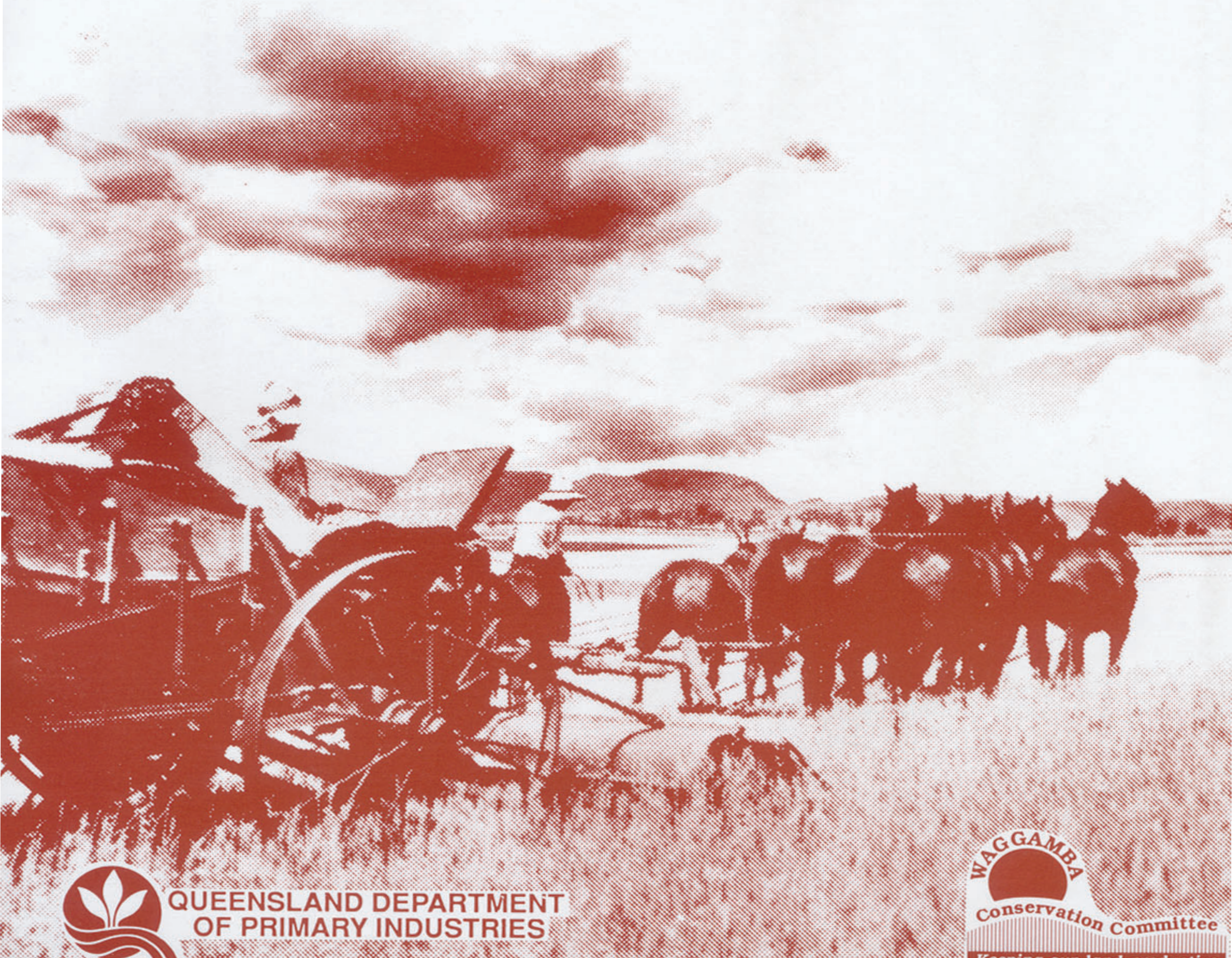
LAND MANAGEMENT MANUAL WAGGAMBA SHIRE

PART A
RESOURCE INFORMATION



QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

WAGGAMBA Conservation Committee

Keeping our land productive

Queensland Government Technical Report

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LAND MANAGEMENT MANUAL

WAGGAMBA SHIRE

PART A

RESOURCE INFORMATION

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SUMMARY

Farm planning for optimum production with minimum land degradation requires the specification of management requirements for both production and erosion control. This specification should be related to a defined land resource base and should be suitable for use by both the farmer and farm planner. Information of this nature is required for the maintenance of long-term agricultural productivity in Waggamba Shire.

This report identifies and describes areas with similar land resources (named Land Resource Areas) for Waggamba Shire as well as the soils that equate to agricultural management units that occur in each Land Resource Area. It also collates available land suitability information on the soils together with current management recommendations. This report forms Part A of a Land Management Manual that has been compiled for Waggamba Shire by officers of the Queensland Department of Primary Industries and members of the Waggamba Conservation Committee as part of a National Soil Conservation Program supported project.

Fifteen Land Resource Areas were identified and their distinguishing features are described here. A simple key, based on the most important characteristics of each Land Resource Area, is also provided. Twenty-nine soils (soil associations) are recognised in Waggamba Shire, their distinguishing morphological features are discussed and a key to the soils is provided. A brief description of the major chemical and physical characteristics that affect agricultural use is presented. The keys and soil descriptions (on detatchable cards) are supplied in Part B of the manual.

The climate, geology, vegetation and current land use in the shire are discussed. Agronomic and animal husbandry management recommendations are given, incorporating soil conservation and property planning specifications that consider the value of rural nature conservation requirements on farms.

Chapter 1

INTRODUCTION

The challenge for today's landholders and land use planners is to achieve optimum production from the land while still maintaining the stability of the nation's soil.

The identification of specific soils, together with their particular management requirements for sustainable production, is an integral part of meeting this challenge. Such information should be presented in a suitable format for use by landholders and land use planners, and needs to be regularly reviewed to keep pace with changes in technology. Information of this nature is required for the maintenance of long-term agricultural and pastoral productivity in Waggamba Shire.

This manual is one of a series detailing the land resources and recommended land management practices for the major cropping and pastoral areas of Queensland. The program was started in late 1979 and has as its objectives:

- The provision of a land resource base for farm planning purposes defining the major agricultural soils for each district;

- The provision of recommendations and specifications for soil conservation measures, agronomic practices and conservation management for those soils;

- The documentation of this information in Land Management Field Manuals; and

- The periodic review of the land resource base information and management recommendations and specifications.

The program involves cooperation between officers of Land Resources, Land Conservation, Agriculture and other Branches of the Queensland Department of Primary Industries (QDPI), as well as other government and agricultural organisations.

This report (Part A of two parts) contains a description of the Land Resource Areas (LRAs) for Waggamba Shire as well as detailed descriptions of the soils that occur in each LRA. It collates soil, vegetation, land use and land degradation information as well as available land suitability data for the soil units together with current management recommendations to overcome a variety of limitations.

The use of this information by landholders, people with the responsibility for land use planning decisions, and research and extension personnel providing technical advice to land users, will lead to the sustainable productivity of the shire's land resources.

This particular manual for Waggamba Shire differs from others in the program in a number of ways. It has involved the cooperation and resources of the Waggamba Conservation Committee, who have produced their own booklet for the manual (Part C) containing landholder's experiences. This manual has also involved a wide range of expertise from seven branches of the QDPI.

The publication was supported in part by funds made available through the National Soil Conservation Program and by sponsorship provided by North West Seed Producers Association. A copy of the manual is provided to each rural landholder in Waggamba Shire as part of the program, which involves training in its application.

Chapter 2

WAGGAMBA SHIRE LAND USE

Greg Salmond
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1. INTRODUCTION

Land use in Waggamba Shire during the last 30 years has become more intensive. During this period the pattern of land use has changed dramatically from predominantly grazing enterprises to diversified farming operations.

1.1 Grazing

Before 1960 wool growing was the main enterprise of Waggamba Shire's landholders. It has been the major industry in the shire since it was settled.

Sheep numbers reached an all-time high in 1965 at 1.3 million. From then onwards the industry went into relative decline with a reduction of numbers in the 1964-65 drought to 975 000 and again in the 1972 drought to 610 000.

After the 1964-65 drought there was a dramatic increase in areas allocated to cropping with the trend away from sheep grazing. From 1969 there was a tendency towards substitution of sheep for cattle with cattle numbers more than doubling from 65 000 to 161 000 by 1973 (Figure 2.1).

Figure 2.1. Waggamba Shire sheep and cattle numbers, 1963-90
(Source: Australian Bureau of Statistics)

In 1972 wool prices were at an all-time low, reconstruction money was available to sheep graziers for cattle purchases, and wheat prices were attractive to make a major change of enterprise. Cattle dominated over sheep through the period 1973 to 1981, at a DSE (dry sheep equivalent) ratio of 3:1. The DSE ratio of cattle to sheep in 1990 is closer to 2:1 owing to a decline in cattle numbers which began in 1978. A low of 95 000 head was reached in 1980 which was a period of severe drought. At this time, sheep numbers rose steadily to 700 000 with the rising floor price for wool from 1975 to 1990.

1.2 Cropping

Cropping was not significant in Waggamba Shire before the late 1950s. Small areas had been cropped since the turn of the century but it was not until after World War II that cultivation was adopted on a large scale. Factors which assisted the development of large scale cropping in the shire were:

- a progressive reduction in the size of holdings;
- the relatively cheaper and faster handling of scrub by heavy tractors;
- a buoyant financial position arising from a succession of good seasons;
- high prices and tax concessions for farm development.

In 1959 an area of 9000 ha had been developed for farming. This area had increased 28-fold to 252 000 ha by 1987-88 (Table 2.1). The area of sown pastures has also increased during that same time by a factor of 15, from 3222 ha to a high of 49 000 ha in 1987-88.

Since the completion of Glenlyon Dam in 1976 there has been a rapid growth in the area developed for broad acre irrigation downstream from Goondiwindi. This has been due to the expansion of irrigated cotton, mainly on the New South Wales side of the Macintyre River. It is anticipated that the major expansion in irrigation development will occur in Waggamba Shire over the next few years.

Table 2.1. Cultivated area of Waggamba Shire[1]

Year	Crops (ha)	Pastures sown (ha)	Cultivation of shire (% of total)
1958-9	9 040	3 222	0.9
1962-3	22 456	5 675	2.0
1966-7	57 334	5 515	4.5
1970-1	124 471	28 264	11.0
1974-5	120 000	37 148	11.3
1978-9	162 703	32 904	14.1
1983-4	219 141	37 492	18.5
1987-8	252 000	49 000	23.0

(Source : Australian Bureau of Statistics 1960-1988)
[1] Area of Waggamba Shire is 1 385 000 ha

2. CURRENT LAND USE OF THE SHIRE

In 1989 the area developed for cropping was about 20% of the total shire area. The area of sown pastures represented only 4% (Table 2.2).

Table 2.2. Shire land use (1987-89)

	Area		Number of producers
	(ha x1000)	(%)	
Cultivation	262	20	254
Sown pastures	46	4	108
Native pastures	267	20	129
Uncleared scrub and regrowth	510	39	*n.a.*
Wetlands	6	<1	*n.a.*
State Forest	80	6	*n.a.*
Not recorded	148	11	*n.a.*
Total	1 319	100	

(Source . Australian Bureau of Statistics 1989)

The production and revenue statistics listed in Table 2.3 highlight the agricultural diversity of Waggamba Shire.

Table 2.3. Gross income revenue from major agricultural industries

Commodity	1983-84 ($m)	1986-87 ($m)	1988-89 ($m)
Wheat	48.0	26.5	70.3
Cotton (irrigated)	3.0	6.1	8.4
Grain sorghum	5.0	2.1	2.5
Barley	1.0	1.4	3.2
Other crops	1.0	1.4	2.3
Total crop	58.0	37.5	86.7
Cattle disposals	20.0	23.5	23.4
Wool	10.0	14.6	24.4
Sheep/lamb disposals	-	2.1	1.6
Pig disposals	-	1.4	2 6
Total livestock	30.0	41.6	52.0
Total income from agriculture	88.0	79.1	138.7

(Source : Australian Bureau of Statistics, 1989)

Wheat provides the major revenue for the shire. Revenue from cotton production is expected to increase in the future as the area planted to the crop increases.

