* and *Senna* spp. (cassias) (HSPG).
2.	30%	**Lower footslopes** - very gently inclined to gently inclined footslopes up to 500 m in extent below unit 1, surface mantles of very abundant pebbles and cobbles of metamorphic rocks and basalt.	Calcareous shallow loams (521) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana, T. plurinervata, T.* spp. or, less frequently, *Triodia pungens* with isolated to scattered shrubs particularly *Acacia inaequilatera* (kanji) and *Senna* spp. (HSPG, PHSG).
3.	15%	**Stony plains** - gently undulating plains up to 1 km in extent, surface mantles of abundant pebbles and cobbles of mixed lithology.	Red shallow loams (522) and minor calcareous shallow loams (521).	Hummock grasslands of *Triodia wiseana, T. lanigera, T. plurinervata* or, less frequently, *T. pungens* with isolated to scattered shrubs of *Acacia* and *Senna* spp. (PHSG, PSSG).
4.	5%	**Drainage floors and channels** - drainage lines as small channels (2-5 m wide) in narrow valleys in upper parts becoming broader floors to 100 m wide downslope, unchannelled or with central channels to 30 m wide and banks up to 3 m high.	Red deep sandy duplex soils (405). Channels with river bed soils (705).	Hummock grasslands of *Triodia pungens* with isolated to very scattered shrubs (ASSG). Scattered to moderately close tall shrublands/woodlands of *Acacia* spp., *Eucalyptus victrix* (coolibah), *E. camaldulensis* (river red gum) with understorey of *T. pungens* or tussock grasses including *Chrysopogon fallax* (ribbon grass) and *Cenchrus ciliaris* (buffel grass) (DAHW, DESG, DEGW).

TANPOOL LAND SYSTEM (68 km^2, 0.04% of the survey area)

Stony plains and low ridges of sandstone and other sedimentary rocks supporting hard spinifex grasslands and snakewood shrublands.

Land type: 6

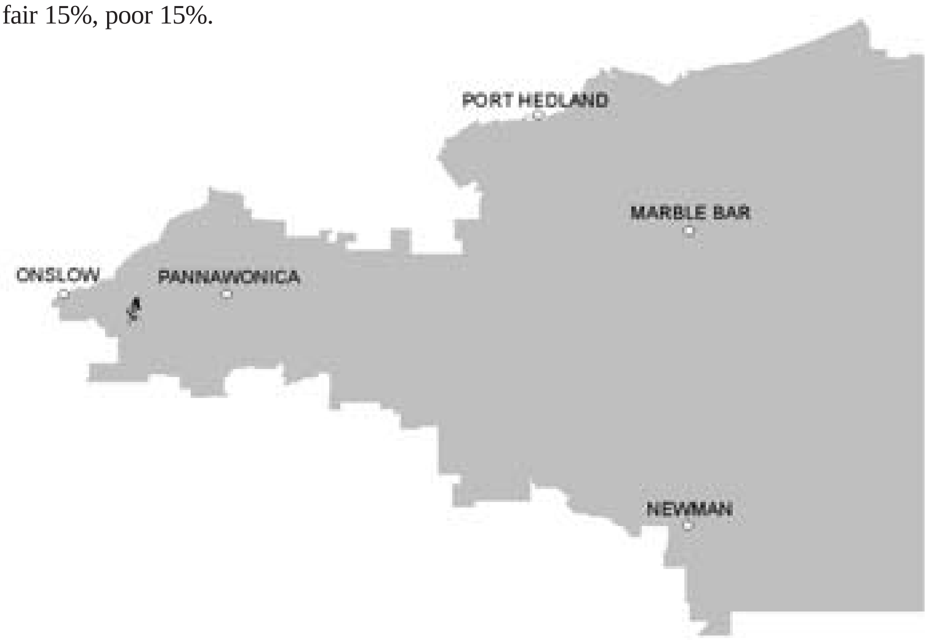
Geology: Proterozoic sandstone, siltstone and shale; Quaternary colluvium, eluvium and alluvium.

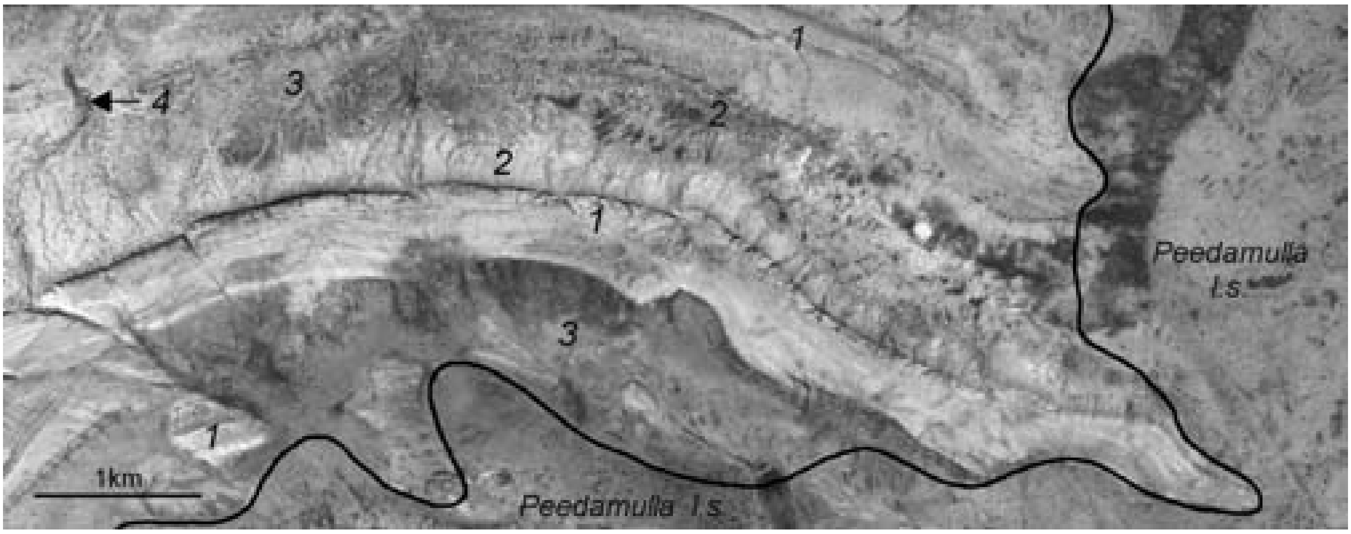
Geomorphology: Mainly erosional surfaces; stony plains below prominent strike ridges and low hills with short footslopes, sparse tributary drainage lines. Relief up to 40 m.

Land management: Hard spinifex vegetation on the system is not preferred by livestock. However, the snakewood communities include low shrubs and tussock grasses which are moderately to highly preferred, and are prone to degradation if overgrazed. Generally the system is not susceptible to erosion.

Traverse condition summary: (13 assessments)
Vegetation - very good 55%, good 15%, fair 15%, poor 15%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Ridge and hill	-	-
2.	Footslope	1	1
3.	Stony plain	12	-
4.	Drainage floor	-	-
	Total	13	1

Tanpool land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	25%	**Ridges and hills** - ridges and low hills up to 10 km long with rounded crests and short moderately inclined upper slopes; surface mantles of abundant to very abundant pebbles and cobbles of sandstone or other sedimentary rocks, also outcrops of parent rock. Relief up to 35 m.	Stony soils (203).	Hummock grasslands of *Triodia wiseana, T. brizoides*, (hard spinifex) with very scattered shrubs such as *Acacia ancistrocarpa* (shiny leaf wattle) and *A. atkinsiana* (HSPG).
2.	15%	**Footslopes** - very gently inclined slopes extending for up to 600 m below unit 1, surface mantles of abundant pebbles and cobbles of sandstone and other sedimentary rocks.	Red shallow sandy duplex soil (406).	Scattered mid height shrublands of *Acacia xiphophylla* (snakewood) and sparse low shrubs mostly *Senna* spp. and patchy hard spinifex *Triodia wiseana* (PHSG).
3.	55%	**Stony plains** - level to very gently undulating plains up to 3 km in extent, surface mantles of abundant to very abundant pebbles of sandstone and other rocks, occasional patches with stony gilgai microrelief.	Red deep loamy duplex soils (506), deep red/brown non-cracking clays (622) and some self-mulching cracking clays (602).	Hummock grasslands of *Triodia wiseana* with isolated to very scattered *Acacia* spp. shrubs (PHSG). Also very scattered to scattered tall or mid height shrublands of *Acacia xiphophylla* with sparse low shrubs and patchy hard spinifex *Triodia wiseana* and tussock grasses *Eragrostis xerophila* (Roebourne Plains grass) (ASHS, SSTS).
4.	5%	**Drainage floors** - floors mostly <200 m wide, surface mantles of common to abundant pebbles of sandstone; minor shallow channels.	Red deep loamy duplex soils (506) and river bed soils (705).	Scattered tall shrublands of *Acacia xiphophylla* with patchy *Triodia* spp. (soft and hard spinifex) and tussock grasses (ASHS).

TAYLOR LAND SYSTEM (129 km^2, 0.07% of the survey area)

Stony plains and isolated low hills of sedimentary rocks supporting hard and soft spinifex grasslands.

Land type: 8

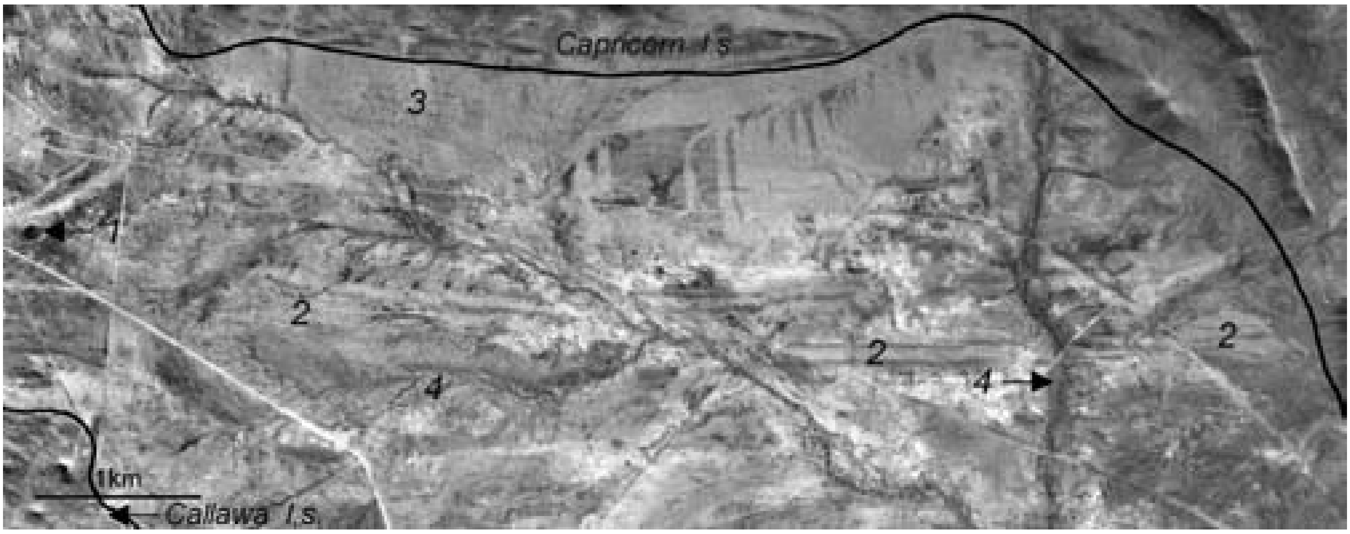
Geology: Proterozoic sandstone, grit, conglomerate and shale.

Geomorphology: Erosional surfaces; gently undulating stony plains and pediments with occasional low hills with relief up to 20 m, minor sandy surfaced plains and moderately spaced tributary drainage floors and channels.

Land management: Young soft spinifex communities on the system are moderately preferred (for 2 or 3 years after burning) by grazing animals. Hard spinifex communities are not preferred. The system is generally not susceptible to degradation or erosion.

Traverse condition summary: (35 assessments)
Vegetation - very good 88%, good 9%, fair 3%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Hill	6	-
2.	Stony plain	18	3
3.	Sandy surfaced plain	5	1
4.	Drainage floor	6	-
	Total	35	4

Taylor land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	3%	**Hills** - isolated low hills up to 750 m in extent and 20 m above surrounding plains, moderately inclined slopes, surface mantles of abundant pebbles and cobbles of sandstone and other sedimentary rocks and outcrops of parent material.	Stony soils (203) with some red shallow sands (423) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana, T.* spp. (hard spinifex) or, occasionally, *T. pungens* (soft spinifex) with isolated to very scattered *Acacia* spp. shrubs (HSPG).
2.	72%	**Stony plains** - level to gently undulating plains and interfluves extending for up to 2 km, surface mantles of many to abundant pebbles and cobbles of mudstone, shale, sandstone or other rocks, occasional outcrop of parent material.	Stony soils (203), red shallow sands (423) and red shallow sandy duplex soils (406).	Hummock grasslands of *Triodia wiseana, T. longiceps* or *T. pungens* (hard and soft spinifex) with isolated to very scattered shrubs such as *Acacia inaequilatera* (kanji), *A. bivenosa* (two vein wattle) (PHSG, PSSG).
3.	10%	**Sandy surfaced plains** - level sandy or loamy plains extending for up to 1 km, surface mantles absent or as few grit and pebbles of quartz or ironstone.	Red sandy earths (463) and red loamy earths (544).	Hummock grasslands and shrubby hummock grasslands with *Triodia pungens* and isolated to scattered mid height and tall shrubs such as *Acacia ancistrocarpa* (shiny leaf wattle) and other *Acacia* spp. (PSSG, SSSG).
4.	15%	**Drainage floors** - almost level floors up to 300 m wide with central channels.	Red loamy earths (544) and river bed soils (705).	Hummock grasslands of *Triodia pungens* with isolated to very scattered shrubs (ASSG) or scattered to moderately close tall shrublands of *Acacia* spp. with understorey of *Triodia pungens* (DAHW).

THREE RIVERS LAND SYSTEM (88 km^2, 0.05% of the survey area)

(modified from Wilcox and McKinnon 1972)

Hardpan plains and minor sandy banks supporting sparse mulga shrublands.

Land type: 12

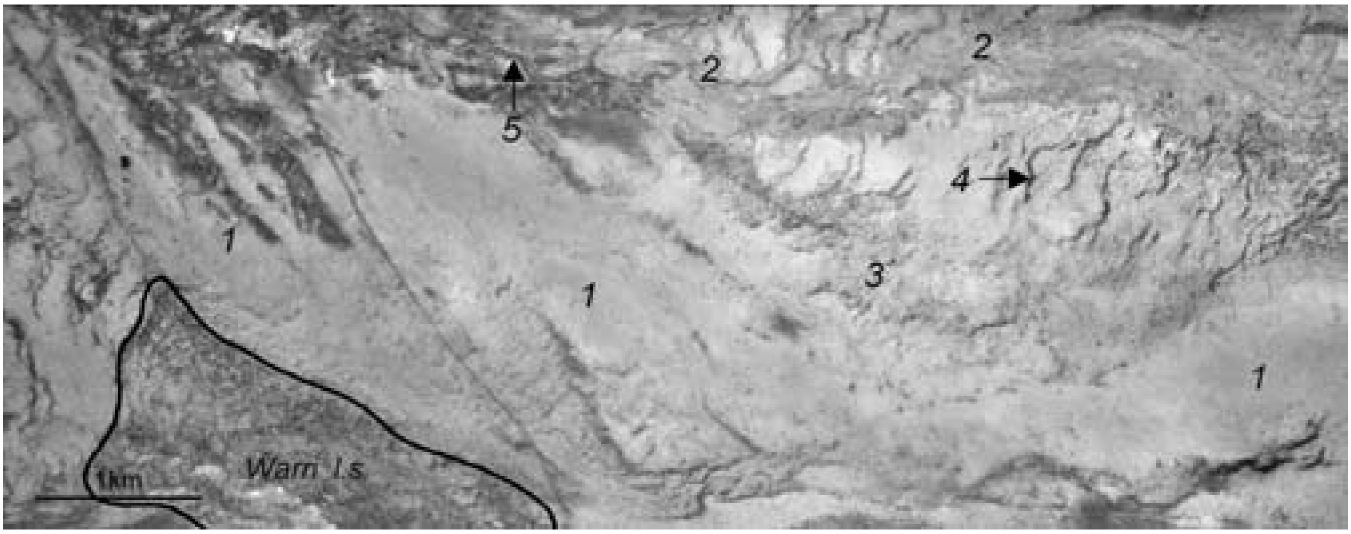
Geology: Partly cemented Quaternary colluvium and alluvium.

Geomorphology: Depositional surfaces; broad, non-saline plains with hardpan at shallow depth and receiving overland sheet flow; sandy banks and occasional groves, plains receiving more concentrated flow; minor tracts with channelled through flow shallowly incised into hardpan. Relief up to 5 m.

Land management: The system supports sparse low shrubs which are moderately preferred by livestock and other animals and will readily degrade under excessive use. Any disturbances (such as roads and tracks) which alter sheet water flow processes on the plains of this system are likely to have adverse impacts on the vegetation. Much of the system is slightly to moderately susceptible to erosion.

Traverse condition summary: (3 assessments)
Vegetation - fair 33%, poor 67%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Hardpan plain	3	1
2.	Plain receiving concentrated sheet flow	-	-
3.	Sandy bank	-	-
4.	Grove	-	-
5.	Channelled drainage zone	-	-
	Total	3	1

Three Rivers land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	60%	**Hardpan plains** - level plains up to 10 km or more in extent subject to sheet overland flow, gravelly surface mantles and hardpan exposures in parts.	Red-brown hardpan shallow loams (523).	Very scattered shrublands with *Acacia aneura* (mulga), *A. rhodophloia* (miniritchie), *Eremophila* spp. and *Solanum lasiophyllum* (flannel bush) (HPMS).
2.	20%	**Plains receiving concentrated sheet flow** - level plains up to 4-5 km long and 3 km wide receiving more concentrated sheet flow than unit 1, variable gravelly surface mantles, some shallow scour lines in parts.	Red-brown hardpan shallow loams (523).	Very scattered to scattered low shrublands with *Acacia* spp., *Eremophila spathulata* and other *Eremophila* spp., *Ptilotus schwartzii* (horse mulla mulla) and *Solanum lasiophyllum* (PSMS, HPMS).
3.	15%	**Sandy banks** - up to 1 m high and 1 km long by 20 m wide occurring on unit 1, or as broader tracts adjacent to drainage zones; uneven, loose surfaces.	Red deep sands (445).	Scattered to moderately close tall shrublands with *Acacia aneura, Psydrax latifolia* (wild lemon) and low shrubs *Eremophila forrestii* (Wilcox bush), *E. margarethae* (sandbank poverty bush), also tussock grasses *Eragrostis eriopoda* (woolly butt), *Monachather paradoxa* (broad-leaved wanderrie) (WABS).
4.	2%	**Groves** - drainage foci on unit 1, up to 400 m long and 20 m wide but commonly much less; receiving run-on from adjacent surfaces.	Red loamy earths (544).	Close to closed tall shrublands/woodlands of *Acacia aneura* and other *Acacia* spp. with low shrubs *Senna, Eremophila* and *Sida* spp., and *Enchylaena tomentosa* (ruby saltbush) (GMUW).
5.	3%	**Channelled drainage zones** - level zones up to 1 km wide with shallow gutters and central channels incised up to 3 m, frequent hardpan exposures.	Red-brown hardpan shallow loams (523). Channels with river bed soils (705).	Scattered tall shrublands or low woodlands of *Acacia aneura* and other *Acacia* spp., becoming denser along channels, low shrubs *Eremophila* and *Senna* spp. (DEAW).

TUREE LAND SYSTEM (581 km^2, 0.3% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Stony alluvial plains with gilgaied and non-gilgaied surfaces supporting tussock grasslands and grassy shrublands.

Land type: 14

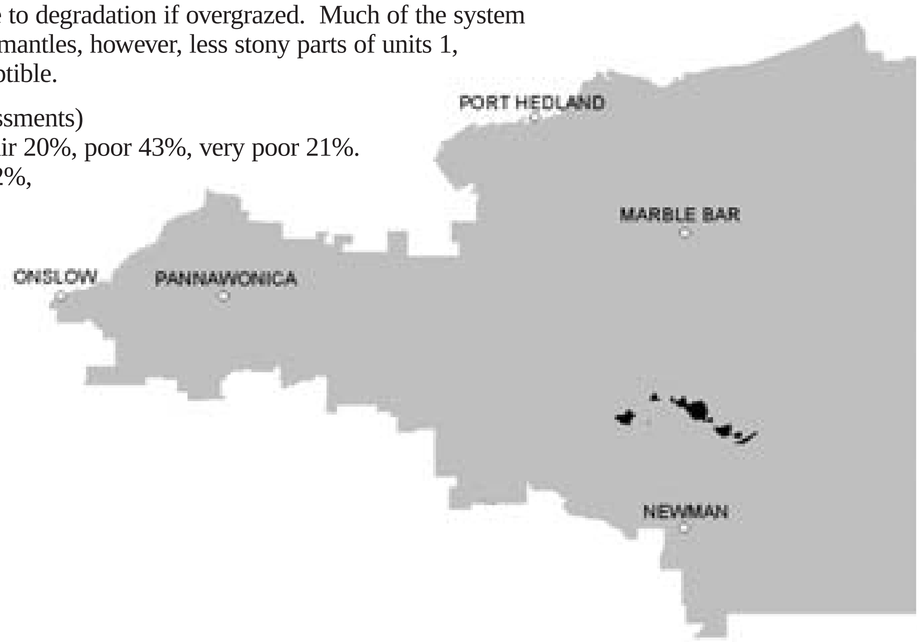
Geology: Quaternary alluvium and colluvium.

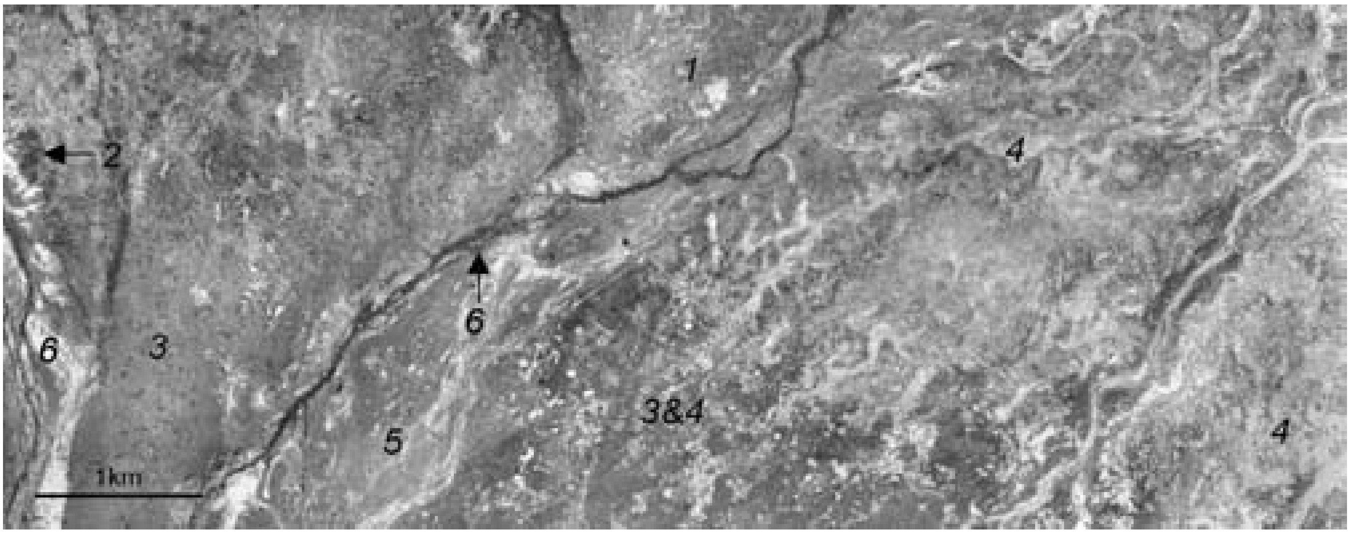
Geomorphology: Depositional surfaces, level plains with a mosaic of stony gilgaied and non-gilgaied surfaces, groved hardpan plains and stony saline alluvial plains subject to sheet flow; sparse through drainage tracts with non-tributary and distributary channels. Relief mostly less than 10 m.

Land management: The system supports tussock grasses and chenopod low shrubs which are moderately to highly preferred by grazing animals and are prone to degradation if overgrazed. Much of the system is protected from erosion by stone surface mantles, however, less stony parts of units 1, 4, 5 and 6 are slightly to moderately susceptible.

Traverse condition summary: (106 assessments)
Vegetation - very good 1%, good 15%, fair 20%, poor 43%, very poor 21%.
Soil erosion - nil 82%, slight 10%, minor 2%, moderate 4%, extreme 2%.

Area mapped as sde: 2,099 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Hardpan plain	10	-
2.	Grove and drainage focus	4	-
3.	Stony plain	12	-
4.	Gilgai plain	54	2
5.	Saline stony plain	15	-
6.	Channelled drainage tract	10	1
	Other	1	-
	Total	106	3

Turee land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	10%	**Hardpan plains** - level plains up to 1.5 km in extent, mantles of very few to common pebbles; usually located on outer margins of system, subject to sheet water flow.	Red-brown hardpan shallow loams (523) or red shallow loams (522).	Very scattered tall or low shrublands with *Acacia aneura* (mulga) and *Eremophila* and *Senna* spp. (HPMS).
2.	1%	**Groves and drainage foci** - up to 200 m in extent but commonly smaller on hardpan plains and stony plains (units 1 and 3), receiving run-on from adjacent surfaces.	Red loamy earths (544) or deep red/brown non-cracking clays (622).	Close tall shrublands of *A. aneura* with *Eremophila* and *Senna* spp. undershrubs and perennial grasses such as *Chrysopogon fallax* (ribbon grass) (GMGW).
3.	24%	**Stony plains** - level plains with mantles of abundant to very abundant pebbles of ironstone and other rocks; up to 5 km in extent or as an irregular mosaic 20-500 m in extent with similarly sized or larger areas of slightly lower gilgai plains (unit 4).	Red shallow loams (522) and red-brown hardpan shallow loams (523).	Very scattered to scattered tall or low shrublands with *Acacia xiphophylla* (snakewood), *A. aneura, Senna artemisioides* subsp. *oligophylla* (blood bush) and *Eremophila* spp. (SAES).
4.	45%	**Gilgai plains** - level plains with gilgai microrelief and mantles of very few to abundant pebbles of ironstone and other rocks; up to 2 km in extent or as an irregular mosaic 20-500 m in extent with slightly higher non-gilgaied stony plains (units 3 and 5).	Self-mulching cracking clays (602) and red deep loamy duplex soils (506).	Tussock grasslands or patchy grassy shrublands with *Eragrostis xerophila* (Roebourne Plains grass), *E. setifolia* (neverfail) and isolated to very scattered shrubs including *Acacia farnesiana* (mimosa bush), *A. victoriae* (prickly acacia), *Senna* and *Eremophila* spp. (ARPG, PMOG, PMGS). Sometimes degraded to annual herbfields.
5.	10%	**Saline stony plains** - level plains with mantles of variable abundance grit and pebbles of ironstone; up to 2 km in extent, subject to sheet flow.	Red deep loamy duplex soils (506).	Very scattered to scattered low shrublands with *Atriplex bunburyana* (silver saltbush), *Maireana* spp. (bluebush), *Senna, Eremophila* and *Acacia* spp. (PCGS, PXHS).
6.	10%	**Channelled drainage tracts** - through going tracts up to 1 km wide but commonly much less, 1-2 m below surrounding plains; short pebble strewn slopes marginal to adjacent plains, pebble mantles of variable abundance; anastomosing channels up to 50 m wide in central parts.	Red deep loamy duplex soils (506). Channels with river bed soils (705).	Small tracts support grassy scattered shrublands with *Acacia farnesiana, Eragrostis setifolia* and *Eriachne benthamii* (swamp grass). Larger tracts with channels support tall shrublands or low woodlands with *Acacia coriacea* (river jam), other acacias, *Eucalyptus victrix* (coolibah) with patchy tussock grasses including *Cenchrus ciliaris* (buffel grass) (DEGW).

UAROO LAND SYSTEM (7,681 km^2, 4.2% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Broad sandy plains supporting shrubby hard and soft spinifex grasslands.

Land type: 11

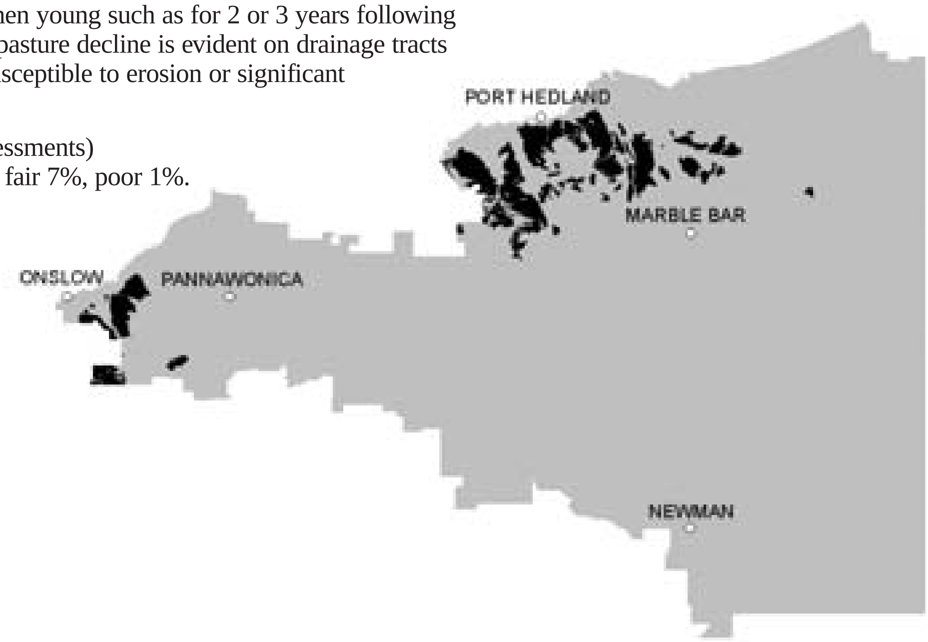
Geology: Quaternary colluvium and alluvium.

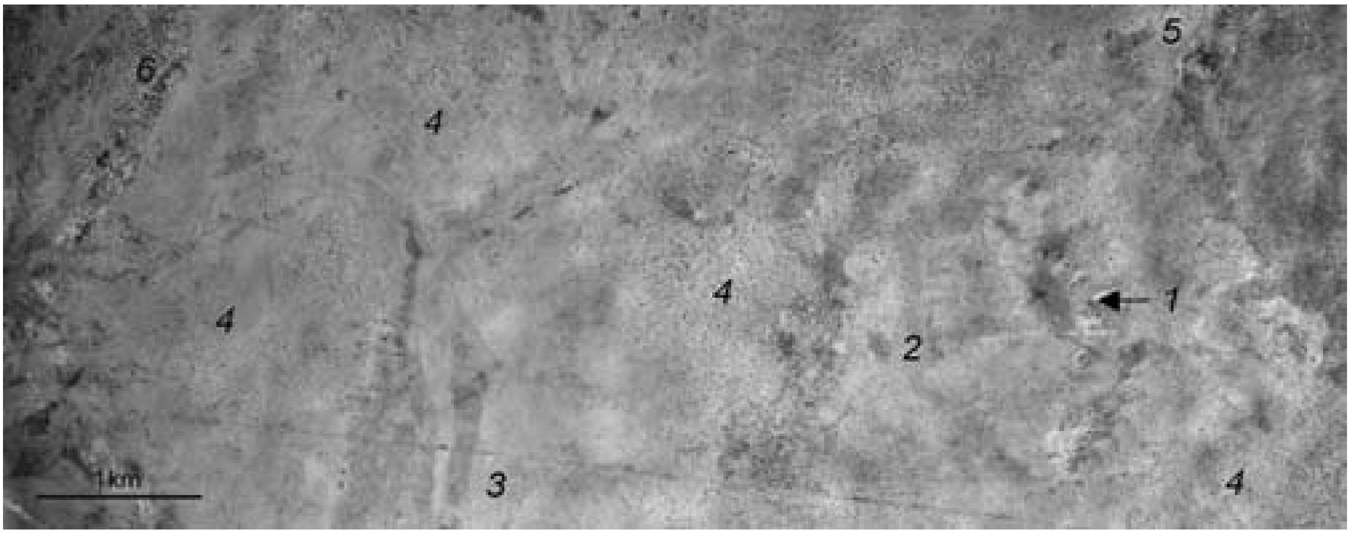
Geomorphology: Depositional surfaces; level sandy plains up to 10 km or more in extent with little organised through drainage; pebbly surfaced plains and plains with calcrete at shallow depth; broad, mostly unchannelled, tracts receiving more concentrated sheet flow, minor low stony hills and rises. Relief mostly less than 10 m but isolated hills up to 30 m.

Land management: The system supports hard spinifex vegetation which is not preferred by grazing animals and soft spinifex which is moderately preferred when young such as for 2 or 3 years following burning. Occasionally some erosion and pasture decline is evident on drainage tracts (unit 6), but generally the system is not susceptible to erosion or significant vegetation degradation.

Traverse condition summary: (808 assessments)
Vegetation - very good 68%, good 24%, fair 7%, poor 1%.
Soil erosion - nil 99%, slight 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low hill	1	-
2.	Low rise	21	2
3.	Pebbly plain	64	2
4.	Sandy/loamy plain	645	21
5.	Calcrete plain	7	-
6.	Tract receiving sheet flow	64	6
	Other	6	-
	Total	808	31

Uaroo land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	<1%	**Low hills** - isolated hills and ridges up to 1 km long, gently inclined to steep stony footslopes, relief up to 30 m above surrounding plains.	Stony soils (203).	Hummock grasslands of *Triodia wiseana, T.* spp. (hard spinifex) with isolated or very scattered shrubs (HSPG).
2.	3%	**Low rises** - gently undulating raised surfaces up to 1.5 km in extent, surface mantles of variable abundance grit and pebbles of quartz and granite, occasional outcrops of granite or other parent rock.	Red shallow sands (423) and red sandy earths (463).	Hummock grasslands of *Triodia pungens, T. epactia* (soft spinifex), with very scattered to scattered *Acacia* spp. shrubs (PSSG). Less frequently with *Triodia* spp. (hard spinifex) (PHSG).
3.	8%	**Pebbly plains** - level plains up to 3 km in extent, marginal to or as patches within sandy plains (unit 4), surface mantles of many to abundant pebbles of quartz and/or ironstone.	Red shallow sandy duplex soils (406), red shallow sands (423), red sandy earths (463) and calcareous shallow earths (521).	Hummock grasslands of *Triodia lanigera, T. plurinervata, T. wiseana* (hard spinifex) with isolated to scattered shrubs such as *Acacia inaequilatera* (kanji) and *A. ancistrocarpa* (shiny leaf wattle) (PHSG). Less frequently with *Triodia pungens* (soft spinifex) (PSSG).
4.	82%	**Sandy/loamy plains** - level plains up to 10 km or more in extent, microrelief often moundy on more sandy sites, no surface mantles.	Red sandy earths (463), red deep sands (445) and red loamy earths (544).	Hummock grasslands or shrubby hummock grasslands of *Triodia pungens, T. epactia, T. schinzii* (soft spinifex) or *T. lanigera, T.* spp. (hard spinifex) with isolated to scattered (occasionally moderately close) shrubs particularly *Acacia stellaticeps* (poverty bush), *A. inaequilatera* (kanji), *A. tumida* (pindan wattle) and occasional eucalypt and other trees (PSSG, SSSG, PHSG, SHSG).
5.	1%	**Calcrete plains** - level surfaces associated with unit 4, up to 1 km in extent, surface mantles of abundant calcareous gravel.	Calcareous shallow loams (521) and red deep sandy duplex soils (405).	Hummock grasslands of *Triodia wiseana, T. lanigera* (hard spinifex) or *T. pungens* (soft spinifex) with isolated to scattered *Acacia* spp. shrubs (CASG).
6.	6%	**Tracts receiving sheet flow** - level tracts up to 2 km wide, slightly lower and extending downslope through unit 4 for many kilometres, unchannelled or occasionally with narrow creeklines, scour lines and scalds.	Red deep sandy duplex soils (405), red deep sands (445) and red sandy earths (463).	Hummock grasslands of *Triodia pungens* or *T.* spp. (soft or hard spinifex) with isolated to very scattered *Acacia* spp. shrubs (ASSG, AHSG). Also scattered tall shrublands/woodlands with *Acacia* and *Eucalyptus* spp. and hummock and tussock grass understoreys (DAHW, DESG).

URANDY LAND SYSTEM (1,311 km^2, 0.7% of the survey area)

Stony plains, alluvial plains and drainage lines supporting shrubby soft spinifex grasslands.