The shire produces cattle destined for both domestic and export markets. Several opportunity and large scale feedlots operate within the shire to provide a grain-fed finished product for various market requirements.

A recent historical event was the drop in wool prices in May 1990 from 870c/kg (clean) to 700c/kg with an accompanying increase in the levy from 8% to 18%. This resulted in a drop of net incomes of 30 to 40%, or an average of $40 000 per wool producer in the shire.

2.1 Cropping and irrigation

The major crops produced in Waggamba Shire in terms of the area used and production are listed in Table 2.4.

Table 2.4. Production of major crops (5 year average to March 1989)

Crop	Area (ha)	Production (t)	Number of producers
Wheat	177 000	276 000	244
Grain sorghum	20 000	20 000	78
Barley	15 000	22 000	83
Forage oats	27 000	*n.a.*	169
Forage sorghum	3 000	*n.a.*	16
Millet	1 000	700	10
Cotton (irrigated[1])	3 500	5 000	8
Cotton (dryland[1])	2 000	720	6
Chickpea[1]	4 500	3 800	12

(Source : Australian Bureau of Statistics, 1989)
[1] QDPI, Goondiwindi predictions at June 1990

Wheat has been, and still is, the major crop of Waggamba Shire (Table 2.4). Both yield and area planted to the crop have continually increased.

Forage crops along with improved pastures have a major effect on the growing and finishing of cattle within the shire. They are becoming increasingly important for sheep management.

The area planted to irrigated cotton has also increased in recent years. Further increases to this area are expected when irrigation projects west of Goondiwindi are completed. Confidence in the cotton industry is reflected by the planned expansion of ginning facilities at Goondiwindi which will be operational for the 1990/1 season. A new gin at Mungindi will gin cotton produced in the western areas of the shire. This gin is expected to be operational for the 1992 season.

Chickpea plantings have also increased in recent years. They are dependent on overseas markets and have comparable returns to wheat.

2.2 Livestock

In terms of sheep numbers (Table 2.5), Waggamba Shire rates seventh on Queensland's shire comparison list.

Periodic flooding of whole properties, except for small patches of high ground, is a problem between the Macintyre and Weir Rivers west of Goondiwindi.

For this reason there are few sheep properties south of the Barwon Highway in the shire.

Table 2.5. Livestock production for Waggamba Shire

	Number of animals		Production		Number of producers	
	1987-88	1988-89	1987-88	1988-89	1987-88	1988-89
Sheep and lambs	747 000	795 000	3 052	3 491	203	221
Cattle and calves	131 000	123 000	*n.a.*	*n.a.*	281	279
Pigs	10 000	10 700	*n.a.*	*n.a.*	16	13
Goats	*n.a.*	800	*n.a.*	*n.a.*	*n.a.*	2

(Source . Australian Bureau of Statistics, 1989)

Opportunities for sheep production include:

- the introduction of improved pastures, which allow the increase in stocking rates and wool cuts;
- the further integration of sheep with cropping, forages and weed control on fallows; and
- dealing, growing and shearing of western lands sheep on either an opportunist or regular basis.

About 3000 prime lambs are turned off annually. This small number is a reflection of high costs and variable saleyard prices.

Waggamba Shire is ideally suited to cattle production. Cattle breeding and fattening are undertaken by 79% of the shire's producers To use surplus feed in good seasons it is common practice for cattlemen to purchase store cattle and fatten. Large numbers of cattle have been brought into the shire for this purpose. Properties which do not have the potential to fatten cattle rely on store markets.

Most fat cattle go to auction sales at Goondiwindi or the Darling Downs centres. Cattle are also sold by private treaty in the paddock, usually to meatworks buyers.

Cashmere and mohair production in the shire are very small industries.

2.3 Other primary industries

2.3 1 Forestry

Waggamba Shire contains approximately 80 000 ha of State Forest within its boundaries.

These State Forests are controlled by the QDPI Queensland Forest Service through the Inglewood sub-district office. The Service controls all millable trees in the State Forests and Timber Reserves in the shire.

In addition, the Crown, through the Queensland Forest Service, owns all timber and controls the harvesting of all timber held under leasehold tenure in the shire.

The main timber produced in the shire is from native cypress pine (*Callitris columellaris*). The management strategy of the Queensland Forest Service allows a harvest of 7000 m^3 annually from the shire's State Forest areas. Using an average 1990 royalty of $28.67/$m^3$, timber harvesting has the potential to generate $200 690 annually from these areas.

Only about 10% of this allowable cut has been removed in recent years. This is due mainly to the lack of markets in, or close to, the shire and the relatively few number of operational sawmills in the region.

2.3.2 Mining

A prospective oil and gas field lies across the extreme north-western boundary of the shire and extends south-east towards the Macintyre River and Goondiwindi. A number of wells have been drilled in this field in the 1970s, but have been abandoned.

2.3.3 Beekeeping

Beekeeping is undertaken extensively throughout the shire although many beekeepers reside outside the shire itself. For this reason income figures are not available for Waggamba Shire from this enterprise.

Chapter 3

CLIMATE

Peter Cooper
QDPI, Goondiwindi

1. INTRODUCTION

The climate of Waggamba Shire is dominated by a system of high pressure cells (anticyclones), that move across central Australia from west to east. To the north of the high pressure system lies the equatorial low pressure system, and to the south lies the Antarctic low pressure system. Both these low pressure systems are rain bearing.

The seasonal fluctuation of the high pressure cells follows that of the sun, that is, moving north in winter and south in summer. It is this movement of the system that defines the climate of the seasons of the shire.

Winter is dominated by stable air masses, ensuring fine, cool days with cool to cold nights. Occasionally cold fronts from the Antarctic lows enter between successive high pressure cells, allowing cool, unstable air to penetrate from the south-west. The cool, unstable air causes rain, and is the chief provider of winter precipitation.

As the high pressure system moves south in summer, a line of troughs is formed over central Queensland. Moist, unstable, tropical air penetrates along the eastern edge of these troughs causing storm activity. Rain depressions move into the shire from the north if the easterly movement of the high pressure cells is stalled. Rain depressions deliver peak rainfall to the shire.

The driest periods of the shire are usually autumn and early spring when the Antarctic and the equatorial rain bearing systems have little influence. However, conditions are rarely normal and variations in seasonal conditions result from changes in the normal paths of the anticyclones. This variation about the norm is shown in Figure 3.1 by the fluctuation of average annual rainfall at Goondiwindi for 40 years.

2. RAINFALL

Figure 3.2 shows average monthly rainfall at Goondiwindi. The shire's rainfall is summer dominant with 60 to 70% falling between October and March. The agriculturally important rains fall in mid-winter. This rain, in association with the lower evaporation rates of winter, make the shire a predominantly winter crop growing area.

Winter rains are generated by the tail end of cold fronts linked to low pressure systems to the south of Australia. Winter rains are typically low in intensity and are widespread.

Early summer rainfall is usually generated by storm activity. The storms are generally quite erratic, very localised and are characterised by short, sharp, heavy downpours.

Mid-summer rains are generated by encroaching low pressure cells and related rain depressions. Consequently mid-summer rains are more widespread and less intense than the storms of early summer.

These rainfall patterns have a strong bearing on agricultural practices in the shire, for example, heavy summer rainfall is more likely to produce large volumes of rapid runoff than the gentler winter rains. This, therefore, creates a need for some form of soil protection.

2.1 Drought

Extended dry periods are a normal and expected feature of the highly variable rainfall of the shire. The condition called 'drought' may often only be the return to normal seasonal rains after a run of good years. An accepted statistical measure of drought is the occurrence of a year or years with rainfall within the lowest 30% of all occurrences recorded. This measure has the advantage of relating each rainfall amount to the entire period of available records and avoids classifying droughts on the basis of expectations built up by a run of good seasons.

Within the record of 1880-1982 the highest rainfall drought frequency was in the period 1915-48 with severe droughts (within the lowest 10% of recorded annual rainfall) occurring in five years within the period of 1915-23. Dry periods of several years duration appear to occur at roughly 20 year intervals (1898-1902; 1915-23; 1939-41; 1965-67; 1979-82) although the pattern is not very regular. Before 1982 the last severe rainfall droughts were 1965 and 1967. The dry year of 1982 fell only within the lowest 30% of recorded annual rainfall.

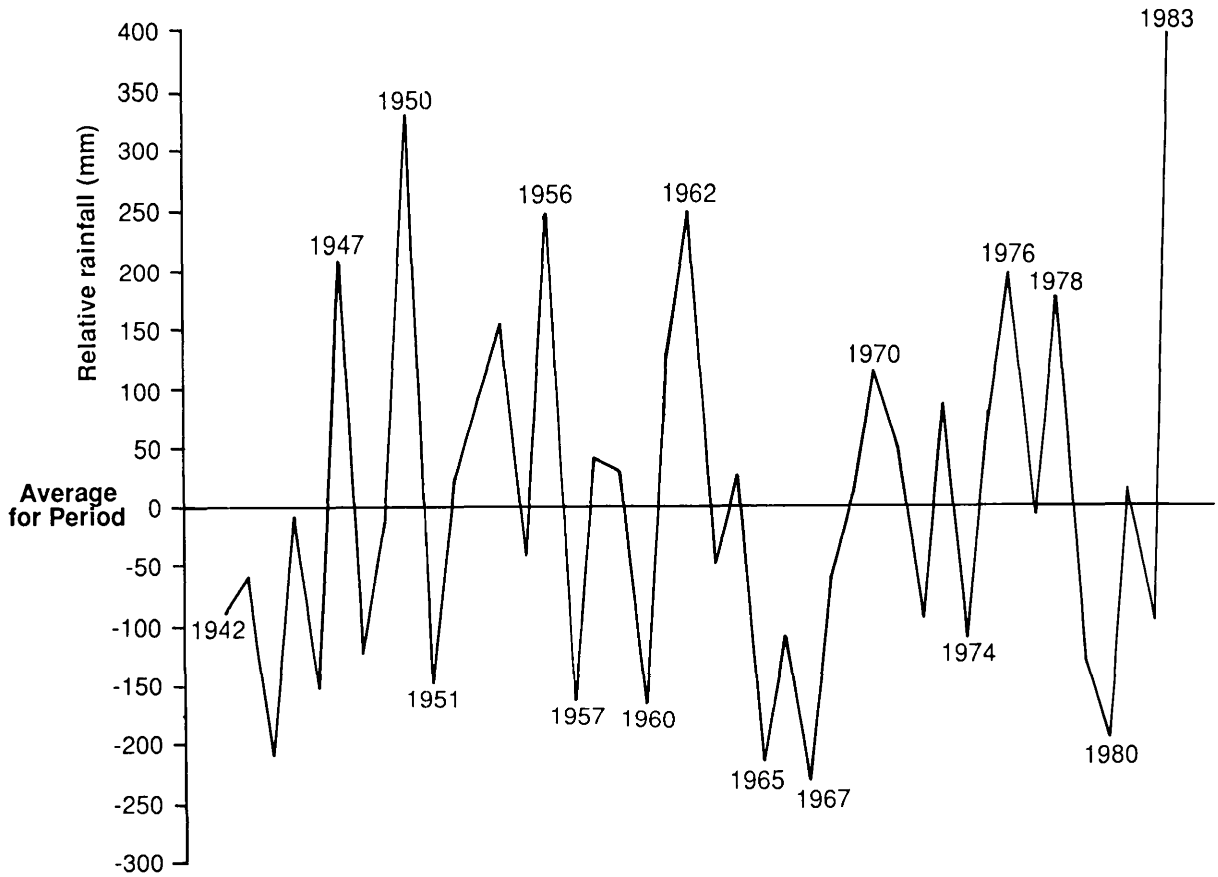

Figure 3.1. Fluctuation of average annual rainfall about the mean for the period 1942-83 at Goondiwindi

3. TEMPERATURE

Waggamba Shire experiences extremes of temperature fluctuation. Figure 3.3 shows average monthly minimum and average monthly maximum temperatures for Goondiwindi.