Land type: 13

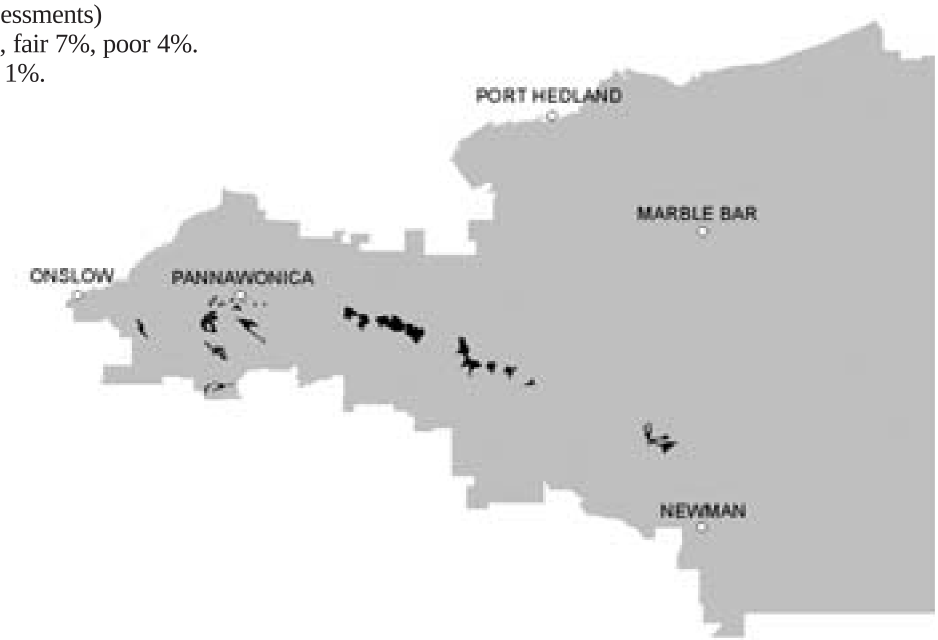
Geology: Quaternary alluvium and colluvium.

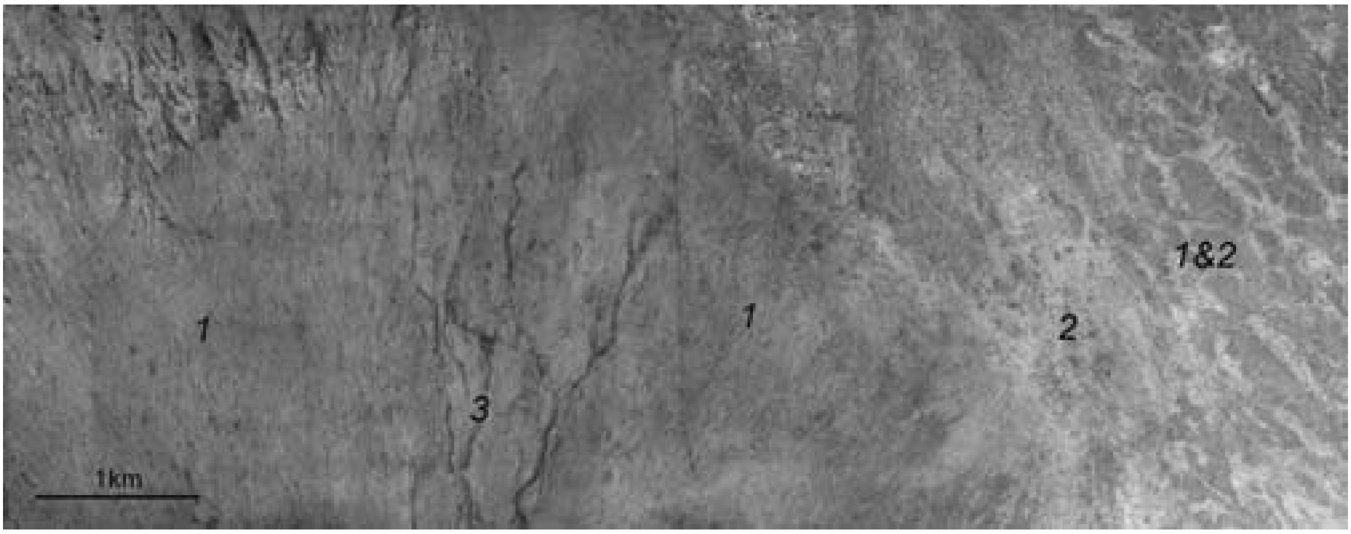
Geomorphology: Depositional surfaces; level stony plains and plains and fans of sandy alluvium with widely spaced through going or sub-parallel distributary creeklines and channels; subject to sheet flow and overbank flooding. Relief less than 10 m.

Land management: The system supports soft spinifex vegetation which, except for old mature stands, is moderately preferred by grazing animals. The system is prone to fairly regular burning. Most of the system is not susceptible to erosion or vegetation degradation.

Traverse condition summary: (134 assessments)
Vegetation - very good 76%, good 13%, fair 7%, poor 4%.
Soil erosion - nil 98%, minor 1%, severe 1%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Stony plain	78	4
2.	Alluvial plain	45	7
3.	Drainage zone and channel	9	-
	Other	2	-
	Total	134	11

Urandy land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	58%	**Stony plains** - level plains extending for up to 3 km, slightly elevated above adjacent alluvial plains (unit 2), subject to overland sheet flow which shed onto unit 2; surface mantles of few to abundant pebbles of ironstone and other rocks.	Red loamy earths (544).	Hummock grasslands of *Triodia pungens* (soft spinifex) with very scattered to moderately close shrubs such as *Acacia aneura* (mulga), *A. ancistrocarpa* (shiny leaf wattle), *A. bivenosa* (two vein wattle) and *A. xiphophylla* (snakewood) (PSSG).
2.	35%	**Alluvial plains** - level plains up to 2-3 km in extent flanking drainage zones and channels (unit 3), subject to overbank flooding and sheet flow; surface mantles vary from nil to abundant pebbles of chert, sandstone, quartz and other rocks.	Red loamy earths (544) with some red shallow sandy duplex soils (406).	Hummock grasslands of *Triodia pungens* with isolated to scattered (occasionally denser) shrubs such as *Acacia victoriae* (prickly acacia), *A. inaequilatera* (kanji) and *A. atkinsiana* and sparse eucalypt trees (ASSG).
3.	7%	**Drainage zones and channels** - tracts up to 200-300 m wide receiving fairly regular overbank flooding, channels up to 50 m wide and banks up to 5 m high, occasional ill defined sandy levees.	Red loamy earths (544), levees of red deep sand (445) and channels with river bed soils (705).	Hummock grasslands of *Triodia pungens* (ASSG) or tall shrublands/woodlands of *Acacia* and *Eucalyptus* spp. with hummock and tussock grass understoreys including *Chrysopogon fallax* (ribbon grass) and *Cenchrus ciliaris* (buffel grass) (DESG, DEGW).

WANNAMUNNA LAND SYSTEM (577 km^2, 0.3% of the survey area)

Hardpan plains and internal drainage tracts supporting mulga shrublands and woodlands (and occasionally eucalypt woodlands).

Land type: 12

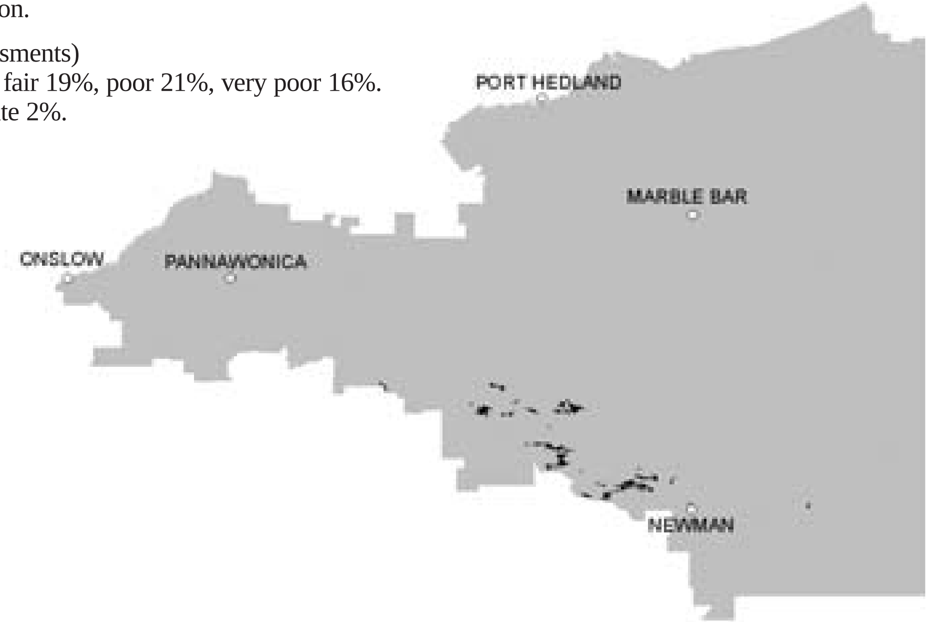
Geology: Quaternary alluvium and colluvium.

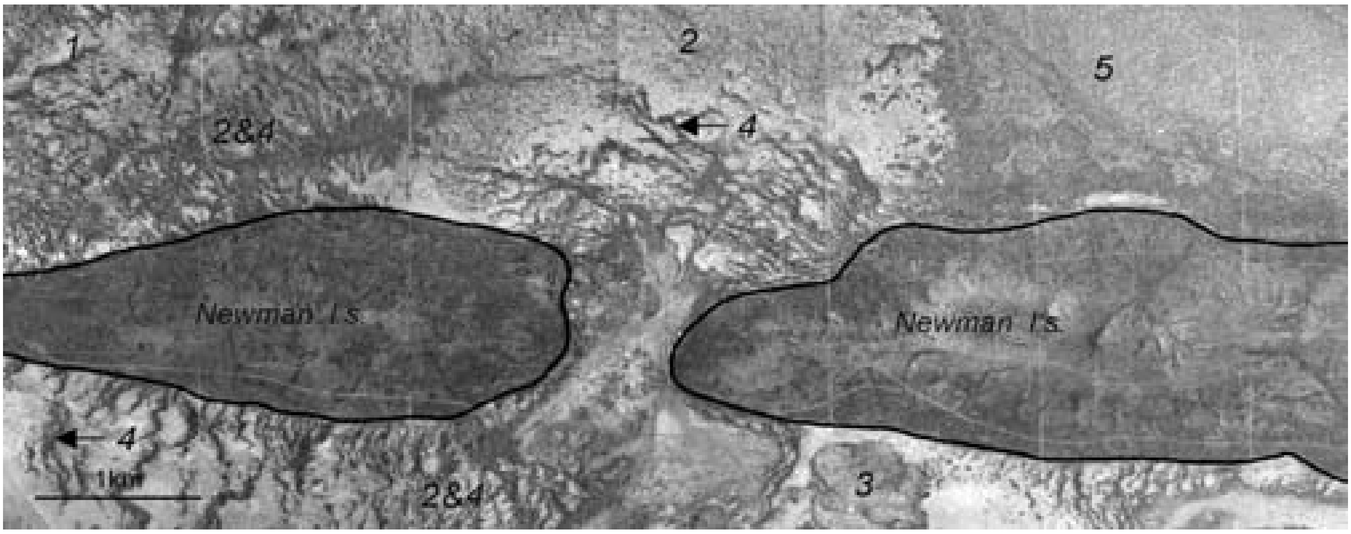
Geomorphology: Depositional surfaces; level hardpan washplains subject to overland sheet flow, drainage foci as discrete arcuate groves and broad internal drainage flats both receiving run-on from adjacent hardpan surfaces; rare channelled tracts but mostly no organised through drainage. Relief up to 5 m.

Land management: The system supports low shrubs and tussock grasses which are highly preferred by grazing animals and are prone to degradation if grazing pressure is excessive. Generally the system has low susceptibility to erosion. Disturbances to overland flow processes by inappropriate positioning or construction of infrastructure such as roads can have adverse effects on vegetation.

Traverse condition summary: (62 assessments)
Vegetation - very good 19%, good 25%, fair 19%, poor 21%, very poor 16%.
Soil erosion - nil 95%, minor 3%, moderate 2%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Stony plain	5	-
2.	Hardpan plain	29	4
3.	Calcrete platform	1	-
4.	Grove	11	2
5.	Internal drainage plain	16	6
	Other	-	1
	Total	62	13

Wannamunna land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	8%	**Stony plains** - level or very gently inclined plains up to 500 m in extent, usually on outer margins of system; surface mantles of abundant pebbles of ironstone.	Red loamy earths (544) and red-brown hardpan shallow loams (523).	Very scattered to scattered tall shrublands of *Acacia aneura* (mulga) with sparse low shrubs and *Triodia* sp. (hard spinifex) understorey (PMSS).
2.	56%	**Hardpan plains** - level plains up to 5-6 km in extent, subject to overland sheet flow; surface mantles of very few to few pebbles of ironstone.	Red-brown hardpan shallow loams (523) and some red shallow loams (522).	Very scattered tall or low shrublands of *Acacia aneura, Eremophila* spp., *Ptilotus obovatus* (cotton bush), *Maireana villosa* (PSMS, HPMS).
3.	1%	**Calcrete platforms** - level plains up to 300 m in extent and raised 1-2 m above adjacent hardpan plains (unit 2); surface mantles of abundant calcrete pebbles and fragments.	Calcareous shallow loams (521).	Scattered shrublands with *Acacia aneura* and other acacias, *Senna* spp. and *Triodia wiseana* (hard spinifex) (CASG).
4.	15%	**Groves** - arcuate drainage foci up to 1 km long and 150 m wide arranged on hardpan plains (unit 2) with long axes at right angles to direction of sheet flow, receiving run-on from adjacent plains; often with gilgai microrelief.	Red deep loamy duplex soils (506), red loamy earths (544) and self-mulching cracking clays (602).	Moderately close to closed woodlands of *Acacia aneura* with numerous undershrubs and tussock grasses such as *Chrysopogon fallax* (ribbon grass) and *Themeda triandra* (kangaroo grass) (GMGW).
5.	20%	**Internal drainage plains** - level plains and drainage sumps up to 5 km in extent, receiving run-on from adjacent hill land systems and hardpan plains (unit 2), microrelief may be gilgaied or non-gilgaied.	Deep red/brown non-cracking clays (622), self-mulching cracking clays (602) and red loamy earths (544).	Moderately close to closed woodlands of *Acacia aneura* and *Eucalyptus victrix* (coolibah) with sparse undershrubs such as *Muehlenbeckia florulenta* (lignum) and *Chenopodium auricomum* (swamp bluebush) and patchy tussock grasses (DEAW). Also grasslands of *Eriachne* sp. with isolated *Eucalyptus victrix* trees and shrubs such as *M. florulenta* (DEGW) or grassy scattered woodlands of *E. victrix* (DEGW).

WARRI LAND SYSTEM (305 km^2, 0.2% of the survey area)

(modified from Wilcox and McKinnon 1972)

Low calcrete platforms and plains supporting mulga and cassia shrublands.

Land type: 18

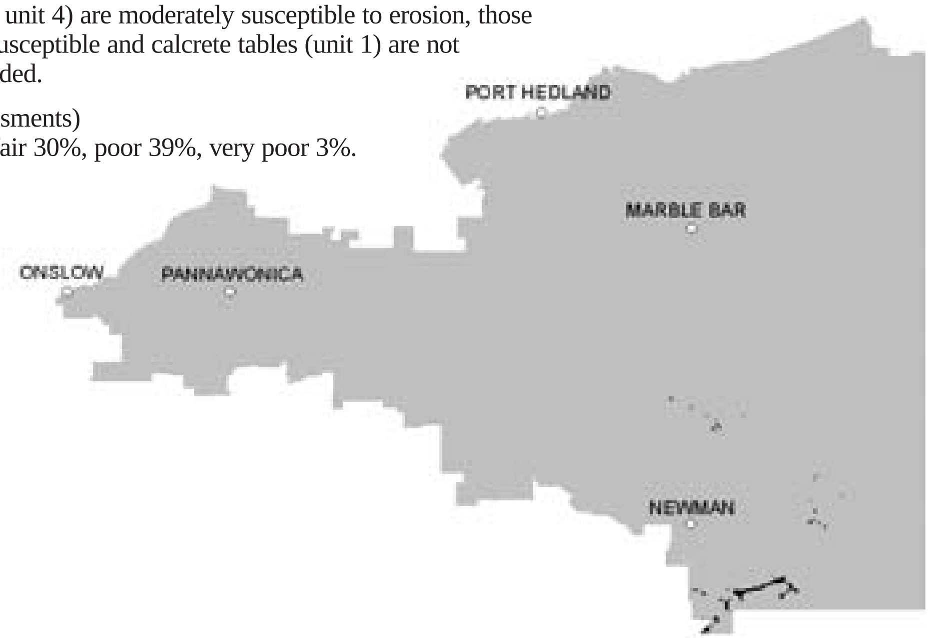
Geology: Tertiary calcrete, calcareous gravel and opaline silica partly overlain by cemented Quaternary colluvium.

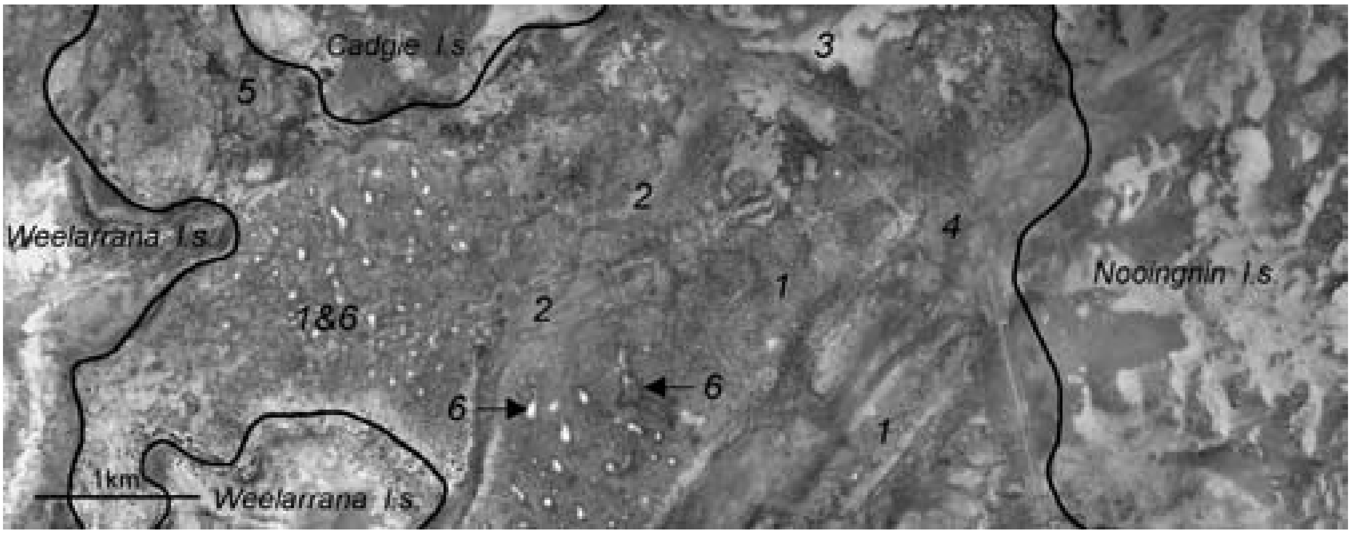
Geomorphology: Depositional surfaces; calcreted valley fills; level plains with a mosaic of calcrete tables elevated up to 3 m above surrounding surfaces, narrow inter-table areas and drainage floor with channels, minor plains on saline alluvium and hardpan plains subject to sheet flow. Overall relief mostly below 5 m.

Land management: The system supports shrubs and grasses highly preferred by grazing animals and is prone to degradation. Units with duplex soils (e.g. unit 4) are moderately susceptible to erosion, those with loam over hardpan (unit 3) are less susceptible and calcrete tables (unit 1) are not normally susceptible though widely degraded.

Traverse condition summary: (57 assessments)
Vegetation - very good 7%, good 21%, fair 30%, poor 39%, very poor 3%.
Soil erosion - nil 95%, moderate 5%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Calcrete table	17	1
2.	Inter-table area	7	2
3.	Hardpan plain	10	-
4.	Saline plain	4	-
5.	Drainage floor	17	-
6.	Drainage focus and sinkhole	1	-
	Other	1	-
	Total	57	3

Warri land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	50%	**Calcrete tables** - level surfaces often oval or rounded in shape, mostly 500 m to 3 km in extent but locally larger, elevated up to 3 m above surrounding units; surface mantles of common to abundant pebbles and fragments of calcrete, also calcrete outcrop.	Calcareous shallow loams (521) and red shallow sands (423).	Scattered mixed height shrublands with *Acacia aneura* (mulga), *A. tetragonophylla* (curara), *A. bivenosa* (two vein wattle), *A. sclerosperma* (limestone wattle), *Ptilotus obovatus* (cotton bush), *Senna* spp. and annual grasses (CACS). Less frequently with *Triodia wiseana* (hard spinifex) or *T. pungens* (soft spinifex) understorey (CASG).
2.	10%	**Inter-table areas** - level inter-table areas up to 300 m wide and slightly lower than tables (unit 1), surface mantles of few to abundant pebbles of calcrete; usually unchannelled.	Calcareous loamy earths (542) and deep red/brown non-cracking clays (622).	Grasslands or grassy shrublands with *Eragrostis setifolia* (neverfail), *E. falcata* (sickle love grass) and isolated to scattered *Acacia, Eremophila* and *Senna* spp. (APNG, PSMS).
3.	15%	**Hardpan plains** - level plains up to 2 km in extent, usually on outer margins of system, surface mantles of few to many pebbles; subject to overland sheet flow.	Red-brown hardpan shallow loams (523).	Very scattered to scattered tall shrublands of *Acacia aneura* and other acacias, *Ptilotus obovatus* and *Eremophila* and *Senna* spp. (HPMS).
4.	9%	**Saline plains** - level plains up to 2 km in extent associated with units 3 and 5, subject to sheet flooding.	Red deep loamy duplex soils (506) and deep red/brown non-cracking clays (622).	Very scattered to scattered low shrublands of *Frankenia* spp. (frankenia), *Maireana pyramidata* (sago bush), *Atriplex* spp. (saltbush) and *Acacia* spp. (PXHS).
5.	14%	**Drainage floors** - almost level zones of through flow extending up to 5-6 km between calcrete tables, up to 500 m wide and 3 m below adjacent tables; central tracts may be channelled or unchannelled.	Self-mulching cracking clays (602).	Grassy woodlands with *Acacia aneura, Eucalyptus victrix* (coolibah) with few shrubs and sparse to dense tussock grasses such as *Eriachne benthamii* (swamp grass), *Eulalia aurea* (silky brown top) and *Chrysopogon fallax* (ribbon grass) (DEGW, DEAW). Also tussock grasslands with *Eragrostis setifolia, E. xerophila* (Roebourne Plains grass), *Eriachne flaccida* (claypan grass) (APXG).
6.	2%	**Drainage foci and sinkholes** - oval or elongated foci on unit 1, 10-200 m in extent and up to 1 m below adjacent surfaces, variable mantles of calcrete fragments.	Calcareous loamy earths (542) and deep red/brown non-cracking clays (622).	Bare surfaces or scattered to moderately close tall shrublands of *Acacia aneura* and other acacias with low shrubs *Ptilotus obovatus, Senna* spp. and tussock grasses (DEGW, DEAW). Also tussock grasslands with *Eriachne* and *Eragrostis* spp.

WASHPLAIN LAND SYSTEM (917 km^2, 0.5% of the survey area)

(modified from Payne and Mitchell 1992)

Hardpan plains supporting groved mulga shrublands.

Land type: 12

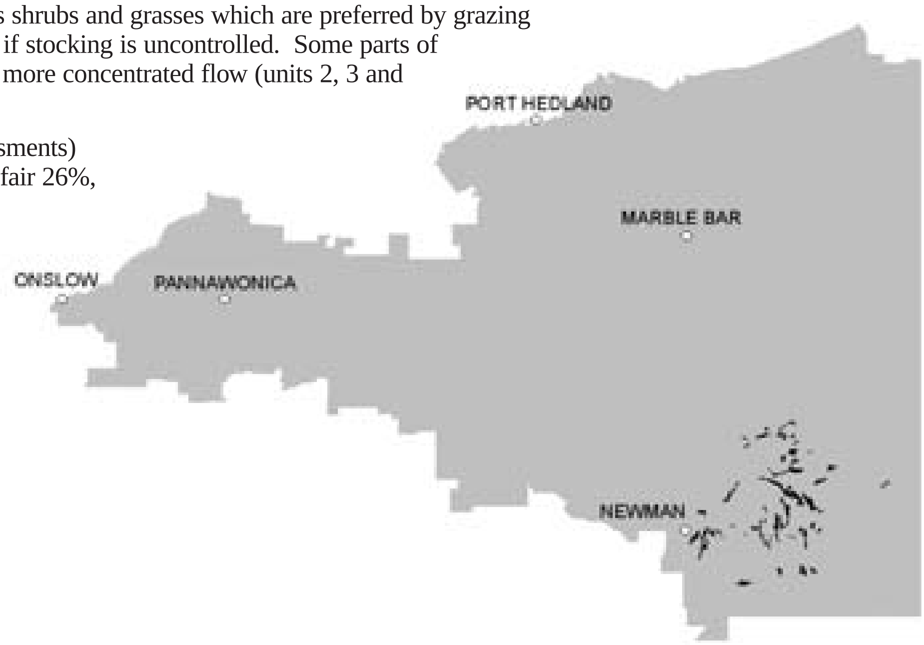
Geology: Quaternary partly cemented alluvium.

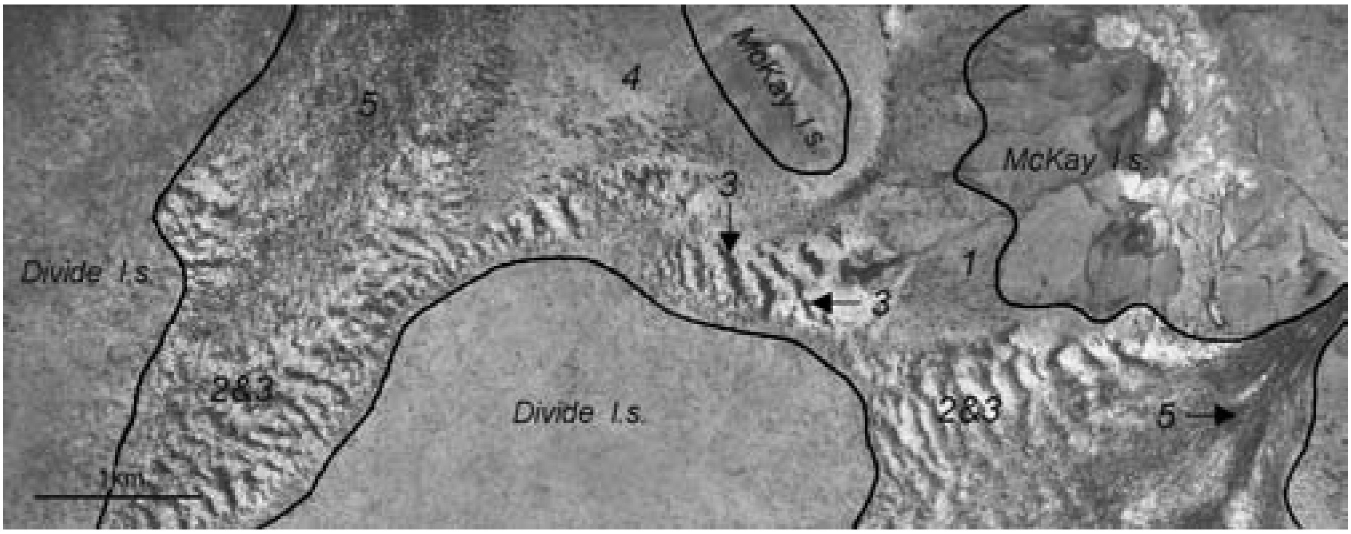
Geomorphology: Depositional surfaces; level alluvial hardpan plains subject to overland sheet flow, discrete drainage foci (groves) arranged with long axes at right angles to direction of sheet flow and drainage tracts receiving more concentrated flow, occasional channels; minor stony plains and sandplains. Relief up to 10 m.

Land management: The system supports shrubs and grasses which are preferred by grazing animals and is prone to vegetation decline if stocking is uncontrolled. Some parts of alluvial plains, groves and tracts receiving more concentrated flow (units 2, 3 and 5) are moderately susceptible to erosion.

Traverse condition summary: (89 assessments)
Vegetation - very good 15%, good 25%, fair 26%, poor 18%, very poor 16%.
Soil erosion - nil 85%, slight 2%, minor 3%, moderate 6%, severe 4%.

Area mapped as sde: 1,348 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Stony plain	6	-
2.	Alluvial hardpan plain	47	2
3.	Grove	11	-
4.	Sandplain	3	-
5.	Tract receiving more concentrated through flow	20	1
	Other	2	-
	Total	89	3*

* Two of these sites described from field work done in 1990 as part of an assessment of the impact of Ophthalmia Dam on the flood plains of the Fortescue River (See Payne and Mitchell 1992).

Washplain land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	6%	**Stony plains** - level plains up to 500 m in extent, surface mantles of abundant or very abundant pebbles and cobbles of ironstone and quartz, some small patches may have weakly gilgaied microrelief.	Red loamy earths (544), deep red/brown non-cracking clays (622) and minor self-mulching cracking clays (602).	Very scattered shrublands of *Acacia aneura* (mulga), *Senna* and *Eremophila* spp. and occasional tussock grasses (SAES, PMGS).
2.	62%	**Alluvial hardpan plains** - level plains up to 4-5 km in extent and subject to overland sheet flow; surface mantles vary from few to very abundant pebbles of ironstone, chert and other rocks.	Red deep sandy duplex (405) and red deep loamy duplex (506) soils.	Herbfields with isolated shrubs or very scattered to scattered shrublands of *Acacia aneura, Eremophila cuneifolia* (royal poverty bush) other eremophilas, *Senna* spp. and small *Maireana* spp. (HPMS, LHAS).
3.	15%	**Groves** - drainage foci 10-50 m wide by up to 500 m long on units 2 and 5, arranged with long axes at right angles to direction of sheet flow.	Red loamy earths (544) and deep red/brown non-cracking clays (622).	Moderately close to closed *Acacia aneura* woodlands or tall shrublands with numerous undershrubs and scattered grasses such as *Chrysopogon fallax* (ribbon grass) and *Digitaria coenicola* (GMGW).
4.	3%	**Sandplains** - level sand sheets up to 500 m in extent.	Red deep sands (445).	Hummock grasslands of *Triodia* spp. (soft and hard spinifex) with very scattered or scattered shrubs (SSSG, SHSG).
5.	14%	**Tracts receiving more concentrated through flow** - almost level tracts as corridors up to 1 km wide through unit 1 and receiving more concentrated through flow than unit 1, usually unchannelled but occasionally with minor channels with shallow incision.	Red deep loamy duplex soils (506) and red loamy earths (544).	Moderately close to closed woodlands or tall shrublands of *Acacia aneura* with scattered low shrubs and occasional perennial grasses (DEAW, DEGW).

WEELARRANA LAND SYSTEM (48 km^2, 0.03% of the survey area)

(after Payne, Mitchell and Holman 1988)

Salt lakes with fringing saline plains and sandy islands supporting halophytic shrublands and hard spinifex grasslands.

Land type: 20

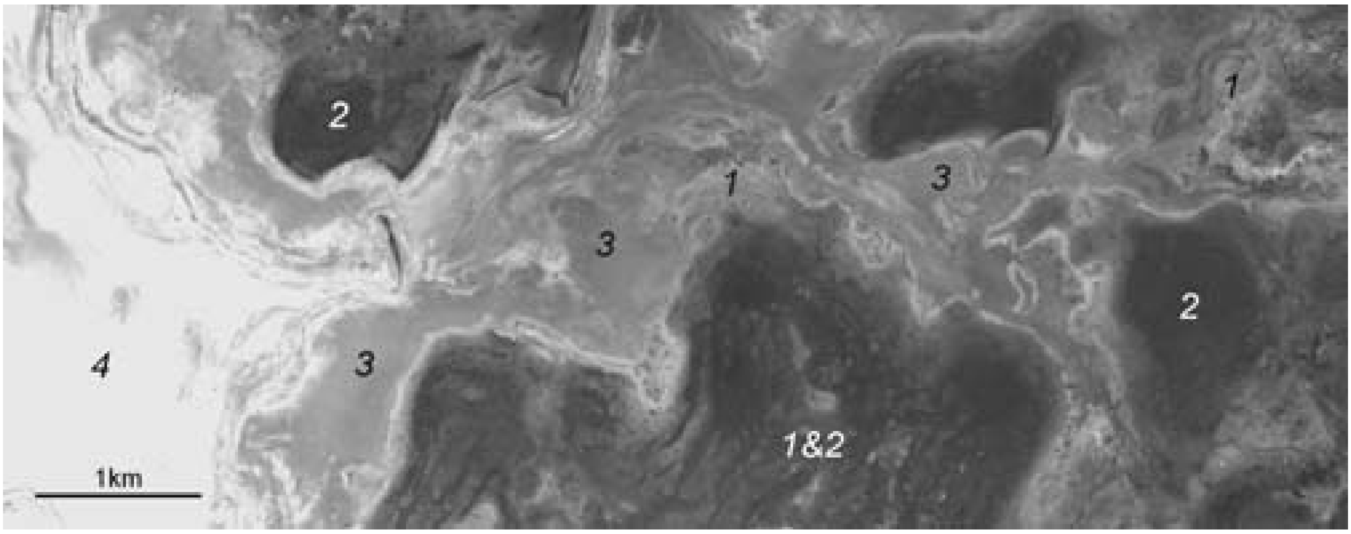
Geology: Quaternary lacustrine deposits of saline sand, silt and clay, and eolian sand.

Geomorphology: Depositional surfaces; salt lakes with bare surfaces, fringing samphire flats with shallow channels and flow lines, slightly more elevated saline plains and irregular sandy banks and islands. Relief up to 5 m.

Land management: Chenopod low shrubs on saline plains (unit 1) are preferentially grazed by livestock and are prone to decline if stocking is uncontrolled. Saline plains and some lake margins have slight to moderate susceptibility to erosion.

Traverse condition summary: (6 assessments)
Vegetation - good 34%, fair 33%, poor 33%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.



No.	Unit name	Traverse recordings	Inventory sites
1.	Saline plain	5	-
2.	Sandy bank and island	-	-
3.	Samphire flat and lake margin	1	1
4.	Salt lake bed	-	-
	Total	6	1

Weelarrana land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	20%	**Saline plains** - level plains up to 2 km in extent mostly on outer margins of system, surface mantles of ironstone gravel and grit of variable abundance.	Red loamy earths (544), red deep sandy duplex (405) and red deep loamy duplex (506) soils.	Very scattered to scattered low shrublands with *Maireana pyramidata* (sago bush), *Atriplex vesicaria* (bladder saltbush) and *Frankenia* spp. (frankenia), (PXHS) or tall shrublands of *Acacia aneura* (mulga) with low shrubs as above (PMCS).
2.	20%	**Sandy banks and islands** - linear and irregular banks up to 1 km long and 200 m wide or islands up to 1.5 km in extent, raised up to 3 m above units 1 and 3; loose, hummocky surfaces.	Red deep sands (445).	Scattered shrublands with *Acacia aneura, Melaleuca* spp., *Eremophila forrestii* (Wilcox bush) with prominent *Triodia* spp. (hard spinifex) ground layer (SHSG).
3.	35%	**Samphire flats and lake margins** - level plains and lake margins raised up to 1 m above unit 4, soft saline surfaces.	Deep red/brown non-cracking clays (622).	Very scattered to scattered low shrublands of *Halosarcia* spp. (samphire) sometimes with patchy grasses such as *Eragrostis falcata* (sickle love grass) (PSPS).
4.	25%	**Salt lake beds** - level, bare saline surfaces extending for 3-4 km.	Saline, deep red/brown non-cracking clays (622).	No vegetation.

WHITE SPRINGS LAND SYSTEM (266 km^2, 0.1% of the survey area)

Stony gilgai plains supporting tussock grasslands and hard spinifex grasslands.

Land type: 9

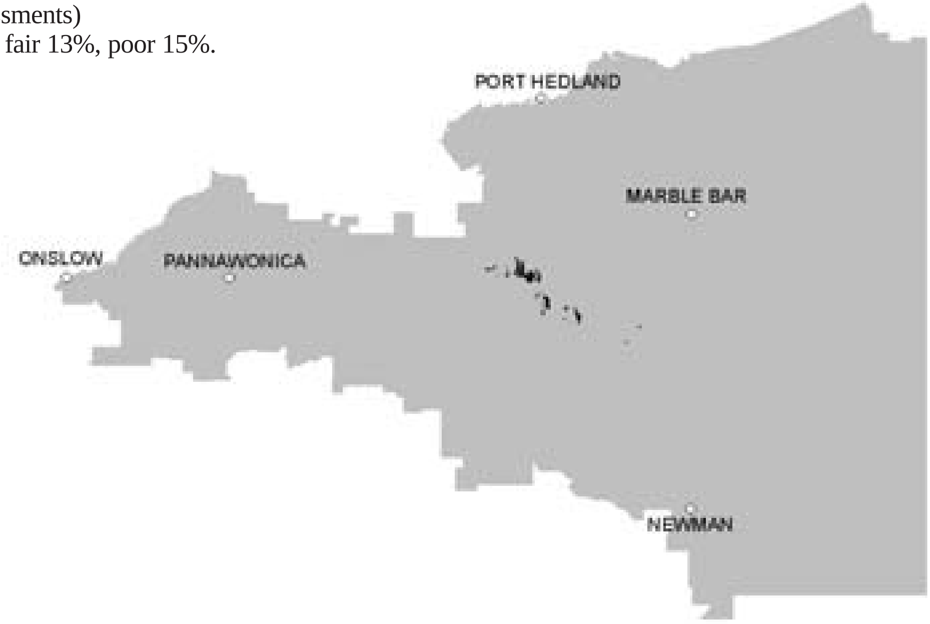
Geology: Quaternary eluvium, residual deposits of clay, basalt pebbles, cobbles and poorly consolidated gravel.

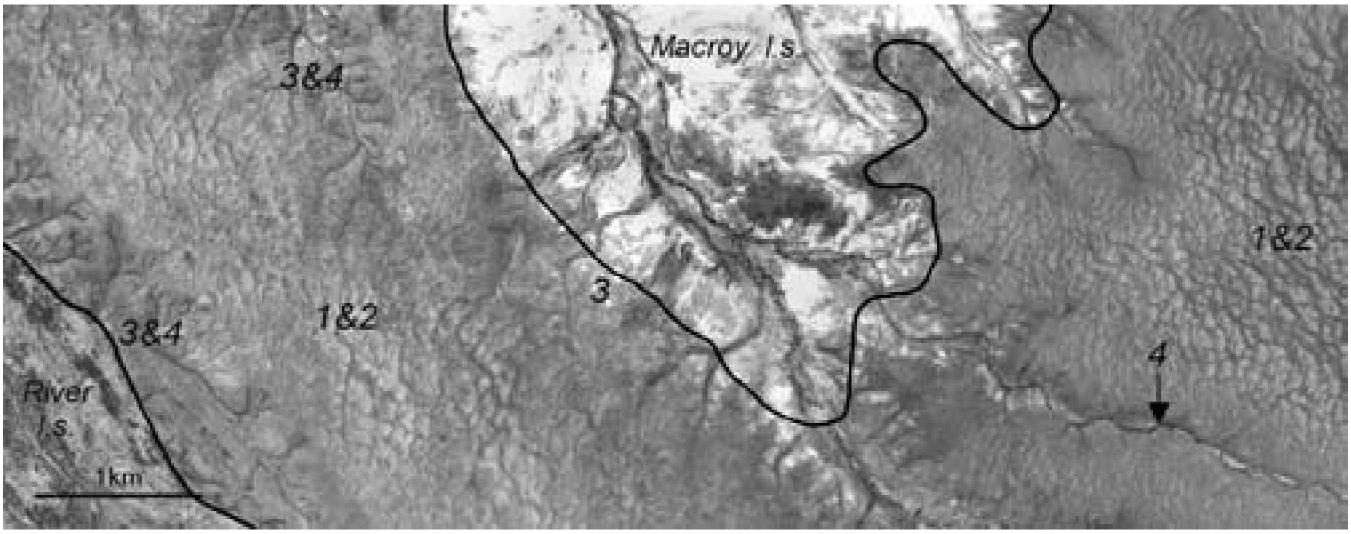
Geomorphology: Mostly depositional surfaces; residual plains with a mosaic of stony non-gilgaied and stony gilgaied surfaces, minor gilgai plains without stone mantles, low rises and short slopes on outer margins of the system. Drainage is internal or as short, dendritic, tributary patterns confined to the outer margins of the system. Relief up to 10 m.

Land management: Tussock grasslands on gilgai plains (unit 2) are preferentially grazed by livestock and other animals, and are prone to degrade if stocking is uncontrolled. Hard spinifex may tend to invade degraded tussock grass sites. The system is generally not susceptible to erosion.

Traverse condition summary: (52 assessments)
Vegetation - very good 55%, good 17%, fair 13%, poor 15%.
Soil erosion - nil 98%, minor 2%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Stony plain	27	2
2.	Gilgai plain	20	2
3.	Outer slope	5	2
4.	Drainage line	-	-
	Total	52	6

White Springs land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	52%	**Stony plains** - level or very gently inclined plains up to 2 km in extent or as much smaller patches in a mosaic with gilgai plains (unit 2); surface mantles of abundant to very abundant pebbles and cobbles of basalt.	Calcareous shallow loams (521).	Hummock grassland of *Triodia wiseana, T. plurinervata, T.* spp. (hard spinifex) with no or isolated shrubs (PHSG).
2.	38%	**Gilgai plains** - level plains up to 500 m in extent or as much smaller patches or somewhat linear arrangements with stony non-gilgaied surfaces (unit 1); surface mantles vary from very few to abundant pebbles of basalt.	Deep red/brown non-cracking clays (622), self-mulching cracking clays (602) and red loamy earths (544).	Tussock grasslands with *Eragrostis xerophila* (Roebourne Plains grass), *Astrebla pectinata* (barley Mitchell grass) and other perennial grasses with isolated to very scattered low shrubs such as *Senna artemisioides* subsp. *hamersleyensis* (creeping cassia) and *S. artemisioides* subsp. *oligophylla* (blood bush) (ARPG, BUTG).
3.	9%	**Outer slopes** - very gently inclined to gently inclined rounded slopes on outer margins of system, usually <750 m long; with numerous small dendritic drainage lines and minor channels.	Deep red/brown non-cracking clays (622).	Hummock grasslands of *Triodia wiseana, T. plurinervata* (hard spinifex) with very scattered to scattered shrubs (PHSG).
4.	1%	**Drainage lines** - narrow, dendritic drainage lines and minor channels usually associated with outer slopes (unit 3).	Shallow red/brown non-cracking clays (622) with channels of river bed soils (705).	Moderately close tall shrubland of *Acacia* spp. with spinifex understorey (DAHW).

WONA LAND SYSTEM (1,815 km2, 1.0% of the survey area)

(modified from Payne, Mitchell and Holman 1988)

Basalt upland gilgai plains supporting tussock grasslands and minor hard spinifex grasslands.

Land type: 9

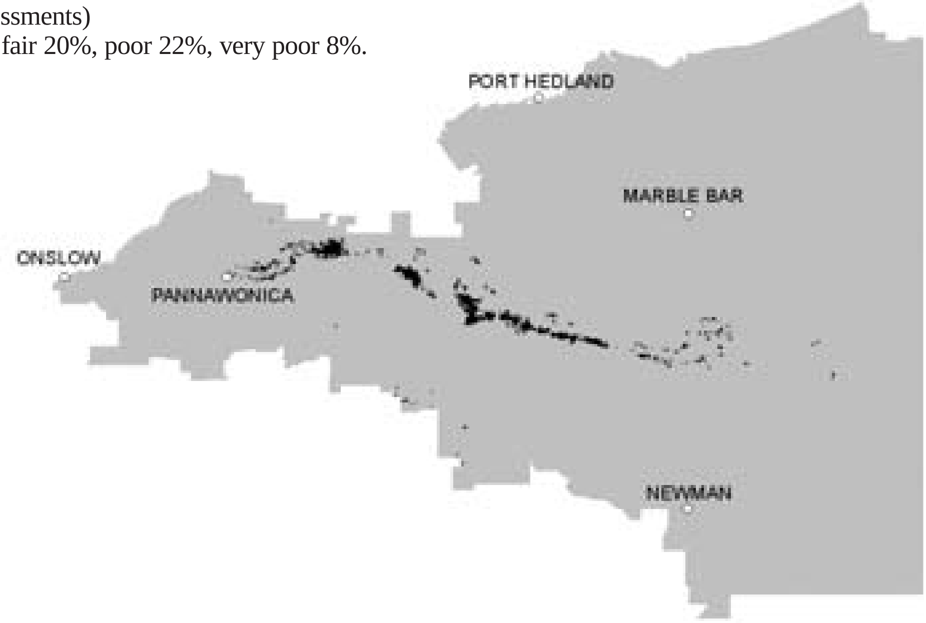
Geology: Lower Proterozoic basalt.

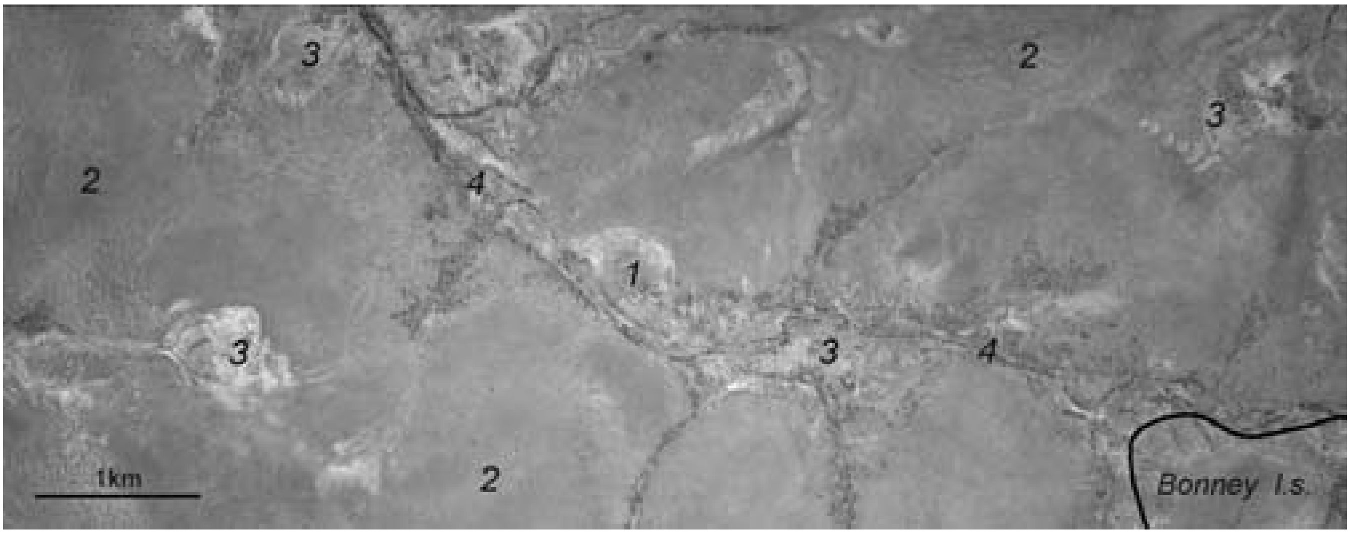
Geomorphology: Mainly erosional surfaces; basalt uplands and subdued plateaux with gently sloping stony gilgai plains, minor basalt hills and benched slopes; sparse patterns of incised drainage with narrow valleys and steep stony slopes. Relief up to about 30 m.

Land management: The system supports tussock grasses and annual grasses and forbs which are highly preferred by livestock and kangaroos. Tussock grasslands degrade to annual grasslands/herbfields if stocking is uncontrolled. The system is not susceptible to erosion except if the stony mantle is removed such as along tracks on sloping plains.

Traverse condition summary: (205 assessments)
Vegetation - very good 30%, good 20%, fair 20%, poor 22%, very poor 8%.
Soil erosion - nil 100%

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Low basalt hill	11	-
2.	Stony gilgai upland plain	135	6
3.	Stony plain and slope	55	5
4.	Drainage line	4	2
	Total	205	13

Wona land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	5%	**Low basalt hills** - isolated hills up to 20 m high and 500 m long, short gently to moderately inclined slopes, surface mantles of abundant or very abundant pebbles and cobbles of basalt.	Stony soils (203) and red shallow loams (522).	Hummock grasslands of *Triodia wiseana* (hard spinifex) with isolated to very scattered *Acacia* and *Senna* spp. shrubs (HSPG). Occasionally *Triodia pungens* (soft spinifex).
2.	70%	**Stony gilgai upland plains** - level to very gently inclined plains up to 4 km in extent, gilgai microrelief with surface mantles of many to very abundant pebbles and cobbles of basalt.	Self-mulching cracking clays (602) and some deep red/brown non-cracking clay (622).	Tussock grasslands with *Astrebla pectinata* (barley Mitchell grass), *A. elymoides* (weeping Mitchell grass), *Eragrostis xerophila* (Roebourne Plains grass), *Aristida latifolia* (feathertop three awn), *Eriachne* spp. (wire grass) and *Sida fibulifera* (creeping sida) (BUTG). Also patches of *Acacia xiphophylla* (snakewood) shrublands with understorey of tussock grasses as above and *Senna* spp. (SSTS).
3.	20%	**Stony plains and slopes** - very gently inclined plains and short gently inclined to steep benched slopes within unit 2 or at margins of unit 1 or leading to incised drainage (unit 4), surface mantles of abundant to very abundant pebbles and cobbles of basalt.	Deep red/brown non-cracking clays (622) and red loamy earths (544).	Hummock grasslands of *Triodia wiseana*, less frequently *T. pungens* with isolated to very scattered (occasionally denser) tall shrubs such as *Acacia inaequilatera* (kanji), *A. aneura* (mulga) and *A. xiphophylla* (PHSG, PSSG).
4.	5%	**Drainage lines** - narrow (<300 m wide), shallow drainage floors and small channels, also more incised channels to 15 m wide in narrow valleys with gently inclined to steep stony marginal slopes.	Red deep sandy duplex soils (405), red shallow loams (522) and shallow red/brown non-cracking clays (622).	Scattered to moderately close tall shrublands of *Acacia xiphophylla* or other acacias with patchy tussock grass understorey (SSTS).

YAMERINA LAND SYSTEM (1,207 km^2, 0.7% of the survey area)

Flood plains and deltaic deposits supporting tussock grasslands, grassy woodlands and minor halophytic low shrublands.

Land type: 17

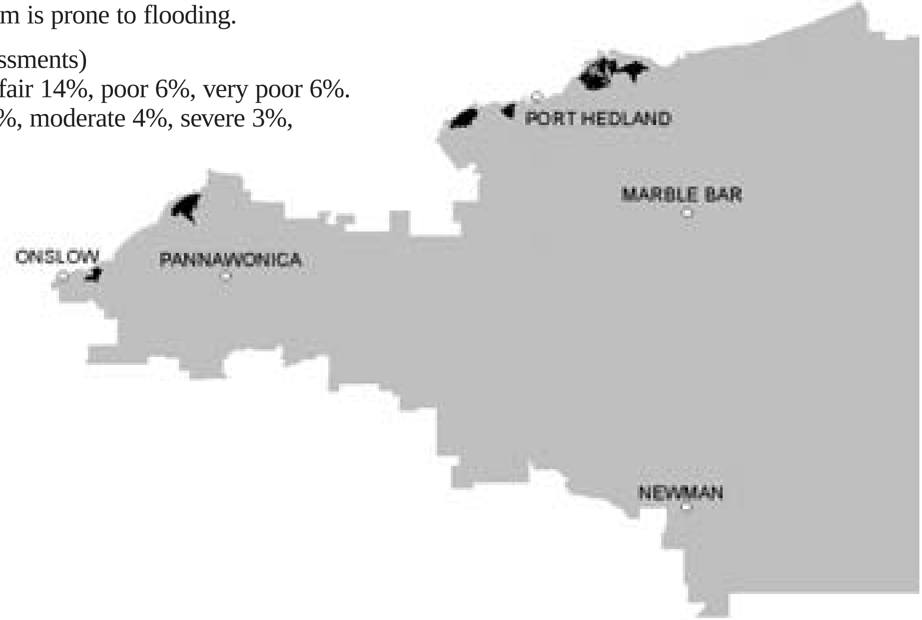
Geology: Quaternary alluvium.

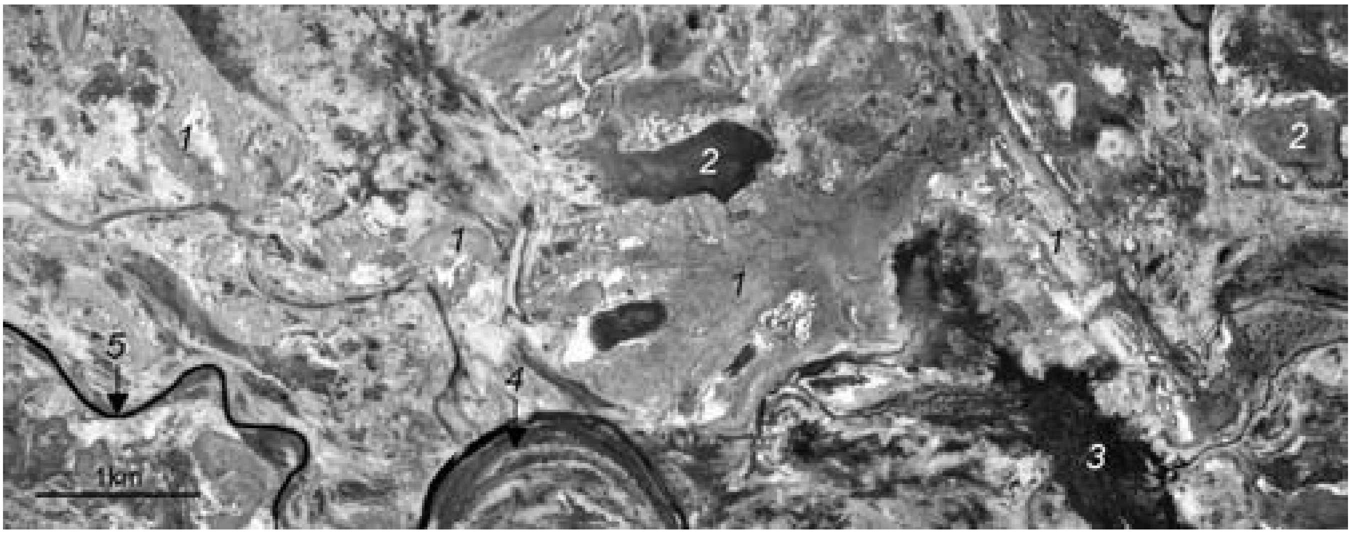
Geomorphology: Depositional surfaces; broad flood plains on non saline and saline alluvium, subject to sheet wash and overbank and channelled flow; gilgai back plains, swampy depressions and levees; sparse to widely spaced major channels in non-tributary and distributary patterns.

Land management: The system supports tussock grasses (including extensive areas of the introduced buffel grass) and saltbush shrubs which are highly preferred by grazing animals. The saltbush and native grasses are prone to degrade under uncontrolled stocking but buffel grass is resilient. Parts of the system have been invaded by mesquite forming dense shrublands with poor accessibility. The more saline parts of flood plains (unit 1) are highly susceptible to erosion if vegetative cover is lost. Much of the system is prone to flooding.

Traverse condition summary: (179 assessments)
Vegetation - very good 26%, good 48%, fair 14%, poor 6%, very poor 6%.
Soil erosion - nil 77%, slight 6%, minor 8%, moderate 4%, severe 3%, extreme 2%.

Area mapped as sde: 1,852 ha.





No.	Unit name	Traverse recordings	Inventory sites
1.	Flood plain	132	14
2.	Gilgai back plain	29	3
3.	Swampy depression	1	1
4.	Levee	8	-
5.	Channel	1	-
	Other	8	-
	Total	179	18

Yamerina land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	80%	**Flood plains** - level plains extending for up to 10 km, subject to fairly regular flooding from localised run-on, overbank flow and channelled flow; surface mantles absent to few, occasionally with weakly gilgaied microrelief; also scalded, puffy and mounded surfaces.	Red deep loamy duplex soils (506) and red loamy earths (544). Some red deep sandy duplex soils (405).	(i) About 68% of the unit supports patchy tussock grasslands with *Cenchrus ciliaris* (buffel grass) and/or *Eragrostis xerophila* (Roebourne Plains grass) and other grasses with very scattered tall shrubs such as *Acacia victoriae* (prickly acacia) (APBG, APXG). Some extensive areas have been invaded by *Prosopis* spp. (mesquite) which forms moderately close tall shrublands with grassy understoreys. Also scattered to moderately close woodlands of *Eucalyptus victrix* (coolibah) with *Cenchrus ciliaris* understorey (AEBW). (ii) About 17% of the unit supports very scattered to scattered low shrublands of *Atriplex bunburyana* (silver saltbush) with tussock grasses *C. ciliaris* and/or *Eragrostis xerophila* (PCGS). (iii) About 15% of the unit supports hummock grasslands of *Triodia secunda* (hard spinifex), *T. pungens* (soft spinifex) and isolated shrubs such as *Sclerolaena hostilis* (giant bindii) (AHSG, ASSG).
2.	14%	**Gilgai back plains** - level plains extending for up to 1.5 km, gilgai microrelief, surface mantles absent or few pebble of ironstone.	Self-mulching cracking clays (602) and deep red/brown non-cracking clays (622).	Tussock grasslands with *Eragrostis xerophila* and *Eriachne benthamii* (swamp grass) (ARPG, APXG, APSG).
3.	2%	**Swampy depressions** - level internal drainage foci, roughly circular or oval in shape and up to 500 m in extent.	Deep red/brown non-cracking clays (622).	Moderately close to close woodlands with *Eucalyptus camaldulensis* (river red gum), *Acacia ampliceps* (black wattle) and grasses such as *Eriachne benthamii* and *Sporobolus virginicus* (salt water couch) (DEGW).
4.	2%	**Levees** - sandy or loamy surfaced levees up to 1 km wide flanking major channels (unit 5), rounded crests raised up to 4-5 m above adjacent flood plains (unit 1).	Red sandy earths (463) and red loamy earths (544).	Tussock grasslands of *Cenchrus ciliaris, Chrysopogon fallax* (ribbon grass) with very scattered trees and shrubs (APBG) or scattered woodlands of *Eucalyptus victrix* with same grasses as understorey (AEBW).
5.	2%	**Channels** - major river channels up to 500 m wide with steep banks up to 15 m higher than channel beds, semi-permanent river pools in places.	River bed soils (705).	Channel beds mostly with no vegetation. Margins and banks support fringing woodlands with *Eucalyptus camaldulensis, E. victrix* and *Melaleuca* spp. (paper bark) often with *Cenchrus ciliaris* understorey (GMEW).

ZEBRA LAND SYSTEM (374 km^2, 0.2% of the survey area)

Hardpan plains with large linear gravelly sand banks supporting acacia shrublands with soft and hard spinifex.

Land type: 12

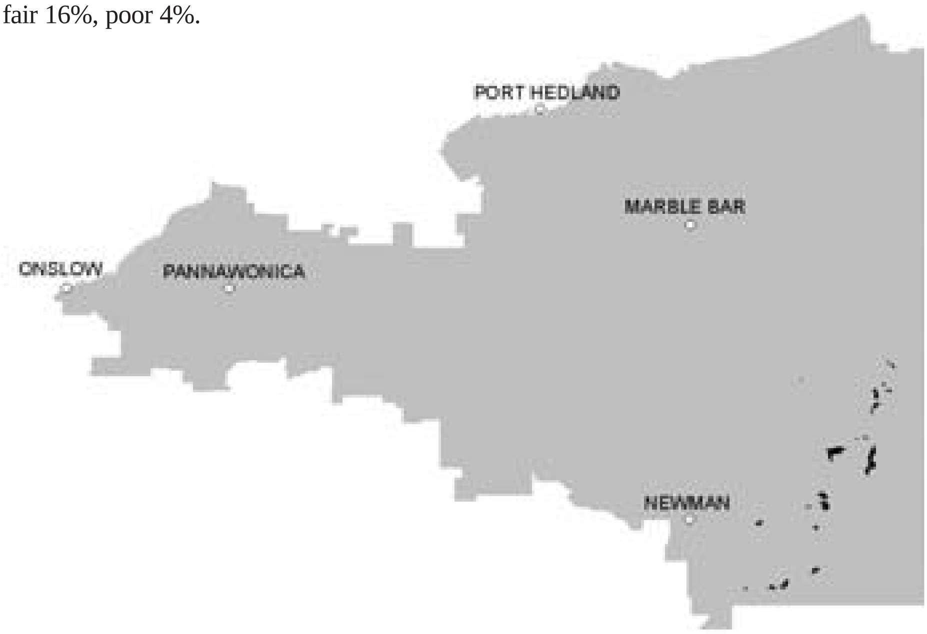
Geology: Quaternary colluvium, eluvium and alluvium - partly ferruginised clay, silt, sand and gravel.

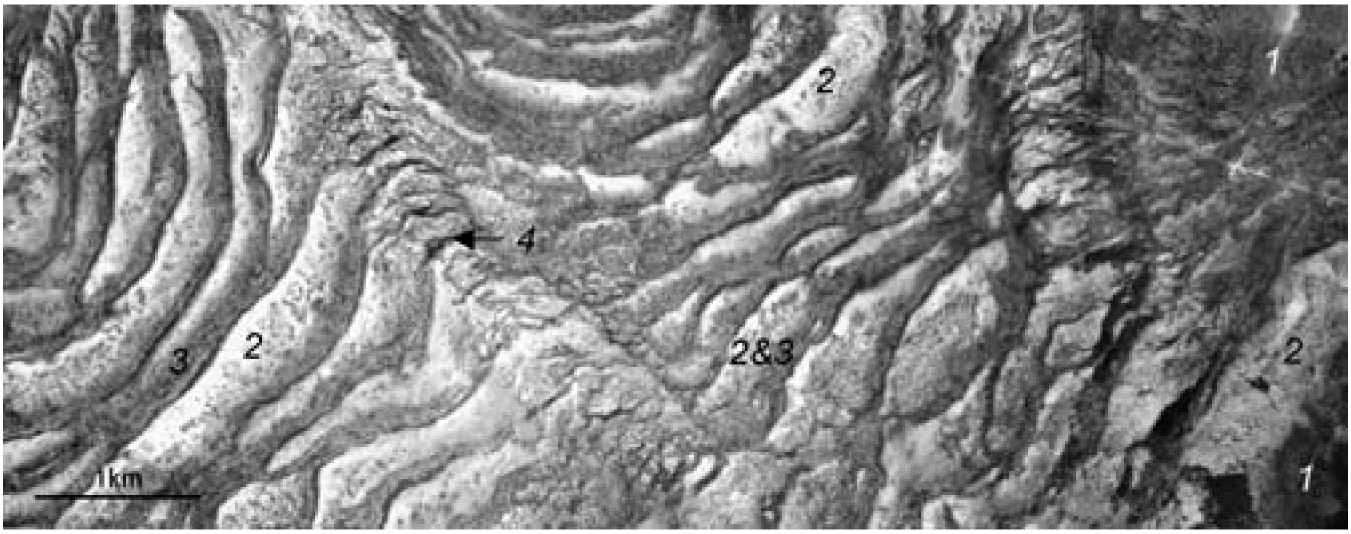
Geomorphology: Depositional surfaces; level alluvial hardpan plains subject to overland sheet flow, linear sandy banks extending up to several kilometres and arranged with long axes at right angles to direction of sheet flow, minor gravelly plains and occasional groves; no channelled drainage. Relief up to 5 m.

Land management: Some low shrubs on the system are moderately preferred by grazing animals and are prone to decline if grazing pressure is excessive. The system is generally not prone to erosion.

Traverse condition summary: (55 assessments)
Vegetation - very good 31%, good 49%, fair 16%, poor 4%.
Soil erosion - nil 100%.

Area mapped as sde: Nil.





No.	Unit name	Traverse recordings	Inventory sites
1.	Gravelly plain	6	-
2.	Hardpan plain	29	3
3.	Sandy bank and sand sheet	17	1
4.	Grove	2	2
	Other	1	-
	Total	55	6

Zebra land system

Unit	Area (%)	Landform	Soil	Vegetation
1.	10%	**Gravelly plains** - level plains up to 1 km in extent, subject to overland sheet flow; surface mantles of abundant to very abundant pebbles of ironstone.	Red shallow loams (522).	Very scattered shrublands with *Acacia aneura* (mulga), other acacias, *Eremophila* spp. and patchy *Triodia* spp. (hard and soft spinifex) (PMSS).
2.	54%	**Hardpan plains** - level plains up to 750 m in extent and inter-bank areas 100-300 m wide between gravelly sand banks (unit 3), subject to overland sheet flow; surface mantles of few to abundant pebbles of ironstone.	Red-brown hardpan shallow loams (523) with some red loamy earths (544).	Very scattered (occasionally scattered) mixed height shrublands with *Acacia aneura*, other acacias, *Eremophila* spp. and *Ptilotus schwartzii* (horse mulla mulla) (HPMS, LHAS); occasionally with *Triodia* sp. (hard spinifex) ground layer (PMSS).
3.	33%	**Sandy banks and sand sheets** - linear or reticulate sandy banks up to 3.5 km long and 200 m wide on hardpan plains (unit 2) arranged with long axes at right angles to direction of sheet flow, also patches of sand sheet up to 1 km in extent; surface mantles of ironstone grit and gravel.	Red deep sands (445) and red sandy earths (463).	Scattered tall shrublands of *Acacia aneura* and *A. catenulata* with sparse *Eremophila* spp. and other low shrubs and prominent *Triodia pungens* (soft spinifex) ground layer (SBAS).
4.	3%	**Groves** - drainage foci up to 600 m long by 50 m wide but commonly much smaller, long axes at right angles to direction of sheet flow, receiving run-on from adjacent hardpan plains (unit 2).	Red loamy earths (544).	Moderately close to closed tall shrublands/woodlands of *Acacia catenulata* and *A. aneura* with numerous low shrubs and occasional tussock grasses or *Triodia pungens* (GMUW).

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Resource condition

A.M.E. Van Vreeswyk

The condition of the vegetation and soils in the survey area was assessed during field work. Traditionally, resource condition assessment in rangelands has focused on the use of land for pastoralism. In this report an attempt has been made to broaden this perspective by assessing, while traversing, the effects of other factors (such as fire, weed incursions, mining disturbance) as well as grazing on ecological integrity. This will increase the relevance of this report beyond the pastoral industry, while still being amenable to pastoral interpretation.

Summary of traverse assessments

As indicated in the Methodology chapter, traverse assessments were used to assess resource condition in the survey area. At one kilometre intervals along pre-selected traverse routes, the condition of the perennial vegetation, and the type and extent of accelerated erosion was assessed within an area of 50 m radius around the vehicle. These assessments were visual subjective ratings. The rating system is fully described in the Methodology chapter.

A total of 12,827 traverse points were described and assessed for various biophysical parameters. Vegetation condition, and the type and the extent of soil erosion were assessed at 12,445 of these points and are summarised in Tables 1, 2 and 3.

A total of 88.5% of all traverse assessments indicated that vegetation was in the very good, good or fair categories. This may be regarded as acceptable condition. The remaining 11.5% indicated poor or very poor condition vegetation, with either considerable loss of palatable perennial plants or general loss of perennial plants, or, in some cases, marked increases in cover by unpalatable species ('woody weeds').

Table 1. Summary of vegetation condition derived from traverse assessments

Perennial vegetation condition	Proportion (%) of traverse assessments
Very good	60.2
Good	17.1
Fair	11.2
Poor	8.1
Very poor	3.4

Accelerated erosion was recorded at 6.5% of the traverse assessments: 5.3% of assessments indicated slight, minor or moderate erosion (i.e. <50% of the surface affected) and 1.2% showed severe or extreme erosion (>50% of the surface affected). Most of the accelerated erosion was caused by water, rather than wind. Scalding and sheeting were the most common types of erosion observed.

Table 2. Summary of accelerated soil erosion derived from traverse assessments

Extent of erosion	Proportion (%) of traverse assessments
Nil	93.5
Slight	1.6
Minor	2.1
Moderate	1.6
Severe	0.8
Extreme	0.4

Table 3. Summary of the dominant types of accelerated erosion recorded in traverse assessments

Type of erosion	Proportion (%) of traverse assessments
Nil	93.5
Scalding/capping	3.4
Microterracing/sheeting	2.2
Rilling/guttering	0.6
Guttering/gullying	0.2
Accelerated accretion of soil material	0.1

Patterns of soil and vegetation condition

Vegetation condition and soil erosion are often closely related. Decline in vegetation condition involving decreases in total shrub or grass cover means that soil surfaces are increasingly unprotected from the effects of wind and water. Erosion is likely to commence (unless the surface is inherently resistant) and to accelerate if vegetation condition continues to decline. However, in some instances of substantial grazing impact, vegetation succession is to dense 'woody weeds' becoming established, which will enhance soil stability. Table 4 shows the association between soil erosion and vegetation condition as seen during the survey.

Table 4. Average vegetation condition scores for classes of extent of soil erosion

Soil erosion	Average vegetation condition
Nil	1.6
Slight	3.1
Minor	3.6
Moderate	4.1
Severe	4.7
Extreme	4.9

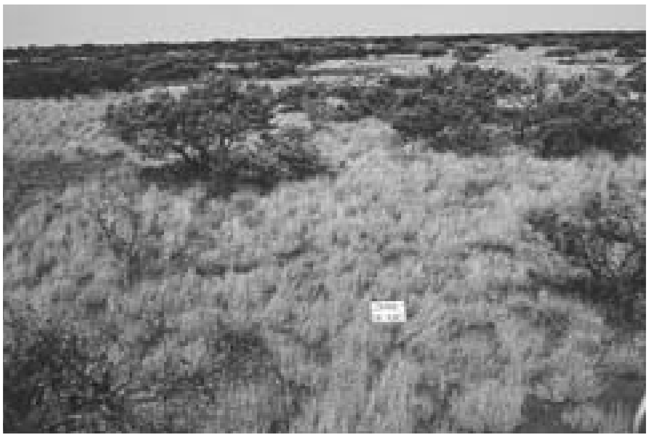
where 1 = very good condition, 2 = good, 3 = fair, 4 = poor and 5 = very poor

Good condition areas

Figure 1 shows the distribution of traverse assessments of very good and good vegetation condition with no soil erosion. A large proportion of these points occurred in site types which are largely unaltered by grazing, such as hard spinifex grasslands.

Pringle (1995) used the inventory information gathered during the north-eastern Goldfields survey (Pringle, Van Vreeswyk and Gilligan 1994) to assess the representativeness of the conservation reserve network in the area. The condition component of rangeland survey findings can be used to identify areas which are in good resource condition and thus are most suitable for reservation for conservation purposes.

Areas which could be used as references for grazing management can also be identified using the survey findings. These areas are important in providing reference data for land managers, researchers and administrators. Blood (1995) examined the findings of the Murchison rangeland survey (Curry *et al.* 1994) to identify, describe and map areas of rangeland in good condition within that region.



This grassy snakewood (Acacia xiphophylla) *shrubland is in good condition. Plant diversity is high, the density and vigour of perennial grasses is near potential and there is no soil erosion.*

Poor condition areas

Figure 2 shows the distribution of traverse assessments of poor and very poor vegetation condition. In regional terms the areas most adversely impacted by grazing are along the Fortescue River valley (tussock grass and mulga communities), in the south-east on hardpan plains, stony plains and alluvial plains (mulga, tussock grass and halophytic shrubland communities) and on the coast in the west (tussock grass and snakewood/halophytic shrub communities). To a lesser extent some alluvial plains along the major rivers (e.g. the De Grey in the north-east) show adverse impacts (tussock grass and some soft spinifex communities).

Severely degraded and eroded areas

Areas of eroded soil surfaces larger than 40 ha in extent have been identified and mapped as being severely degraded and eroded (sde). These areas usually have little or no perennial vegetation remaining. They were interpreted from aerial photographs, and, in nearly all cases, the extent verified in the field. The distribution of severely degraded and eroded areas in the survey area is shown in Figure 3 and on the land system map accompanying this report. The area totals about 310.2 km^2 which represents 0.17% of the survey area.

Severely degraded and eroded areas were identified in 25 of the 102 land systems, representing 10 of the 20 land types (see Table 5). The land types with more than 1% severely degraded and eroded land are those characterised by alluvial plains with snakewood shrublands (land type 15) and river plains with grassy woodlands and shrublands, and tussock grasslands (17). Land types with 0.5 to 1% severely degraded and eroded land were alluvial plains with tussock grasslands or grassy shrublands (14), alluvial plains with soft spinifex grasslands (13) and wash plains on hardpan with mulga shrublands (12).

Severely degraded and eroded land was also identified in land types with salt lakes and fringing alluvial plains (20), coastal plains, dunes, mudflats and beaches (19), stony plains and low hills with spinifex grasslands (6), sandy plains with spinifex grasslands (11) and stony plains with acacia shrublands (10).

Severely degraded and eroded areas are generally not found in land types characterised by hills and ranges (land types 1 and 2), plateaux and breakaways (3 and 4), dissected plains (5), stony plains and low hills with acacia shrublands and with spinifex grasslands (7 and 8), stony gilgai plains (9), alluvial plains with halophytic shrublands (16) or calcreted drainage plains (18).