Temperatures are measured in a Stevenson Screen at 1.25m above the ground level. Heat waves are classified as screen temperatures above 38°C and frosts as screen temperatures of 2°C and below. As a general rule 2°C in the screen equates to a light frost and 0°C in the screen is a heavy frost.

3.1 Frosts

Frosts are common in the district and are important for variety choice and planting time of wheat crops. Frosts in the shire are commonly of the radiation type; they are associated with still, stable air and clear nights. Heat is radiated from the ground surface to an extent that allows ground temperatures to drop below 0°C. Any moisture in the air cools and is deposited as dew. As the ground temperature drops below 0°C crystallisation of the dew occurs. This process usually has little effect on the vegetative parts of the crop, but can be lethal to floral parts. Table 3.1 shows dates for the first and last frosts (of varying severity) and the risk of those frosts occurring from a certain date.

Table 3.1*a*. Date of first frost for year at Goondiwindi before July 15

		(Light)		Temperature °C		(Severe)	
		3	2	1	0	-1	-2
Earliest first frost		Apr 5	Apr 17	May 8	May 8	May 9	May 17
% risk of first frost	10	Apr 29	May 6	May 14	May 25	June 3	June 1
	30	May 10	May 18	May 28	June 9	June 18	June 28
	50	May 18	May 26	June 8	June 20	July 1	*n.a.*
	70	May 26	June 3	June 18	July 4	*n.a.*	*n.a.*
	90	June 9	June 19	July 11	*n.a.*	*n.a.*	*n.a.*
Latest first frost		July 5	July 3	July 14	July 11	July 12	July 12
Probability of first frost occurring *before* July 15 (%)		99	97	92	81	66	48

Table 3.1*b*. Date of last frost for year at Goondiwindi after July 15

		(Severe)		Temperature °C		(Light)	
		-2	-1	0	1	2	3
Earliest last frost		July 17	July 17	July 17	July 17	July 29	Aug 14
% risk of last frost	90	*n.a.*	*n.a.*	*n.a.*	July 28	Aug 10	Aug 23
	70	*n.a.*	*n.a.*	July 30	Aug 12	Aug 23	Sept 4
	50	*n.a.*	July 22	Aug 10	Aug 22	Sept 2	Sept 12
	30	July 19	Aug 7	Aug 20	Sept 1	Sept 11	Sept 20
	10	Aug 12	Aug 22	Sept 3	Sept 16	Sept 25	Oct 2
Latest last frost		Sept 7	Sept 7	Sept 27	Oct 16	Oct 16	Oct 16
Probability of last frost occurring *after* July 15 (%)		39	61	84	99	100	100

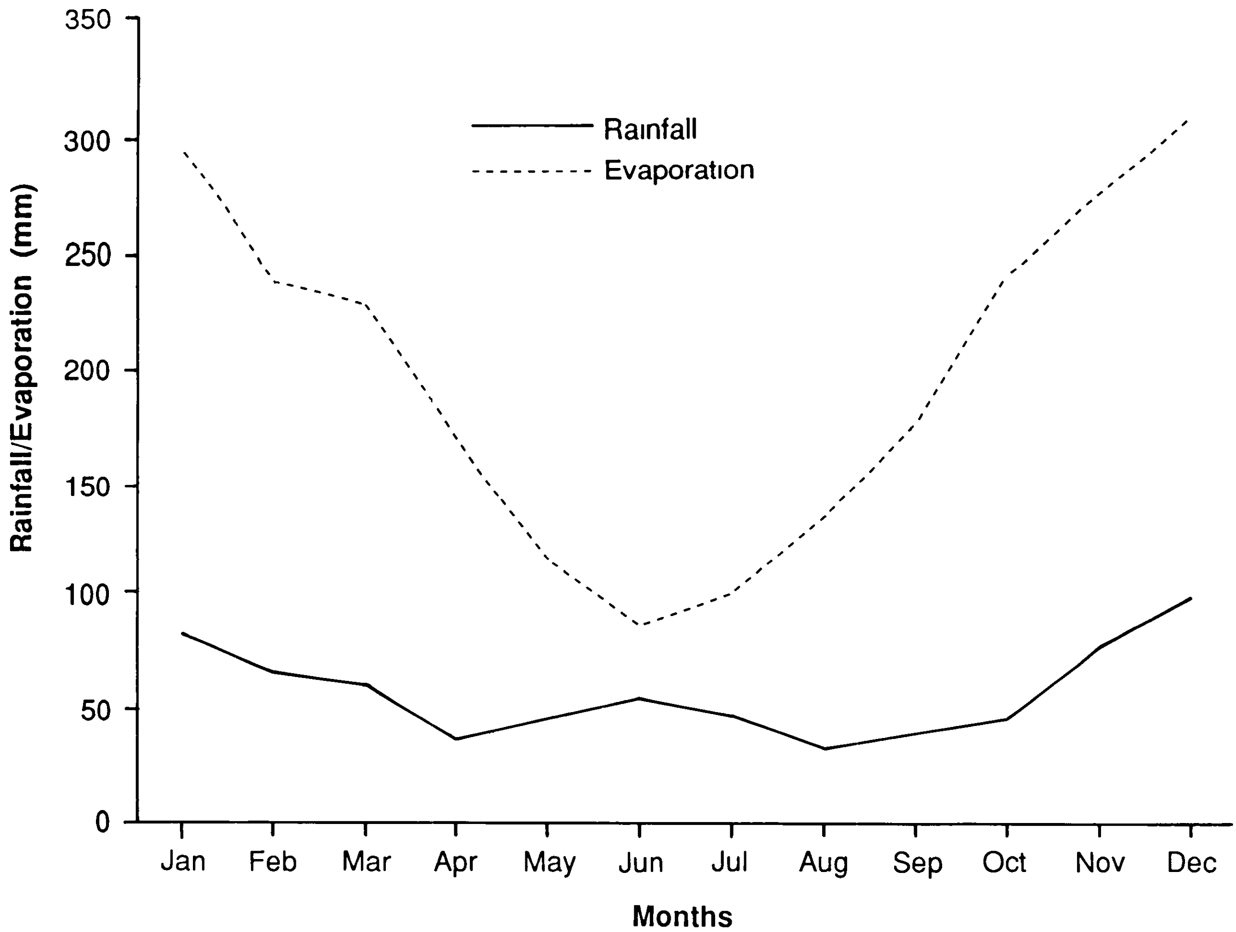

Figure 3.2. Average monthly rainfall and Class A-pan evaporation for Goondiwindi

4. EVAPORATION

Evaporation is recorded as the measured loss of water from a free water surface using a standard Class A evaporimeter. Rates of evaporation in the shire are important for determining soil water storage. Evaporation in the shire is lowest in winter and increases by almost 400% in the summer months. Figure 3.2 shows average monthly rainfall and potential evaporation.

5. WIND

Wind is not an important climatic feature in the shire. Localised strong winds are associated with summer thunderstorms and can affect substantial wind erosion. Certain soils are more susceptible than others to wind erosion (see Chapter 7) but it also depends upon land management practice. Shadelines are an effective measure against the gusty type of winds experienced in the shire (see Chapter 11).

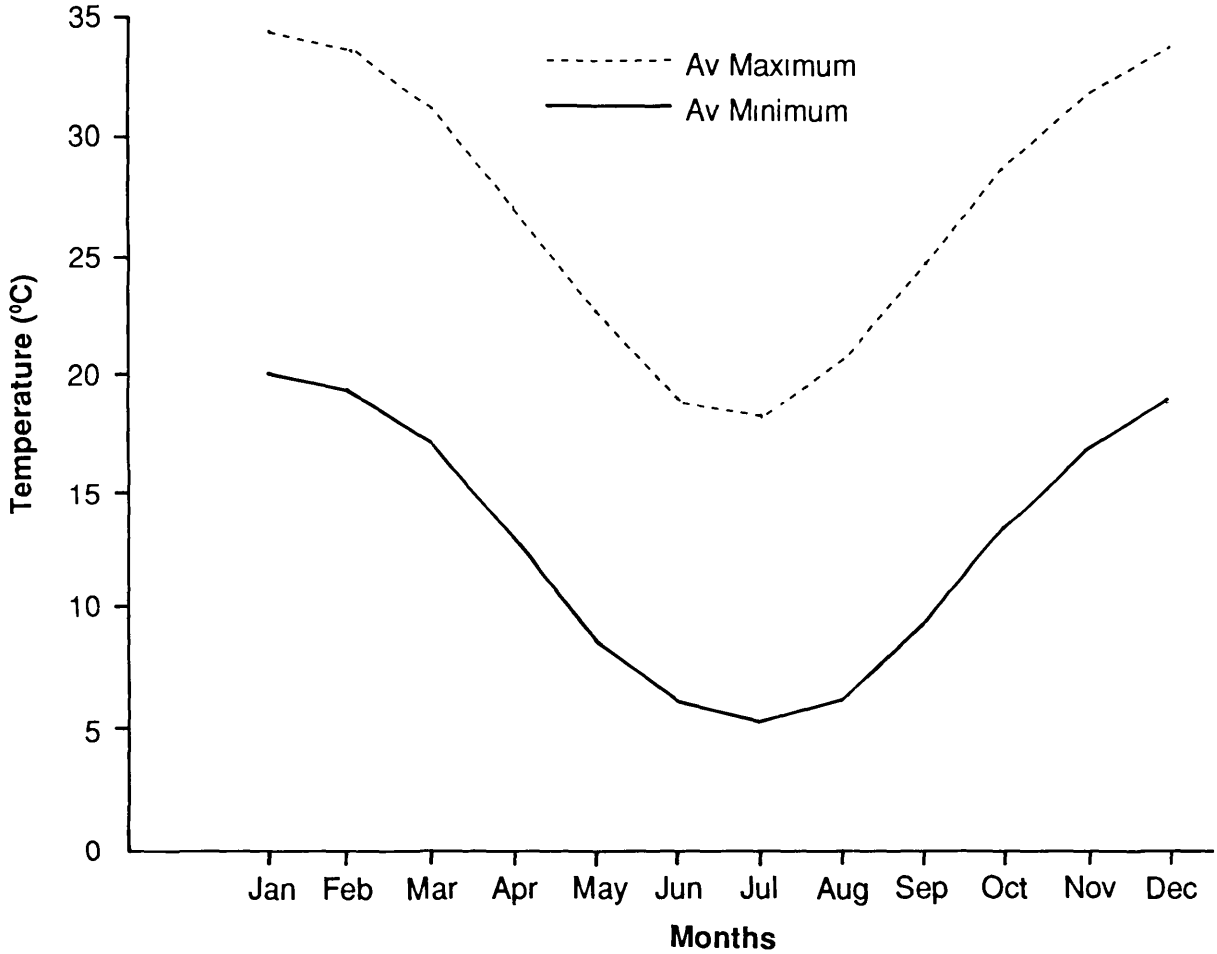

Figure 3.3. Average monthly minimum and maximum temperatures for Goondiwindi

Chapter 4

GEOLOGY

Brian Slater
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1. INTRODUCTION

Geology is the study of sub-surface materials and processes. These materials and processes are important factors in the formation, character and behaviour of our land resources.

Soil parent material is a dominant factor in soil formation in southern Queensland. An understanding of the geology of a region is helpful in explaining the distribution of land resources and the processes acting on them.