Table 5. The extent of severely degraded and eroded land (sde) within each land type

Land type	Area (km^2)	Area (%)	sde (ha)	sde (%)
1	58,369	32.12	0	0
2	739	0.41	0	0
3	7,488	4.12	0	0
4	432	0.24	0	0
5	4,270	2.35	0	0
6	3,059	1.68	156	0.05
7	1,390	0.76	0	0
8	24,978	13.74	100	<0.1
9	2,081	1.15	0	0
10	2,583	1.42	0	0
11	40,466	22.27	0	0
12	9,190	5.06	5,730	0.62
13	5,347	2.94	4,434	0.83
14	4,619	2.54	4,170	0.90
15	1,795	0.99	2,825	1.57
16	383	0.21	239	0.62
17	8,182	4.50	11,418	1.40
18	1,799	0.99	0	0
19	3,319	1.83	1529	0.46
20	1,024	0.56	415	0.41
Other	210	0.12	0	0
Totals	181,723		31,016	0.17

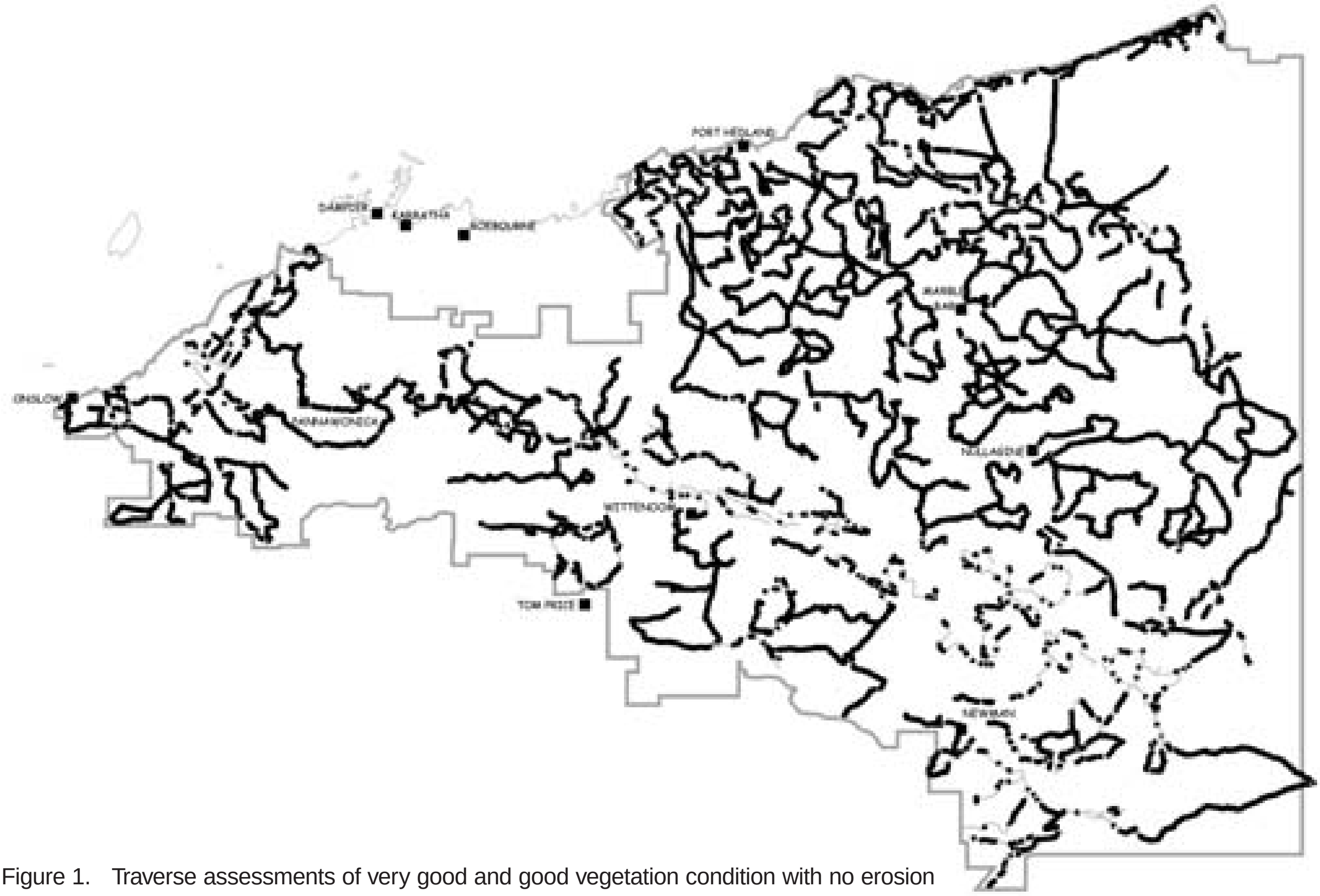


Figure 1. Traverse assessments of very good and good vegetation condition with no erosion

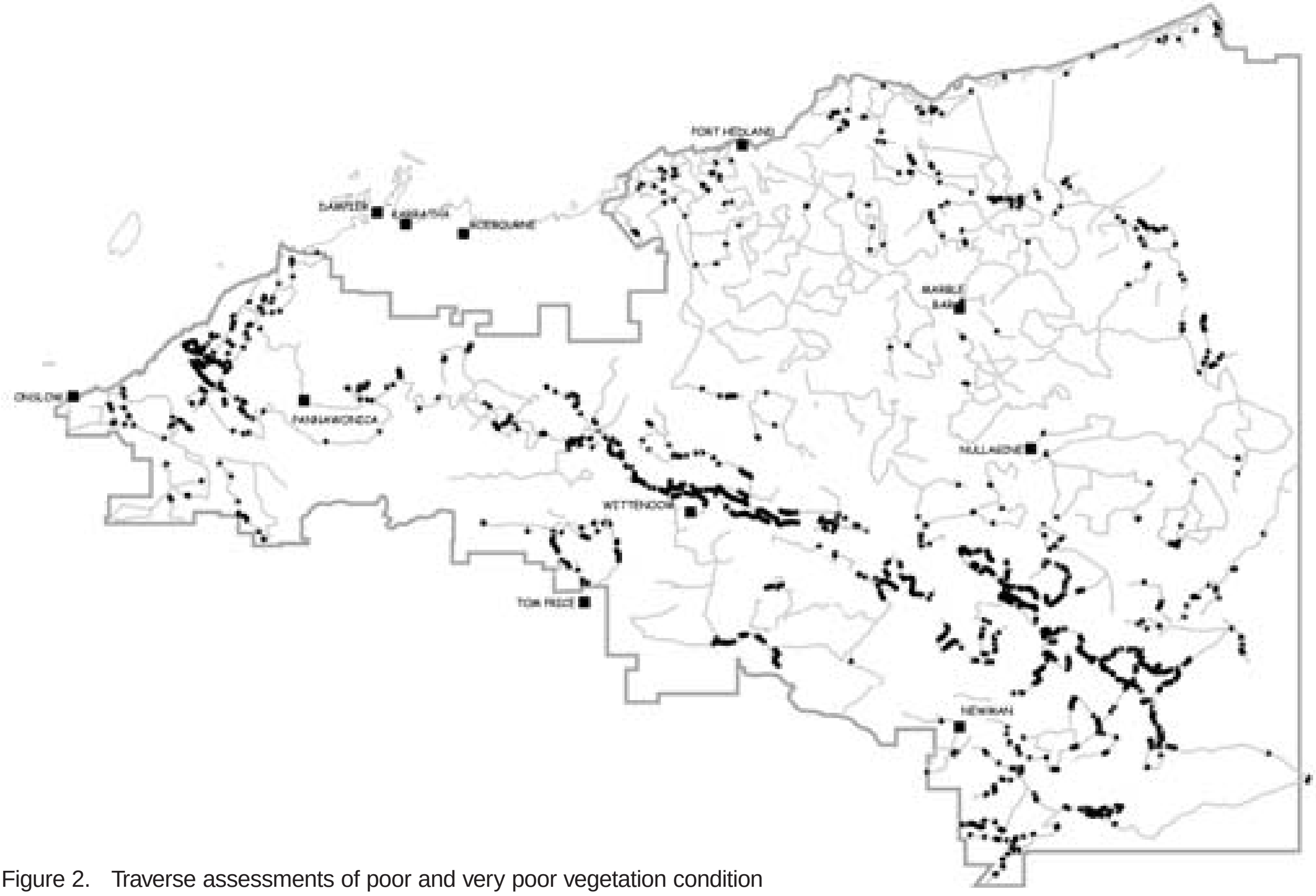


Figure 2. Traverse assessments of poor and very poor vegetation condition

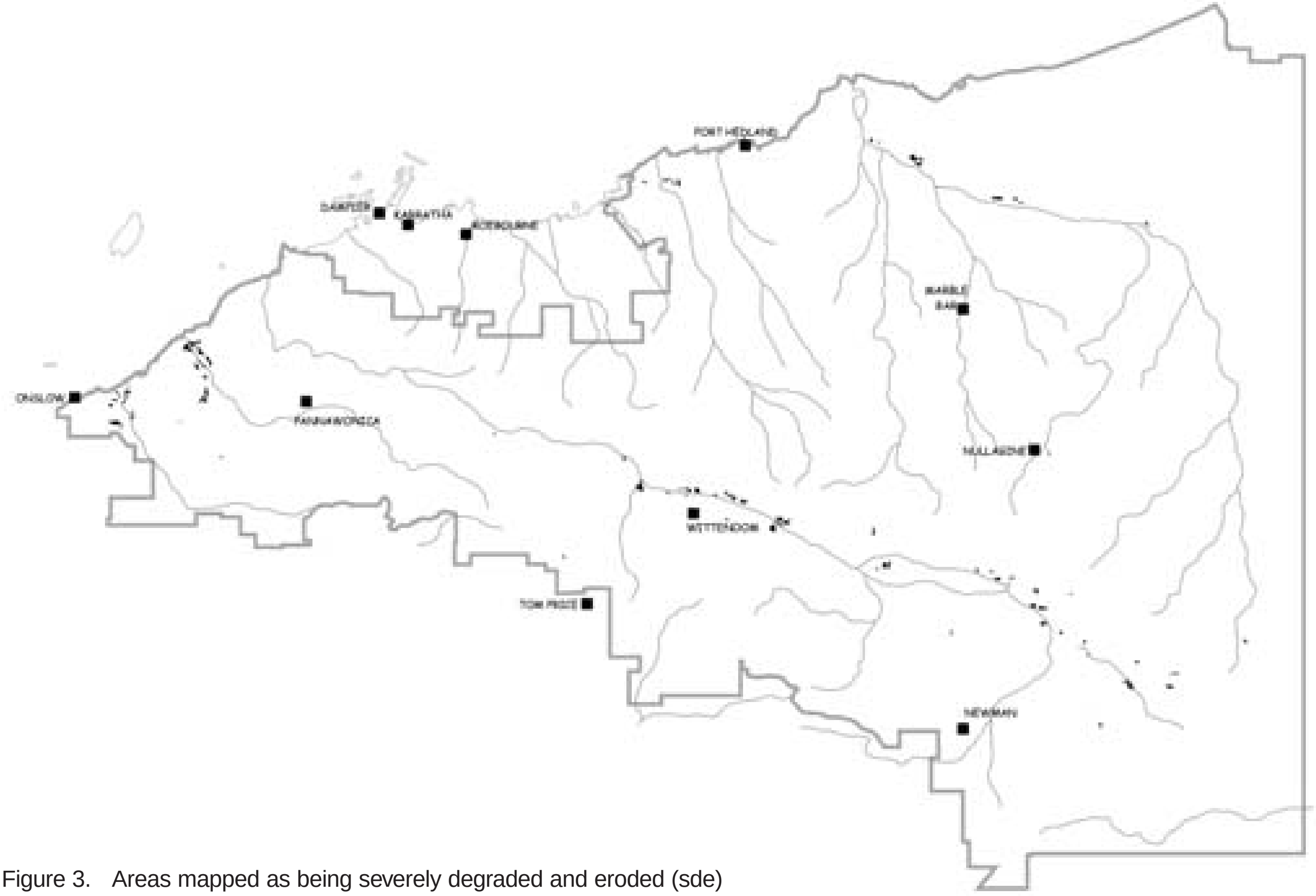


Figure 3. Areas mapped as being severely degraded and eroded (sde)

This drainage floor of the Mosquito land system is considerably degraded. The duplex soils have been eroded to expose the sub-soil. A few saltbushes <u>(Atriplex spp.)</u> *survive on remnant soil patches.*

Comparison with other regional surveys

Table 6 shows a summary of the resource condition in the survey area compared with other surveys undertaken by the Department of Agriculture and the Department of Land Information. 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 7.

The Pilbara survey area is in considerably better condition than all other survey areas. Also the proportion of land which has been mapped as being severely degraded and eroded (about 0.2%) is considerably less than the proportion of severely degraded and eroded land across all survey areas. A large proportion of the Pilbara supports spinifex grasslands which are largely unaltered by grazing. A significant area is not used for pastoralism because it is inaccessible to stock and supports hard spinifex grasslands which are not grazed.

Condition of land systems

The average number of traverse assessments for soil and vegetation condition per land system is 127, however, this varies between 0 and 1,502. Table 3 in the Land systems chapter shows the sampling intensity for each system. Augustus, Collier, Lochinvar and Roebuck were not traversed. Cundelbar, Giralia, Gregory, Kumina, Pyramid, Table, Talawana and Three Rivers were assessed less than five times; for these land systems sampling intensity is too low for reasonable comparisons with other systems.

Table 8 shows the extent of severely degraded and eroded land mapped in each land system and Table 9 shows the condition of perennial vegetation and the extent of soil erosion for each land system based on traverse assessments.

Cane, Christmas and Turee land systems have the highest proportion (7.10%, 5.34% and 3.62% respectively) of severely degraded and eroded land. These land systems are highly susceptible to erosion because they consist of plains

Table 6. Resource condition summaries for regional rangeland surveys

Region surveyed (and year commenced)	Total area (km^2)	No. of traverse assessments	Severely degraded and eroded area (as mapped)		Resource condition classes (% of traverse assessments)		
			km^2	%	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
All areas surveyed	844,079	74,757	7,086	0.8	44	31	25

* Not mapped, estimate only.

Table 7. 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)

which are subject to run-on, have inherently susceptible soils with surfaces which are not generally protected by stony mantles and support vegetation which is subject to preferential grazing.

Other land systems with more than 2% severely degraded and eroded areas were Coolibah, Cowra, Jurrawarrina and Paradise. These systems also support vegetation which is preferentially grazed by stock and are dominated by soils which are inherently susceptible to erosion.

The average resource condition score for each of the land systems which were sufficiently traversed was derived as follows: Average resource condition score = [(% of traverese records in good resource condition x1) + (% of traverse records in fair resource condition x2) + (% of traverse records in poor resource condition x3)] ÷ 100. Table 10 shows these land systems ranked according to their average resource condition score.

Of the 91 land systems sufficiently traversed, 59 were closest to good resource condition (average score between 1.0 and 1.5), 30 were closest to fair condition (average score between 1.5 and 2.5) and 2 were closest to poor condition (average score between 2.5 and 3).

Condition of land systems according to pastoral potential

Land systems were grouped according to their pastoral potential (Table 11). This is discussed in the companion report on pastoral management in the survey area (Van Vreeswyk, Payne and Leighton 2004). The average resource condition score for the groups is summarised in Table 12.

The land of moderately high pastoral potential was in the worst resource condition and had the highest proportion of severely degraded and eroded land (sde). The moderately high and high pastoral potential groups were on average closest to fair condition and had 1.12% of their combined areas identified as severely degraded and eroded. The very high, moderate, low and very low pastoral potential groups were on average closest to good condition. The moderate and low pastoral potential groups had less than 0.1% severely degraded and eroded land and the very low pastoral potential group had no significant areas of severely degraded and eroded land.

The very high pastoral potential group was on average in better resource condition than the high and moderately high groups. This reflects the resilience of the vegetation on the very high pastoral potential land systems Anna, Eighty Mile and Yamerina. These systems support extensive area of the introduced buffel and Birdwood grasses (*Cenchrus* spp.) which are relatively resistant to grazing. Land systems in the moderately high and high groups often have fragile soils which are inherently susceptible to erosion, and support native tussock grasses which are more sensitive to grazing than the *Cenchrus* grasses.

Table 8. The extent of severely degraded and eroded land (sde) within each land system

Land system	Area (ha)	sde (ha)	sde (%)
Adrian	23,465	0	0
Anna	59,848	0	0
Augustus	6,134	0	0
Balfour	148,042	0	0
Billygoat	223,455	0	0
Black	16,516	0	0
Bonney	75,343	0	0
Boolaloo	150,183	0	0
Boolgeeda	774,790	0	0
Brockman	73,489	442	0.60
Buckshot	277,985	0	0
Cadgie	49,521	0	0
Calcrete	144,391	0	0
Callawa	100,266	0	0
Cane	81,207	5,768	7.10
Capricorn	529,617	0	0
Charley	21,841	0	0
Cheerawarra	19,701	0	0
Christmas	23,186	1,238	5.34
Collier	16,891	0	0
Coolibah	101,381	2,582	2.55
Coongimah	324,383	0	0
Cowra	20,295	624	3.07
Cundelbar	3,716	0	0
Divide	529,266	0	0
Dollar	8,743	0	0
Dune	13,846	0	0
Egerton	46,575	0	0
Eighty Mile	35,232	497	1.41
Elimunna	61,737	0	0
Fan	148,172	331	0.22
Ford	8,482	0	0
Fortescue	50,388	221	0.44
Giralia	6,637	0	0
Granitic	401,990	0	0
Gregory	11,289	0	0
Hooley	59,001	963	1.63
Horseflat	126,061	1,389	1.10
Houndstooth	42,667	0	0
Jamindie	207,423	1,927	0.93
Jigalong	71,314	995	1.40
Jurrawarrina	66,416	2,124	3.20
Kanjenjie	15,158	0	0
Kumina	15,083	0	0
Laterite	35,468	0	0
Lime	5,044	0	0
Little Sandy	1,328,287	0	0
Littoral	157,712	260	0.16
Lochinvar	28,724	0	0
Macroy	1,309,544	0	0
Mallina	255,729	83	0.03
Mannerie	18,986	0	0
Marandoo	45,948	0	0
Marillana	41,862	0	0
Marsh	97,667	415	0.42
McKay	420,246	0	0
Mosquito	184,022	156	0.08
Nanutarra	69,745	0	0
Narbung	15,948	0	0
Newman	1,457,984	0	0
Nirran	16,272	0	0
Nita	1,124,978	0	0
Nooingnin	89,771	0	0
Oakover	152,875	0	0
Onslow	42,432	772	1.82
Paraburdoo	56,506	0	0
Paradise	147,864	4,351	2.94
Paterson	81,782	0	0
Peedamulla	58,727	0	0
Pindering	35,088	0	0
Platform	156,990	0	0
Prairie	122,060	0	0
Pullgarah	56269	240	0.43
Pyramid	14,195	0	0
River	408,842	0	0
Robe	86,460	0	0
Robertson	271,437	0	0
Rocklea	2,299,251	0	0
Roebuck	3,076	0	0
Ruth	34,575	0	0
Satirist	37,677	0	0
Sherlock	19,242	0	0
Spearhole	126,957	0	0
Stuart	179,408	100	0.06
Sylvania	107,701	0	0
Table	7,724	0	0
Talga	212,429	0	0
Talawana	16,093	239	1.49
Tanpool	6,843	0	0
Taylor	12,945	0	0
Three Rivers	8,790	0	0
Turee	58,055	2,099	3.62
Uaroo	768,141	0	0
Urandy	131,115	0	0
Wannamunna	57,711	0	0
Warri	30,494	0	0
Washplain	91,674	1,348	1.47
Weelaranna	4,749	0	0
White Springs	26,564	0	0
Wona	181,540	0	0
Yamerina	120,670	1,852	1.54
Zebra	37,436	0	0
Mining	4,877		
Totals	18,172,327	31,016	0.17

Table 9. The condition of perennial vegetation and extent of soil erosion on each land system (derived from traverse assessments)

Land system	No. of assessments	Condition of perennial vegetation (%)			Extent of soil erosion (%)			
		Good or very good	Fair	Poor or very poor	Nil	Slight or minor	Moderate	Severe or extreme
Adrian	15	86	7	7	100	0	0	0
Anna	140	81	14	5	98	1	1	0
Augustus	0	-	-	-	-	-	-	-
Balfour	221	39	24	37	87	8	4	1
Billygoat	269	94	3	3	100	0	0	0
Black	12	92	8	0	100	0	0	0
Bonney	122	95	4	1	100	0	0	0
Boolaloo	71	100	0	0	100	0	0	0
Boolgeeda	596	95	4	1	100	0	0	0
Brockman	149	45	21	34	89	5	5	1
Buckshot	91	98	1	1	100	0	0	0
Cadgie	24	100	0	0	100	0	0	0
Calcrete	177	89	8	3	99	1	0	0
Callawa	19	100	0	0	100	0	0	0
Cane	129	42	18	40	45	21	14	20
Capricorn	138	98	2	0	100	0	0	0
Charley	12	67	33	0	100	0	0	0
Cheerawarra	29	68	14	18	90	3	7	0
Christmas	49	6	27	67	86	4	6	4
Collier	0	-	-	-	-	-	-	-
Coolibah	182	23	17	60	72	11	10	7
Coongimah	130	97	2	1	99	1	0	0
Cowra	37	35	40	25	87	10	3	0
Cundelbar	3	67	0	33	67	33	0	0
Divide	177	94	3	3	98	1	0	1
Dollar	17	70	18	12	100	0	0	0
Dune	22	95	5	0	100	0	0	0
Egerton	19	100	0	0	100	0	0	0
Eighty Mile	80	93	6	1	100	0	0	0
Elimunna	84	39	35	26	99	1	0	0
Fan	140	24	31	45	84	10	5	1
Ford	7	14	57	29	100	0	0	0
Fortescue	111	27	23	50	65	20	9	6
Giralia	4	100	0	0	100	0	0	0
Granitic	113	99	1	0	100	0	0	0
Gregory	4	50	50	0	100	0	0	0
Hooley	121	41	26	33	91	4	1	4
Horseflat	248	47	22	31	82	7	5	6
Houndstooth	46	93	7	0	98	2	0	0
Jamindie	221	48	25	27	93	5	1	1
Jigalong	90	9	19	72	69	15	8	8
Jurrawarrina	117	32	19	49	70	11	5	14
Kanjenjie	31	78	16	6	100	0	0	0
Kumina	3	100	0	0	100	0	0	0
Laterite	27	81	15	4	100	0	0	0
Lime	5	40	60	0	100	0	0	0
Little Sandy	173	97	3	0	100	0	0	0
Littoral	49	90	10	0	96	4	0	0
Lochinvar	0	-	-	-	-	-	-	-
Macroy	1,502	94	5	1	98	2	0	0
Mallina	423	78	15	7	87	10	3	0
Mannerie	35	69	14	17	97	0	3	0
Marandoo	8	50	50	0	100	0	0	0
Marillana	33	40	36	24	94	0	0	6
Marsh	23	65	26	9	82	9	9	0
McKay	132	96	3	1	99	1	0	0
Mosquito	153	95	3	2	97	1	1	1
Nanutarra	5	80	0	20	100	0	0	0
Narbung	25	52	20	28	76	20	4	0

Table 9. continued…

		Condition of perennial vegetation (%)			Extent of soil erosion (%)			
Land system	No. of assessments	Good or very good	Fair	Poor or very poor	Nil	Slight or minor	Moderate	Severe or extreme
Newman	228	98	1	1	99	0.5	0.5	0
Nirran	29	97	3	0	86	14	0	0
Nita	300	89	8	3	100	0	0	0
Nooingnin	115	35	35	30	98	1	1	0
Oakover	120	95	1	4	99	1	0	0
Onslow	47	81	4	15	87	4	0	9
Paraburdoo	84	73	14	13	95	3	2	0
Paradise	225	54	27	19	53	32	10	5
Paterson	133	84	8	8	92	5	2	1
Peedamulla	64	78	6	16	95	5	0	0
Pindering	61	87	8	5	100	0	0	0
Platform	95	100	0	0	100	0	0	0
Prairie	83	35	46	19	89	9	1	1
Pullgarah	93	43	22	35	67	21	6	6
Pyramid	3	100	0	0	100	0	0	0
River	401	82	13	5	94	5	1	0
Robe	98	92	6	2	100	0	0	0
Robertson	44	85	11	4	100	0	0	0
Rocklea	880	96	2	2	100	0	0	0
Roebuck	0	-	-	-	-	-	-	-
Ruth	18	83	11	6	100	0	0	0
Satirist	53	88	8	4	100	0	0	0
Sherlock	27	56	0	44	96	4	0	0
Spearhole	107	73	21	6	100	0	0	0
Stuart	211	83	10	7	98	1	0	1
Sylvania	111	39	41	20	91	6	3	0
Table	1	100	0	0	100	0	0	0
Talga	144	97	3	0	100	0	0	0
Talawana	3	0	33	67	0	33	0	67
Tanpool	13	70	15	15	100	0	0	0
Taylor	35	97	3	0	100	0	0	0
Three Rivers	3	0	33	67	100	0	0	0
Turee	106	16	20	64	82	12	4	2
Uaroo	808	92	7	1	99	1	0	0
Urandy	134	89	7	4	98	1	0	1
Wannamunna	62	44	19	37	95	3	2	0
Warri	57	28	30	42	95	0	5	0
Washplain	89	40	26	34	85	5	6	4
Weelaranna	6	34	33	33	100	0	0	0
White Springs	52	72	13	15	98	2	0	0
Wona	205	50	20	30	100	0	0	0
Yamerina	179	74	14	12	77	14	4	5
Zebra	55	80	16	4	100	0	0	0
Averages		77	11	12	93	4	2	1

Table 10. 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)	
Boolaloo	71	100	0	0	1.00
Cadgie	24	100	0	0	1.00
Callawa	19	100	0	0	1.00
Egerton	19	100	0	0	1.00
Platform	95	100	0	0	1.00
Granitic	113	99	1	0	1.01
Capricorn	138	98	2	0	1.02
Buckshot	91	98	1	1	1.03
Coongimah	130	97	2	1	1.03
Little Sandy	173	97	3	0	1.03
Nirran	29	97	3	0	1.03
Talga	144	97	3	0	1.03
Taylor	35	97	3	0	1.03
Newman	228	98	1	1	1.04
Dune	22	95	5	0	1.05
McKay	132	96	3	1	1.05
Bonney	122	95	4	1	1.06
Macroy	1,502	94	5	1	1.06
Rocklea	880	96	2	2	1.06
Boolgeeda	596	95	4	1	1.07
Houndstooth	46	93	7	0	1.07
Mosquito	153	95	3	2	1.07
Black	12	92	8	0	1.08
Eighty Mile	80	93	6	1	1.08
Oakover	120	95	1	4	1.09
Billygoat	269	94	3	3	1.10
Divide	177	94	3	3	1.10
Littoral	49	90	10	0	1.10
Robe	98	92	6	2	1.10
Uaroo	808	92	7	1	1.10
Calcrete	177	90	8	2	1.13
Nita	300	89	8	3	1.14
Satirist	53	88	8	4	1.15
Urandy	134	89	7	4	1.15
Pindering	61	87	8	5	1.18
Adrian	15	86	7	7	1.20
Robertson	44	84	11	5	1.20
Laterite	27	81	15	4	1.22
Ruth	18	83	11	6	1.22
Paterson	133	84	8	8	1.23
River	401	83	12	5	1.23
Anna	140	81	14	5	1.24
Stuart	211	83	10	7	1.24
Zebra	55	80	16	4	1.24
Kanjenjie	31	78	16	6	1.29
Mallina	423	78	14	8	1.30
Spearhole	107	73	21	6	1.32
Charley	12	67	33	0	1.33
Onslow	47	81	4	15	1.34
Peedamulla	64	78	6	16	1.38
Yamerina	179	74	14	12	1.39
Nanutarra	5	80	0	20	1.40
Paraburdoo	84	73	14	13	1.40
Dollar	17	70	18	12	1.41
White Springs	52	72	13	15	1.44
Tanpool	13	70	15	15	1.46
Cheerawarra	29	69	14	17	1.48
Mannerie	35	69	14	17	1.49
Gregory	4	50	50	0	1.50
Marandoo	8	50	50	0	1.50
Marsh	23	66	17	17	1.52

Table 10. continued…

Land system	No. of. assessments	Resource condition % Good (1)	 % Fair (2)	 % Poor (3)	Average resource condition score
Lime	5	40	60	0	1.60
Paradise	225	54	25	21	1.67
Narbung	25	52	20	28	1.76
Jamindie	221	48	25	27	1.80
Sylvania	111	39	41	20	1.81
Wona	205	50	20	30	1.81
Horseflat	248	48	21	31	1.83
Prairie	83	35	46	19	1.84
Marillana	33	40	36	24	1.85
Elimunna	84	39	35	26	1.87
Cowra	37	35	41	24	1.89
Sherlock	27	56	0	44	1.89
Brockman	149	45	20	35	1.90
Pullgarah	93	43	22	35	1.92
Hooley	121	41	25	34	1.93
Wannamunna	62	44	19	37	1.94
Washplain	89	39	27	34	1.94
Nooingnin	115	35	35	30	1.95
Balfour	221	39	24	37	1.98
Weelarrana	6	34	33	33	2.00
Cane	129	42	15	43	2.02
Ford	7	14	57	29	2.14
Warri	57	28	30	42	2.14
Jurrawarrina	117	32	19	49	2.18
Fan	140	24	31	45	2.21
Fortescue	111	27	18	55	2.28
Coolibah	182	23	17	60	2.37
Turee	106	16	19	65	2.49
Christmas	49	6	27	67	2.61
Jigalong	90	9	19	72	2.63

* Note where 1 = good resource condition, 2 = fair resource condition, 3 = poor resource condition.

Condition of site types and site type groups

The land unit and site type at each traverse assessment was recorded. Site types are an ecological classification at a plant community/landform scale (see the Site type ecology chapter).

The vegetation condition and extent of soil erosion of the site types based on the traverse assessments are presented in Table 13. The site type groups and numbers are those used in the Site type ecology chapter, where each site type is defined and discussed. Very good and good ratings for condition of perennial vegetation were combined as a single good category and poor and very poor ratings were combined as a single poor category. Slight and minor erosion ratings, and severe and extreme ratings were combined as minor and severe respectively for extent of soil erosion.

The average resource condition score for each site type was derived using the matrix to combine vegetation condition and extent of soil erosion (see Table 7). Table 14 shows the site types ranked according to their average resource condition score.

Of the 44 site types, 22 were closest to good resource condition (average score between 1.0 and 1.5) and 22 were closest to fair condition (average score between 1.5 and 2.5). No site types were closest to poor condition (average score between 2.5 and 3).

Fourteen of the site types closest to good resource condition were spinifex hummock grassland site types (groups A, D, G and H). Most of the component species are unattractive or only moderately attractive to livestock and are largely unaltered by grazing. They are susceptible to fire, and vegetation composition and structure can vary considerably depending on fire history.

Three of the 22 site types closest to good resource condition are buffel grass grasslands. These communities have very high pastoral value and are resilient to grazing.

The drainage shrubland and woodland site types of Group K range from high to low pastoral potential. Four of the site types were closest to good condition and two were closest to fair condition. Generally these site types are impacted as they provide shelter and grazing for livestock and palatable shrubs and grasses can be removed through excessive grazing pressure.

One of the site types on alluvial plains supporting chenopod shrublands (Group J) is closest to good condition. This site type, *Plain samphire shrubland* (PSPS), is resilient to grazing as the major component, samphire, is generally unattractive to livestock. The remaining three site types in this group are closest to fair resource condition and are in the lower rankings with one, *Plain mixed halophytic shrubland* (PXHS), being in the poorest condition of the survey area. These site types are preferentially grazed by stock and have duplex soils which are inherently susceptible to erosion, but the condition data presented here suggest that they have not been universally overgrazed and degraded.

Group I comprises alluvial plains supporting tussock grasslands (and occasionally grassy shrublands) site types with very high to moderately high pastoral potential. The site types which are dominated by the introduced buffel grass are closest to good condition while the site types dominated by native tussock grasses are closest to fair condition, with some in the lower rankings, except for *Saline plain sporobolus grassland* (SPSG) which may be less attractive to stock than other site types because of high salt levels.

Basaltic upland tussock grassland (BUTG) in Group C is a unique site type which is of high pastoral potential but parts of it are now largely degraded to annual herbfields. In pastoral terms it is still productive as it produces abundant annual herbage in season, but now has little drought durability. Due to its cracking clay soils and flat topography there is generally no accelerated erosion.

All but one site type in Groups E and F are on average closest to fair condition. Group E comprises site types mostly with low pastoral potential and Group F comprises site types with mostly low to moderate pastoral potential. Grazing is likely to reduce the number of sensitive palatable shrubs and site types in Group F are susceptible to sheet erosion through overland flow.

Table 11. Land systems in each pastoral potential group

Pastoral potential	Land systems				
Very high	Anna	Eighty Mile	Yamerina		
High	Brockman Coolibah	Fortescue Hooley	Horseflat Jurrawarrina	Kanjenjie Pullgarah	River Roebuck
Moderately high	Balfour Cane Christmas	Dune Elimunna Jigalong	Marillana Marsh Onslow	Paraburdoo Paradise Turee	Wannamunna Wona
Moderate	Bonney Boolgeeda Cadgie Cheerawarra Cowra Cundelbar	Dollar Fan Jamindie Macroy Mallina Mannerie	Marandoo Narbung Nirran Nita Paterson Peedamulla	Prairie Satirist Sherlock Stuart Sylvania Talawana	Taylor Urandy Warri Washplain White Springs
Low	Billygoat Boolaloo Calcrete Callawa Collier Coongimah	Ford Giralia Gregory Houndstooth Laterite	Lime Little Sandy Lochinvar Nanutarra Nooingnin	Oakover Pindering Pyramid Robe Spearhole	Table Tanpool Three Rivers Uaroo Zebra
Very low	Adrian Augustus Black Buckshot	Capricorn Charley Divide Egerton	Granitic Kumina Littoral McKay	Mosquito Newman Platform Robertson	Rocklea Ruth Talga Weelarrana

Table 12. 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 score	sde (ha)	% sde
			Good (1)	Fair (2)	Poor (3)			
Very high	2,157	399	80	3	7	1.27	2,349	1.09
High	9,363	1,453	51	19	30	1.79	5,837	0.62
Moderately high	10,781	1,380	44	22	34	1.90	16,767	1.56
Moderate	48,745	4,563	81	11	8	1.27	3,720	0.08
Low	39,949	2,321	88	8	4	1.16	1,927	0.05
Very low	70,679	2,329	95	3	2	1.07	416	<0.01
Total	181,674*	12,445	77	11	12	1.35	31,016	0.17

* this summary does not include the 49 km^2 of mining disturbance

Table 13. The condition of perennial vegetation and extent of soil erosion for site types (derived from traverse assessments)

Site type group	Site type no.	Site type	No. of assessments	Vegetation condition (%)			Extent of erosion (%)			
				Good	Fair	Poor	Nil	Minor	Moderate	Severe
A	1	HSPG	563	100	0	0	100	0	0	0
	2	HESG	164	100	0	0	100	0	0	0
B	3	HMGS	23	39	39	22	100	0	0	0
C	4	BUTG	131	22	31	47	100	0	0	0
D	5	PHSG	2,804	98	2	0	100	0	0	0
	6	PSSG	1,799	93	6	1	98	2	0	0
	7	PMSS	406	91	8	1	100	0	0	0
	8	CASG	335	98	2	0	100	0	0	0
	9	SSCG	67	87	9	4	96	0	3	1
E	10	SAES	187	37	36	27	96	2	1	1
	11	PAGS	133	37	47	16	89	9	2	0
	12	PMGS	67	24	24	52	84	12	4	0
	13	CACS	15	20	47	33	100	0	0	0
F	14	HPMS	317	32	28	40	92	4	2	2
	15	LHAS	39	23	44	33	95	5	0	0
	16	PSMS	154	26	24	50	84	9	4	3
	17	GMGW	110	30	41	29	93	4	2	1
	18	GMUW	64	47	28	25	94	5	0	1
	19	PMCS	19	68	21	11	95	5	0	0
G	20	SHSG	422	97	3	0	100	0	0	0
	21	SSSG	708	88	9	3	99	1	0	0
	22	CDSG	2	100	0	0	100	0	0	0
	23	CDBG	26	92	8	0	100	0	0	0
	24	SBAS	23	91	9	0	100	0	0	0
H	25	AHSG	255	81	14	5	78	20	1	1
	26	ASSG	525	76	17	7	78	15	5	2
	27	ASHS	96	35	38	27	81	12	1	6
I	28	APTG	410	52	17	31	84	8	5	3
	29	ARPG	335	30	25	45	73	11	9	7
	30	APBG	283	79	17	4	93	5	1	1
	31	AEBG	42	90	5	5	88	10	0	2
	32	PMOG	127	21	35	44	80	14	5	1
	33	SPSG	35	86	11	3	94	3	3	0
	34	SSTS	171	17	27	56	73	8	9	10
J	35	PSCS	138	20	22	58	74	16	4	6
	36	PXHS	126	17	21	62	78	11	7	4
	37	PSPS	50	92	6	2	100	0	0	0
	38	PCGS	81	47	12	41	47	23	15	15
K	39	DAHW	253	91	7	2	98	2	0	0
	40	DESG	120	97	3	0	98	2	0	0
	41	DEGW	490	65	16	19	93	3	2	2
	42	DEAW	58	57	31	12	97	0	3	0
	43	DMES	25	60	24	16	96	0	4	0
	44	GMEW	34	94	6	0	100	0	0	0

Grazing and other impacts

Condition assessments for the use of rangelands for pastoralism are made on the basis of the perceived effects of grazing on the palatable components of the vegetation and on soil status. However, country assessed as being in good condition for pastoralism (see definitions in the Methodology chapter) or in the good resource condition class (see Table 7 in this chapter) is also likely to be in good condition for other purposes such as conservation and eco-tourism. Conversely, country in poor condition for pastoralism is likely to be in poor condition for most other uses.

Although grazing widely impacts the condition and ecological integrity of Pilbara landscapes many other factors have impacts at the broadscale and local level. Such factors include fire, seasonal variation, flooding, weed incursions, mining activities and the placement of infrastructure such as roads and railway lines. As well as variations caused by these factors and grazing there is natural variation within vegetation types/site types which needs to be taken into account when assessing rangelands for any particular use.

The various condition statements in this 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 or preferred by herbivores this is demonstrably the case. In communities that are least preferred or not preferred at all such as hard spinifex grasslands, grazing is clearly not a major factor and the variations seen are due to other factors such as season and fire. For pastoral purposes most hard spinifex communities in the Pilbara would be classified as being in good condition regardless of seral stage. In this instance good condition does not imply high pastoral value, in fact pastoral value of these communities is very low to useless.

Clear evidence of grazing induced changes in vegetation was obvious throughout the survey area as fence line effects between paddocks, piosphere effects (as reduced biomass, reductions in key palatable plants and loss of diversity) around watering points and decline of key plants in preferred communities.

The incidence of soil erosion in the Pilbara is documented in this chapter. There is no doubt that most of the accelerated erosion is due to the direct (trampling) and indirect (loss of vegetative cover) effects of inappropriate grazing pressure. Erosion is closely associated with those plant communities that are highly preferred or preferred by herbivores. It is also closely associated with the presence of artificial and natural water supplies that have been used by the pastoral industry since the early days of settlement.

Flooding, particularly the occasional large event, associated with the major rivers of the area is a cause of erosion on some alluvial plains, floodplains and drainage floors. The effects of flooding will be exacerbated if ground cover has been lost or degraded by overgrazing.

In sandy systems on the coast there are some extensive areas of unvegetated coastal dune blow-outs. Some of these are likely to have been initiated from old stock watering

Table 14. Site types ranked according to their resource condition score

Site type group	Site type no.	Site type	No. of assessments	Resource condition (%)			Average score
				Good (1)	Fair (2)	Poor (3)	
A	1	HSPG	563	100	0	0	1.00
A	2	HESG	164	100	0	0	1.00
G	22	CDSG	2	100	0	0	1.00
D	5	PHSG	2,804	98	2	0	1.02
D	8	CASG	335	98	2	0	1.02
G	20	SHSG	422	97	3	0	1.03
K	40	DESG	120	97	3	0	1.03
K	44	GMEW	34	94	6	0	1.06
D	6	PSSG	1,799	93	6	1	1.08
G	23	SDBG	26	92	8	0	1.08
G	24	SBAS	23	91	9	0	1.09
D	7	PMSS	406	91	8	1	1.10
J	37	PSPS	50	92	6	2	1.10
K	39	DAHW	253	91	7	2	1.11
G	21	SSSG	708	88	9	3	1.15
I	31	AEBG	42	90	5	5	1.15
D	9	SSCG	67	87	9	4	1.17
I	33	SPSG	35	86	11	3	1.17
H	25	AHSG	255	81	14	5	1.24
I	30	APBG	283	79	17	4	1.25
H	26	ASSG	525	76	15	9	1.33
F	19	PMCS	19	68	21	11	1.43
K	41	DEGW	490	65	16	19	1.54
K	42	DEAW	58	57	31	12	1.55
K	43	DMES	25	60	24	16	1.56
F	18	GMUW	64	47	28	25	1.78
E	11	PAGS	133	37	47	16	1.79
I	28	APTG	410	52	15	33	1.81
B	3	HMGS	23	39	39	22	1.83
E	10	SAES	187	37	36	27	1.90
H	27	ASHS	96	35	38	27	1.92
J	38	PCGS	81	47	10	43	1.96
F	17	GMGW	110	30	41	29	1.99
F	14	HPMS	317	32	28	40	2.08
F	15	LHAS	39	23	44	33	2.10
E	13	CACS	15	20	47	33	2.13
I	29	ARPG	335	30	25	45	2.15
F	16	PSMS	154	26	24	50	2.24
C	4	BUTG	131	22	31	47	2.25
I	32	PMOG	127	20	35	45	2.25
E	12	PMGS	67	24	24	52	2.28
I	34	SSTS	171	17	27	56	2.39
J	35	PSCS	138	20	20	60	2.40
J	36	PXHS	126	17	20	63	2.46

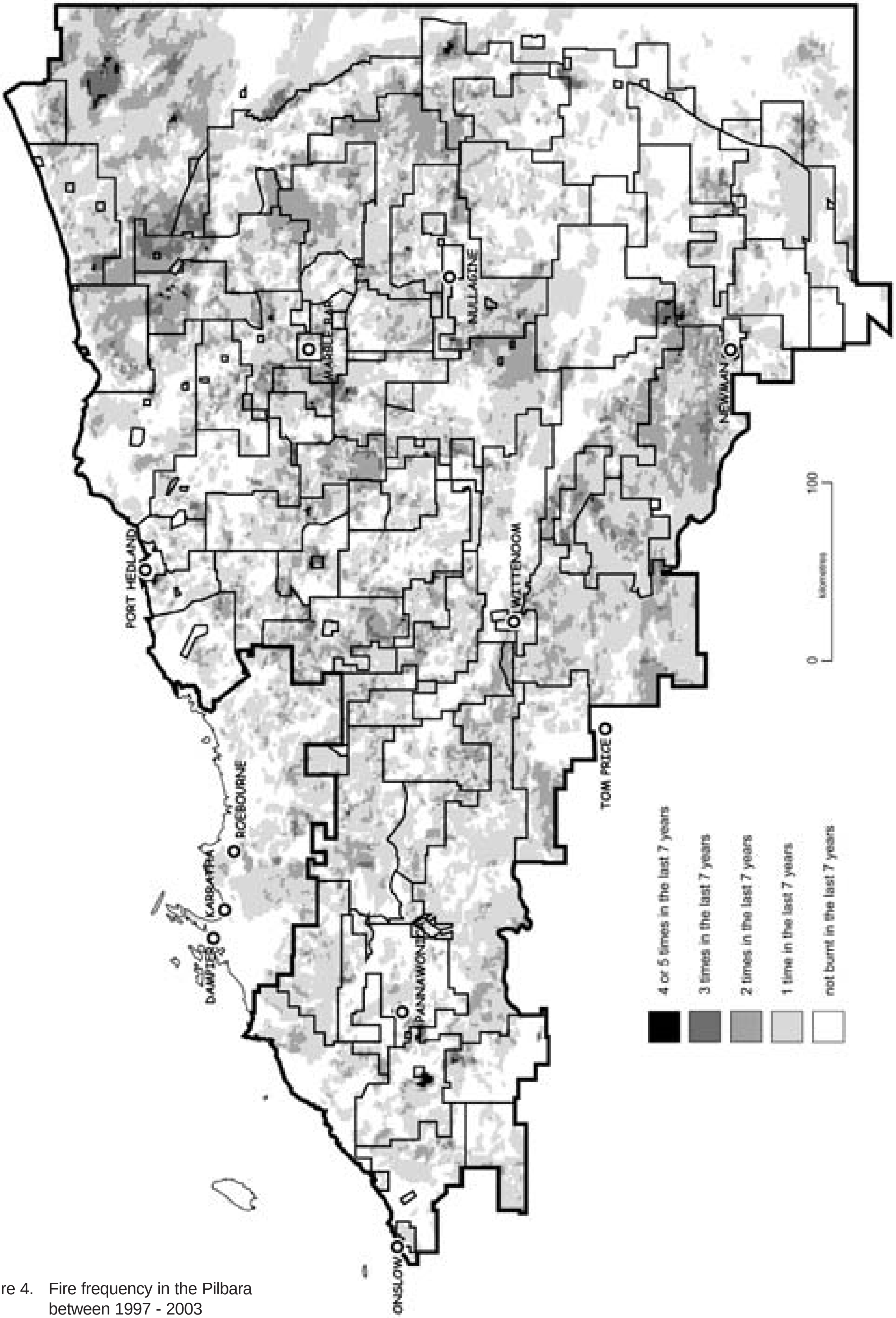


Figure 4. Fire frequency in the Pilbara between 1997 - 2003

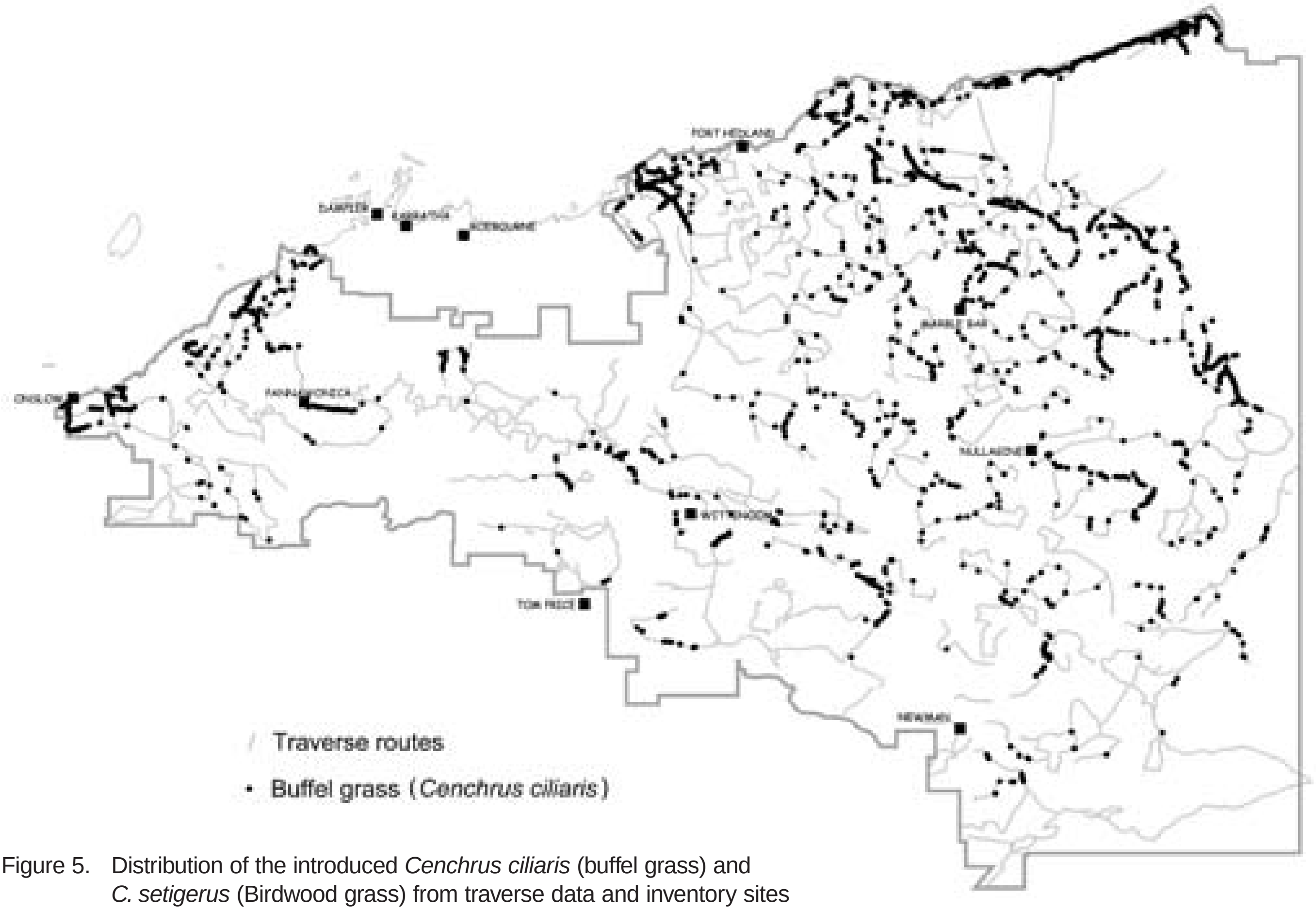


Figure 5. Distribution of the introduced *Cenchrus ciliaris* (buffel grass) and *C. setigerus* (Birdwood grass) from traverse data and inventory sites

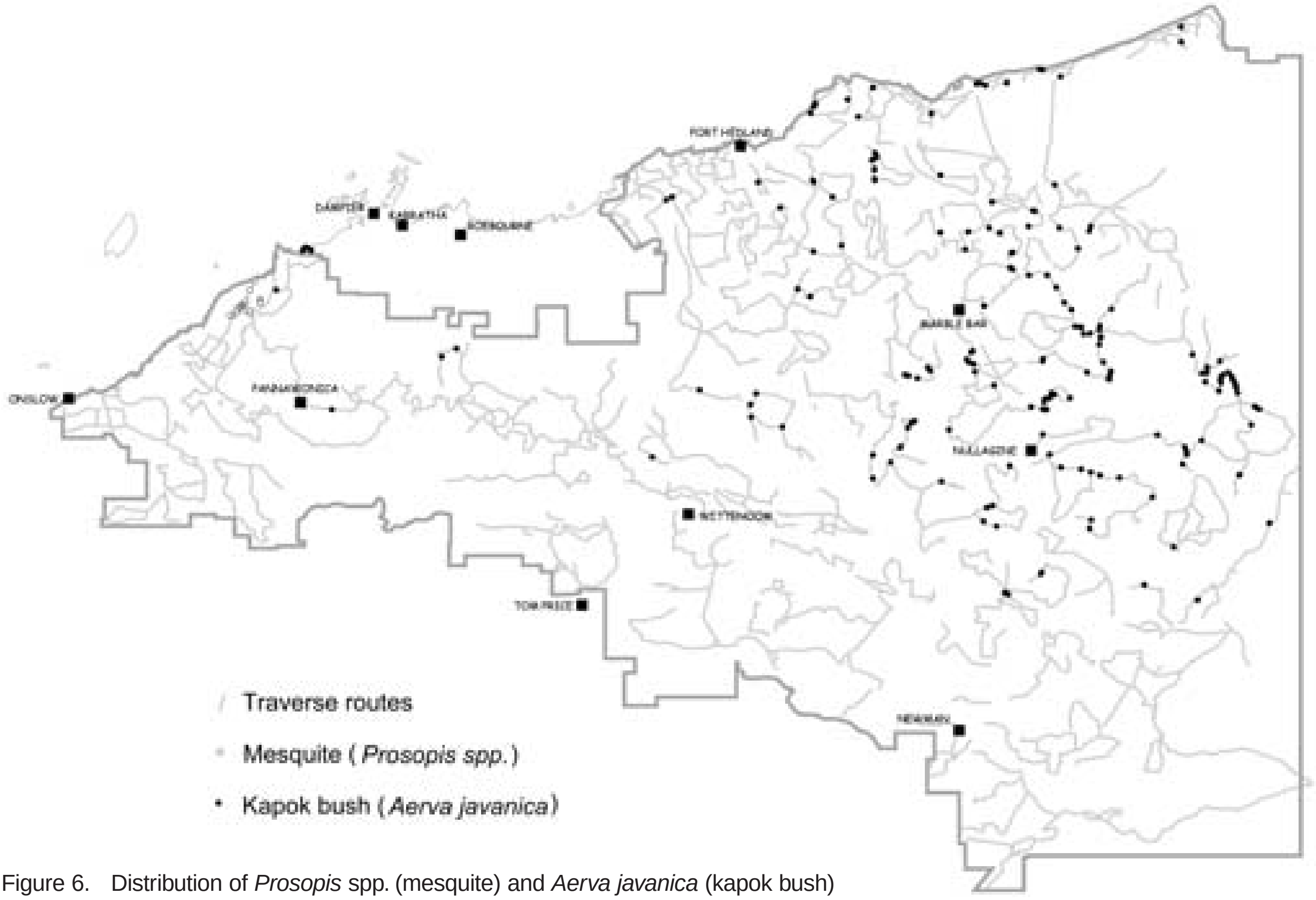


Figure 6. Distribution of *Prosopis* spp. (mesquite) and *Aerva javanica* (kapok bush) in the survey area from traverse data and inventory sites.

points behind the foredunes where supplies of fresh water were obtained. Fires, coupled with poor seasonal conditions and strong coastal sea breezes are also likely causal agents.

Accidental, deliberate and naturally occurring fires occur widely throughout the Pilbara in most years. Figure 4 shows the number of times the Pilbara has been burnt during the seven years period 1997 to 2003.

Nearly all plant communities are subject to at least occasional fire but the extensive, highly flammable spinifex communities are likely to be burnt at least once every 5 or 6 years.

Fire effects, coupled with seasonal conditions, can produce a wide range of seral states sometimes with markedly different short term suites of plant species for the same broad vegetation community. Fires in soft spinifex hummock grasslands may promote dense stands of shrubs (such as *Acacia ancistrocarpa*, *A. stellaticeps* and *Senna notabilis*) which persist for some years after burning. From a pastoral point of view these shrubs are classed as undesirable woody weeds. Vegetation condition for pastoralism is poor and would remain so until the community proceeds through a number of seral stages and returns to dominance by spinifex and a structure of spinifex grassland rather than acacia shrubland.

Disturbance as a result of mining or mineral exploration was recorded at 42 traverse points during the survey. This represents 0.3% of traverse assessments and indicates the generally localised nature of mining impacts. About 4,900 ha of mine dumps and mine pits from current mining activity and eroded spoil dumps from old mining activity, representing 0.03% of the survey area, were identified and mapped. Because of the limitations of scale and ongoing mining activity this will be an under estimation.

Environmental impacts caused by inappropriately located, constructed or maintained tracks and roads were recorded at 62 traverse points (0.5% of total traverse records). The results were gully and rill erosion along tracks and downslope water starvation effects caused by tracks or roads disrupting sheet flow processes on broad, near level plains.

Inappropriately located tracks can lead to erosion. This former track is now effectively a channel for diverting overland water flow away from other areas.

Occurrence records for nine exotic weeds or plants with weedy properties were made at traverse points during the survey. *Cenchrus ciliaris* (buffel grass) and *C. setigerus* (Birdwood grass) are very useful pasture plants and colonisers of degraded areas but are also regarded as environmental weeds. They are now widely naturalised (see Figure 5) and occurred at 1,493 traverse points (12%) and 264 inventory sites (35%). These grasses and their impacts on native vegetation are described further in the Vegetation chapter.

Figure 6 shows the distribution of two other exotics *Prosopis* spp. (mesquite) and *Aerva javanica* (kapok bush). The former is a serious weed which is described in the Declared plants and animals chapter and the Vegetation chapter. *Aerva javanica* is an introduced pasture plant now widely found in the Pilbara and Kimberley. It is an excellent primary coloniser of bared country particularly on calcareous soils. It has some weedy properties but experience on the Ord River Regeneration Project in the East Kimberley shows that, although it may dominate in the early recovery stages on degraded country, it is unable to compete and declines markedly as tussock grasses re-establish (Payne, Watson and Novelly 2004).

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Appendices

1. **Plant species lists (A.M.E. Van Vreeswyk[1] and P.Hennig[1])**
   - **(i). Plant species recorded in the survey area**
   - **(ii). Common plants in the survey area**
2. **Land system maps**

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[1] Rangelands Program, Department of Agriculture, Western Australia

Appendix 1 (i). Plant species recorded in the survey area

Key to table at end of chapter.

Family Botanical name	Taxon id.	Collec no.	Growth form	Site type group												Total sites
				A	B	C	D	E	F	G	H	I	J	K	O	
Acanthaceae																
Dicladanthera forrestii	7164	PRP694	LS	-	-	-	1	1	1	-	2	3	1	-	-	9
Dicladanthera glabra	7165	PRP1093	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Dipteracanthus australasicus	7169	PRP775	LS	-	-	-	2	-	-	-	-	2	1	3	-	8
Dipteracanthus australasicus subsp. *australasicus*	11320	PRP134	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Rostellularia adscendens var. *clementii*	7174	PRP182	LS	-	-	-	-	1	1	-	1	4	-	3	-	10
Adiantaceae																
Ceratopteris thalictroides	30	PRP1690	Q	-	-	-	-	-	-	-	-	-	-	1	-	1
Cheilanthes austrotenuifolia	31	PRP650	F	1	-	-	-	-	4	-	-	-	-	-	-	5
Cheilanthes lasiophylla	37	PRP1189	F	1	-	-	-	-	-	-	-	-	-	-	-	1
Cheilanthes sieberi	41	PRP1088	F	1	-	-	-	-	-	-	-	-	-	-	-	1
Agavaceae																
* *Agave americana*	1505	PRP1803	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Aizoaceae																
Trianthema cussackiana	2825	PRP395	PH	-	-	-	1	-	-	-	1	1	-	-	-	3
Trianthema glossostigma	2826	PRP261	AH	2	-	-	6	-	2	-	-	-	-	-	-	10
Trianthema pilosa	2829	PRP891	AH	-	-	-	2	-	-	5	-	-	-	2	-	9
Trianthema triquetra	2832	PRP1775	AH	1	-	-	7	-	-	-	14	9	6	-	1	38
Trianthema turgidifolia	2833	PRP345	LS	-	-	-	3	-	-	-	2	10	5	2	1	23
Zaleya galericulata	2834	PRP1056	PH	-	-	-	-	1	-	-	-	-	1	-	-	2
Amaranthaceae																
Achyranthes aspera	2645	PRP867	AH	1	-	-	1	-	-	2	1	1	-	2	-	8
* *Aerva javanica*	2646		LS	8	-	-	11	1	-	13	1	4	-	5	2	45
Alternanthera angustifolia	2647	PRP1659	LS	-	-	-	1	-	-	-	1	-	-	-	-	2
Alternanthera nana	2651		AH	-	-	-	1	-	-	-	1	-	-	2	-	4
Alternanthera nodiflora	2652	PRP559	AH	-	-	-	-	-	3	-	-	4	1	10	2	20
Amaranthus mitchellii	2666	PRP615	AH	7	-	-	4	1	4	-	5	2	-	2	-	25
Gomphrena canescens	2676	PRP183	AH	2	3	-	10	7	2	-	14	11	8	4	1	62
Gomphrena cunninghamii	2680	PRP223	AH	16	-	-	6	-	-	-	1	-	-	1	1	25
Gomphrena leptoclada subsp. *leptoclada*	18257	PRP1410	AH	-	-	-	1	1	-	-	-	-	-	-	-	2
Hemichroa diandra	2688	PRP1785	LS	-	-	-	-	-	-	-	-	1	-	-	-	1
Ptilotus aervoides	2690	PRP30	AH	6	-	1	20	7	3	-	6	12	2	1	5	63
Ptilotus aphyllus	2693	PRP1172	LS	-	-	-	1	-	-	3	-	-	-	-	-	4
Ptilotus appendiculatus var. *appendiculatus*	11701	PRP1635	LS	-	-	-	7	-	-	-	6	-	-	2	-	15
Ptilotus arthrolasius	2695	PRP329	LS	-	-	-	-	-	-	3	-	-	-	-	-	3
Ptilotus astrolasius	2696	AAM3778	LS	10	-	-	48	-	-	10	7	-	-	7	-	82
Ptilotus auriculifolius	2698	PRP383	AH	11	-	-	15	-	-	-	-	-	-	1	-	27
Ptilotus axillaris	2699	PRP790	AH	1	-	-	19	-	-	6	3	2	-	5	-	36
Ptilotus calostachyus	2704	PRP1757	LS	45	-	-	64	-	-	4	2	-	-	3	1	119
Ptilotus carinatus	2706	PRP117	AH	-	-	4	4	1	-	-	1	18	1	2	-	31
Ptilotus clementii	2711	PRP524	AH	3	-	-	21	-	1	-	-	1	-	-	1	27
Ptilotus divaricatus var. *divaricatus*	2717	PRP815	LS	-	-	-	-	-	-	-	-	1	-	-	-	1
Ptilotus drummondii	2718	PRP74	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Ptilotus exaltatus	2721		AH	21	2	2	65	4	8	7	12	23	7	8	2	161
Ptilotus fusiformis	2725	PRP56	AH	2	-	-	8	1	-	5	1	-	-	2	-	19
Ptilotus gaudichaudii	2727	PRP132	AH	2	-	-	5	-	5	-	-	-	-	5	1	18
Ptilotus gomphrenoides	2728	PRP202	AH	-	-	5	4	3	3	-	4	30	6	10	3	68
Ptilotus gomphrenoides var. *gomphrenoides*	11236	PRP1429	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Ptilotus gomphrenoides var. *roseo-albus*	11518	PRP556	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Ptilotus helipteroides var. *helipteroides*	2731	PRP218	AH	8	1	-	19	11	6	-	-	3	-	4	-	52
Ptilotus incanus var. *elongatus*	11840	PRP362	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Ptilotus incanus var. *incanus*	11436	PRP296	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Ptilotus latifolius	2738	PRP1728	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Ptilotus macrocephalus	2741		AH	1	-	-	3	1	6	-	-	5	-	10	3	29
Ptilotus murrayi	2745	PRP1722	AH	1	1	-	3	-	-	-	4	1	3	-	1	14
Ptilotus obovatus	2747		LS	14	1	-	22	17	13	1	3	5	3	15	2	96
Ptilotus petiolatus	2749	PRP142	AH	-	-	-	-	-	-	-	1	4	-	-	-	5
Ptilotus polystachyus	2751		AH	3	-	-	12	1	5	8	2	-	-	5	1	37

Family Botanical name	Taxon id.	Collec no.	Growth form	Site type group												Total sites
				A	B	C	D	E	F	G	H	I	J	K	O	
Ptilotus roei	2754	PRP52	LS	-	-	-	2	4	6	-	-	-	-	-	1	13
Ptilotus rotundifolius	2755		MS	8	2	-	5	-	-	-	-	-	-	-	-	15
Ptilotus schwartzii	2757	PRP1416	LS	-	-	-	1	2	9	-	-	-	-	-	1	13
Ptilotus sessilifolius	10809	PRP858	LS	1	-	-	3	-	-	-	-	-	-	-	-	4
Ptilotus stipitatus	2762	PRP1215	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Anthericaceae																
Corynotheca micrantha var. *micrantha*	11283	PRP326	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Corynotheca pungens	1286	PRP317	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Tricoryne trudgeniana ms	14603	PRP688B	LS	1	-	-	-	-	-	-	-	-	-	-	-	1
Apiaceae																
Daucus glochidiatus	6218	PRP719A	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Trachymene bialata	6273	PRP466B	AH	2	-	-	-	-	-	1	-	-	-	-	1	4
Trachymene oleracea subsp. *oleracea*	6278	PRP620	AH	14	-	-	8	-	-	-	-	-	-	5	-	27
Trachymene pilbarensis	19053	PRP1653	AH	-	-	-	-	-	-	1	-	-	-	-	-	1
Apocynaceae																
Alstonia linearis	6563	PRP1780	TR	-	-	-	-	-	-	-	-	-	-	-	-	-
Carissa spinarum	19982	PRP774	TS	1	-	-	9	-	-	7	13	12	1	7	3	53
Aponogetonaceae																
Aponogeton euryspermus	18488	PRP830	Q	-	-	-	-	-	-	-	-	-	-	1	-	1
Araliaceae																
Astrotricha hamptonii	6202		MS	1	-	-	-	-	-	-	-	-	-	-	-	1
Arecaceae																
Livistona alfredii	1039	PRP1480	TR	-	-	-	-	-	-	-	-	-	-	-	-	-
* *Phoenix dactylifera*	1042		TR	-	-	-	-	-	-	-	-	-	-	1	-	1
Asclepiadaceae																
Cynanchum floribundum	6584	AAM3599	C	2	-	-	-	-	-	-	-	1	-	-	-	3
Gymnanthera cunninghamii	12832	PRP853	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsdenia angustata	16537	PRP907	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsdenia australis	12949		C	-	-	-	1	-	-	-	-	-	-	-	-	1
Rhyncharrhena linearis	6599	PRP155	C	-	-	-	1	-	-	-	-	-	-	-	-	1
Sarcostemma viminale subsp. *australe*	13006	PRP1128	MS	-	-	-	1	-	1	-	-	-	1	1	-	4
Asphodelaceae																
* *Asphodelus fistulosus*	1364	PRP1312	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Bulbine pendula	14312	PRP707	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Asteraceae																
Angianthus acrohyalinus	7822	PRP1655	AH	-	-	-	1	-	-	-	1	-	-	-	-	2
Angianthus tomentosus	7836	PRP573	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
* *Bidens bipinnata*	7854	PRP154	AH	-	-	-	1	-	6	-	-	-	-	5	-	12
Blumea tenella	7866	PRP758	AH	1	-	-	-	-	-	-	-	1	-	1	-	3
Brachyscome ciliaris	7871		PH	-	-	-	-	-	1	-	-	-	-	4	1	6
Brachyscome ciliocarpa	7872		AH	-	-	-	-	-	1	-	-	-	-	-	-	1
Brachyscome oncocarpa	7881	PRP1022	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Bracteantha bracteata	12609	PRP648	AH	-	-	-	-	-	-	-	-	-	-	1	-	1
Calocephalus francisii	7891	PRP1667	AH	1	-	-	1	-	-	-	-	-	-	-	-	2
Calocephalus knappii	7893	PRP555	AH	1	-	-	3	-	-	-	3	-	-	-	-	7
Calocephalus sp. nova. (Wittenoom-Newman)		PRP540	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Calotis hispidula	7903	PRP542	AH	-	-	-	-	-	1	-	1	2	-	-	-	4
Calotis latiuscula	7904	PRP692	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Calotis multicaulis	7905	PRP445	AH	-	-	-	-	-	2	-	-	6	-	5	1	14
Calotis plumulifera	7906	PRP1139	AH													
Centipeda minima	7919	PRP448	AH	-	-	-	1	-	-	-	-	2	-	4	-	7
Centipeda thespidioides	7918	PRP561	AH	-	-	-	-	-	-	-	-	2	-	-	-	2
Chrysocephalum apiculatum	12612	PRP1182B	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Chrysocephalum pterochaetum	12614	PRP488	LS	-	-	-	1	2	-	-	-	1	-	1	-	5
Chrysocephalum puteale	13138	PRP83	LS	-	-	-	-	-	-	3	-	-	-	-	1	4
Decazesia hecatocephala	7958	PRP1651	AH	-	-	-	-	-	-	2	-	-	-	-	-	2
Flaveria australasica	7975	PRP630	AH	-	-	4	1	-	-	-	-	11	1	5	1	23
Flaveria sp. Tom Price D275 (M.E. Trudgen 11246)	14318	PRP1476	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Gnephosis arachnoidea	7988	PRP663	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Helichrysum gilesii	8021	PRP494	AH	-	-	-	-	-	-	-	-	-	-	2	-	2
Ixiochlamys cuneifolia	8088	PRP633	AH	-	-	-	2	-	-	-	-	-	-	-	-	2

Family Botanical name	Taxon id.	Collec no.	Growth form	Site type group												Total sites
				A	B	C	D	E	F	G	H	I	J	K	O	
Minuria integerrima	8109	PRP194	PH	-	-	-	-	-	-	-	1	2	2	1	-	6
Minuria leptophylla	8110	PRP1019	PH	-	-	-	-	-	1	-	-	-	-	-	-	1
Myriocephalus oldfieldii ms	8119	PRP728	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Myriocephalus rudallii	8121	PRP593	AH	-	-	-	-	-	-	-	-	1	-	-	-	1
Olearia stuartii	8151	PRP1357	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Olearia xerophila	8153	PRP674	LS	1	-	-	-	-	-	-	-	-	-	-	-	1
Pentalepis trichodesmoides	13494	AAM3757B	LS	2	-	-	5	-	-	-	2	-	-	-	-	9
Pluchea dentex	8167	PRP628	AH	1	-	-	1	-	-	-	1	-	-	2	-	5
Pluchea dunlopii	17817	PRP1276	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Pluchea ferdinandi-muelleri	17816	PRP881	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Pluchea rubelliflora	8168	PRP1162	PH	-	-	-	3	-	-	1	8	3	1	1	-	17
Pluchea sp. B Kimberley Flora (K.F. Kenneally 9526A)	19790	PRP1787	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Pluchea tetranthera	8170		LS	3	-	-	19	-	-	7	24	6	2	6	-	67
Podolepis canescens	8172	PRP472	AH	1	-	-	-	2	-	2	-	-	-	1	-	6
Podolepis capillaris	8173	PRP1203	AH	2	-	-	-	-	-	-	1	-	1	-	-	4
* *Pseudognaphalium luteo-album*	8189	PRP780	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Pterocaulon serrulatum	8191	PRP971	AH	2	-	-	6	-	-	-	4	-	-	1	-	13
Pterocaulon sphacelatum	8192	PRP543	AH	8	-	-	32	2	3	5	22	10	3	18	1	104
Pterocaulon sphaeranthoides	8193	PRP977	PH	2	-	-	2	-	-	-	1	-	-	-	-	5
Rhodanthe charsleyae	13308	PRP470	AH	-	-	-	1	1	3	-	-	-	-	6	2	13
Rhodanthe floribunda	13301		AH	-	-	-	1	-	3	-	-	4	-	3	1	12
Rhodanthe humboldtiana	13246	PRP1428	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhodanthe margarethae	13310	PRP824	AH	5	-	-	-	-	-	-	-	-	-	-	-	5
Rhodanthe propinqua	13251	PRP163	AH	-	-	-	-	-	-	-	-	-	-	2	1	3
Rhodanthe psammophila	13297	PRP1650	AH	-	-	-	-	-	-	1	-	-	-	-	-	1
Rhodanthe sterilescens	13303	PRP463	AH	-	-	-	-	2	-	-	-	1	-	-	-	3
Rhodanthe stricta	13254	PRP1283	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Rutidosis helichrysoides	8198	PRP611	AH	-	-	-	1	-	1	-	-	-	-	-	-	2
Schoenia ayersii	13285	PRP1372	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Senecio lautus	8211	PRP1195	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Senecio magnificus	8213	PRP714	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
* *Sigesbeckia orientalis*	8223	PRP1504	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
* *Sonchus asper*	8230	PRP1947	AH	-	-	-	-	-	-	-	-	1	-	-	-	1
* *Sonchus oleraceus*	8231	PRP1519	AH	-	-	-	-	-	1	-	-	-	-	1	-	2
Streptoglossa bubakii	8235	PRP483	PH	1	-	4	12	1	2	-	7	15	3	1	1	47
Streptoglossa cylindriceps	8236	PRP464	AH	-	-	-	-	-	-	-	-	1	5	1	1	8
Streptoglossa decurrens	8237	PRP666	AH	8	-	-	15	1	-	-	6	3	1	5	2	41
Streptoglossa liatroides	8238	PRP407	AH	-	-	-	-	1	-	-	-	1	1	-	-	3
Streptoglossa macrocephala	8239	PRP927	PH	-	-	-	-	-	-	2	-	-	-	1	-	3
Streptoglossa odora	8240	PRP1670	AH	-	-	-	4	-	1	-	5	9	1	3	1	24
Streptoglossa tenuiflora	8241	PRP444	PH	-	-	-	-	1	-	-	-	-	-	-	-	1
Vittadinia arida	8259	PRP647	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Vittadinia eremaea	8265	PRP1352	AH	-	-	-	-	-	-	-	-	-	-	1	-	1
Vittadinia obovata	8270	PRP679	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Vittadinia sulcata	8273	PRP1333	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Avicenniaceae																
Avicennia marina	6828	PRP1536	TS	-	-	-	-	-	-	-	-	-	-	-	1	1
Bignoniaceae																
Dolichandrone heterophylla	7115	PRP303	TR	-	-	-	2	-	-	2	2	-	-	2	1	9
Pandorea pandorana	7117	PRP1100	C	-	-	-	-	-	-	-	-	-	-	1	-	1
Boraginaceae																
Coldenia procumbens	6676		AH	-	-	-	-	-	-	-	-	-	-	1	-	1
Ehretia saligna	6682	PRP1037	TR	-	-	-	-	-	-	1	1	4	-	1	-	7
Halgania erecta	6688	PRP1219	LS	-	-	-	-	-	-	1	-	-	-	-	-	1
Halgania gustafsenii	6690	PRP48	LS	1	-	-	1	-	-	5	-	-	-	-	-	7
Halgania gustafsenii var. *compactus* ms	17484	PRP675B	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Halgania solanacea	6697	PRP57	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Halgania stipitata	17483	PRP1399	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Heliotropium ammophilum	17299	PRP1903	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Heliotropium chrysocarpum	17301		AH	-	-	-	1	-	-	-	-	-	-	-	-	1
Heliotropium crispatum	6705	PRP230	AH	1	-	1	1	-	-	-	2	1	-	1	-	7
Heliotropium cunninghamii	6706	PRP792	AH	1	-	-	3	1	-	-	-	-	-	-	-	5
Heliotropium curassavicum	6707	PRP1288	AH	-	-	-	1	-	-	-	-	-	-	-	-	1
Heliotropium diversifolium	6708	PRP372	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Heliotropium foliatum	10882	PRP335	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Heliotropium glanduliferum	17305	PRP525	LS	-	1	-	8	1	-	-	-	-	-	-	-	10
Heliotropium heteranthum	6712	PRP769	AH	2	-	-	4	2	1	-	-	2	-	-	2	13
Heliotropium inexplicitum	17307	PRP567	AH	-	-	-	1	-	-	1	1	-	-	1	-	4
Heliotropium murinum	17393	PRP1578	LS	-	-	-	1	-	-	-	-	-	-	-	-	1
Heliotropium muticum	10891	PRP1919	LS	-	-	-	-	-	-	-	-	-	-	-	-	-