Unfamiliar terms used in this chapter are explained in the Glossary.

2. MAJOR GEOLOGICAL FEATURES

- Sub-surface and outcropping rock materials in the Goondiwindi district are mostly of sedimentary origin. Most of the rocks were deposited in the Mesozoic Era (230 to 65 million years ago[1]) in a large area called the Surat Basin. The Goondiwindi district is located in the south-central section of the Surat Basin in Queensland. Later, in the early part of the Cainozoic or Tertiary Era (65 million years ago to the present[1]), the exposed rocks were deeply weathered.

More recently, large areas of these older rocks have been eroded and redeposited. They occur now either as consolidated sedimentary rocks, or as unconsolidated alluvium, particularly in the south.

- The major parent materials for soil formation in the district are consequently freshly exposed Mesozoic sedimentary rocks, deeply weathered rocks, and alluvium.

The sequence of outcropping rocks and alluvia is summarised in Table 4.1.

3. GEOLOGICAL HISTORY

The major geological units in the Waggamba district are shown in Figure 4.1 and Table 4.1.

3.1 Jurassic Surat Basin sediments

Below the layered sequence of rocks which currently outcrop in the district is a basement of Permian to Triassic age rocks (195 to 280 million years old). The sedimentary rocks of the Surat Basin were laid down on top of these basement rocks. During the Jurassic Period (more than 100 million years ago), sequences of sediments were deposited in streams, lakes and swamps. In the Goondiwindi district, surface exposures of these rocks and some younger sedimentary rocks have been altered by intense weathering and are therefore difficult to classify. They are shown on the geological maps as a composite unit called the Kumbarilla Beds. The Kumbarilla Beds outcrop in the north-east of the district, and mostly consist of labile to quartzose sandstones, with some siltstone, mudstone and conglomerate.

3.2 Cretaceous Surat Basin sediments

In the early Cretaceous Period, the sea encroached on the Surat Basin, depositing what is now the Bungil Formation. Exon (1976) maps the Bungil Formation separately from the Kumbarilla Beds in the area to the north of Billa Billa. The major materials are labile sandstone, siltstone and mudstone; the rocks are deeply weathered in the north.

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[1] See Table 4 1

A number of subsequent marine incursions resulted in the deposition of the Wallumbilla Formation (the oldest member of the Rolling Downs Group of sedimentary rocks, which occur widely in inland Queensland). South of Moonie, exposures of both the Doncaster and Coreena Members of the Wallumbilla Formation occur. These rocks are mostly mudstones, with some associated siltstone and labile sandstone strata.

The sea retreated, and delta and freshwater sediments were deposited. These are known as the Griman Creek Formation, consisting mostly of siltstone, mudstone and lithic sandstone, outcrops near Tarewinnabar. The Griman Greek Formation is deeply weathered where it is exposed elsewhere.

3.3 Tertiary deep weathering

During the late Cretaceous and early Tertiary times, most of inland Queensland was subjected to a period of erosion and planation. The exposed rocks were extensively weathered, most probably during prolonged cycles of variable rainfall and fluctuating water tables. The chemical alteration of the rocks involved:

- leaching of the calcium-rich cement which previously bound the constituent particles together to form the rocks;
- a progressive transformation of feldspar minerals, clay minerals and labile fragments to form a new matrix of kaolinite white clay;
- the alteration of iron-rich minerals to form iron oxides (red colour); and
- mobilising and recrystallising of silica produced from the breakdown of minerals; more resistant lithic and quartz grains were relatively unaffected.

Current exposures of the these kaolinised[2], ferruginised[2] and silicified[2] materials show a variety of features:

- The classic lateritic profile[2], with duricrust[2], ferruginous, mottled and pallid zones, is not evident in the district.
- An original duricrust is not usually present, though an occasional outcrop is capped by a metre or more of ferruginised gravel, probably representing disaggregated and recemented material.
- Most outcrops of deeply weathered rocks consist of pallid coloured materials, with various degrees of mottling. The mottling appears mostly as a pattern of white, red and purple patches, 8 to 30 cm in diameter, within a pale pink to yellow matrix.
- Generally, the original bedding characteristics, lithology and grain size can be identified. Fine-grained homogeneous rocks have frequently weathered to blocks, while well-bedded materials still show evidence of layered orientation.

The deeply weathered profiles have been interpreted by geologists as evidence for a major, widespread weathering event in the Tertiary Period (2 to 65 million years ago). Dating of similar profiles from western Queensland has established that two major weathering events occurred there, in the Late Cretaceous and early Tertiary Periods. Later weathering in the middle Tertiary may have produced some of the mottled features now seen in the outcrops.

3.4 Cainozoic sediments: clay sheets and alluvia

Following deep weathering, the sediments were tilted slightly downwards to the south, and precursors of the present-day drainage systems were established. The sedimentary strata now dip gently to the south-west over most of the district. Some sandy (quartzose) sediments were deposited during the Late Tertiary in the upper reaches of the Weir River and Western Creek, and in the Westmar area.

Erosion and deposition has continued across the landscape since the Tertiary. The old land surface has been dissected, leaving remnants of the weathered profiles and exposures of older unweathered rocks and this was accompanied by the deposition of large areas of the most recent Quaternary age sediment on floodplains.

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[2] See Glossary

Table 4.1. Stratigraphy of major geological units exposed in Waggamba Shire

Era	Age (Period/Epoch)	Time B P (years x 10^6)	Stratigraphic unit	Map symbol	Environment of deposition and lithology
Cainozoic	Quaternary Pleistocene/Recent	0.5 to present	-	Qa	Alluvia of present-day stream channels and floodplains; unconsolidated sediments a) clay b) clay, silt, sand, gravel
	Mostly Pleistocene	2 to recent	-	Q	Alluvia deposited by older drainage systems, some colluvia, aeolian materials and deeply weathered clays; unconsolidated clays, some sand and soil, clay sheets
			-		
	Mid-Tertiary	30 to 15	-	T	River deposits of ancestral Weir River system; partly consolidated labile to quartzose sandstone and some conglomerate
			Chemically altered Cretaceous and Jurassic sediments	(Klg) (Kw) (Kly) (J/Kk)	Remnants of deep weathering profiles
Mesozoic	Lower Cretaceous	~ 100	Griman Creek Formation	Klg	Shallow marine, delta or river deposited, fine to medium, calcium-rich, lithic sandstone with siltstone, minor mudstone
			Wallumbilla Formation· · Coreena Member	Kw	Shallow marine and coastal plain, siltstone, mudstone, fine calcium- rich labile sandstone, minor conglomerate
		~ 110	· Doncaster Member		Shallow marine, delta or river deposited, calcium-rich labile sandstone, siltstone and mudstone
		~ 120	Bungil Formation	Kly	Shallow marine, delta or river deposited; calcium-rich labile sandstone, siltstone and mudstone
	Middle Jurassic to Upper Cretaceous	~ 170 to 100	Kumbarilla Beds	J/Kk	Streams, lakes and swamps, lithic to quartzose sandstone, some siltstone, mudstone and conglomerate

Considerable areas of flat to gently undulating plains occur in the east and north-east of the district and are shown as Quaternary alluvium (Q or Qa in Figure 4.1). These 'clay sheets' originally supported brigalow dominated vegetation. The associated soils are typically deep, dark or grey cracking clays, often with well developed gilgai microrelief. Dense acid clays below the soil profiles grade into mottled materials. A variety of theories have been advanced to explain the origin of the clay sheets: a wind-borne or lake deposit origin was proposed for their occurrence on virtually featureless plains (Isbell, 1957); van Dijk (1985) concluded that the clay sheets had a mixed origin being:

- weathered in place;
- colluvial deposition on slopes; or
- deposited by streams.

During the most recent times (less than 10 000 years ago), fine-textured alluvial materials were deposited on the floodplains of the Macintyre and Weir Rivers; some coarser sediments occur on more elevated parts of the landscape such as levees. Recent alluvial deposits occur adjacent to drainage lines throughout the district. Deep sandy deposits occur adjacent to old and current drainage lines of the Weir and Macintyre River systems. These sands may have been picked up and redeposited by wind action.

4. GEOLOGY AND SOIL RELATIONSHIPS

Soil geography in the district is largely governed by the distribution of

- alluvia;
- other transported materials;
- areas of remnant deeply weathered rocks; and
- freshly exposed older rocks.

Table 4.2 lists the important substrates for soil formation and the major associated soil attributes and relates the units to the major Land Resource Areas.

Sources of information

Geological maps document the distribution of major rock types and surface materials. Geological features of the Goondiwindi district are discussed in detail in a series of explanatory booklets accompanying 1:250 000 scale geological maps of the following areas:

Goondiwindi (Senior, 1973)
Dalby (Mond, 1973)
St George (Senior, 1972)
Surat (Reiser, 1971)

An overview of the geology of southern inland Queensland is presented by Exon (1976) together with a 1:1 000 000 scale map.

Table 4.2. Major substrates for soil formation and associated soil attributes

Substrate*	Associated soil attributes	LRA
Recent clay alluvia deposited mostly on backplains of major streams	Very deep, cracking clays	Macintyre
Silty and fine sandy alluvia of major stream terraces	Hard setting duplex soils, loamy surfaces	Dumaresq
Fine sandy and clay alluvia of minor streams	Layered alluvial soils, uniform sands and loams, hard setting solodic soils; soft solodic soils with sandy surfaces	Dumaresq
Fine sandy and clayey alluvia of minor streams	Hard setting solodic soils	Serpentine Boogara
Sand deposits, perhaps reworked by wind, overlying clay alluvia near major streams	Deep, uniform, earthy and siliceous sands	Broomfield
Transported material clay sheets	Deep cracking clays, often with gilgai, hard setting solodic soils with shallow clay loam surfaces	Commoron Bungunya North
Transported material relict alluvia	Soft or hard setting solodic soils or solodized solonetz, solonetz soils	Goodar Desert
Quartzose sedimentary rocks	Duplex soils with impermeable subsoils, some duplex soils with permeable subsoils; deep uniform sands, some shallow, gravelly or stony sands and loams	Westmar Goodar
Freshly exposed labile sedimentary rocks	Moderately deep cracking clays, often with linear gilgai, some shallow clays	Lundavra
Labile sedimentary rocks partially affected by chemical alteration (deep weathering)	Deep cracking clays, solodic soils, clay loam surfaces	Commoron Bungunya North Billa Billa
Deeply weathered labile sedimentary rocks	Hard setting solodized solonetz soils, red massive earths and solodics	Boondandilla Geralda Goodar
Remnants of deeply weathered profiles including ferruginous gravel and pallid/mottled materials	Shallow stony soils, shallow gravelly, massive earths	Jumpup

* See Glossary for explanation of this term and others in this column

Chapter 5

VEGETATION

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1. INTRODUCTION

In Waggamba Shire, as in other areas of south and west Queensland, there is a strong relationship between soil type and vegetation. For this reason communities described here are based on soil type rather than on floristics or structure. The chapter is designed primarily for reference and the following descriptions merely indicate the prevalent associations and their structure and floristics found in each Land Resource Area (LRA).

Some vegetation changes, and soil changes, may be abrupt, for example vegetation of the sand ridges changes rapidly to the vegetation of the alluvial plains. More commonly there is a transitional zone, or ecotone, between distinct communities, for example where brigalow grades into predominantly belah woodland.

The vegetation characteristics of each LRA are determined by a number of factors. Environmental factors such as climate, soil type and landform combine with land use and disturbance to influence the composition and structure of the vegetation communities. The vegetation composition of the area is not naturally static, but changes slowly.

Large areas of the shire's vegetation have been modified by clearing, burning and grazing of stock. Clearing ranges from complete removal of the vegetation for cultivation to selective thinning of trees and shrubs to increase palatable grass species. Stock preferences and tolerance of plants to grazing affect the composition of the ground flora and have brought about changes to the vegetation type and composition over large areas of the shire.