Family Botanical name	Taxon id.	Collec no.	Growth form	Site type group A	B	C	D	E	F	G	H	I	J	K	O	Total sites
Heliotropium ovalifolium	6713	PRP1267	AH	-	-	-	15	-	-	1	2	-	-	2	-	20
Heliotropium pachyphyllum	17309	PRP1553	LS	-	-	-	1	-	-	-	-	-	-	-	-	1
Heliotropium skeleton	17313	PRP915	PH	-	-	-	5	-	-	1	1	-	-	-	-	7
Heliotropium tenuifolium	6718	PRP691	LS	1	-	-	-	-	-	2	-	-	-	-	-	3
Heliotropium transforme	17031	PRP354	LS	-	-	-	-	-	-	2	-	-	-	-	-	2
Heliotropium ventricosum	6720		AH	-	-	-	-	-	-	3	-	-	-	-	-	3
Heliotropium vestitum	11057	PRP361	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichodesma zeylanicum	6727		AH	16	2	-	39	2	4	5	1	2	-	14	1	86
Brassicaceae																
Cuphonotus andraeanus	3010	PRP509	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepidium amelum	17998	PRP1408	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepidium echinatum	3025	PRP162	AH	-	-	-	-	-	2	-	-	-	-	1	-	3
Lepidium muelleri-ferdinandii	3032	PRP454	AH	-	-	-	-	-	1	-	-	-	-	-	-	1
Lepidium oxytrichum	3033	PRP1184	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepidium pedicellosum	3035	PRP459	AH	4	-	-	2	3	-	-	1	-	2	-	-	12
Lepidium phlebopetalum	3037	PRP61	AH	2	-	-	5	4	4	-	-	4	1	-	2	22
Lepidium pholidogynum	3038	PRP640	AH	3	-	-	4	1	-	-	-	-	-	-	-	8
Lepidium platypetalum	3039	PRP100	LS	-	-	-	-	1	-	-	-	1	-	-	-	2
* *Sisymbrium orientale*	3072	PRP1270	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenopetalum anfractum	3074	PRP510	AH	-	-	-	-	-	1	1	-	-	-	-	-	2
Stenopetalum decipiens	3075	PRP1353	AH	-	-	-	-	-	-	-	-	-	-	1	-	1
Stenopetalum nutans	3078	PRP507	AH	-	-	-	-	-	2	-	-	-	-	1	-	3
Stenopetalum pedicellare	3079	PRP619	AH	1	-	-	1	-	-	-	-	-	-	1	-	3
Byblidaceae																
Byblis liniflora	3179	PRP274	AH	-	-	-	-	-	-	2	1	2	-	1	-	6
Cactaceae																
* *Opuntia stricta*	5227	PRP1841	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Caesalpiniaceae																
Bauhinia cunninghamii	12757	PRP1564	TR	-	-	-	-	-	-	6	2	4	-	1	-	13
Chamaecrista pumila	14810	PRP1626	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Erythrophleum chlorostachys	3662	PRP356	TR	-	-	-	-	-	-	4	-	-	-	-	-	4
* *Parkinsonia aculeata*	3673	PRP969	TR	-	-	-	-	-	-	-	-	-	-	-	-	-
Petalostylis cassioides	3674		MS	1	-	-	1	-	-	3	1	-	-	-	1	7
Petalostylis labicheoides	3675	PRP899	MS	4	-	-	8	-	1	2	2	-	-	7	1	25
Senna artemisioides	17645	PRP387	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Senna artemisioides subsp. *filifolia*	12276		MS	-	1	-	1	3	1	-	-	-	-	-	1	7
Senna artemisioides subsp. *helmsii*	12279		LS	11	3	-	41	22	8	7	9	11	6	18	2	138
Senna artemisioides subsp. *oligophylla*	12280	PRP07	LS	21	2	-	44	10	2	5	17	16	-	17	3	137
Senna artemisioides subsp. x *artemisioides*	17558		MS	2	-	-	10	3	1	-	-	-	1	2	-	19
Senna artemisioides subsp. x *sturtii*	12283		LS	2	-	1	9	7	9	2	2	-	4	6	1	43
Senna curvistyla	12152	PRP1758	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Senna ferraria	18443	PRP588	MS	7	-	-	5	-	-	-	-	-	-	2	-	14
Senna glutinosa	18346		MS	46	-	-	45	1	-	3	2	-	-	10	2	109
Senna glutinosa subsp. *chatelainiana*	12305		MS	-	-	-	-	1	-	-	1	3	-	1	-	6
Senna glutinosa subsp. *glutinosa*	12307	AAM3796	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Senna glutinosa subsp. *pruinosa*	12309	PRP10	MS	24	-	-	20	-	-	-	-	-	-	1	-	45
Senna glutinosa subsp. x *luerssenii*	12308	PRP157	MS	19	4	-	57	13	6	1	3	2	4	6	2	117
Senna hamersleyensis	18451	PRP98	LS	-	-	-	2	2	-	-	2	8	4	-	-	18
Senna notabilis	12312		AH	11	-	-	59	-	-	15	26	14	-	14	5	144
* *Senna occidentalis*	10848	PRP1809	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Senna sericea	19347	PRP1608	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Senna sp. Karijini (M.E. Trudgen 10392)	18595	PRP538	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Senna sp. Meekatharra (E. Bailey 1-26)	14577	PRP548	MS	1	-	-	4	4	-	1	9	3	7	7	-	36
Senna stricta	18445	PRP522	LS	-	-	-	1	3	1	-	-	-	-	-	1	6
Senna symonii	18450	PRP713B	MS	6	-	1	21	-	-	-	2	-	-	1	-	31
Senna venusta	12319	AAM3773	MS	6	-	-	-	-	-	-	-	-	-	3	-	9
Campanulaceae																
Wahlenbergia caryophylloides	12725	PRP1491A	AH	-	-	-	-	-	-	-	-	-	-	1	-	1
Wahlenbergia tumidifructa	7393	PRP439	AH	-	-	-	-	-	1	-	1	2	-	1	-	5

Family Botanical name	Taxon id.	Collec no.	Growth form	Site type group												Total sites
				A	B	C	D	E	F	G	H	I	J	K	O	
Capparaceae																
Capparis jacobsii	2975		TS	1	-	-	-	-	-	-	-	-	-	-	-	1
Capparis lasiantha	2976	PRP684	LS	2	-	-	4	1	2	-	1	2	1	3	-	16
Capparis spinosa	2981		MS	2	-	-	2	-	-	2	1	2	-	3	1	13
Capparis spinosa var. *nummularia*	11670	PRP1122	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Capparis umbonata	2982	PRP683	TS	1	-	-	2	-	-	-	1	-	-	-	-	4
Cleome oxalidea	2985	PRP161	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Cleome uncifera	2987	PRP276	LS	-	-	-	5	-	-	3	2	-	-	-	-	10
Cleome viscosa	2988	PRP1597	AH	18	1	-	45	5	4	4	10	13	1	13	6	120
Caryophyllaceae																
Polycarpaea corymbosa	2898	PRP358	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Polycarpaea holtzei	2901	PRP603	AH	4	-	-	2	-	-	-	-	-	-	-	-	6
Polycarpaea longiflora	2903	PRP281	AH	7	-	-	-	-	-	2	-	-	-	-	-	9
Casuarinaceae																
Allocasuarina decaisneana	1724	PRP77	TR	-	-	-	-	-	-	2	-	-	-	-	-	2
Celastraceae																
Maytenus cunninghamii	4723	PRP584	MS	1	-	-	-	-	-	-	-	-	-	1	-	2
Chenopodiaceae																
Atriplex amnicola	2450	PRP571	MS	-	-	-	-	-	-	-	-	-	1	-	-	1
Atriplex bunburyana	2451	PRP318	LS	-	-	-	-	-	-	-	1	3	17	1	2	24
Atriplex codonocarpa	2453	PRP1272	AH	-	-	-	3	-	-	-	-	-	7	-	-	10
Atriplex flabelliformis	2485	PRP1025	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Atriplex holocarpa	2459		AH	-	-	-	-	-	-	-	-	-	6	-	-	6
Atriplex lindleyi subsp. *conduplicata*	17520	PRP1262	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Atriplex lindleyi subsp. *inflata*	12042		AH	-	-	-	-	-	-	-	-	2	-	-	-	2
Atriplex mundak	20005	PRP1940	LS	-	-	-	-	-	-	-	-	-	1	-	-	1
Atriplex semilunaris	2476	PRP1645	AH	-	-	-	-	-	-	1	-	1	-	-	1	3
Atriplex spinulosa	2477	PRP958	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Chenopodium auricomum	2485	PRP1329	MS	-	-	-	-	-	-	-	-	-	-	1	-	1
Chenopodium gaudichaudianum	2489	PRP1160	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Chenopodium melanocarpum	2492	PRP131	AH	-	-	-	-	-	1	-	-	4	-	2	-	7
* *Chenopodium murale*	2494	PRP1271	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Dissocarpus paradoxus	2499	PRP1021	AH	-	-	-	-	-	-	-	1	-	2	-	-	3
Dysphania kalpari	2502	PRP610	AH	-	-	-	5	-	1	1	-	-	-	2	2	11
Dysphania rhadinostachya	2506	PRP586	AH	17	1	1	46	1	2	3	16	3	-	7	2	99
Dysphania sphaerosperma	2508	PRP791	AH	-	-	-	2	-	-	-	-	-	-	-	-	2
Enchylaena tomentosa	2511		LS	3	1	-	4	7	6	2	4	8	13	7	1	56
Eremophea spinosa	2513	PRP1290	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Halosarcia auriculata	2515	PRP581	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Halosarcia calyptrata	2517	PRP1151	LS	-	-	-	-	-	-	-	-	-	1	-	-	1
Halosarcia halocnemoides	2522	PRP1547	LS	-	-	-	-	-	-	-	-	-	-	-	1	1
Halosarcia halocnemoides subsp. *tenuis*	11374	PRP580	LS	-	-	-	-	-	-	-	-	-	1	-	-	1
Halosarcia indica	2523	PRP579	LS	-	-	-	-	-	-	-	-	3	-	-	-	3
Halosarcia indica subsp. *bidens*	12121	HJRP64	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Halosarcia pruinosa	2529	PRP1549	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Halosarcia pterygosperma	2530		LS	-	-	-	-	-	-	-	-	-	1	-	-	1
Halosarcia pterygosperma subsp. *denticulata*	11234	PRP1548	LS	-	-	-	-	-	-	-	-	-	1	-	-	1
Halosarcia sp. Roy Hill (H. Pringle 62)	16691	PRP1287	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Maireana amoena	2533	PRP480	LS	-	-	-	-	-	-	-	-	-	2	-	-	2
Maireana aphylla	2534	PRP1256	LS	-	-	-	-	-	-	-	-	-	2	-	-	2
Maireana carnosa	2538	PRP1167	LS	-	-	-	1	2	-	-	-	-	5	-	-	8
Maireana convexa	2539		MS	-	-	-	-	1	2	-	-	-	1	-	-	4
Maireana eriosphaera	2543	PRP403	LS	-	-	-	-	-	-	-	-	-	1	-	-	1
Maireana georgei	2544	PRP962	LS	3	-	-	6	3	2	2	1	-	5	-	-	22
Maireana glomerifolia	2545		LS	-	-	-	-	-	-	-	-	-	3	-	-	3
Maireana integra	2546		LS	-	-	-	-	-	-	-	-	-	1	-	-	1
Maireana luehmannii	2549	PRP582	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Maireana melanocoma	2551	PRP997	LS	5	-	-	9	1	2	-	-	-	1	-	-	18
Maireana planifolia	2556	PRP137	LS	2	1	-	7	11	6	2	6	1	4	7	-	47
Maireana planifolia x *villosa*		PRP518	LS	-	-	-	5	1	8	1	-	-	-	2	-	17
Maireana platycarpa	2557	PRP1286	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Maireana pyramidata	2560		LS	-	-	-	-	-	1	-	-	1	7	1	1	11
Maireana suaedifolia	2565		LS	-	-	-	-	1	-	-	-	-	-	-	-	1
Maireana thesioides	2566	PRP643	LS	-	-	-	1	1	-	-	-	-	-	-	-	2
Maireana tomentosa	2567	PRP474	LS	-	-	-	5	5	3	1	-	1	9	-	1	25
Maireana tomentosa subsp. *tomentosa*	11662	PRP816	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Maireana triptera	2569	PRP963	LS	2	1	-	3	3	1	-	-	-	4	1	-	15

Family Botanical name	Taxon id.	Collec no.	Growth form	Site type group												Total sites
				A	B	C	D	E	F	G	H	I	J	K	O	
Maireana villosa	2571	PRP265	LS	2	-	-	8	3	13	1	-	1	-	7	1	36
Neobassia astrocarpa	2573	PRP342	AH	-	-	-	-	-	-	2	-	2	1	-	1	6
Rhagodia eremaea	2582		MS	8	1	-	15	13	15	2	8	20	10	11	3	106
Rhagodia preissii	2584		LS	-	-	-	-	-	-	1	-	-	-	-	-	1
Salsola tragus	18599		AH	13	3	1	28	7	2	3	6	21	9	7	4	104
Sclerolaena alata	2595	PRP481	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Sclerolaena bicornis	2598	PRP378	AH	-	-	-	1	-	-	-	1	9	6	-	-	17
Sclerolaena costata	2604	PRP375	AH	1	-	-	8	4	-	2	6	7	1	-	1	30
Sclerolaena cuneata	2606	PRP39	AH	-	-	-	7	8	-	-	5	3	16	2	2	43
Sclerolaena densiflora	2607	PRP1363	PH	5	1	-	17	7	1	-	2	7	9	3	2	54
Sclerolaena deserticola	2608	PRP523	PH	2	1	-	17	13	4	1	1	7	4	-	3	53
Sclerolaena diacantha	2609	PRP552	PH	3	-	-	8	-	-	-	1	1	1	-	-	14
Sclerolaena eriacantha	2611	PRP512	PH	-	-	-	2	1	-	-	-	-	-	-	-	3
Sclerolaena glabra	2616	PRP320	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Sclerolaena hostilis	2617	PRP1394	PH	-	-	-	2	-	-	-	2	5	3	-	1	13
Sclerolaena uniflora	2633	PRP443	PH	-	-	-	3	3	1	3	-	2	7	1	-	20
Sclerostegia disarticulata	2635	HJRP21	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Tecticornia verrucosa	2642	PRP1332	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Threlkeldia diffusa	2644	PRP1706	LS	-	-	-	-	-	-	1	-	-	-	-	-	1
Chloanthaceae																
Dicrastylis cordifolia var. *purpurea*	6754	PRP1397	LS	-	-	-	2	-	-	2	-	-	-	-	-	4
Dicrastylis doranii	6757	PRP930	LS	-	-	-	-	-	-	2	-	-	-	-	1	3
Dicrastylis georgei	6761	PRP51	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Dicrastylis sp. Kumarina (A.A. Mitchell 623)	19164	PRP434	LS	-	-	-	-	-	-	1	-	-	-	-	-	1
Newcastelia cephalantha	6786	PRP1097	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Newcastelia cladotricha	6789	PRP88	LS	-	-	-	-	-	-	4	-	-	-	-	-	4
Pityrodia aff. *lepidota*		PRP90	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Pityrodia loricata	6813	PRP1232	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Pityrodia loxocarpa	6814	PRP1640	LS	-	-	-	-	-	-	1	-	-	-	-	-	1
Pityrodia paniculata	6818	PRP1726	LS	-	-	-	-	-	-	1	-	-	-	-	-	1
Spartothamnella teucriiflora	6827		LS	1	-	-	2	-	2	-	-	-	-	2	-	7
Colchicaceae																
Wurmbea deserticola	1392	PRP1360	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Combretaceae																
Terminalia canescens	5300	PRP279	TR	3	-	-	-	-	-	-	-	-	-	-	2	5
Terminalia cunninghamii	5302	PRP1774	TS	-	-	-	-	-	-	1	-	-	-	-	-	1
Commelinaceae																
Commelina ensifolia	1165	PRP1048	AH	1	-	-	-	-	-	-	-	1	-	-	-	2
Convolvulaceae																
Bonamia alatisemina	6603	PRP286	C	-	-	-	9	-	-	4	2	-	-	1	1	17
Bonamia erecta	11167		LS	2	-	-	21	-	-	8	5	-	-	7	-	43
Bonamia linearis	6605	PRP351	AH	1	-	-	1	-	-	3	-	-	-	-	-	5
Bonamia media	6606		LS	1	-	-	7	-	-	-	1	1	-	1	-	11
Bonamia media var. *villosa*	17514	PRP637	AH	1	-	-	1	-	-	-	-	-	-	-	-	2
Bonamia pannosa	6608	PRP27	AH	-	-	-	5	-	-	-	3	-	-	2	-	10
Bonamia rosea	6609		LS	2	-	-	14	2	-	10	-	2	-	1	-	31
Convolvulus angustissimus	19880		C	-	-	-	-	1	2	-	-	-	-	1	-	4
Evolvulus alsinoides	6617	PRP178	PH	10	3	-	30	7	16	12	14	4	-	20	2	118
Evolvulus alsinoides var. *villosicalyx*	11200	PRP625B	PH	-	-	-	1	-	-	-	-	-	-	-	-	1
Ipomoea calobra	6621	PRP264	C	-	-	-	-	-	1	1	-	-	-	1	-	3
Ipomoea coptica	6623	PRP1830	AH	-	-	-	-	-	-	-	2	-	-	-	-	2
Ipomoea costata	6624	PRP1716	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Ipomoea diamantinensis	6625	PRP243	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Ipomoea lonchophylla	6631	PRP147	AH	-	-	-	-	-	1	-	-	-	-	1	-	2
Ipomoea muelleri	6633	PRP838	C	-	-	1	1	1	1	1	10	13	-	9	1	38
Ipomoea plebeia	6636	PRP1069	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Ipomoea polymorpha	6637	PRP312	AH	-	-	-	-	-	-	-	-	2	-	-	-	2
Merremia davenportii	6645	PRP311	C	-	-	-	-	-	-	-	-	-	-	-	-	-
* *Merremia dissecta*	6646	PRP1900	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Merremia sp. B Kimberley Flora (B.J. Carter 533)	15923	PRP36	C	-	-	-	1	-	1	-	-	-	-	-	-	2
Operculina aequisepala	6651	PRP138	AH	-	-	1	-	-	1	-	-	2	-	-	-	4
Operculina brownii	6652		AH	-	-	-	-	-	-	-	-	1	-	-	-	1
Polymeria ambigua	6653	PRP236	C	1	-	-	11	-	-	3	3	1	-	4	-	23
Polymeria calycina	6655		C	-	-	-	-	-	-	-	-	3	-	-	-	3
Polymeria distigma	9232	PRP708	C	-	-	-	-	-	-	-	-	2	-	-	-	2
Polymeria lanata	17513	PRP797	C	-	-	-	-	-	-	-	-	2	-	-	-	2
Polymeria longifolia	13966	PRP1047	PH	2	-	-	2	-	-	-	-	-	-	-	1	5
Porana commixta	6656	PRP541	C	-	-	-	9	-	1	-	2	2	-	6	1	21
Porana sericea	6657		C	3	-	-	3	1	2	-	1	-	-	3	-	13

Family Botanical name	Taxon id.	Collec no.	Growth form	Site type group												Total sites
				A	B	C	D	E	F	G	H	I	J	K	O	
Cucurbitaceae																
* *Citrullus colocynthis*	7369	PRP923	C	-	-	-	-	-	-	-	-	-	-	-	-	-
* *Citrullus lanatus*	7370	PRP1685	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Cucumis melo	7371	PRP1280	C	1	-	-	-	-	-	-	-	-	-	-	-	1
Cucumis melo subsp. *agrestis*	12039	PRP231	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Mukia maderaspatana	7380	PRP868	C	11	-	-	18	1	2	11	9	4	-	7	3	66
Mukia sp. 'D' Flora of Australia (A.A. Mitchell PRP1121)	18253	PRP1121	C	-	-	1	1	-	-	-	-	-	-	-	-	2
Trichosanthes cucumerina	7381	PRP1839	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichosanthes cucumerina var. *cucumerina*	12032	PRP280	C	-	-	-	-	-	-	-	-	-	-	-	1	1
Cupressaceae																
Callitris glaucophylla	94	PRP170	TR	-	-	-	-	-	-	-	-	-	-	1	-	1
Cuscutaceae																
Cuscuta victoriana	13733	PRP60	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyperaceae																
Baumea arthrophylla	740	PRP1103	PS	-	-	-	-	-	-	-	-	-	-	1	-	1
Bulbostylis barbata	750		AS	3	-	-	10	-	-	1	3	1	-	-	-	18
Bulbostylis burbidgeae	751	PRP1323	AS	2	-	-	2	-	-	3	1	-	1	1	-	10
Bulbostylis turbinata	752	PRP1854	AS	-	-	-	-	-	-	-	1	-	-	-	-	1
Cyperus bifax	774	PRP244	PS	-	-	-	-	-	-	-	-	2	-	-	-	2
Cyperus blakeanus	12801	PRP1905	PS	-	-	-	-	-	-	-	-	3	-	-	-	3
Cyperus bulbosus	777	PRP1036	PS	-	-	-	-	1	-	-	-	-	1	-	-	2
Cyperus concinnus	782	PRP564	PS	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyperus cunninghamii	786	PRP1014	PS	5	-	-	-	-	-	-	-	-	-	-	-	5
Cyperus difformis	789	PRP1459	PS	-	-	-	-	-	-	-	-	-	-	-	-	-
Cyperus iria	798	PRP208	PS	-	-	-	1	-	-	-	1	-	2	1	-	5
Cyperus ixiocarpus	799	PRP993	PS	-	-	-	-	-	-	-	1	1	-	2	-	4
Cyperus polystachyos	806	PRP1101	PS	-	-	-	-	-	-	-	-	-	-	1	-	1
Cyperus rigidellus	809	PRP1840	PS	1	-	-	-	-	-	-	-	-	-	-	-	1
* *Cyperus rotundus*	810		PS	-	-	-	-	-	-	-	-	-	1	-	-	1
Cyperus squarrosus	814	PRP215	AS	-	-	-	1	-	-	-	-	2	-	-	-	3
Cyperus vaginatus	818	AAM3593	PS	-	-	-	-	-	-	-	-	1	-	7	-	8
Eleocharis atropurpurea	823	PRP1515	AS	-	-	-	-	-	-	-	-	-	-	1	-	1
Eleocharis dulcis	826	PRP1491B	PS	-	-	-	-	-	-	-	-	-	-	-	-	-
Eleocharis geniculata	827	PRP1102	PS	-	-	-	-	-	-	-	-	-	-	1	-	1
Fimbristylis dichotoma	851	PRP112	PS	3	-	-	7	1	2	1	7	3	-	-	-	24
Fimbristylis neilsonii	865	PRP371	AS	-	-	-	-	-	-	-	-	-	-	-	-	-
Fimbristylis oxystachya	870	PRP94	PS	-	-	-	-	-	-	-	-	-	-	-	-	-
Fimbristylis rara	878	PRP1569	AS	-	-	-	-	-	-	-	-	-	-	-	-	-
Fimbristylis simulans	12159	PRP1557	AS	-	-	-	5	-	-	-	-	-	-	-	-	5
Fimbristylis sp. Shay Gap (K.R. Newbey 10293)	16263	PRP1403	AS	-	-	-	-	-	-	-	-	-	-	-	-	-
Fuirena ciliaris	896	PRP1914	AS	-	-	-	-	-	-	-	-	-	-	-	-	-
Schoenoplectus dissachanthus	962	PRP563	PS	-	-	-	-	-	-	-	-	-	-	-	-	-
Schoenoplectus laevis	963	PRP396	AS	-	-	-	-	-	-	-	-	-	-	-	-	-
Schoenoplectus litoralis	965	AAM3594	PS	-	-	-	-	-	-	-	-	-	-	-	-	-
Schoenoplectus subulatus	16257	PRP809	PS	-	-	-	-	-	-	-	-	-	-	1	-	1
Schoenus falcatus	989	PRP1482	PS	-	-	-	-	-	-	-	-	-	-	-	-	-
Droseraceae																
Drosera indica	3103	PRP1361	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Elatinaceae																
Bergia pedicellaris	5184	PRP742	AH	-	-	-	1	-	-	-	-	-	-	-	-	1
Bergia perennis subsp. *perennis*	11912	PRP865	AH	-	-	-	-	-	-	-	-	-	-	2	-	2
Bergia trimera	5186	PRP596	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Euphorbiaceae																
Adriana tomentosa var. *hookeri*	17422	PRP1070	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Adriana urticoides	20595	PRP850	MS	-	-	-	-	-	-	3	-	-	-	1	-	4
Croton aridus	19409	PRP1823	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Euphorbia alsiniflora	4614	PRP120	AH	-	-	-	1	1	3	3	2	1	-	4	-	15
Euphorbia australis	4617	PRP219	AH	16	1	-	47	4	3	7	13	8	-	13	-	112
Euphorbia boophthona	4620	PRP597	AH	6	-	-	18	3	3	4	3	5	-	7	1	50
Euphorbia drummondii	4626		AH	-	-	-	2	1	-	-	-	-	-	-	-	3
Euphorbia schultzii	4642	PRP225	AH	2	-	-	1	-	-	-	-	-	-	1	-	4
Euphorbia stevenii	4646	PRP26	AH	1	-	-	-	-	-	-	-	-	-	-	-	1
Euphorbia tannensis subsp. *eremophila*	12097	PRP941	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Euphorbia vachellii	4649		AH	-	-	-	1	-	-	-	-	-	-	-	-	1
Euphorbia wheeleri	4650	PRP1492	AH	-	-	-	-	-	-	-	-	-	-	-	-	-

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Flueggea virosa	4654	PRP224	MS	1	-	-	-	-	-	-	-	-	-	1	-	2
Leptopus decaisnei	4657	PRP1934	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Mallotus nesophilus	4658	PRP973	TR	1	-	-	-	-	-	-	-	-	-	-	-	1
Phyllanthus lacunarius	4679	PRP1456	AH	1	-	-	4	-	-	-	-	-	-	-	-	5
Phyllanthus maderaspatensis	4680	PRP605	AH	-	-	-	2	-	-	-	1	10	-	4	-	17
Phyllanthus reticulatus	4684	PRP1514	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
* *Ricinus communis*	4705	PRP843	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Frankeniaceae																
Frankenia ambita	5188	PRP1770	LS	-	-	-	-	-	-	-	-	2	1	-	1	4
Gentianaceae																
Centaurium spicatum	6541	PRP1494	AH	-	-	-	-	-	-	-	-	-	1	1	-	2
Goodeniaceae																
Brunonia australis	7413	PRP431	AH	-	-	-	2	2	1	1	-	-	-	1	-	7
Dampiera atriplexifolia	7423	PRP1106	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Dampiera candicans	7424	PRP62	AH	14	-	-	5	-	-	4	1	-	-	3	-	27
Dampiera cinerea	7426	PRP85A	LS	-	-	-	-	-	-	1	-	-	-	-	-	1
Goodenia azurea	7493	PRP58	LS	-	-	-	1	-	-	-	-	-	-	-	-	1
Goodenia berardiana	7495	PRP529	AH	2	-	-	1	-	-	-	-	1	-	1	-	5
Goodenia cusackiana	12517	PRP1391	LS	1	-	-	-	-	-	-	-	-	-	-	-	1
Goodenia forrestii	7509	PRP1873	AH	-	-	-	1	-	-	-	-	-	-	-	-	1
Goodenia heterochila	7515	PRP1083	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Goodenia lamprosperma	7521	PRP210	AH	1	-	-	-	-	-	-	-	-	-	8	-	9
Goodenia lyrata	12529	PRP1349	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Goodenia microptera	7526	PRP698	AH	3	-	-	23	3	2	9	5	3	-	5	-	53
Goodenia muelleriana	12552	PRP181	AH	-	-	-	5	-	-	-	1	-	-	-	-	6
Goodenia nuda	7530	PRP697	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Goodenia omearana ms	18639	PRP727	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Goodenia pascua	12571	PRP719B	AH	-	-	1	-	1	-	-	-	7	-	2	-	11
Goodenia pinnatifida	7535	PRP492	AH	-	-	-	-	-	-	-	-	-	-	1	-	1
Goodenia prostrata	12574	PRP374	AH	-	1	-	-	2	5	-	-	-	2	2	3	15
Goodenia stellata	7550	PRP670	AH	-	-	-	-	-	-	-	-	-	-	2	-	2
Goodenia stobbsiana	10982	PRP59	LS	34	-	-	32	-	2	-	2	1	-	6	-	77
Goodenia triodiophila	7558	PRP609	AH	4	-	-	6	-	1	3	1	-	-	2	-	17
Scaevola acacioides	12578	PRP639	MS	1	-	-	-	-	-	-	-	-	-	-	-	1
Scaevola amblyanthera	12723	PRP877	LS	2	-	-	7	-	-	1	1	2	-	-	-	13
Scaevola amblyanthera var. *centralis*	13178	PRP634	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Scaevola browniana	12579	PRP65	LS	1	-	-	8	-	-	1	-	-	-	-	-	10
Scaevola crassifolia	7606	PRP1784	LS	-	-	-	-	-	-	1	-	-	-	-	-	1
Scaevola parviflora	7633	PRP87	LS	-	-	-	4	1	-	12	1	-	-	2	1	21
Scaevola spinescens	7644	PRP78	LS	1	-	-	6	2	-	4	2	4	6	3	2	30
Velleia connata	7654	PRP614	AH	-	-	-	2	-	-	-	-	-	-	1	-	3
Velleia panduriformis	7663	PRP89	AH	-	-	-	-	-	-	2	-	-	-	-	-	2
Gyrocarpaceae																
Gyrocarpus americanus	2960	PRP1869	TR	-	-	-	-	-	-	-	-	-	-	-	-	-
Gyrostemonaceae																
Codonocarpus cotinifolius	2778		TR	1	-	-	7	-	-	-	1	-	-	1	-	10
Gyrostemon tepperi	2789	PRP1805	LS	-	-	-	1	-	-	4	-	-	-	-	-	5
Haloragaceae																
Gonocarpus ephemerus	6151	PRP1931	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Haloragis gossei	6174	PRP503	AH	3	-	-	4	-	-	-	1	-	-	2	1	11
Haloragis odontocarpa forma pterocarpa	16371	PRP546	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Myriophyllum verrucosum	6201	PRP831	Q	-	-	-	-	-	-	-	-	-	-	1	-	1
Hydrocharitaceae																
Vallisneria nana	17793	PRP945	Q	-	-	-	-	-	-	-	-	-	-	1	-	1
Juncaginaceae																
Triglochin hexagona	145	PRP1202	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Lamiaceae																
Basilicum polystachyon	6830	PRP768	AH	-	-	-	-	-	-	-	-	-	-	1	-	1
Clerodendrum floribundum	6729	PRP253	TR	6	-	-	1	-	-	-	-	1	-	1	1	10
Clerodendrum tomentosum	6732	PRP82	TS	-	-	-	-	-	-	2	-	-	-	-	-	2
Cyanostegia cyanocalyx	6745	PRP1767	LS	-	-	-	-	-	-	1	-	-	-	-	-	1
Plectranthus intraterraneus	6910	AAM3628	AH	-	-	-	-	-	-	-	-	-	-	1	-	1
Teucrium pilbaranum	19366	PRP733	PH	-	-	-	-	-	-	-	-	1	-	1	-	2
Teucrium racemosum	6936	PRP735	LS	-	-	-	-	-	-	-	-	1	-	-	-	1
Cassytha capillaris	2949	PRP298	C	5	-	-	16	-	-	9	6	1	-	8	-	45

Family Botanical name	Taxon id.	Collec no.	Growth form	A	B	C	D	E	F	G	H	I	J	K	O	Total sites
Lobeliaceae																
Lobelia heterophylla	7403	PRP625A	AH	1	-	-	-	-	-	1	-	-	-	-	-	2
Lobelia quadrangularis	7404	PRP750	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Loganiaceae																
Logania centralis	12969	PRP1236	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Mitrasacme connata	6519	PRP1930	AH	-	-	-	-	-	-	1	-	-	-	-	-	1
Loranthaceae																
Amyema fitzgeraldii	2372	PRP545	Mi	-	-	-	1	-	-	-	-	-	-	1	-	2
Amyema miquelii	2380	PRP642	Mi	-	-	-	-	-	-	-	-	-	-	-	-	-
Amyema pyriformis	13264	PRP1867	Mi	-	-	-	-	-	-	-	-	-	-	-	-	-
Amyema sanguinea	2385	PRP920	Mi	-	-	-	-	-	-	-	-	-	-	2	-	2
Amyema sanguinea var. *pulcher*	11427	PRP668	Mi	-	-	-	-	-	-	-	-	-	-	-	-	-
Amyema sanguinea var. *sanguinea*	11874	PRP1440	Mi	-	-	-	-	-	-	-	-	-	-	-	-	-
Lysiana casuarinae	2396	PRP1520	Mi	-	-	-	1	-	-	-	-	1	-	1	-	3
Lythraceae																
Ammannia baccifera	5277	PRP1198	AH	-	-	-	-	-	-	-	-	-	-	1	-	1
Ammannia multiflora	5278	PRP389	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Rotala diandra	5285		AH	-	-	-	1	-	-	-	-	2	-	-	-	3
Malvaceae																
Abutilon amplum	4886	PRP453	LS	-	-	-	-	1	-	1	-	1	-	1	-	4
Abutilon cryptopetalum	4889	PRP33	LS	-	-	-	1	-	1	-	-	-	-	4	-	6
Abutilon cunninghamii	9080	PRP765	LS	1	-	-	1	-	1	-	-	-	-	-	1	4
Abutilon diocium ms	19589	PRP12	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Abutilon fraseri	4891		MS	1	-	-	-	1	1	-	1	-	-	1	-	5
Abutilon fraseri subsp. *fraseri*	18120	PRP1079	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Abutilon indicum	4894	PRP1759	MS	-	-	-	-	-	-	2	1	-	-	-	-	3
Abutilon indicum var. *austaliense*	11325	PRP870	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Abutilon lepidum	4895	PRP460	LS	16	2	-	20	1	2	-	1	4	2	4	-	52
Abutilon leucopetalum	4896	PRP1623	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Abutilon macrum	4898	PRP660	MS	-	-	-	-	1	-	-	-	-	-	1	-	2
Abutilon malvifolium	4899	PRP676	MS	-	-	-	2	-	-	-	-	9	-	1	-	12
Abutilon otocarpum	4901	AAM3617	LS	-	-	-	8	1	5	6	1	4	1	4	1	31
Abutilon oxycarpum	4902	PRP1266	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Abutilon pritzelianum	16917	PRP1932	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Abutilon trudgenii	16916	PRP1322	MS	-	-	-	4	-	-	-	1	1	-	-	-	6
Abutilon uncinatum ms	18122	PRP1719	MS	-	-	-	1	-	-	-	1	-	-	-	-	2
Alyogyne pinoniana	4907	PRP479	LS	-	-	-	1	-	-	1	-	-	-	-	-	2
Gossypium australe	4910	PRP1451	MS	8	-	-	18	1	-	4	9	-	-	8	1	49
* *Gossypium hirsutum*	4913	PRP1532	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Gossypium robinsonii	4918	PRP1833	TS	4	-	-	1	-	-	-	2	1	-	8	1	17
Gossypium sturtianum	4919		MS	-	-	-	2	-	-	-	-	-	-	-	-	2
Hibiscus brachychlaenus	4922	PRP836	MS	1	-	-	5	-	-	2	1	4	2	-	-	15
Hibiscus brachysiphonius	4923	PRP189	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Hibiscus burtonii	4924	PRP54B	LS	2	-	-	18	5	8	5	5	-	-	5	1	49
Hibiscus coatesii	4925	PRP636	LS	6	-	-	7	1	1	-	1	-	-	4	-	20
Hibiscus gardneri	17349	PRP1435	MS	-	-	-	1	-	-	-	1	-	-	1	-	3
Hibiscus goldsworthii	4930	PRP277	TS	3	-	-	-	-	-	-	-	-	-	2	-	5
Hibiscus krichauffianus	4932		LS	3	-	-	2	-	-	-	-	-	-	-	-	5
Hibiscus leptocladus	4933	PRP1750	MS	-	-	-	1	-	-	2	-	-	-	-	-	3
Hibiscus panduriformis	4936	PRP1744	LS	-	-	-	-	-	-	-	1	1	-	2	-	4
Hibiscus sturtii	4942	PRP285	LS	5	-	-	21	2	6	6	14	2	2	11	1	70
Hibiscus sturtii var. *platychlamys*	11477	PRP1396	LS	-	-	-	-	-	-	1	-	-	-	-	-	1
Hibiscus sturtii var. *truncatus*	11893	PRP66	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Hibiscus trionum	4944	PRP206	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Lawrencia densiflora	4953	PRP1204	AH	-	-	-	-	-	-	-	-	-	1	-	1	2
Lawrencia glomerata	19462	PRP1796	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Lawrencia viridigrisea	4960	PRP1792	PH	-	-	-	-	-	-	-	-	1	1	-	1	3
* *Malvastrum americanum*	4962	PRP699	LS	-	1	-	10	1	5	-	8	25	2	17	1	70
Sida ammophila	16479		LS	-	-	-	1	-	-	-	-	-	-	-	-	1
Sida arenicola	4966	PRP835	MS	-	-	-	5	-	-	3	-	-	-	-	-	8
Sida atrovirens	16922	PRP08	LS	-	-	-	1	-	-	-	-	-	-	-	-	1
Sida billbarkeri	19671	PRP363	LS	1	-	-	2	-	-	4	-	-	-	-	-	7
Sida brownii	4969	PRP1187	LS	-	1	-	1	1	-	-	-	-	-	-	-	3
Sida calyxhymenia	4970	PRP1230	MS	-	-	-	2	3	6	-	-	-	-	-	-	11
Sida cardiophylla	4971	PRP487	LS	2	-	-	17	1	1	1	5	1	-	3	-	31
Sida chrysocalyx	19590	PRP1214	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Sida clementii	4972	PRP21	LS	-	-	-	8	2	-	-	2	1	-	2	-	15
Sida echinocarpa	4976	PRP159	LS	11	2	-	25	4	1	1	4	-	1	4	-	53
Sida excedentifolia	16930	PRP1431	LS	2	-	-	1	-	-	-	-	-	-	-	1	4