2. VEGETATION DESCRIPTIONS FOR EACH LRA

The structural formation classes of Walker and Hopkins in McDonald *et al.* (1984) have been used in the following descriptions. Table 5.1 shows the structural and height classes used and Table 5.2 is a complete species list.

2.1 Dumaresq

In the extreme south-east of the shire, tall, open forests, chiefly of *Eucalyptus camaldulensis* (river red gum), border the Dumaresq River. *Eucalyptus populnea* (poplar box) and *Eucalyptus melanophloia* (silver leaved ironbark) are less dominant and there can also be patches of *Eucalyptus microtheca* (coolibah) and *Eucalyptus tessellaris* (carbeen). These forests are associated with the river levee features.

On the river terraces from Bengalla westwards, tall woodlands of *Eucalyptus populnea* and *Eucalyptus melanophloia* predominate. *Angophora intermedia* (roughbark apple) is less common with *Eucalyptus crebra* (narrow leaved ironbark), *Eucalyptus camaldulensis* and *Eucalyptus microtheca* are also present.

From around the Kildonan area *Eucalyptus populnea* predominates until near Goondiwindi. The forests of the levee system then take precedence westward.

Ground cover composition changes as the forest species change. However, the major species are *Bothriochloa decipiens* (pitted bluegrass), *Stipa verticillata* (slender bamboo grass) and *Aristida* spp.[1]

[1] Spp is an abbreviation of the word 'species', referring to more than one species of the genus named

(wiregrasses). Other species occurring include *Bothriochloa bladhii* (forest bluegrass) and *Chloris* spp. (windmill grasses).

2.2 Macintyre

The most distinguishing feature of this association is the ground cover. This is mostly in the form of a tussock grassland to open tussock grassland of *Astrebla lappacea* (curly mitchell grass) and *Dichanthium sericeum* (Queensland bluegrass). Several other grasses are found throughout at varying densities, namely *Astrebla elymoides* (hoop mitchell grass), *Iseilema membranaceum* (small flinders grass), *Panicum decompositum* (native millet), *Paspalidium globoideum* (shot grass), *Dactylotenium radulans* (button grass), *Eriochloa pseudoarotricha* (early spring grass), *Eulalia fulva* (brown top), *Bothriochloa bladhii* (forest bluegrass) and *Chloris* spp. (windmill grasses).

Tree species occur as tall, open woodlands, tall isolated trees or tall isolated clumps of trees. *Eucalyptus microtheca* (coolibah) is the predominant species however *Heterodendrum oleifolium* (boonaree) can be found throughout. West of Toobeah, *Acacia pendula* (myall) and *Casuarina cristata* (belah) are present and become dominant in the south-west. *Eremophila* spp. (fuchsias) may also be scattered throughout.

The landform of this LRA is relatively flat alluvial plains and there are a number of associated communities growing on stream meanders, levees and low rises. Depressions, back slope deposits and swamps have a woodland or open woodland of *Eucalyptus camaldulensis* (river red gum) and *Eucalyptus microtheca* associated with the tussock grassland.

On the slightly elevated levees and scroll bars of the meander plains, *Eucalyptus populnea* forms open woodlands with *Eremophila mitchellii* (false sandalwood), *Heterodendrum oelifolium*, *Geijera parviflora* (wilga), with some *Casuarina cristata* and *Ventilago viminalis* (supplejack).

The intermediate areas between levees and alluvial plains support woodlands of *Casuarina cristata* with *Eucalyptus populnea*, *Eucalyptus microtheca*, *Eremophila mitchellii* and *Heterodendrum oleifolium*.

The low rises adjacent to meanders support woodlands to open forests of *Eucalyptus tessellaris* (carbeen), *Eucalyptus camaldulensis*, *Callitris columellaris* (cypress pine), *Eucalyptus polycarpa* (long fruited bloodwood) and *Eucalyptus dealbata* (tumbledown gum).

2.3 Serpentine

Eucalyptus populnea (poplar box) is the predominant species of the characteristic tall open woodland. *Eremophila mitchellii* (false sandalwood) and *Geijera parviflora* (wilga) are the main species of the understorey.

Distribution is confined to major creeks and drainage floors of the brigalow-belah landscapes as well as the slightly elevated landforms associated with both active and abandoned drainage systems of the flood plains.

In the drainage floors of the brigalow-belah landscapes, *Acacia pendula* (myall) and *Casuarina cristata* (belah) may be present in the upper stratum.

Ground cover is composed chiefly of *Chloris divaricata* (slender chloris), *Chloris truncata* (windmill grass) and *Chloris acicularis* (curly windmill grass). Occasionally *Sporobulus caroli* (fairy grass) and *Dichanthium sericeum* (Queensland bluegrass) may be present.

2.4 Boogara

Eucalyptus populnea (poplar box) predominates in a tall, open woodland. *Casuarina cristata* (belah) may also be present occasionally, and to a lesser extent *Eucalyptus melanophloia* (silver leaved ironbark). *Eremophila mitchellii* (false sandalwood) is dominant in the shrub layer.

Other species occurring in the canopy and understorey include *Atalaya hemiglauca* (whitewood), *Acacia excelsa* (ironwood), *Brachychiton populneus* (kurrajong), *Heterodendrum oleifolium* (boonaree), and very occasionally *Flindersia maculosa* (leopard wood).

Low shrubs may be scattered throughout. *Carissa* spp. (currant bushes), *Cassia* spp., *Dodonea* spp. (hopbushes) and *Eremophila* spp. (fuchsias) are the most common.

Ground cover is continuous and composed mainly of *Chloris* spp. *Chloris divaricata* (slender chloris) is the main species with *Chloris truncata* (windmill grass), *Chloris acicularis* (curly windmill grass) also present. *Sporobulus caroli* (fairy grass) and *Dicanthium sericium* (Queensland bluegrass) are less prevalent. *Aristida* spp. (wiregrasses) favour the sandier soils in this LRA.

2.5 Broomfield

Eucalyptus tessellaris (carbeen), *Eucalyptus polycarpa* (long fruited bloodwood) and *Eucalyptus dealbata* (tumbledown gum) are the main vegetative indicators for this LRA. In some areas *Eucalyptus dealbata* dominates to form tall, open woodlands. Associated species include *Callitris columellaris* (cypress pine), *Acacia excelsa* (ironwood), *Eucalyptus populnea* (poplar box), *Alstonia constricta* (bitter bark) and *Angophora costata* (rusty gum).

Ground cover is sparse with *Aristida* spp. (wiregrasses) and *Eragrostis* spp. (lovegrasses) predominating.

2.6 Goodar

Callitris columellaris (cypress pine) is the main indicating species for this LRA. In the east of the shire it forms tall open forests with associated *Eucalyptus dealbata* (tumbledown gum), *Eucalyptus crebra* (narrow leaved ironbark) and *Angophora costata* (rusty gum). *Casuarina leuhmannii* (bull oak) dominates the understorey with *Acacia* spp. making a shrub layer.

Around the Umbercollie State Forest in the centre of the shire, *Callitris columellaris* forms tall woodlands with associated *Eucalyptus populnea* (poplar box). *Geijera parviflora* (wilga) and *Eremophila mitchellii* (false sandalwood) make a sparse understorey.

Ground cover throughout is sparse with *Aristida* spp. (wire grasses) and *Eragrostis* spp. (lovegrasses) being the major components.

2.7 Desert

Stunted *Melaleuca adnata*, forming low, isolated clumps, is the major vegetative indicator for this LRA. However *Casuarina leuhmannii* (bull oak) and *Casuarina cristata* (belah) may be present as isolated tall trees. On the fringes of the area *Eucalyptus pilligaensis* (gum-topped box or mallee box) and *Eucalyptus populnea* (poplar box) can also be found. Ground cover is very sparse and consists mainly of *Chloris* spp. (windmill grasses). *Triodia irritans* (spinifex) grows where soil conditions are favourable.

2.8 Commoron

Communities form tall, closed forests grading to tall, open forests of *Acacia harpophylla* (brigalow) and *Casuarina cristata* (belah), with occasional trees of *Eucalyptus populnea* (poplar box). Pure stands of virgin *Acacia harpophylla* are rare but regrowth areas can be dominated by it.

To the north, on the footslopes of the jumpups, *Acacia harpophylla* dominates with isolated *Casuarina cristata*, *Eucalyptus populnea*, *Eucalyptus pilligaensis* (gum-topped box or mallee box) and *Geijera parviflora* (wilga). *Casuarina cristata* appears to more heavily populate the drainage lines.

Ground cover is sparse but small shrubs and herbaceous plants are common in open areas. They include *Carissa ovata* (currant bush), *Rhagodia spinescens* (berry saltbush), *Salsola kali* (soft roly-poly), *Sclerolaena muricata* (prickly roly-poly), *Sclerolaena tetracuspis* (brigalow burr), *Atriplex semibaccata* (creeping saltbush), *Chenopodium trigonon* (fishweed) and *Maireana microphylla* (cottonbush).

Grasses include *Paspalidium caespitosum* (brigalow grass), *Paspalidium gracile* (slender panic), *Enteropogon acicularis* (spider grass), and *Chloris* spp. (windmill grasses). Minor grasses include *Sporobulus caroli* (fairy grass), *Eragrostis leptostachya* (paddock lovegrass) and *Eragrostis parviflora* (weeping lovegrass).

In damper environments, such as in and around gilgais, *Melaleuca bracteata* (black tea-tree), *Carex* spp. (sedges) and *Cypress bifax* (downs nutgrass) are common. *Diplachne parviflora* (beetle grass), *Marsilea drummondii* (nardoo) and *Leptochloa digitata* (canegrass) may also be present.

2.9 Billa Billa

Casuarina cristata (belah) stands as tall, open forests and occasionally as tall, closed forests. *Acacia harpophylla* (brigalow) may also be present. *Geijera parviflora* (wilga) and *Eremophila mitchellii* (false sandalwood) form understoreys. *Capparis lasiantha* (nipan) and, less commonly, *Capparis mitchellii* (wild orange) with *Anthobolus leptomerioides* and *Exocarpus aphyllus* may be present.

Vegetational structure changes on moving in to drainage depressions. In shallow drainage depressions *Casuarina cristata* still dominates but the canopy is more open and individual trees tend to branch lower down the trunk. *Eucalyptus populnea* (poplar box) becomes dominant in more defined drainage lines with vegetation characteristics of Serpentine LRA.

In some areas large dead trunks of *Eucalyptus* trees can be found either standing or fallen and this may suggest that belah forests are spreading.

The majority of the belah country was cleared by the late 1950s and now is mainly confined to tree lines surrounding paddocks.

2.10 Bungunya North

On the level and gently undulating plains *Casuarina cristata* (belah) forms a tall, open forest. *Acacia harpophylla* (brigalow) may also be present at varying densities. In almost pure stands of *Casuarina cristata* the understorey can be almost absent. In thinner stands *Geijera parviflora* (wilga) and *Eremophila mitchellii* (false sandalwood) are present.

On the gently undulating plains and rises *Acacia harpophylla* (brigalow) becomes dominant and can form almost pure stands. *Eucalyptus thozetiana* (yapunyah) and *Eucalyptus populnea* (poplar box) may also be present. *Geijera parviflora* and *Eremophila mitchellii* are present as an understorey in open areas.

Ground cover is similar for both communities. *Chloris* spp. (windmill grasses) dominate, with *Paspalidium caespitosum* (brigalow grass) also common. *Sporobulus caroli* (fairy grass) and *Eragrostis* spp. (lovegrasses) are common in some areas.

2.11 Lundavra

There are two distinct communities associated with this LRA. On the upper slopes and crests of ridges *Eucalyptus melanophloia* (silver leaved ironbark) and *Eucalyptus populnea* (poplar box) form tall, open woodlands. *Geijera parviflora* (wilga) may be present as an understorey.