Family Botanical name	Taxon id.	Collec no.	Growth form	Site type group												Total sites
				A	B	C	D	E	F	G	H	I	J	K	O	
Sida fibulifera	4977	PRP03	LS	-	-	5	21	8	12	-	20	46	11	15	3	141
Sida macropoda	4983	PRP1815	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Sida pilbarensis	19160	PRP847	LS	2	-	-	3	1	-	4	1	-	-	2	-	13
Sida platycalyx	4986	PRP175	LS	-	-	-	1	3	2	-	1	1	-	-	1	9
Sida rhytidocarpa	18121	PRP1087	LS	-	-	-	1	-	-	-	-	-	-	-	-	1
Sida rohlenae	4988	PRP307	LS	5	-	1	2	1	-	3	7	4	-	8	3	34
Sida sp. A Flora of Central Australia (P.A. Fryxell and L.A. Craven 3900)	15227	PRP1731	MS	1	-	-	1	-	-	4	-	-	-	-	-	6
Sida sp. Barlee Range (S. van Leeuwen 1642)	16616	PRP1057	LS	1	-	-	-	-	-	-	-	-	-	-	-	1
Sida sp. Pilbara (S. van Leeuwin 4377)	20259	PRP1058	LS													
Sida sp. sand dunes (A.A. Mitchell PRP1208)	18145	PRP1208	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Sida sp. spiciform panicles (E. Leyland s.n.14/8/1990)	16617	PRP589	MS	2	1	-	7	-	-	-	-	-	-	4	-	14
Sida sp. tiny glabrous fruit (A.A. Mitchell PRP1152)	18144	PRP1152	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Sida sp. unisexual (N.H. Speck 574)	16925	PRP410	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Sida sp. verrucose glands (F.H. Mollemans 2423)	16948	PRP661	LS	-	-	-	1	1	-	-	1	-	-	3	-	6
Sida sp. Wittenoom (W.R. Barker 1962)	14111	PRP209	LS	1	-	-	3	-	-	1	2	-	1	1	-	9
Sida spinosa	4989	PRP204	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Sida subarticulata	19341	PRP1605	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Sida tescorum	19834	PRP1217	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Sida trichopoda	16923	PRP188	LS	-	-	-	-	-	-	-	-	2	1	-	-	3
Marsileaceae																
Marsilea drummondii	74	PRP805	F	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsilea exarata	75	PRP1257	F	-	-	-	-	-	-	-	-	-	-	-	-	-
Marsilea hirsuta	76	PRP1293	F	-	-	-	-	-	-	-	-	-	-	-	-	-
Meliaceae																
Owenia reticulata	4518		TR	-	-	-	-	-	-	3	-	-	-	1	2	6
Menispermaceae																
Tinospora smilacina	2942	PRP1679	C	3	-	-	1	-	-	5	-	1	-	3	1	14
Mimosaceae																
Acacia acradenia	3198	PRP855	MS	5	-	-	15	-	-	-	2	1	-	4	-	27
Acacia adoxa var. *adoxa*	11215	PRP13	LS	10	-	-	2	-	-	2	-	-	-	-	-	14
Acacia adsurgens	3205	PRP1737	TS	-	-	-	1	-	-	-	-	-	-	-	-	1
Acacia ampliceps	3209	PRP1602	MS	-	-	-	2	-	-	-	1	6	-	4	1	14
Acacia anaticeps	3212	PRP1778	MS	-	-	-	-	-	-	2	-	-	-	-	-	2
Acacia ancistrocarpa	3214		TS	11	-	-	85	1	1	15	17	3	1	17	2	153
Acacia ancistrocarpa x *trachycarpa*	11097	PRP919	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia aneura	3217	PRP760	TS	12	4	-	26	22	28	4	-	3	5	27	4	135
Acacia aneura 'weeping'		PRP496	TR	-	-	-	-	-	2	-	-	-	-	1	-	3
Acacia aphanoclada	13073	PRP399	TS	1	-	-	-	-	-	-	-	-	-	-	-	1
Acacia arida	3223	PRP221	TS	3	-	-	3	-	-	1	1	-	-	2	1	11
Acacia arrecta	3224	PRP793	LS	-	-	-	3	-	-	-	-	-	-	-	-	3
Acacia atkinsiana	3228	PRP607	TS	10	-	-	19	1	1	-	1	-	-	5	-	37
Acacia balsamea	14622	PRP1251	TS	-	-	-	2	-	-	-	-	-	-	-	-	2
Acacia bivenosa	3241	PRP949	TS	22	-	-	86	-	1	3	14	1	1	14	-	142
Acacia catenulata	19571	PRP514	TS	1	-	-	2	-	5	1	-	-	-	-	-	9
Acacia citrinoviridis	3260	PRP787	TR	-	-	-	5	-	-	-	-	2	-	6	-	13
Acacia colei var. *colei*	17013	AAM3768	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia colei var. *ileocarpa*	17014	PRP1513	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia coolgardiensis subsp. *coolgardiensis*	15276	PRP1157	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia coriacea	3270	PRP1235	TR	2	-	-	7	-	-	10	2	4	1	9	1	36
Acacia coriacea subsp. *sericophylla*	13501	PRP1235	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia coriacea var. *pendens*	13502	HJRP61	TR	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia cowleana	3272	PRP585	TS	-	-	-	1	-	-	-	-	-	-	-	-	1
Acacia cuthbertsonii subsp. *cuthbertsonii*	15280	PRP1220	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia cyperophylla var. *omearana*	14087	PRP1460	TR	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia dictyophleba	3300	PRP68	TS	1	-	-	8	-	-	2	1	-	-	2	-	14
Acacia distans	3305	PRP549	TR	-	-	-	-	-	-	-	-	-	-	3	-	3
Acacia drepanocarpa subsp. *latifolia*	16162	PRP1798	MS	-	-	-	-	-	-	2	-	-	-	-	-	2

Family Botanical name	Taxon id.	Collec no.	Growth form					Site type group								Total sites
				A	B	C	D	E	F	G	H	I	J	K	O	
Acacia elachantha	16174	PRP1689	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia eriopoda	3326	PRP908	TS	1	-	-	3	-	-	4	-	-	-	-	-	8
Acacia farnesiana	3333		TS	1	-	-	2	-	1	-	10	19	2	9	3	47
Acacia gilesiana	3348	PRP1224	MS	-	-	-	-	-	-	1	-	-	-	-	-	1
Acacia glaucocaesia	12673	PRP925	TS	1	-	-	1	1	-	-	1	2	-	-	-	6
Acacia grasbyi	3355		TS	-	-	-	1	1	1	-	-	-	-	-	-	3
Acacia hamersleyensis	3360	PRP622	MS	1	-	-	-	-	-	-	-	-	-	1	-	2
Acacia hilliana	3370	PRP501	LS	14	-	-	5	-	-	-	-	-	-	-	-	19
Acacia holosericea	3372		TS	1	-	-	13	-	-	9	5	3	-	14	-	45
Acacia inaequilatera	3377	AAM3774	TS	29	-	1	101	1	1	9	24	14	-	14	2	196
Acacia levata	15289	PRP287	MS	-	-	-	1	-	-	-	-	-	-	-	-	1
Acacia ligulata	3419	PRP527	MS	6	-	-	10	-	1	3	1	-	-	1	-	22
Acacia maitlandii	3434	PRP1178	MS	15	-	-	13	-	-	1	-	-	-	1	-	30
Acacia marramamba	3435	AAM3766	TS	6	-	-	1	-	1	1	-	-	-	1	-	10
Acacia monticola	3447	PRP623	TS	6	-	-	2	-	-	4	2	-	-	2	-	16
Acacia orthocarpa	3471	PRP366	TS	16	-	-	6	-	-	1	-	-	-	1	-	24
Acacia pachyacra	3475	PRP1005	TS	-	-	-	-	1	-	-	-	-	-	-	-	1
Acacia pachycarpa	3476		MS	-	-	-	2	-	-	-	1	1	-	-	-	4
Acacia prainii	3495	PRP1200	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia pruinocarpa	3500	PRP970	TR	12	2	-	27	6	7	1	-	3	-	4	1	63
Acacia ptychophylla	3501	PRP917	LS	2	-	-	5	-	-	2	-	-	-	-	-	9
Acacia pyrifolia	3506	PRP820	MS	10	-	-	11	-	-	3	3	1	-	16	1	45
Acacia ramulosa var. *linophylla*	19483	PRP484	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia retivenea subsp. *cladestina*	15215	PRP1344	TS	4	-	-	1	-	-	1	-	-	-	-	-	6
Acacia rhodophloia	3519	PRP533	TS	2	-	-	1	3	1	-	-	1	-	-	1	9
Acacia sabulosa	15203	PRP1540	TS	-	-	-	1	-	-	2	-	-	-	-	-	3
Acacia sclerosperma subsp. *sclerosperma*	13078	AAM3783	TS	-	-	-	8	1	1	5	7	9	4	10	1	46
Acacia sibilans	3544	PRP511	TR	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia sphaerostachya	3551	PRP860	TS	-	-	-	-	-	-	2	-	-	-	-	-	2
Acacia spondylophylla	3553	PRP743	LS	3	-	-	1	-	-	-	-	-	-	-	-	4
Acacia sp. Weelarrana (A.A. Mitchell PRP468)		PRP468	MS	-	-	-	1	-	2	-	-	-	-	-	-	3
Acacia stellaticeps	19456	PRP884	LS	6	-	-	22	-	-	21	13	2	-	4	1	69
Acacia stenophylla	3556	PRP731	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia stowardii	3561	PRP535	TS	-	-	-	1	-	-	-	-	-	-	1	-	2
Acacia synchronicia	13070	PRP92	TS	1	-	-	9	-	1	-	1	1	-	1	-	14
Acacia tenuissima	3573	PRP664	TS	3	-	-	7	-	-	1	-	-	-	-	-	11
Acacia tetragonophylla	3577	PRP671	TS	10	1	-	11	18	5	2	2	7	7	15	4	82
Acacia trachycarpa	3579	PRP591	TS	4	-	-	18	-	-	4	4	7	-	17	3	57
Acacia tumida var. *pilbarensis*	20319	PRP1808	TS	9	-	-	13	-	-	8	2	2	-	13	2	49
Acacia validinervia	3592	PRP673	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Acacia victoriae	3595	PRP1294	TS	6	-	-	32	9	1	2	28	21	13	11	7	130
Acacia wanyu	3598	PRP64	TS	1	1	-	9	2	2	-	1	-	-	3	1	20
Acacia xiphophylla	3606	PRP1485	TS	-	-	-	6	-	1	-	15	15	9	3	-	49
* *Leucaena leucocephala*	3613	PRP1531	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Neptunia dimorphantha	3614	PRP122	PH	-	-	3	2	1	-	-	6	20	6	-	1	39
Neptunia monosperma	3617		PH	-	-	-	-	-	-	-	-	-	-	-	1	1
* *Prosopis glandulosa x velutina*	18373	PRP1686	TS	-	-	-	1	-	-	-	-	3	3	-	-	7
Molluginaceae																
Glinus lotoides	2835	PRP455	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Glinus oppositifolius	2836	PRP871	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Mollugo molluginis	2843	PRP308	PH	19	-	-	67	1	2	8	18	3	-	8	1	127
Moraceae																
Ficus brachypoda	19648	PRP357	TS	4	-	-	1	-	-	1	-	-	-	2	-	8
Ficus opposita	1752		TS	-	-	-	-	-	-	-	-	1	-	-	-	1
Myoporaceae																
Eremophila caespitosa ms	14509	PRP653	LS	-	1	-	-	-	1	-	-	-	-	-	-	2
Eremophila canaliculata	15167	PRP700	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Eremophila clarkei	7189	PRP506	LS	-	-	-	-	-	2	-	-	-	-	-	-	2
Eremophila compacta	7190		LS	1	-	-	1	1	-	-	-	-	-	-	-	3
Eremophila cuneifolia	7192	PRP520	LS	3	-	-	9	7	1	-	1	-	4	3	-	28
Eremophila exilifolia	7205	PRP99	LS	5	-	-	8	4	2	1	-	-	-	-	-	20
Eremophila flaccida	16301	PRP409	LS	-	-	-	-	1	-	-	-	-	-	-	-	1
Eremophila forrestii	7208		LS	5	2	-	20	10	12	1	4	2	2	12	-	70
Eremophila forrestii subsp. *forrestii* ms	15052	PRP737	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Eremophila fraseri	16698	PRP1193	MS	1	2	-	1	4	4	-	-	-	-	2	1	15
Eremophila fraseri subsp. *parva*	7209	PRP413A	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Eremophila incisa	15166	PRP406	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Eremophila jucunda	17518		LS	-	-	-	1	-	1	-	-	-	-	-	-	2
Eremophila jucunda subsp. *jucunda* ms	17171	PRP491	LS	-	-	-	-	1	-	-	-	-	-	-	-	1

Family Botanical name	Taxon id.	Collec no.	Growth form	Site type group												Total sites
				A	B	C	D	E	F	G	H	I	J	K	O	
Eremophila lachnocalyx	7228		MS	-	-	-	-	1	-	-	-	-	1	-	-	2
Eremophila lanceolata	16940	PRP118	LS	-	-	-	1	3	11	1	1	1	2	7	1	28
Eremophila latrobei	7230		LS	8	1	-	17	9	13	4	1	-	1	6	2	62
Eremophila latrobei subsp. *glabra* ms	17169	PRP381	LS	-	-	-	2	-	-	-	-	-	-	-	-	2
Eremophila latrobei subsp. *latrobei* ms	17576	PRP936	LS	1	-	-	-	-	-	-	-	-	-	-	-	1
Eremophila longifolia	7234	PRP1317	TS	6	-	-	13	2	1	-	2	5	2	7	2	40
Eremophila maculata	7237	PRP1253	LS	-	-	-	-	-	-	-	-	1	2	1	-	4
Eremophila magnifica ms	14512	PRP1099	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Eremophila margarethae	7239	PRP471	LS	-	-	-	-	3	2	-	-	1	-	-	-	6
Eremophila pachomai ms	15159	PRP97	MS	-	-	-	-	1	-	-	-	-	-	-	-	1
Eremophila pantonii	7250		LS	2	-	-	3	2	1	-	-	-	-	-	-	8
Eremophila pensilis	17546	PRP1263	LS	-	-	-	2	4	3	2	-	-	1	2	-	14
Eremophila pilosa ms	15028	PRP1274	LS	-	-	-	1	-	-	-	-	-	-	-	-	1
Eremophila pterocarpa	7255		TS	-	-	-	-	-	-	-	-	-	-	1	-	1
Eremophila spathulata	7270		MS	-	-	-	-	-	1	-	-	-	-	-	-	1
Eremophila spongiocarpa ms	17363	PRP575	LS	-	-	-	-	-	-	-	-	-	3	-	1	4
Eremophila youngii	7285		MS	-	-	-	-	1	-	-	-	-	2	-	-	3
Eremophila youngii subsp. *lepidota* ms	16040	PRP550	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Myoporum montanum	17158	PRP1713	MS	1	-	-	1	-	-	-	-	-	-	-	-	2
Myrtaceae																
Aluta maisonneuvei susp. maisonneuvei	19469	PRP73	MS	-	-	-	-	-	-	2	-	-	-	-	-	2
Calytrix carinata	5446	PRP72	LS	3	-	-	4	-	-	2	-	-	-	-	-	9
Corymbia aspera	17073	PRP1733	TR	-	-	-	3	-	1	3	4	1	1	5	-	18
Corymbia candida	16783	PRP404	TR	-	-	-	1	-	1	-	-	-	-	6	-	8
Corymbia candida subsp. *dipsodes*	16780	PRP1146	TR	-	-	-	-	-	-	-	-	-	-	-	-	-
Corymbia candida subsp. *lautifolia*	16781	PRP1535	TR	-	-	-	-	-	-	-	-	-	-	-	-	-
Corymbia chippendalei	17094	PRP1223	TR	-	-	-	-	-	-	2	-	-	-	-	-	2
Corymbia deserticola subsp. *deserticola*	17083	PRP09	TR	2	-	-	3	-	-	1	-	-	-	-	-	6
Corymbia ferriticola	17077	PRP1130	TR	1	-	-	-	-	-	-	-	-	-	-	-	1
Corymbia flavescens	14650	PRP392	TR	-	-	-	-	-	-	1	-	2	-	5	-	8
Corymbia hamersleyana	17093	PRP736	TR	20	-	-	55	-	2	2	13	4	-	23	1	120
Corymbia opaca	17092	PRP71	TR	-	-	-	-	-	-	-	-	-	-	-	-	-
Corymbia semiclara	16751	PRP1633	TR	-	-	-	-	-	-	-	-	-	-	-	-	-
Corymbia zygophylla	17084	PRP293	TR	-	-	-	1	-	-	8	-	-	-	-	-	9
Eucalyptus camaldulensis	5580	PRP1500	TR	-	-	-	-	-	-	-	1	4	-	11	3	19
Eucalyptus gamophylla	5655	PRP06	TR	3	-	-	6	-	-	3	1	-	-	2	-	15
Eucalyptus kingsmillii subsp. *kingsmillii*	13528	PRP1071	Ma	1	-	-	-	-	-	1	-	-	-	-	-	2
Eucalyptus leucophloia	5698	PRP952	TR	28	-	-	19	-	-	1	-	-	-	3	1	52
Eucalyptus leucophloia subsp. *leucophloia* ms	18088	PRP05	TR	-	-	-	-	-	-	-	-	-	-	-	-	-
Eucalyptus lucasii	5703	PRP955	TS	-	-	-	1	-	-	-	-	-	-	1	-	2
Eucalyptus microtheca	5714		TR	-	-	-	-	-	-	-	-	-	-	1	-	1
Eucalyptus odontocarpa	5724	PRP1252	Ma	-	-	-	1	-	-	-	-	-	-	1	-	2
Eucalyptus pilbarensis	5744	PRP1129	Ma	1	-	-	-	-	-	-	-	-	-	-	-	1
Eucalyptus socialis	5773	PRP418	Ma	-	-	-	2	1	-	-	-	-	-	-	-	3
Eucalyptus trivalvis	5794	PRP1137	Ma	-	-	-	1	-	-	-	-	-	-	-	-	1
Eucalyptus victrix	14548	PRP316	TR	-	-	-	2	-	2	-	-	16	-	25	1	46
Eucalyptus xerothermica ms	15592	PRP659	TR	1	-	-	2	1	2	-	-	-	-	5	-	11
Lamarchea sulcata	5846	PRP93	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Melaleuca alsophila	9178	PRP348	TS	-	-	-	1	-	-	-	1	3	-	3	1	9
Melaleuca argentea	5875	PRP856	TR	-	-	-	-	-	-	-	-	1	-	5	-	6
Melaleuca bracteata	5879	PRP606	TR	-	-	-	-	-	-	-	-	-	-	1	-	1
Melaleuca eleuterostachya	5908	PRP531	MS	-	-	-	4	-	-	-	1	-	-	-	-	5
Melaleuca glomerata	5915	PRP347	TS	-	-	-	2	-	-	1	-	1	-	5	-	9
Melaleuca lasiandra	5923	PRP367	TS	-	-	-	-	-	-	4	-	1	-	5	1	11
Melaleuca linophylla	5933	PRP391	TS	-	-	-	-	-	-	-	-	-	-	2	-	2
Melaleuca xerophila	5991	PRP1023	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Najadaceae																
Najas marina	138	AAM3791	Q	-	-	-	-	-	-	-	-	-	-	1	-	1
Nyctaginaceae																
Boerhavia burbidgeana	2769	PRP803	C	-	-	-	1	-	-	-	-	-	-	1	1	3
Boerhavia coccinea	2770	PRP213	C	1	1	-	-	1	2	-	1	1	-	1	-	8
Boerhavia gardneri	2772	PRP1467	C	3	-	-	2	-	-	-	1	-	-	-	-	6
Boerhavia paludosa	2773	PRP1051A	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Commicarpus australis	2776	PRP1657	C	2	-	-	-	-	1	-	-	1	-	-	-	4

Family Botanical name	Taxon id.	Collec no.	Growth form	Site type group												Total sites
				A	B	C	D	E	F	G	H	I	J	K	O	
Oleaceae																
Jasminum didymum subsp. *lineare*	12059	PRP24	C	4	-	-	2	-	-	3	-	-	-	8	1	18
Ophioglossaceae																
Ophioglossum sp.		PRP417	F	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxalidaceae																
Oxalis perennans	4355	PRP519B	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Papaveraceae																
* *Argemone ochroleuca* subsp. *ochroleuca*	17797	PRP1695	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Papilionaceae																
Abrus precatorius	3678	PRP1802	C	-	-	-	-	-	-	1	-	-	-	-	-	1
Aenictophyton reconditum	3679	PRP1639	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Aeschynomene indica	3680	PRP205	AH	-	-	-	-	-	-	-	-	3	-	2	1	6
Alysicarpus muelleri	17147	PRP241	AH	-	-	-	2	-	1	-	7	6	-	4	1	21
Cajanus acutifolius	10852	AAM3779	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Cajanus cinereus	11055	PRP984	LS	2	-	-	4	-	-	1	1	1	-	5	-	14
Cajanus lanceolatus	11111		MS	1	-	-	-	-	-	-	-	-	-	-	-	1
Cajanus marmoratus	10972	PRP863	C	-	-	1	2	-	-	-	1	-	-	-	-	4
Canavalia rosea	3749	PRP1529	C	-	-	-	-	-	-	3	-	-	-	-	-	3
Crotalaria crispata	3773	PRP1845	LS	-	-	-	2	-	-	7	1	1	-	2	1	14
Crotalaria cunninghamii	3774		LS	-	-	-	-	-	-	9	1	1	-	2	2	15
Crotalaria dissitiflora subsp. *benthamiana*	19378	PRP240	AH	-	-	-	-	-	-	-	-	3	-	1	-	4
* *Crotalaria juncea*	3780	PRP744	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Crotalaria medicaginea	3783	PRP534	AH	1	-	1	9	-	-	2	4	5	-	7	1	30
Crotalaria novae-hollandiae	3785	PRP1509	AH	1	-	-	-	-	-	-	1	-	-	-	-	2
Crotalaria novae-hollandiae subsp. *novae-hollandiae*	11231	PRP713A	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Crotalaria ramosissima	19398	PRP846	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Crotalaria smithiana	14859	PRP456	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Crotalaria sp. Chichester Tablelands (A.A. Mitchell PRP226)	17400	PRP226	AH	-	-	1	-	-	-	-	-	-	-	-	-	1
Cullen cinereum	17117	PRP268	AH	-	-	-	-	-	1	-	-	15	2	4	-	22
Cullen graveolens	17436	PRP271	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Cullen lachnostachys	17439	PRP1320	LS	-	-	-	1	-	-	-	-	1	-	1	-	3
Cullen leucanthum	17118	PRP752	LS	1	-	-	-	-	-	-	2	1	-	3	-	7
Cullen leucochaites	17119	PRP721	LS	-	-	-	6	-	-	1	2	-	-	-	1	10
Cullen martinii	17116	PRP762	MS	-	-	-	8	-	-	3	3	1	-	1	-	16
Cullen pogonocarpum	17120	PRP717	AH	-	-	-	6	-	-	-	6	1	-	2	1	16
Cullen pustulatum	17447	PRP1799	LS	-	-	-	1	-	-	-	-	-	-	-	-	1
Cullen stipulaceum	15714	PRP902	LS	3	-	-	-	-	-	-	1	1	-	-	-	5
Desmodium campylocaulon	3852	PRP140	AH	-	-	-	-	-	-	-	-	8	-	-	-	8
Desmodium filiforme	3853	PRP233	AH	-	-	-	3	-	-	1	1	1	-	-	-	6
Desmodium pullenii	18249	PRP893	AH	-	-	-	-	-	-	1	-	-	-	-	-	1
Erythrina vespertilio	3871	PRP992	TR	-	-	-	-	-	-	-	-	1	-	1	-	2
Gastrolobium grandiflorum	3903	PRP254	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Glycine canescens	3938	PRP1181	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Glycine falcata	3940	PRP734	PH	-	-	-	-	-	-	-	-	4	-	-	-	4
Glycine tomentella	3942		PH	-	-	-	-	1	-	-	-	-	-	2	-	3
Gompholobium polyzygum	10995	PRP1406	LS	8	-	-	1	-	-	-	-	-	-	-	-	9
Indigastrum parviflorum	14587	PRP203	AH	1	-	-	1	-	-	3	-	7	-	2	-	14
Indigofera ammobia	3969	PRP895	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Indigofera boviperda	3971	PRP373	LS	-	-	-	4	-	-	3	2	-	-	4	-	13
Indigofera boviperda subsp. *boviperda*	17113	PRP810	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Indigofera boviperda subsp. *eremaea*	17870		AH	-	-	-	-	-	-	1	-	-	-	-	-	1
Indigofera colutea	3973	PRP106	AH	3	-	-	13	3	1	6	9	3	-	8	-	46
Indigofera fractiflexa ms	17961	PRP1105	LS	1	-	-	-	-	-	-	-	-	-	-	-	1
Indigofera georgei	3974	PRP490	LS	-	-	-	3	1	1	3	-	-	-	1	-	9
Indigofera linifolia	3980		AH	-	-	-	2	-	-	5	3	5	-	1	-	16
Indigofera linnaei	3981	PRP1908	AH	4	-	1	6	2	-	8	6	8	-	3	1	39
Indigofera monophylla	3982	PRP1053	LS	35	1	-	68	6	-	15	11	1	-	29	2	168
* *Indigofera oblongifolia*	16061	AAM3566	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Indigofera rugosa	3985	PRP635	LS	3	-	-	4	-	-	1	-	-	-	1	-	9
Indigofera trita	3987	PRP1325	AH	-	-	1	1	-	-	2	3	12	-	-	-	19
Isotropis atropurpurea	3989	PRP67	LS	2	-	-	9	-	-	5	1	1	-	4	-	22
Isotropis forrestii	3994	PRP497	LS	-	-	-	-	-	1	-	-	-	-	3	-	4
Isotropis parviflora	17790	PRP169	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Jacksonia aculeata	3996	PRP75	LS	-	-	-	-	-	-	5	-	-	-	-	-	5
Kennedia prorepens	4043	PRP482	AH	-	-	-	1	1	-	-	-	-	-	-	-	2

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Leptosema anomalum	4054	PRP840	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Lotus australis	4060	PRP452	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Lotus cruentus	4061	PRP465	AH	-	-	-	-	-	-	-	-	2	-	-	-	2
Mirbelia viminalis	4105	PRP689	LS	-	-	-	2	-	-	-	-	-	-	-	-	2
Otion simplicifolium	17141	PRP86	LS	-	-	-	-	-	-	3	-	-	-	-	-	3
Rhynchosia minima	4191	PRP761	C	5	1	4	19	2	4	11	22	44	1	27	1	141
Rhynchosia sp. Bungaroo Creek (M.E. Trudgen 12402)	16392	PRP826	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Sesbania cannabina	4196	PRP304	AH	1	-	-	1	-	-	-	1	5	3	-	-	11
Sesbania formosa	4198	PRP1486	TR	-	-	-	-	-	-	-	-	-	-	1	-	1
* *Stylosanthes hamata*	12353	PRP1877	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Swainsona campylantha	4219	PRP1741	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Swainsona canescens	4220	PRP655	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Swainsona complanata	13596	PRP1663	AH	1	-	-	-	-	-	-	-	-	-	-	-	1
Swainsona decurrens	4223	PRP442	AH	2	-	-	-	-	-	-	-	-	-	-	-	2
Swainsona formosa	12356	PRP1671	AH	1	-	-	7	-	-	1	3	-	-	4	-	16
Swainsona kingii	4231	PRP458	AH	-	-	-	-	-	-	-	1	2	-	2	-	5
Swainsona leeana	4233	PRP544	AH	-	-	-	-	-	-	-	-	1	-	-	-	1
Swainsona maccullochiana	4234	PRP513	AH	1	-	-	-	-	-	-	-	-	-	-	-	1
Swainsona microphylla	4235	PRP1207	AH	-	-	-	-	-	-	1	-	-	-	-	-	1
Swainsona paucifoliolata	13586	PRP462	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Swainsona pterostylis	4242	PRP1646	AH	-	-	-	1	-	-	1	-	-	-	-	-	2
Swainsona sp. Hamersley Station (A.A. Mitchell 196)	17030	PRP196	AH	-	-	-	-	-	-	-	-	3	-	-	-	3
Swainsona stenodonta	4244	PRP532	AH	3	-	-	10	1	-	-	1	-	-	-	-	15
Swainsona tanamiensis	13587	PRP1291	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Templetonia egena	4252	PRP1004	TS	1	-	-	-	-	-	2	-	-	-	-	-	3
Templetonia hookeri	4253	PRP1604	TS	1	-	-	1	-	-	-	-	-	-	-	-	2
Tephrosia arenicola	4259	PRP928	LS	-	-	-	-	-	-	3	-	-	-	1	-	4
Tephrosia bidwillii	4260	PRP1497	LS	2	-	-	-	-	-	-	-	-	-	1	-	3
Tephrosia clementii	4263	PRP121	LS	3	-	2	10	1	-	1	2	10	-	1	1	31
Tephrosia coriacea	4265	PRP1649	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Tephrosia densa	17770	PRP1299	LS	1	-	-	1	-	-	-	-	-	-	-	-	2
Tephrosia remotiflora	4279	PRP767	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Tephrosia rosea	4280	PRP876	LS	2	-	-	4	-	-	6	3	1	-	7	-	23
Tephrosia savannicola	13923	PRP1677	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Tephrosia simplicifolia	4281	PRP1761	LS	-	-	-	-	-	-	1	-	-	-	-	-	1
Tephrosia sp. B Kimberley Flora (C.A. Gardner 7300)	15947	AAM3794	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Tephrosia sp. Bungaroo Creek (M.E. Trudgen 11601)	17768	AAM3762	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Tephrosia sp. Cathedral Gorge (F.H. Mollemans 2420)	15444	PRP1415	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Tephrosia spechtii	13924	PRP913	MS	2	-	-	1	-	-	-	-	-	-	-	-	3
Tephrosia sphaerospora	4282	PRP1928	LS	4	-	-	-	-	-	-	-	-	-	1	-	5
Tephrosia aff. *stipuligera*		PRP985	LS	-	-	-	1	-	-	-	-	-	-	-	-	1
Tephrosia supina	4285	PRP804	LS	1	1	-	6	5	-	2	4	1	-	3	-	23
Tephrosia uniovulata	4286	PRP211	MS	1	-	-	17	-	-	1	6	1	-	-	-	26
Thinicola incana	19862	PRP1730	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Trigonella suavissima	4316	PRP313	AH	-	-	-	-	-	-	-	-	-	-	1	-	1
Vigna lanceolata	4323	PRP324	C	-	-	-	-	-	-	-	-	-	-	1	-	1
Vigna sp. Pilbara (A.A. Mitchell PRP1066)		PRP1066	C	-	-	-	-	-	2	-	-	2	-	5	-	9
Zornia chaetophora	4327	PRP1801	PH	-	-	-	-	-	-	1	-	-	-	-	-	1
Zornia muelleriana subsp. *congesta*	12679	PRP862	PH	1	-	-	3	-	-	-	1	-	-	-	-	5
Passifloraceae																
* *Passiflora foetida var. hispida*	14096	PRP948	C	-	-	-	-	-	-	-	-	-	-	-	-	-
Pedaliaceae																
Josephinia eugeniae	7118	PRP1846	LS	-	-	-	-	-	-	-	1	-	-	-	-	1
Josephinia sp. Marandoo (M.E. Trudgen 1554)	14322	PRP1412	AH	-	-	-	-	1	-	-	-	-	-	-	-	1
Josephinia sp. Mt Edgar Station (N.T. Burbidge 1194)	19261	PRP1828	AH													
Plantaginaceae																
Plantago sp. Hamersley (M.E. Trudgen 11207)	14324	PRP678	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Plumbaginaceae																
Muellerolimon salicorniaceum	6490	PRP1292	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Plumbago zeylanica	6491	PRP1055	LS	-	-	-	-	-	-	-	-	-	-	1	-	1
Poaceae																
Acrachne racemosa	172	PRP397	AG	-	-	-	-	-	-	-	-	-	-	-	-	-
Amphipogon caricinus	196	PRP256	TG	6	-	-	10	-	-	1	-	-	-	2	-	19

Family Botanical name	Taxon id.	Collec no.	Growth form	Site type group												Total sites
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Amphipogon caricinus var. *sericeus*	11426	PRP627	TG	-	-	-	1	-	-	-	-	-	-	-	-	1
Aristida anthoxanthoides	203	PRP1387	TG	-	-	-	-	-	-	-	1	1	-	-	1	3
Aristida burbidgeae	204	PRP284	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Aristida calycina var. *calycina*	11512	PRP1089	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Aristida contorta	207		AG	20	3	1	75	29	26	9	15	27	15	20	6	246
Aristida holathera	210	PRP70	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Aristida holathera var. *holathera*	12063	PRP167	TG	6	-	-	33	3	3	33	11	6	1	9	3	108
Aristida hygrometrica	211	PRP1533	TG	-	-	-	-	-	-	-	2	-	-	1	1	4
Aristida inaequiglumis	212		TG	-	-	-	2	-	-	4	1	-	-	1	-	8
Aristida ingrata	213	PRP1820	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Aristida jerichoensis var. *subspinulifera*	17918	PRP651	TG	1	-	-	-	-	2	-	-	-	-	-	-	3
Aristida latifolia	215	PRP124	TG	-	-	5	14	1	4	1	4	21	2	6	-	58
Aristida lazaridis	216	PRP1343	TG	1	-	-	-	-	-	-	-	-	-	-	-	1
Aristida obscura	218	PRP1347	TG	-	-	-	1	-	2	-	-	-	-	-	-	3
Aristida pruinosa	221	PRP168	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Astrebla elymoides	227	PRP139	TG	-	-	2	1	-	-	-	-	5	-	1	-	9
Astrebla lappacea	228	PRP191	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Astrebla pectinata	229	PRP269	TG	-	-	3	-	-	-	-	-	14	1	-	1	19
Bothriochloa bladhii subsp. *bladhii*	16329	PRP184	TG	-	-	-	1	-	-	-	-	4	-	2	-	7
Brachyachne convergens	241	PRP143	AG	-	-	4	4	-	2	-	3	15	-	1	1	30
Brachyachne prostrata	242	PRP104	AG	2	-	-	10	3	-	-	9	5	9	-	-	38
* *Cenchrus ciliaris*	258	PRP757	TG	8	1	-	31	3	-	19	39	55	22	28	11	217
* *Cenchrus echinatus*	259	PRP1654	AG	-	-	-	-	-	-	-	-	-	-	-	-	-
* *Cenchrus setigerus*	263		TG	-	-	-	-	-	-	-	2	16	4	4	2	28
Chloris lobata	268	PRP1092	AG	-	-	-	-	-	1	-	-	-	-	-	-	1
Chloris pectinata	269	PRP141	AG	-	-	-	1	-	-	-	-	3	1	1	1	7
Chloris pumilio	270	PRP1773	AG	-	-	-	-	-	-	-	-	1	-	1	1	3
* *Chloris virgata*	272	PRP145	AG	-	-	-	-	-	4	-	1	2	2	1	-	10
Chrysopogon fallax	273	PRP251	TG	-	3	-	24	5	15	15	30	34	5	42	5	178
Cymbopogon ambiguus	279	PRP4	TG	18	2	1	6	-	1	-	4	-	-	3	-	35
Cymbopogon obtectus	281	PRP166	TG	1	-	-	2	-	-	-	3	-	-	4	2	12
Cymbopogon procerus	282	PRP1094	TG	2	-	-	1	-	-	-	-	1	-	5	-	9
* *Cynodon dactylon*	283		TG	-	-	-	-	-	-	-	-	1	-	-	-	1
Dactyloctenium radulans	290		AG	-	-	-	3	-	5	-	10	4	7	1	1	31
Dichanthium fecundum	303	PRP23	TG	-	1	-	-	-	2	-	-	6	1	4	1	15
Dichanthium sericeum	304		TG	-	-	-	-	-	4	1	3	9	2	3	-	22
Dichanthium sericeum subsp. *sericeum*	11964	PRP1074	TG	-	-	-	9	-	1	-	6	19	5	3	1	44
Digitaria ammophila	308	PRP148	TG	-	-	-	-	-	3	-	-	-	1	2	1	7
Digitaria brownii	310	PRP101	TG	3	-	-	1	3	2	2	-	-	-	3	-	14
Digitaria coenicola	312		TG	-	-	-	-	-	2	2	-	-	-	1	-	5
Digitaria ctenantha	313	PRP01	TG	-	-	-	2	1	-	-	-	-	-	-	-	3
Digitaria longiflora	316	PRP1165	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
* *Digitaria sanguinalis*	320	AAM3591	AG	-	-	-	-	-	-	-	-	-	-	-	-	-
* *Echinochloa colona*	328	PRP18	AG	-	-	-	-	-	-	-	-	-	-	-	-	-
Elytrophorus spicatus	355	PRP1384	AG	-	-	-	-	-	-	-	-	-	-	-	-	-
Enneapogon avenaceus	356	PRP109	AG	-	-	-	-	2	-	-	-	1	-	1	-	4
Enneapogon caerulescens	357	PRP1073	AG	13	4	1	42	15	4	2	6	14	3	4	2	110
Enneapogon cylindricus	358	PRP796	TG	3	1	-	13	5	8	2	1	2	3	5	-	43
Enneapogon lindleyanus	360	PRP164	AG	-	-	-	-	-	-	-	-	-	-	-	-	-
Enneapogon oblongus	362	PRP1600	TG	5	-	-	1	-	-	-	-	1	-	3	2	12
Enneapogon pallidus	363	PRP346	TG	-	-	-	-	-	-	1	-	1	-	-	-	2
Enneapogon polyphyllus	365	PRP110	AG	4	-	1	8	2	6	1	3	1	2	10	1	39
Enneapogon purpurascens	12749	PRP800	TG	-	-	-	-	1	-	-	-	2	-	-	-	3
Enteropogon acicularis	366	PRP32	TG	-	-	-	-	1	-	-	3	4	13	3	-	24
Eragrostis cumingii	375	PRP174	AG	-	-	-	2	-	-	2	6	2	-	6	1	19
Eragrostis desertorum	377	PRP1061	TG	1	-	-	-	2	-	1	1	-	-	2	-	7
Eragrostis dielsii	378	PRP411	AG	-	-	-	4	-	-	-	4	-	2	-	1	11
Eragrostis elongata	379	PRP1182A	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Eragrostis eriopoda	380	PRP156	TG	2	-	-	23	7	2	29	8	5	3	6	2	87
Eragrostis falcata	381	PRP321	TG	-	-	-	2	1	-	1	-	4	12	2	2	24
Eragrostis laniflora	386	PRP1355	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Eragrostis lanipes	387		TG	1	-	-	2	1	1	-	-	1	1	-	1	8
Eragrostis olida	17608	PRP1734	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Eragrostis parviflora	391	PRP259	AG	-	-	-	-	-	-	-	-	-	-	-	-	-
Eragrostis pergracilis	392	PRP160B	AG	-	-	-	3	-	6	1	1	-	4	3	1	19
Eragrostis setifolia	393	PRP398	TG	-	-	-	1	2	3	-	-	20	4	6	-	36
Eragrostis speciosa	395	PRP1745	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Eragrostis tenellula	398	PRP17	AG	-	-	-	2	-	1	-	1	11	2	5	-	22
Eragrostis xerophila	399	PRP1199B	TG	-	-	-	9	6	7	-	19	49	21	9	3	123
Eriachne aristidea	400	PRP310	AG	5	-	-	27	3	1	10	10	4	1	6	2	69
Eriachne benthamii	403	PRP179	TG	-	-	-	3	1	5	-	9	36	5	15	3	77
Eriachne ciliata	404	PRP1582	AG	2	-	-	1	-	-	-	-	-	-	-	-	3
Eriachne flaccida	408	PRP41	TG	-	-	-	-	-	1	-	-	2	-	2	-	5