On mid to lower slopes and on the flatter area between ridges *Acacia pendula* (myall) and *Eucalyptus microtheca* (coolibah) communities form tall, open woodlands.

Ground cover is continuous throughout the communities, dominated by *Dichanthium sericeum* (Queensland bluegrass) with *Bothriochloa intermedia* (forest bluegrass), *Panicum decompositum* (native millet) and *Aristida latifolia* (feathertop wiregrass).

On the slopes of some of the ridges linear gilgais are present and here the *Dichanthium sericeum* is restricted to the depressions. The puffs or ridges are occupied by *Aristida latifolia*. *Chloris* spp. (windmill grasses) are also present throughout the area.

2.12 Geralda

Varying landscape components dominate the vegetation of this LRA. Higher landscape features are characterised by tall woodlands of *Eucalyptus melanophloia* (silver leaved ironbark) and *Eucalyptus populnea* (poplar box). *Callitris columellaris* (cypress pine), *Acacia aneura* (mulga) and *Brachychiton populneus* (kurrajong) may also be present.

An understorey is usually absent but can be composed of scattered *Eremophila mitchellii* (false sandalwood) and *Geijera parviflora* (wilga). A low shrub layer may be present, consisting of *Cassia nemophila* (birdseye cassia), *Dodonea attenuata* (hopbush) and *Carissa ovata* (currant bush).

In lower areas *Eucalyptus populnea* predominates with only occasional *Eucalyptus melanophloia, Brachychiton populneus* and *Casuarina cristata* (belah). There is a distinct understorey of *Eremophila mitchellii* with the occasional *Geijera parviflora*.

Ground cover is dominated by *Aristida* spp. (wiregrasses) with some *Neurachne* spp. (mulga grasses) and *Eragostis* spp. (lovegrasses).

2.13 Boondandilla

Casuarina leuhmannii (bull oak) dominates a mid-high, open forest with a lesser presence of *Callitris columellaris* (cypress pine). *Eucalyptus crebra* (narrow leaved ironbark), *Eucalyptus populnea* (poplar box) and *Angophora costata* (rusty gum) may be scattered throughout as tall trees above the general canopy layer.

Understoreys are generally absent but there are saplings of the dominant component species.

Ground cover is sparse with *Aristida* spp. (wire grasses) and *Eragrostis* spp. (lovegrasses) being the most common.

2.14 Westmar

The predominant vegetation of this area is a tall woodland of *Eucalyptus melanophloia* (silver leaved ironbark). A number of other trees may also be present, namely *Eucalyptus crebra* (narrow leaved ironbark), *Eucalyptus dealbata* (tumbledown gum), *Callitris columellaris* (cypress pine), with the occasional *Brachychiton populneus* (kurrajong) and *Eucalyptus polycarpa* (long fruited bloodwood).

Localised communities of *Acacia sparsiflora* (lancewood) are also present. *Eucalyptus crebra, Alphitonia excelsa* (red ash) and occasionally *Casuarina leuhmannii* (bull oak) can also be present. *Acacia spectabilis* (kogan wattle) may also be present.

On lower slopes and valley flats *Eucalyptus populnea* (poplar box) becomes more frequent but does not dominate. Here the understory comprises *Geijera parviflora* (wilga) *Acacia* spp. and *Petalostigma pubescens* (native quinine bush).

In areas of deep, sandy alluvium *Callitris columellaris* forms a tall open forest with emergent *Eucalyptus melanophloia* (silver leaved ironbark), *Angophora costata* (rusty gum), *Eucalyptus crebra* and *Eucalyptus trachyphloia* (brown bloodwood). *Petalostigma pubescens* and *Acacia* spp. form an understorey. Ground cover is limited to *Triodia* spp. (spinifex).

2.15 Jumpup

The vegetation of this LRA grades from east to west in response to available water.

In the east of the shire *Eucalyptus crebra* (narrow leaved ironbark) and *Eucalyptus melanophloia* (silver leaved ironbark) form tall woodlands. *Eucalyptus populnea* (poplar box) and *Callitris columellaris* (cypress pine) may also be present.

The understorey is predominantly *Acacia* spp. with a sparse ground cover of *Aristida* spp. (wire grasses).

In the west of the shire *Acacia aneura* (mulga) and *Acacia catenulata* (bendee) become dominant with *Eucalyptus crebra* scattered throughout as tall trees.

Ground cover is very sparse with *Aristida* spp. (wire grasses) and *Eragrostis* spp. (lovegrasses) dominanting.

3. VEGETATION CLASSES AND SPECIES LIST

The vegetation classification and description used in this manual is simplified from that of McDonald *et al.* (1984) and is summarised in Table 5.1. A species list for all vegetation types mentioned in Parts A and B of this manual is given in Table 5.2.

Table 5.1. Classes and terms used for vegetation description in this manual

a) Height classes and names for vegetation forms

Vegetation class	Height (m)
Extremely tall	more than 35
Very tall	20 to 35
Tall	12 to 20
Mid-high	6 to 12
Low	3 to 6

b) Structural formation classes defined by growth form and cover separation

	Field criteria for crown separation				
	touching - overlap	slight separation	clearly separated	well separated	isolated
Structural formation class	closed forest	open forest	woodland	open woodland	isolated

c) Structural formation classes for tussock grass

	Cover (%)				
	more than 70	30 to 70	10 to 30	10 to 1	less than 1
Structural formation class:	closed grassland	grassland	open grassland	sparse grassland	isolated clumps or isolated grasses

Table 5.2. List of species found in Waggamba Shire and their common names

Acacia aneura	mulga
Acacia catenulata	bendee
Acacia excelsa	ironwood
Acacia harpophylla	brigalow
Acacia pendula	myall
Acacia sparsiflora	lancewood
Acacia spectabilis	kogan wattle
Alphitonia excelsa	red ash
Alstonia constricta	bitter bark
Angophora costata	rusty gum
Angophora intermedia	roughbark apple
Anthobolus leptomerioides	-
Aristida latifolia	feathertop wiregrass
Aristida spp.	wiregrasses
Astrebla elymoides	hoop mitchell grass
Astrebla lappacea	curly mitchell grass
Atalaya hemiglauca	whitewood
Atriplex semibaccata	creeping saltbush
Bothriochloa bladhii	forest bluegrass
Bothriochloa decipiens	pitted bluegrass
Bothriochloa intermedia	forest bluegrass
Brachychiton populneus	kurrajong
Callitris columellaris	cypress pine
Capparis lasiantha	nipan
Capparis mitchellii	wild orange
Carex spp.	sedges
Carissa ovata	currant bush
Carissa spp.	currant bushes
Cassia nemophila	birdseye cassia
Casuarina cristata	belah
Casuarina leuhmannii	bull oak
Chenopodium trigonon	fishweed
Chloris acicularis	curly windmill grass
Chloris divaricata	slender chloris
Chloris truncata	windmill grass
Chloris spp.	windmill grasses
Cypress bifax	downs nutgrass
Dactylotenium radulans	button grass
Dichanthium sericeum	Queensland bluegrass
Diplachne parviflora	beetle grass
Dodonea attenuata	hopbush
Enteropogon acicularis	spider grass
Eragrostis leptostachya	paddock lovegrass
Eragrostis parviflora	weeping lovegrass
Eremocitrus glauca	limebush
Eremophila mitchellii	false sandalwood
Eremophila spp.	fuchsias
Eriochloa pseudoarotricha	early spring grass
Eucalyptus camaldulensis	river red gum
Eucalyptus crebra	narrow leaved ironbark
Eucalyptus dealbata	tumbledown gum
Eucalyptus melanophloia	silver leaved ironbark
Eucalyptus microtheca	coolibah

Eucalyptus pilligaensis	gum-topped box or mallee box
Eucalyptus polycarpa	long fruited bloodwood
Eucalyptus populnea	poplar box
Eucalyptus tessellaris	carbeen
Eucalyptus thozetiana	yapunyah
Eulalia fulva	brown top
Exocarpus aphyllus	-
Flindersia maculosa	leopard wood
Geijera parviflora	wilga
Heterodendrum oleifolium	boonaree
Iseilema membranaceum	small flinders grass
Leptochloa digitata	canegrass
Maireana microphylla	cottonbush
Marsilea drummondii	nardoo
Melaleuca adnata	-
Melaleuca bracteata	black tea-tree
Neurachne spp.	mulga grasses
Panicum decompositum	native millet
Paspalidium caespitosum	brigalow grass
Paspalidium globoideum	shot grass
Paspalidium gracile	slender panic
Petalostigma pubescens	native quinine bush
Rhagodia spinescens	berry saltbush
Salsola kali	soft roly-poly
Sclerolaena muricata	prickly roly-poly
Sclerolaena tetracuspis	brigalow burr
Sporobulus caroli	fairy grass
Stipa verticillata	slender bamboo grass
Triodia irritans	spinifex
Ventilago viminalis	supplejack

spp. = species, where more than one species of a genus is indicated

Source for common names: Stanley and Ross (1983)

Chapter 6

WATER RESOURCES IN WAGGAMBA SHIRE

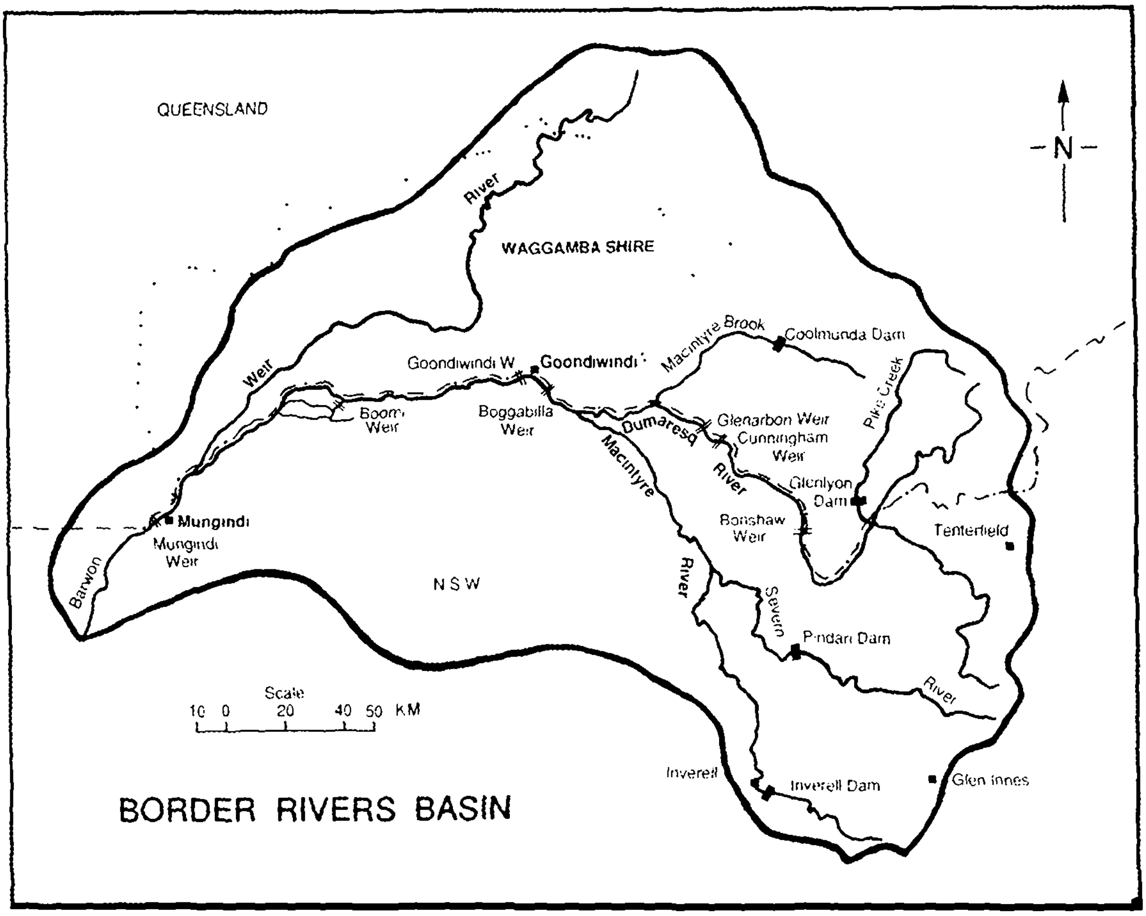
Mark Pearson
QDPI, Goondiwindi

1. INTRODUCTION

The two river systems which drain Waggamba Shire are:

- The Border Rivers system, the major rivers of which are the Dumaresq, Macintyre and Barwon; and
- the Weir River system.

The catchments of these rivers and their tributaries as they relate to Waggamba Shire are shown in Figure 6.1. The Border Rivers system flows westwards, forming the southern boundary of the shire and the state border between Queensland and New South Wales. The Weir River rises in the north-east and flows south-westwards across the shire eventually entering the Border Rivers system near the south-west corner.



3.1 Artesian supplies

The shire is on the eastern extremity of the Great Artesian Basin and lies within the Surat Basin[1]. The major artesian aquifers (water bearing rock) of the shire are associated with the geological formations known as the Mooga and Gubbermunda sandstones.

These are shown in cross-section in Figure 6.3; the fault line shown in this diagram roughly follows the Leichhardt Highway.

These aquifer formations outcrop to the east of the shire and it is in this region that recharge (water filling) takes place. As recharge zones are elevated above the general ground level for much of the shire, most artesian bores are free-flowing under head pressure, except for bores close to the recharge areas themselves.

Bores to the east of the fault line range in depth from 100 metres to 400 metres and have flows of 0.2 to 2 litres per second (l/sec). Those to the west of the fault range in depth from 900 metres to 1200 metres and have flow rates occurring of up to 20 l/sec.

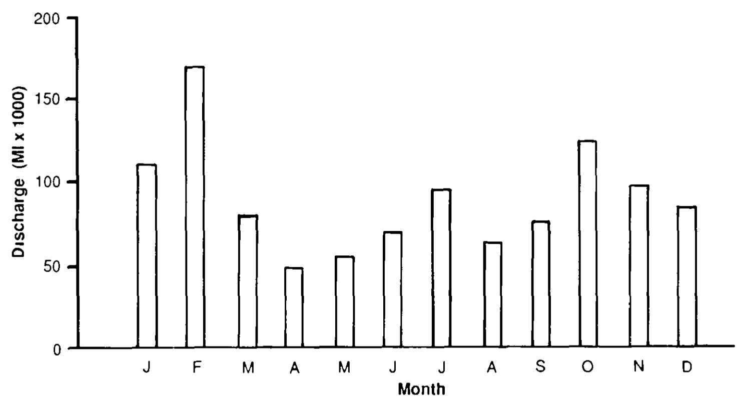


Figure 6.2a. Mean monthly flows for the Macintyre River at Goondiwindi

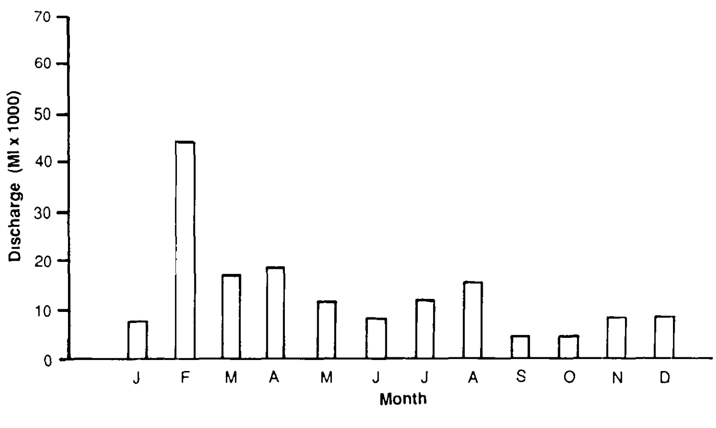


Figure 6.2b. Mean monthly flows for the Weir River at Talwood

[1] See Chapter 4 concerning the geology of the Surat Basin

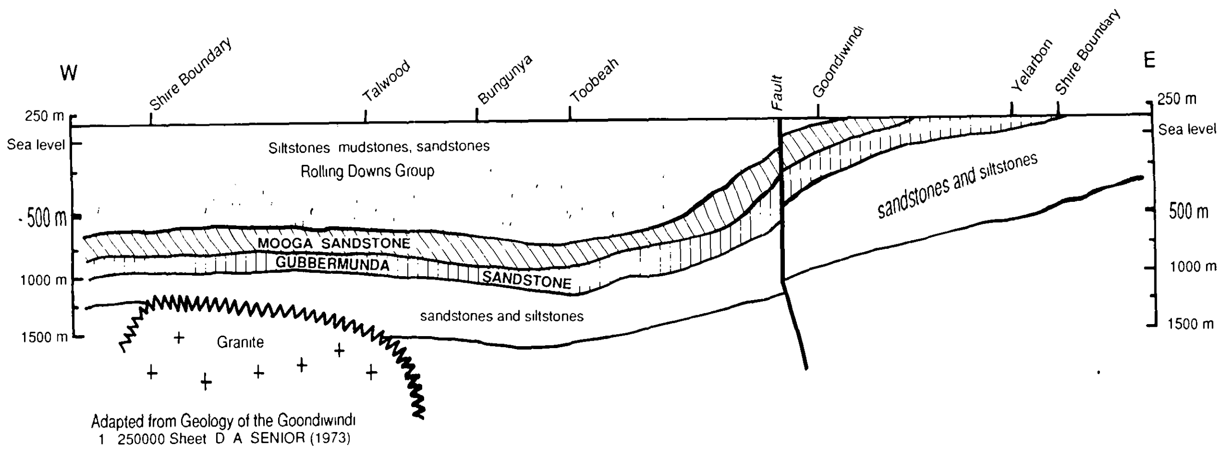


Figure 6.3. Simplified cross-section of the geology underlying Waggamba Shire showing the major aquifers

The quality of the artesian supplies, while being suitable for stock and some domestic purposes, is mostly unsuitable for irrigation. The Water Resources Commission's policy is to give priority of supply from artesian aquifers to stock and domestic purposes.

3.2 Sub-artesian supplies

Little is known at present about the groundwater supplies associated with the alluvial deposits of the Weir River. However, a number of shallow aquifers associated with minor alluvia of the Dumaresq River exist in the eastern shire. These aquifers usually occur in the top 20 to 30 metres of the alluvial beds and have flows ranging from 0 6 to 20 l/sec.

Water quality is generally suitable for irrigation close to the main streams but decreases markedly in areas remote from rivers or streams.

4. IRRIGATION DEVELOPMENT

4.1 Existing development

Two irrigation projects have been established in the Border Rivers area:

- the Macintyre Brook Irrigation Project served by Coolmunda Dam; and
- the Border Rivers Irrigation Project served by Glenlyon Dam.

The latter project relates more specifically to Waggamba Shire as it provides regulated supplies to landholders along the Macintyre and Barwon Rivers. This project was established in conjunction with the New South Wales Department of Water Resources, through the Dumaresq-Barwon Border Rivers Commission. Summary statistics for the Border Rivers Irrigation Project are given in Table 6.3.

Of the 10 500 ha irrigated on the Queensland side of this project, 6100 ha are located within Waggamba Shire.

Figure 6.4 shows the growth in the area irrigated within the shire for the years 1981 to 1990. This growth in irrigation development has increased rapidly since the introduction of cotton. It has taken over from the staple irrigation crops of lucerne and pasture which were originally developed to assist graziers in drought proofing their properties.

The expansion has not been based solely on the regulated supplies from Glenlyon Dam, because the opportunities of water-harvesting surplus flows in the river system have been recognised by irrigators. When surplus flows occur in the system, periods may be declared during which irrigators may divert water without it being debited against their allocation.

The use of this water-harvested surplus flow has required the individual irrigators to develop on-farm storage to make the best use of the resource. With the use of large on-farm storages, water-harvesting regularly provides between 60 and 90% of the total supplies of typical irrigation enterprises. Figure 6.5 shows the trend regarding the increased use of on-farm storages in Waggamba Shire.

Table 6.3. The Border Rivers Irrigation Project

	QLD	NSW
Number of Irrigators	143	167
Area Irrigated 1989/90	10 500 ha	30 000 ha
Value of Production 1989/90	$28m	$89m

- Storage capacity of Glenlyon Dam: 254 000 megalitres (Ml) (Completed 1976)

- Length of river in project, from Glenlyon Dam to Mungindi: 500km

Source: Dumaresq-Barwon Border Rivers Commission Annual Report

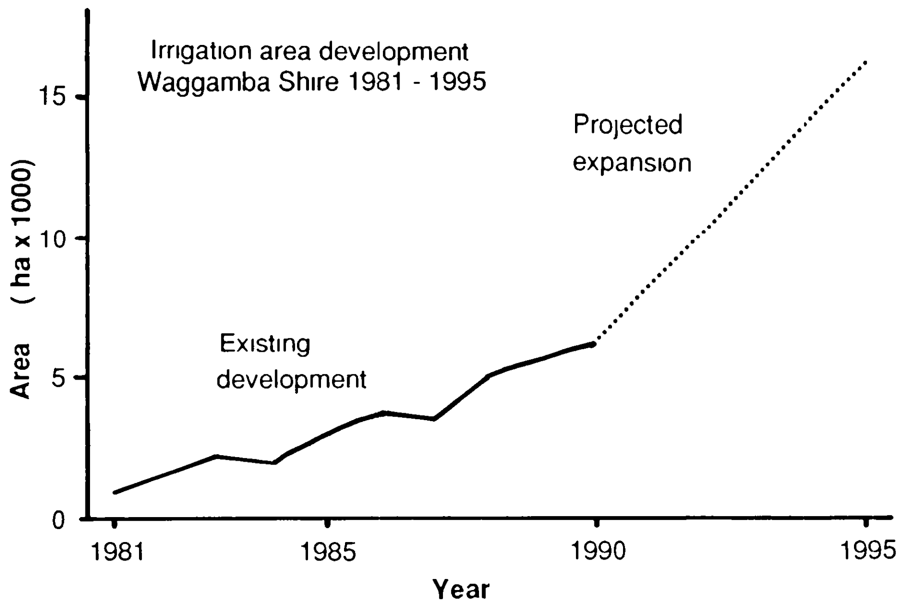


Figure 6.4. Current and projected growth in irrigated area in Waggamba Shire 1981-95

4.2 Future development

The use of the surface water resources in the shire is likely to continue to expand rapidly over the next few years. The projected likely increases in irrigated area and volume of on-farm storage in Waggamba Shire over the next few years are shown in Figures 6.4 and 6.5. This expansion of water resource use will be due mainly to the increase in irrigated cotton development in the shire and is most likely to occur in the following localities:

- *Yambocully Water Area* - A group irrigation scheme based on pumped diversions from the Macintyre River near Goondiwindi to 13 properties along Yambocully Creek and the Weir River.

- *Callandoon Water Area* - A group irrigation scheme based on gravity diversion into Callandoon Creek, an effluent stream of the Macintyre River, to 11 irrigation properties along the creek.

- *Weir River-Macintyre River area downstream of Talwood* - Individual landholders in this area have plans to develop up to 3000 ha of irrigation area in conjunction with 15 000 Ml of on-farm storage. Developments in this area have the added advantage of access to flows from the Macintyre River and the Weir River.

This further development will be based on more effective use of existing water allocations from the irrigation projects of the area, and on the release of additional allocations resulting from the construction of Boggabilla Weir.

The water-harvesting resource available from the rivers in the shire will also contribute to this development. Although mainly associated with the Border Rivers, some water-harvesting potential is available from the Weir River.