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Eriachne gardneri	409	PRP28	TG	-	-	-	-	-	-	1	-	-	-	1	1	3
Eriachne glauca	410	PRP1565	AG	-	-	-	-	-	-	-	1	2	1	1	-	5
Eriachne glauca var. *glauca*	12055	PRP319	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Eriachne helmsii	411	PRP1210	TG	-	-	-	1	1	1	2	-	-	-	-	-	5
Eriachne lanata	13660	PRP888	TG	2	-	-	2	-	-	-	-	-	-	-	-	4
Eriachne melicacea	412	PRP327	AG	-	-	-	-	-	-	-	-	-	-	-	-	-
Eriachne mucronata	413	PRP186	TG	20	1	1	6	-	1	2	1	-	-	3	-	35
Eriachne obtusa	414	PRP300	TG	6	1	2	13	-	4	10	4	5	-	9	3	57
Eriachne pulchella subsp. *dominii*	16485	PRP103	AG	1	-	-	11	1	2	1	1	1	-	-	-	18
Eriachne tenuiculmis	421	PRP1054	AG	-	-	-	-	1	1	-	-	1	-	4	-	7
Eriochloa procera	425	PRP450	AG	-	-	-	-	-	-	-	-	-	-	1	-	1
Eulalia aurea	11011	PRP1039	TG	-	1	-	5	1	-	2	7	10	-	20	1	47
Heteropogon contortus	443		TG	-	-	-	-	-	-	-	-	1	-	-	-	1
Ischaemum albovillosum	12663	PRP25	TG	-	-	2	-	-	-	-	-	-	-	-	-	2
Iseilema dolichotrichum	458	PRP185	AG	-	1	-	1	-	-	-	3	2	-	-	-	7
Iseilema eremaeum	459	PRP238	AG	-	-	-	2	-	-	-	-	1	-	-	-	3
Iseilema membranaceum	464	PRP114	AG	-	-	-	1	-	2	-	1	3	-	5	1	13
Iseilema vaginiflorum	465		AG	-	-	1	-	-	1	-	-	3	-	-	-	5
Leptochloa digitata	471	PRP807	TG	-	-	-	-	-	-	-	-	-	-	1	-	1
Leptochloa fusca	19061	PRP263	TG	-	-	-	1	-	-	-	-	-	-	1	-	2
Leptochloa fusca subsp. *fusca*	19124	AAM3592	TG	-	-	-	-	-	-	-	-	-	1	-	-	1
Leptochloa fusca subsp. *muelleri*	19126		TG	-	-	-	1	-	-	-	-	-	-	-	-	1
Mnesithea formosa	487	PRP1118	AG	-	1	-	-	-	-	-	-	-	-	-	-	1
Monachather paradoxus	490	PRP1268	TG	-	-	-	-	2	4	1	-	-	-	-	-	7
Neurachne minor	494	PRP1008	TG	-	-	-	-	-	1	-	-	-	-	-	-	1
Oxychloris scariosa	500	PRP1324	AG	-	-	-	-	-	-	-	-	-	-	-	-	-
Panicum decompositum	503	PRP1326	TG	-	-	-	3	-	1	2	1	10	5	2	-	24
Panicum effusum	504		TG	-	-	-	-	-	2	-	-	1	-	1	-	4
Panicum effusum var. *effusum*	16096	PRP616	TG	-	-	-	1	-	-	-	-	-	-	-	-	1
Panicum laevinode	505	PRP447	TG	-	-	1	-	-	-	1	-	13	-	1	-	16
Paractaenum refractum	514	PRP81	AG	-	-	-	-	-	-	3	-	-	-	-	-	3
Paraneurachne muelleri	515	PRP133	TG	9	1	-	35	1	-	10	7	4	-	8	-	75
Paspalidium basicladum	10975	PRP1882	AG	-	-	-	-	-	-	1	-	-	-	1	-	2
Paspalidium clementii	518	PRP257	AG	3	-	-	6	-	2	-	2	-	1	6	-	20
Paspalidium jubiflorum	522	PRP247	TG	1	-	-	1	-	-	-	-	-	1	-	-	3
Paspalidium tabulatum	525	PRP1305	TG	2	-	-	-	-	-	-	-	-	-	-	1	3
Perotis rara	546	PRP1579	AG	-	-	-	-	1	1	-	2	1	-	2	1	8
Phragmites karka	556	PRP1488	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
* *Polypogon monspeliensis*	582	PRP554	AG	-	-	-	-	-	-	-	-	-	-	-	-	-
Setaria dielsii	606	PRP108	AG	-	-	-	1	-	2	-	3	3	2	5	1	17
Setaria surgens	612	PRP328	AG	-	-	-	-	-	-	-	-	-	-	-	-	-
* *Setaria verticillata*	613	PRP1123	AG	-	-	-	-	-	1	-	-	1	-	-	-	2
Sorghum plumosum	619	PRP14	TG	-	-	-	-	-	-	-	-	-	-	2	-	2
Sorghum timorense	12923	PRP237	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Spinifex longifolius	625	PRP339	HG	-	-	-	-	-	-	1	-	-	-	-	-	1
Sporobolus actinocladus	628	PRP315	TG	-	-	1	2	1	-	-	4	6	6	2	-	22
Sporobolus australasicus	629		AG	5	-	1	48	1	-	1	34	19	2	8	4	123
Sporobolus mitchellii	633	PRP323	TG	-	-	-	-	-	-	-	-	5	2	2	1	10
Sporobolus virginicus	635	PRP343	TG	-	-	-	-	-	-	-	-	4	3	2	1	10
Themeda avenacea	672	PRP822	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda sp. Hamersley Station (M.E. Trudgen 11431)	17820	PRP199	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Themeda triandra	673	PRP165	TG	5	3	1	6	-	4	-	2	2	-	15	1	39
Thyridolepis xerophila	676	PRP1364	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Tragus australianus	678	PRP1120	AG	-	-	-	-	1	-	-	-	1	-	-	1	3
Triodia angusta	679	PRP126	HG	1	-	1	6	-	-	-	2	-	1	1	-	12
Triodia basedowii	680	PRP42	HG	1	-	-	2	-	1	3	-	-	1	-	1	9
Triodia biflora	17886	PRP1098	HG	4	-	-	-	-	-	-	-	-	-	-	-	4
Triodia bitextura	17889	PRP258	HG	-	-	-	-	-	-	-	-	-	-	-	-	-
Triodia brizoides	681	PRP171	HG	17	-	-	13	-	-	-	2	-	-	-	-	32
Triodia concinna	682	PRP1218	HG	1	-	-	-	-	-	1	-	-	-	-	-	2
Triodia epactia	13131	PRP364	HG	4	-	-	8	-	-	16	2	4	1	1	2	38
Triodia lanigera	689	PRP290	HG	12	-	-	34	3	2	5	6	1	1	5	-	69
Triodia longiceps	690	PRP43	HG	4	1	-	33	2	1	-	21	6	2	7	1	78
Triodia melvillei	17877	PRP150	HG	1	-	-	2	-	-	1	-	-	-	-	-	4
Triodia plurinervata	694		HG	7	-	-	19	-	2	-	-	-	-	2	-	30
Triodia pungens	696	PRP55	HG	55	-	1	109	6	5	23	70	21	7	42	7	346
Triodia schinzii	17873	PRP207	HG	-	-	-	1	-	-	15	-	-	-	-	1	17
Triodia secunda	700	PRP306	HG	-	-	-	4	-	-	1	12	3	1	-	-	21
Triodia sp. nova aff. *longiloba*		PRP897	HG	-	-	-	-	-	-	-	-	-	-	-	-	-
Triodia sp. nova *hedgehog*		PRP149	HG	6	-	-	2	-	-	-	-	-	-	-	-	8
Triodia spicata	701	PRP1381	HG	1	-	-	-	-	-	-	-	-	-	-	-	1
Triodia ‘weeping Indee’		PRP848	HG	1	-	-	4	-	-	7	-	-	-	-	-	12
Triodia wiseana	704	PRP125	HG	36	1	-	86	4	3	3	13	3	-	8	1	158
Tripogon loliiformis	705	PRP412	TG	4	-	-	9	4	-	-	2	-	3	-	1	23

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Triraphis mollis	706	PRP1136	AG	-	-	-	1	-	-	-	-	1	-	2	-	4
Urochloa gilesii subsp. *occidentalis*	13759	PRP37	AG	-	-	-	-	-	2	-	-	-	-	1	-	3
Urochloa holosericea	712	PRP333	AG	-	-	-	-	-	-	-	-	-	-	-	-	-
Urochloa piligera	711	PRP135	AG	-	-	-	-	-	-	-	-	-	-	-	-	-
Whiteochloa airoides	725		TG	-	-	-	-	-	-	8	-	1	-	-	1	10
Whiteochloa capillipes	727	PRP192	AG	-	-	-	-	-	-	2	-	-	-	-	-	2
Xerochloa imberbis	730	PRP879	TG	-	-	-	-	-	-	-	-	-	-	-	-	-
Xerochloa laniflora	731	PRP245	AG	-	-	-	-	1	-	-	6	5	7	-	-	19
Yakirra australiensis	732	PRP289	AG	3	-	-	33	-	-	13	8	3	1	2	-	63
Polygalaceae																
Polygala isingii	4572	PRP657	AH	2	-	-	4	-	-	-	1	1	-	1	-	9
* *Acetosa vesicaria*	17739		AH	-	-	-	-	1	1	-	-	-	-	2	-	4
Muehlenbeckia florulenta	16982		MS	-	-	-	-	-	1	-	-	-	-	3	-	4
* *Persicaria lapathifolia*	16984	PRP944	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Portulacaceae																
Calandrinia balonensis	2844	PRP498A	AH	-	-	-	-	-	-	-	-	-	-	-	1	1
Calandrinia corrigioloides	2848		AH	-	-	-	-	-	-	1	-	-	-	-	-	1
Calandrinia eremaea	2853	PRP489	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Calandrinia ptychosperma	2864	PRP686	AH	-	-	-	-	-	2	-	-	-	2	-	-	4
Calandrinia pumila	2865	PRP566	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Calandrinia quadrivalvis	2866	PRP337	AH	-	-	-	1	-	-	-	3	1	-	-	-	5
Calandrinia schistorhiza	2869	PRP508	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Calandrinia sp. Mt Bruce (M.E. Trudgen 1544)	20169	PRP40	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Calandrinia stagnensis	2870	PRP1568	AH	-	-	-	1	-	-	-	3	1	-	-	-	5
Calandrinia strophiolata	2871		AH	-	-	-	-	-	-	-	1	-	-	-	-	1
Portulaca conspicua	2878	PRP262	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Portulaca filifolia	2881	PRP402	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Portulaca oleracea	2884		AH	3	1	-	14	2	5	1	4	2	3	2	-	37
Portulaca pilosa	2886	PRP1935	AH	-	-	-	-	-	-	-	-	1	-	-	-	1
Potamogetonaceae																
Potamogeton pectinatus	112	PRP873	Q	-	-	-	-	-	-	-	-	-	-	-	-	-
Potamogeton tricarinatus	113	PRP1443	Q	-	-	-	-	-	-	-	-	-	-	1	-	1
Ruppia polycarpa	116	PRP1190	Q	-	-	-	-	-	-	-	-	-	-	-	-	-
Primulaceae																
Samolus sp.		PRP1284	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Samolus sp. Millstream (M.I.H. Brooker 2076)	14027	PRP1453	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Proteaceae																
Grevillea eriostachya	2001	PRP934	TS	-	-	-	-	-	-	4	-	-	-	-	1	5
Grevillea pyramidalis	15975		TS	10	-	-	19	-	-	5	7	-	-	6	-	47
Grevillea refracta subsp. *refracta*	2081	PRP882	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Grevillea stenobotrya	2096	PRP79	TS	-	-	-	-	-	-	1	-	-	-	-	1	2
Grevillea striata	2099		TR	-	-	-	-	2	1	-	-	-	-	-	-	3
Grevillea wickhamii	2121		TS	24	-	-	35	-	-	5	3	1	-	8	-	76
Hakea lorea subsp. *suberea*	19137		TR	27	-	-	75	9	11	18	22	18	-	25	4	209
Hakea macrocarpa	2178	PRP933	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Hakea preissii	2196		TS	-	-	-	-	2	-	-	-	-	1	-	-	3
Hakea rhombales	2200	PRP1212	MS	-	-	-	1	-	-	1	1	-	-	-	-	3
Hakea stenophylla subsp. *stenophylla*	2207	PRP1641	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Persoonia falcata	2263	PRP1866	TS	-	-	-	-	-	-	1	-	-	-	-	-	1
Rhamnaceae																
Cryptandra monticola	16189	PRP1110	LS	1	-	-	-	-	-	-	-	-	-	-	-	1
Ventilago viminalis	4846		TR	-	-	-	-	-	-	-	1	4	-	1	1	7
Rhizophoraceae																
Rhizophora stylosa	5295	PRP1537	TR	-	-	-	-	-	-	-	-	-	-	-	1	1
Rubiaceae																
Dentella asperata	7317	PRP1945	AH	-	-	-	-	-	-	-	-	1	-	-	-	1
Dentella minutissima	7318	PRP864	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Dentella pulvinata	17959	PRP1545	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Gardenia pyriformis subsp. *keartlandii*	15234	PRP325	TS	-	-	-	-	-	-	-	-	-	-	-	-	-
Oldenlandia crouchiana	7338	PRP227	AH	8	-	1	4	-	-	-	-	4	-	-	-	17
Oldenlandia pterospora	7341	PRP892	PH	-	-	-	-	-	-	2	-	-	-	-	-	2
Oldenlandia sp. Hamersley Station (A.A. Mitchell PRP 14797)	19640	PRP195	AH	-	-	-	1	-	-	-	-	-	-	-	-	1

Family Botanical name	Taxon id.	Collec no.	Growth form	A	B	C	D	E	F	G	H	I	J	K	O	Total sites
									Site type group							
Psydrax latifolia	18154	PRP1125	TS	2	-	-	4	1	8	2	-	1	-	3	-	21
Psydrax suaveolens	18155	PRP967	TS	1	1	-	3	-	5	1	-	-	-	3	1	15
Spermacoce aff. *leptoloba*	13960	PRP1923	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Synaptantha tillaeacea	7363	PRP598	AH	-	-	-	2	-	-	1	5	1	-	1	-	10
Santalaceae																
Anthobolus leptomerioides	2333	PRP515	TS	1	-	-	8	1	1	1	1	-	-	1	-	14
Exocarpos sparteus	10765		TS	2	-	-	-	-	1	-	-	-	-	1	-	4
Santalum lanceolatum	2357		TS	1	-	-	2	1	1	-	-	-	-	5	1	11
Santalum spicatum	2359	PRP1033	TS	-	-	-	-	1	1	-	-	-	-	1	-	3
Sapindaceae																
Alectryon oleifolius	4739	PRP759	TS	-	-	-	1	-	-	1	-	1	-	-	-	3
Atalaya hemiglauca	4740	PRP842	TR	3	-	-	3	-	-	1	7	7	-	7	3	31
Diplopeltis eriocarpa	4745		LS	-	-	-	-	-	-	1	-	-	-	-	-	1
Diplopeltis stuartii var. *stuartii*	12023	PRP69	LS	-	-	-	-	-	-	2	-	-	-	-	-	2
Dodonaea coriacea	4759	PRP76	LS	5	-	-	7	-	-	5	1	-	-	2	-	20
Dodonaea lanceolata var. *lanceolata*	11406	PRP1078	MS	-	-	-	-	-	-	-	-	-	-	1	-	1
Dodonaea petiolaris	4773	PRP536	MS	1	1	-	1	-	1	-	1	-	-	2	-	7
Scrophulariaceae																
Buchnera linearis	7047	PRP232	AH	-	-	-	-	-	-	1	-	2	-	-	-	3
Mimulus gracilis	7082	PRP446	AH	-	-	-	-	-	-	-	-	2	-	1	1	4
Mimulus uvedaliae	13721	PRP216	AH	-	-	-	-	-	-	-	-	4	-	5	-	9
Peplidium aithocheilum	12486	PRP1199A	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Peplidium muelleri	7092	PRP1277	AH	-	-	-	-	-	-	-	-	-	-	1	-	1
Peplidium sp. C Evol.Fl. Fauna Arid Aust. (N.T. Burbidge and A. Kanis 8158)	18463	PRP595	AH	-	-	-	-	-	-	-	-	-	-	1	-	1
Peplidium sp. E Evol.Fl. Fauna Arid Aust. (A.S. Weston 12768)	18462	PRP565	AH	-	-	-	-	-	-	-	-	-	-	1	-	1
Stemodia florulenta	12487	PRP1484	LS	-	-	-	-	-	-	-	1	-	-	-	-	1
Stemodia grossa	7098	PRP629	LS	-	-	-	1	-	-	-	-	-	-	3	-	4
Stemodia kingii	7099	PRP260	LS	-	-	-	1	-	-	-	3	17	-	2	1	24
Stemodia sp. Battle Hill (A.L. Payne 1006)	17296	PRP1006	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Stemodia sp. Onslow (A.A. Mitchell 76/148)	17295	PRP1638	LS	-	-	-	-	-	-	2	-	-	-	1	-	3
Stemodia viscosa	7102	PRP451	AH	2	-	-	1	-	-	-	2	2	-	1	-	8
Solanaceae																
* *Datura leichhardtii*	6962	PRP715	AH	-	-	-	-	-	1	-	-	-	-	-	-	1
Duboisia hopwoodii	6966	PRP1753	TS	-	-	-	-	-	-	1	-	-	-	-	-	1
Newcastelia sp. Hamersley Range (S. van Leeuwin 4264)	20252	PRP1097	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Nicotiana benthamiana	6971	AAM3781	AH	9	-	-	-	-	-	-	-	-	-	-	1	10
Nicotiana occidentalis subsp. *obliqua*	11331	PRP1433	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Nicotiana rosulata	6977	PRP1285	AH	-	-	-	-	-	-	-	-	-	1	1	-	2
Nicotiana rosulata subsp. *rosulata*	11734	PRP416	AH	-	-	-	-	-	2	-	-	-	-	-	-	2
Nicotiana simulans	6979	PRP34	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Physalis minima	6982	PRP1863	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Solanum ashbyae	6989	PRP53	LS	1	-	-	-	-	-	-	-	-	-	-	-	1
Solanum centrale	6995	PRP1174	LS	-	-	-	2	-	-	4	-	-	-	-	-	6
Solanum cleistogamum	6998	PRP1188	LS	2	-	-	8	-	-	-	2	-	1	-	-	13
Solanum dioicum	7001	PRP384	LS	3	-	-	3	-	-	2	1	-	-	-	-	9
Solanum diversiflorum	7002	AAM3615B	LS	9	-	-	21	-	-	9	10	1	1	6	1	58
Solanum aff. *echinatum*		PRP1127	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Solanum esuriale	7007	PRP340	LS	-	1	-	4	-	-	4	1	12	1	1	1	25
Solanum ferocissimum	7008	PRP176	LS	1	-	-	1	-	4	-	-	-	1	-	-	7
Solanum gabrielae	7009	PRP720	LS	1	-	-	1	-	1	-	-	-	-	1	1	5
Solanum horridum	7014	PRP530	LS	18	2	1	15	2	1	1	9	7	-	5	1	62
Solanum lasiophyllum	7018	PRP681	LS	19	3	1	39	24	19	10	7	12	13	19	5	171
Solanum lucani	7021	PRP295	LS	-	-	-	-	-	-	1	-	-	-	-	1	2
* *Solanum nigrum*	7022	PRP1946	AH	-	-	-	-	-	-	-	-	1	-	-	-	1
Solanum phlomoides	7029	PRP583	LS	13	-	-	13	-	-	-	3	-	-	5	1	35
Solanum sturtianum	7036	PRP553	LS	-	1	-	8	-	3	-	-	3	1	3	1	20
Stackhousiaceae																
Macgregoria racemigera	4728		AH	-	-	-	1	-	-	-	-	-	-	1	-	2
Stackhousia intermedia	4731	PRP1496	AH	2	-	-	-	-	-	-	-	-	-	-	-	2
Stackhousia muricata	4734	PRP469	AH	1	-	-	1	1	-	-	1	-	-	-	-	4

Family Botanical name	Taxon id.	Collec no.	Growth form	Site type group												Total sites
				A	B	C	D	E	F	G	H	I	J	K	O	
Sterculiaceae																
Brachychiton acuminatus	12716	PRP975	TR	2	-	-	-	-	-	-	-	-	-	1	-	3
Keraudrenia nephrosperma	5024	PRP839	LS	5	-	-	4	-	-	2	1	-	-	2	-	14
Keraudrenia velutina subsp. *elliptica* ms	19636	PRP690	LS	-	-	-	-	-	-	-	-	-	-	-	-	
Melhania oblongifolia	5051	PRP180	PH	-	2	-	2	-	1	1	-	1	-	4	-	11
* *Melochia pyramidata*	5053	PRP1936	PH	-	-	-	-	-	-	-	-	-	-	-	-	-
Rulingia kempeana	5061	PRP1437	MS	-	-	-	-	-	-	-	-	-	-	1	-	1
Rulingia loxophylla	5062	PRP84	LS	-	-	-	1	-	-	3	-	2	-	1	-	7
Waltheria indica	5106	PRP309	LS	-	-	-	-	-	-	1	2	-	-	7	1	11
Waltheria virgata	5107	PRP1228	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Stylidiaceae																
Stylidium desertorum	7711	PRP467	AH	-	-	-	1	-	-	2	-	-	-	-	-	3
Surianaceae																
Stylobasium spathulatum	3182	PRP1275	MS	-	-	-	4	1	1	3	2	-	-	-	-	11
Thymelaeaceae																
Pimelea ammocharis	5230	PRP420	MS	-	-	-	2	-	-	1	-	-	-	-	1	4
Pimelea forrestiana	5245	PRP1111	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Pimelea holroydii	5250	PRP1483	AH	-	-	-	-	-	-	-	-	-	-	-	-	-
Pimelea microcephala subsp. *microcephala*	5256	PRP1201	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Tiliaceae																
Corchorus aestuans	12767	PRP1850	AH	-	-	-	1	-	-	-	1	3	-	-	-	5
Corchorus crozophorifolius	13560	PRP1282	LS	-	-	-	-	-	-	-	-	-	-	3	-	3
Corchorus elachocarpus	4857	PRP1563	LS	-	-	-	5	-	-	1	4	1	-	-	-	11
Corchorus incanus	17339	PRP834	LS	1	-	-	1	-	-	2	-	-	-	-	-	4
Corchorus laniflorus	13659	PRP1628	LS	8	-	-	7	-	-	2	2	-	1	3	1	24
Corchorus lasiocarpus	17405	PRP943	LS	2	-	-	1	-	-	-	-	2	-	-	-	5
Corchorus lasiocarpus subsp. *lasiocarpus* ms	18409	PRP1186	LS	4	1	-	6	1	1	-	1	-	-	2	-	16
Corchorus lasiocarpus subsp. *parvus* ms	18408	PRP1060	AH	-	-	-	-	-	-	-	1	-	-	-	-	1
Corchorus parviflorus	4862	PRP903	LS	5	-	-	7	-	-	-	1	-	-	-	-	13
Corchorus saxicola	17594	PRP1463	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Corchorus sericeus	13417	PRP275	LS	1	-	-	2	-	-	-	-	-	-	-	-	3
Corchorus sidoides	4864	PRP365	LS	9	-	-	41	1	-	9	12	3	1	7	4	87
Corchorus tectus ms	17661	PRP1135	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Corchorus walcottii	4867	PRP983	LS	5	-	-	22	2	-	10	3	3	-	5	-	50
Triumfetta appendiculata	4873	PRP273	LS	1	-	-	1	-	-	-	-	-	-	1	1	4
Triumfetta chaetocarpa	4875	PRP912	LS	2	-	-	7	1	-	-	3	1	-	1	-	15
Triumfetta clementii	14694	PRP1301	LS	-	-	-	3	-	-	-	-	-	-	1	-	4
Triumfetta deserticola	16306	PRP1754	MS	-	-	-	-	-	-	-	-	-	-	-	-	-
Triumfetta echinata	17524	PRP1720	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Triumfetta johnstonii	4878	PRP1665	LS	-	-	-	-	-	-	-	-	-	-	-	-	-
Triumfetta maconochieana	14942	PRP278	LS	8	-	-	2	-	1	1	-	-	-	2	-	14
Triumfetta propinqua	17317	PRP900	LS	1	-	-	1	-	-	-	-	-	-	-	-	2
Triumfetta ramosa	13481	PRP849	LS	-	-	-	2	-	-	1	-	-	-	-	-	3
Typhaceae																
Typha domingensis	98		PS	-	-	-	-	-	-	-	-	-	-	2	-	2
Verbenaceae																
* *Phyla nodiflora* var. *nodiflora*	6734	PRP1772	PH	-	-	-	-	-	-	-	-	-	-	-	1	1
Violaceae																
Hybanthus aurantiacus	5215	PRP246	LS	7	1	-	13	-	3	6	8	-	-	8	1	47
Xanthorrhoeaceae																
Xanthorrhoea thorntonii	1257	PRP1366	TR	-	-	-	-	-	-	-	-	-	-	-	-	-
Zygophyllaceae																
Tribulopis angustifolia	4368	PRP322	AH	-	-	-	-	-	-	1	-	-	-	-	-	1
Tribulus astrocarpus	4374	PRP153	AH	-	-	-	2	-	2	-	-	1	-	-	1	6
Tribulus cistoides	4375		AH	-	-	-	1	-	-	-	-	-	-	-	-	1
Tribulus hirsutus	4377	PRP292	AH	3	-	-	14	-	-	-	2	-	-	1	-	20
Tribulus macrocarpus	4379	PRP16	AH	3	-	-	8	-	-	1	1	-	-	1	-	14
Tribulus occidentalis	4380	PRP46	AH	-	-	-	3	1	-	-	-	-	-	1	1	6
Tribulus platypterus	4381	PRP802	LS	27	1	-	21	2	4	-	1	-	-	-	1	57
Tribulus suberosus	18072		LS	13	-	-	3	1	-	-	-	-	-	-	-	17
Tribulus terrestris	4383	PRP45	AH	1	-	-	-	-	1	-	-	1	-	-	-	3
Zygophyllum aurantiacum	4386		AH	-	-	-	-	1	-	-	-	-	-	-	-	1
Zygophyllum tesquorum	4396		AH	1	-	-	3	-	-	-	-	-	-	-	-	4

Key to Appendix 1 (i)

Family and botanical names

Species identifier from the Western Australian Herbarium.

* denotes naturalised species, not native to Western Australia.

Taxon identification

Unique species identification number from the Western Australian Herbarium.

Collection number

PRP numbers were collected within the survey area by the rangeland survey team during the survey. AAM numbers were collected within the survey area by A.A. Mitchell.

Growth form

TR	tree
Ma	mallee
TS	tall shrub (> 2 m)
MS	mid shrub (1- 2m)
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

Site type group

The number of inventory sites in each of the following site type groups at which the species was recorded (the total number of inventory sites in each site type group is in brackets):

A	Hill hummock grassland site types (98 sites)
B	Hill sclerophyll shrubland site types (4 sites)
C	Upland plain tussock grassland site types (5 sites)
D	Plain hummock grassland site types (216 sites)
E	Stony plain and low rise sclerophyll shrubland site types (30 sites)
F	Sheet flood hardpan plain sclerophyll shrubland or woodland site types (29 sites)
G	Sandplain and dune grassland site types (53 sites)
H	Alluvial plain hummock grassland (and occasionally grassy shrubland) site types (84 sites)
I	Alluvial plain tussock grassland (and occasionally grassy shrubland) site types (93 sites)
J	Alluvial plain halophytic shrubland site types (38 sites)
K	Drainage shrubland and woodland site types (85 sites)
O	Other undescribed site types (28 sites)

Total sites

The number of inventory sites at which the species was recorded.

Appendix 1 (ii). Common plants in the survey area

Species recorded at 20 or more inventory sites

Botanical name	Common name	Botanical name	Common name
Trees and tall shrubs (commonly >2m)			
Acacia aneura	mulga	*Acacia xiphophylla*	snakewood
Acacia ancistrocarpa	shiny leaf wattle	*Atalaya hemiglauca*	whitewood
Acacia atkinsiana		*Carissa spinarum*	conkerberry
Acacia coriacea	river jam	*Corymbia hamersleyana*	Hamersley bloodwood
Acacia farnesiana	mimosa bush, false mesquite		
Acacia holosericea	candelabra wattle	*Eremophila longifolia*	berrigan
Acacia inaequilatera	kanji bush	*Eucalyptus camaldulensis*	river red gum
Acacia orthocarpa	needle leaf wattle	*Eucalyptus gamophylla*	twin leaf mallee
Acacia pruinocarpa	gidgee	*Eucalyptus leucophloia*	snappy gum
Acacia tetragonophylla	curara	*Eucalyptus victrix*	coolibah
Acacia trachycarpa	miniritchie	*Grevillea wickhamii*	Wickham's grevillea
Acacia tumida	pindan wattle	*Hakea lorea* subsp. *suberea*	corkwood
Acacia victoriae	prickly acacia, bardi bush	*Psydrax latifolia*	native currant
Acacia wanyu			
Mid shrubs (commonly 1-2 m)			
Acacia acradenia		*Petalostylis labicheoides*	
Acacia bivenosa	two vein wattle	*Rhagodia eremaea*	tall saltbush
Acacia ligulata	umbrella wattle	*Scaevola spinescens*	currant bush
Acacia maitlandii	Maitland's wattle	*Senna symonii*	
Acacia pyrifolia	fire wattle	*Senna glutinosa*	sticky cassia
Acacia sclerosperma subsp. *sclerosperma*	limestone wattle	*Senna glutinosa* subsp. *pruinosa*	white cassia
		Senna glutinosa subsp. x *luerssenii*	
Gossypium australe	wild cotton	*Senna* sp. Meekatharra	straight leaf cassia
Grevillea pyramidalis	caustic bush		
Low shrubs (commonly <1m)			
Abutilon lepidum		*Maireana tomentosa*	felty bluebush
Abutilon otocarpon	desert Chinese lantern	*Maireana villosa*	silky bluebush
Acacia stellaticeps	poverty wattle	**Malvastrum americanum*	spiked malvastrum
**Aerva javanica*	kapok bush	*Pluchea tetranthera*	
Atriplex bunburyana	silver saltbush	*Ptilotus astrolasius*	
Bonamia erecta		*Ptilotus calostachyus*	tall mulla mulla
Bonamia rosea		*Ptilotus obovatus*	cotton bush
Corchorus laniflorus		*Senna artemisioides* subsp. *oligophylla*	blood bush
Corchorus sidoides	flannel weed	*Sida cardiophylla*	
		Sida echinocarpa	
Corchorus walcottii	woolly corchorus	*Sida fibulifera*	creeping sida
Dodonaea coriacea		*Sida rohlenae*	
Enchylaena tomentosa	ruby saltbush	*Solanum diversiflorum*	bush tomato
Eremophila cuneifolia	royal poverty bush	*Solanum esuriale*	quena
Eremophila exilifolia	little turpentine poverty bush	*Solanum horridum*	
Eremophila lanceolata		*Solanum lasiophyllum*	flannel bush
Eremophila forrestii	Wilcox bush	*Solanum phlomoides*	wild tomato
Eremophila latrobei	warty fuchsia bush	*Stemodia kingii*	black soil poison
Goodenia stobbsiana		*Scaevola parviflora* subsp. *parviflora*	
Halosarcia spp.	samphire	*Senna artemisioides* subsp. *helmsii*	crinkled cassia
Hibiscus burtonii		*Senna artemisioides* subsp. x *sturtii*	variable cassia
Hibiscus coatesii		*Tephrosia clementii*	
Hibiscus sturtii		*Tephrosia rosea*	Flinders River poison
Hybanthus aurantiacus		*Tephrosia supina*	
Indigofera monophylla	one leaved indigofera	*Tephrosia uniovulata*	
Isotropis atropurpurea	lamb's tongue poison	*Trianthema turgidifolia*	
Maireana georgei	golden bluebush	*Tribulus platypterus*	corky bark
Maireana planifolia	flat-leaved bluebush		

Botanical name	Common name	Botanical name	Common name
Perennial herbs			
Evolvulus alsinoides		*Sclerolaena deserticola*	bindii
Mollugo molluginis		*Sclerolaena uniflora*	bindii
Neptunia dimorphantha	sensitive plant	*Streptoglossa bubakii*	
Sclerolaena densiflora	bindii		
Perennial grasses			
Aristida holathera var. *holathera*	erect kerosene grass	*Eriachne obtusa*	wire grass
Aristida latifolia	feathertop three awn	*Eulalia aurea*	silky brown top
Astrebla pectinata	barley Mitchell grass	*Panicum decompositum*	native panic
**Cenchrus ciliaris*	buffel grass	*Paraneurachne muelleri*	hop-along grass
**Cenchrus setigerus*	Birdwood grass	*Sporobolus actinocladus*	
Chrysopogon fallax	ribbon grass	*Themeda triandra*	kangaroo grass
Cymbopogon ambiguus	lemon scented grass	*Triodia brizoides*	echidna spinifex
Dichanthium sericeum	Queensland bluegrass	*Triodia epactia*	grey soft spinifex
Enneapogon cylindricus	jointed nineawn	*Triodia lanigera*	hard spinifex
Enteropogon acicularis	curly windmill grass	*Triodia longiceps*	knitting needle spinifex
Eragrostis eriopoda	woolly butt	*Triodia plurinervata*	pincushion spinifex
Eragrostis falcata	sickle love grass	*Triodia pungens*	soft spinifex
Eragrostis setifolia	neverfail	*Triodia secunda*	porcupine spinifex
Eragrostis xerophila	Roebourne Plains grass	*Triodia wiseana*	limestone spinifex
Eriachne benthamii	swamp grass	*Tripogon loliiformis*	five minute grass
Eriachne mucronata	stony wanderrie grass		
Creepers			
Cassytha capillaris		*Polymeria ambigua*	
Ipomoea muelleri	poison morning glory	*Porana commixta*	
Mukia maderaspatana		*Rhynchosia minima*	
Sedges			
Bulbostylis barbata		*Fimbristylis dichotoma*	
Annual forbs			
Alternanthera nodiflora		*Ptilotus axillarus*	
Amaranthus mitchellii	red weed	*Ptilotus auriculifolius*	
Cleome viscosa	mustard bush, tick weed	*Ptilotus carinatus*	
Crotalaria medicaginea		*Ptilotus exaltatus*	purple mulla mulla
Cullen cinereum	marsh mallow	*Ptilotus gardneri*	
Dampiera candicans		*Ptilotus gomphrenoides*	
Dysphania rhadinostachya		*Ptilotus helipteroides*	
Euphorbia alsiniflora		*Ptilotus macrocephalus*	green mulla mulla
Euphorbia australis		*Ptilotus murrayi*	
Euphorbia boophthona	Gascoyne spurge	*Ptilotus polystachyus*	
Flaveria australasica	speedy weed	*Salsola tragus*	roly poly
Gomphrena canescens	batchelors button	*Sclerolaena costata*	
Gomphrena cunninghamii		*Sclerolaena cuneata*	yellow bindii
Goodenia microptera		*Senna notabilis*	cockroach bush
Heliotropium heteranthum		*Streptoglossa decurrens*	
Indigofera colutea		*Streptoglossa odora*	stinkweed
Indigofera linnaei		*Trachymene oleracea*	
Lepidium phlebopetalum	fat cress	*Trianthema triquetra*	red spinach weed
Portulaca oleracea		*Tribulus hirsutus*	
Pterocaulon sphacelatum		*Trichodesma zeylanicum*	camel bush
Ptilotus aervoides	creeping ptilotus		
Annual grasses			
Aristida contorta	wind grass	*Eriachne aristidea*	false wanderrie
Brachyachne convergens	Kimberley couch	*Eriachne pulchella*	
Brachyachne prostrata		*Iseilema membranaceum*	Flinders grass
Dactyloctenium radulans	button grass	*Paspalidium clementii*	
Enneapogon caerulescens	limestone grass	*Sporobolus australasicus*	fairy grass
Enneapogon polyphyllus	leafy nineawn	*Yakirra australiensis*	
Eragrostis tenellula	delicate lovegrass		

* denotes naturalised species, not native to Western Australia

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