Table 6.4 shows the estimated water-harvesting opportunities for the Macintyre River at Goondiwindi and the Weir River at Talwood.

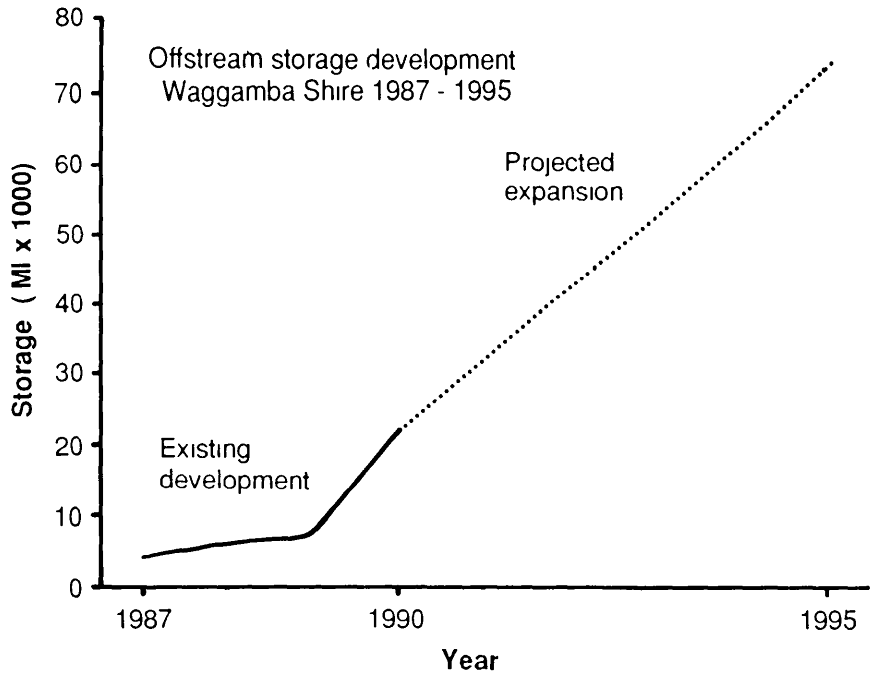


Figure 6.5. Current and projected growth of on-farm storage in Waggamba Shire 1987-95

Table 6.4. Water-harvesting opportunities

River	Station	Water-harvesting opportunity (days)	
		50% of years	75% of years
Macintyre	Goondiwindi	50	21
Weir	Talwood	21	9

Further information on water-harvesting (opportunities and thresholds) is available at the Water Resources Commission in Goondiwindi.

5. FLOODING

Flooding occurs frequently owing to the low topography of land within the shire, particularly the gentle gradients adjacent to the major rivers. This presents a hazard to low lying lands forming the river floodplains. During periods of high stream flow these major rivers become multichannelled, inundating land between the channels. Recent major floods occurred in 1956, 1976, 1983, 1984, and 1988. However, moderate flood events can be of significant benefit to the grazing industry by naturally irrigating large areas of native and improved pastures.

The costs associated with irrigated agriculture and the damage which can be caused by flooding have led to the construction of levees to prevent inundation of cultivated land, particularly irrigated cotton.

The Waggamba Shire Council and the Water Resources Commission monitor and control the construction of levee banks on the floodplain and adjacent to watercourses with the assistance of guidelines. Any works on the floodplain which may affect flooding requires a permit, from the Council or a licence from the Commission, depending on the nature of the works and the location. If the works are outside the guidelines or are significant in terms of size or location, a detailed study of the effects of the works on flood flows may be required before permits or licences can be issued.

Together these agencies are ensuring that any developments on the floodplain within the shire have minimal effect on adjacent properties.

More information on control of works on the floodplain can be obtained from the Commission and the Waggamba Shire Council in Goondiwindi.

6. WATER QUALITY

A water quality monitoring program is continuing in the Border Rivers area. Recent upgrading of this program has meant more frequent sampling at an increased number of sites.

The water quality issues of concern are salinity, turbidity, and agricultural chemicals. High levels of salinity can be harmful to irrigated crops and aquatic life, as well as making water unattractive for domestic use. High levels of turbidity cause difficulties in the treatment of town water supplies, while agricultural chemicals in water can be toxic to people and animals who drink it, as well as to aquatic life.

The analysis of water samples taken to date show that:

- water salinity levels are generally low enough for the water to be suitable for most uses;
- turbidity levels are generally at a reasonable level, except during flood events.

Because of the high cost of analysing samples for agricultural chemicals, only limited analyses have been undertaken. Increasing community concern about agricultural chemical residue in watercourses is likely to lead to more attention being paid to effective monitoring programs in the future.

Chapter 7

LAND RESOURCES:

LAND RESOURCE AREAS AND SOILS

Jon Burgess
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Summary

* Three topographic regions have been identified within the Waggamba Shire: alluvial plains, lowlands and uplands. Within these, fifteen land resource areas (LRAs) have been mapped. The relationship between the topographic regions and LRAs is outlined in the key to the LRAs in Part B of this manual.

* Each LRA represents a distinctive group of related soils developed on similar geology, and often with similar landforms and vegetation types. The important characteristics of each LRA are described fully in the map reference.

* The variability within individual LRAs has been described on the basis of the dominant or most typical soil(s). These are termed the major soils. Twenty-nine major soils and associated landscapes have been identified. Most LRAs comprise one or two major soils.

* Soil properties identified as important for land management in Waggamba Shire include moisture availability, fertility, seedbed conditions, soil erosion, microrelief and subsoil characteristics such as sodicity, salinity, and acidity.

1. LAND RESOURCE AREAS

1.1 Introduction

A land resource area (LRA) is a broadscale mapping unit which depicts a distinctive group of related soils developed on similar geology, or substrate, and often with similar landforms and vegetation types. Fifteen land resource areas have been identified within Waggamba Shire, based on the soil associations of Isbell (1957) and land systems of Galloway *et al.* (1974).

Often, there is considerable landscape variability within individual LRAs. Some LRAs are relatively simple and consist of only a single geology-landform-vegetation-soil association, for example, the Desert LRA, while others, such as the Billa Billa LRA, may represent a few such related associations.

Within the 15 land resource areas 29 geology-landform-vegetation-soil associations have been identified. Each association is characterised by a dominant or *major soil*, as well as a distinctive combination of geology, landform and vegetation. Where more than one association has been identified within a land resource area, additional major soils are described.

The range of typical landscapes and level of variability to be expected across the shire have been characterised through the identification of the major soils and associated landscapes in each LRA. No attempt has been made to document all possible soils or landscapes however.

1.2 Description

The major distinguishing characteristics of each LRA are described in the map reference. An outline of the relationships between individual LRAs is presented in the key to the Land Resource Areas which can be found in Part B of this manual.

The key groups LRAs primarily on the basis of landscape position.

Three broad topographic regions were defined for this purpose:

- Alluvial plains
- Lowlands
- Uplands

1.2.1 Alluvial plains

The alluvial plains are represented by relatively low lying, level landscapes that have formed from alluvium deposited by present or past rivers and streams. They may be recent, active landforms that are still subject to flooding, that is, flooded more often than once in 100 years; or else relict landforms that are developed on alluvium associated with past rivers and streams (usually no longer flooded). They are usually developed on fine sandy, silty or clay alluvia.

- Recent, active floodplains:

    - Narrow floodplains (1 to 5 km); adjacent to the upper Macintyre, Dumaresq and Weir Rivers: **Dumaresq LRA**

      These include, (i) gently undulating low terraces and levees, often dissected by active channels and floodways that lie adjacent to main river and stream channels, and (ii) level, high terraces, that are usually much more extensive. The high terraces show little relief apart from narrow elevated levees where they occur adjacent to main river channels and low lying backplain drainage areas (see map). The low terraces are developed mainly on fine sandy alluvium while the high terraces are developed on silty alluvium.

    - Wide floodplains (10 to 40 km), associated with the lower Macintyre and Weir Rivers: **Macintyre and Serpentine LRAs**

      The alluvial plains of the Macintyre and Weir Rivers combine just west of Goondiwindi and form an extensive, level plain. It includes low lying open clay plains that are mostly active flood plains, as well as elevated alluvial landforms (levees, terraces, and other deposits) associated with current and former floodplain streams. The plain is characterised by complex drainage, and lower lying areas are prone to regular flooding. Low lying areas are developed mainly on clay alluvium. Elevated areas are developed on fine sandy and clay alluvia deposited by floodplain streams.

    - Narrow floodplains (1 to 2 km), adjacent to major creeks: **Serpentine and Boogara LRAs**

      Most of the major creeks that drain the uplands and lowlands across the shire have narrow floodplains. These are usually level or gently undulating and less than 1 to 2 km wide. Soils and vegetation are usually quite different from the surrounding lowlands they traverse. These areas are usually developed on fine sandy and clay alluvia deposited by local streams.

- Relict or barely active forms occur as elevated features within current alluvial plains; or as relict, level plains that are no longer directly associated with major rivers or streams.

    - Elevated, low sand rises and relict dunes: **Broomfield LRA**

      These are elevated, sand ridges that were most probably laid down as point bar or stream bed deposits and subsequently affected by wind processes. They occur either as very low, broad, sand rises with a local relief of less than 5 m; or as elevated ridges that are elongated and distinctly dune-like, with a local relief of 5 to 9 m. Both forms are widely distributed throughout the wide alluvial plains of the lower Macintyre and Weir Rivers. There are minor occurrences elsewhere in the shire which are probably associated with former drainage systems. These sand deposits mainly overlie clay alluvium.

    - Extensive, elevated, level, sandy plains, with cypress pine - poplar box forest: **Goodar LRA**

      These occur as level or very gently undulating plains that are associated with relict fans and terraces deposited where the alluvial plains of the Macintyre and Weir Rivers combine, south-west of Goodar. Many alluvial features such as old levees and stream channels indicate the Weir system has moved back and forth and reworked these sediments a number of times. Some channels may still be barely reworked these sediments a number of times. Some channels may still be barely active in large floods. Similar deposits also occur within the current alluvial plain of the Weir River, north of Goodar. These are usually elevated, representing high river terraces. All areas are developed either on fine sandy alluvium or other transported material (relict alluvia).

- Elevated, eroded, level, silty plains, with sparse tea-tree shrublands and spinifex: **Desert LRA**

  The 'Yelarbon Desert,' as it is colloquially known, is restricted to an area of about 7000 ha immediately north and south of Yelarbon. It is a level, relict alluvial plain, probably a stranded terrace, that is associated with the confluence of the Macintyre Brook and Dumaresq River. It is barely active and is flooded irregularly by the Macintyre Brook from overbank flows further upstream. It is developed mainly on transported material (relict silty alluvia).

  It occupies an intermediate level between the alluvial plains to the south and the more elevated brigalow clay plains to the north. Isolated areas also occur further east, and south of the Dumaresq River in NSW.

1.2.2 Lowlands

This region comprises mainly level plains or gently undulating lowlands. Some restricted areas of more undulating lowlands also occur. It is the major topographic unit within the shire and covers a range of land resource areas. Most lowland areas have a local relief of less than 30 m and slopes mostly between 1 and 3%, occasionally up to 5%. The lowlands have developed either from transported materials of unspecified origins, particularly on the level plains, or from labile, quartzose or deeply weathered sedimentary rocks in undulating areas.

- Level plains with brigalow belah forest: **Commoron LRA**

  These are relatively flat, melonholed, brigalow-belah plains that lie mainly to the east and north-east of Goondiwindi. They are developed mostly on transported material (clay sheets), and represent elevated plains that are above current flood levels. Slopes are usually less than 1%. Isolated areas along the eastern margins of the shire may be gently undulating with slopes between 1 and 3%.

- Level plains with belah forest: **Billa Billa and Bungunya North LRAs**

  These are relatively flat, belah plains with microrelief either minor or absent. They are developed mostly on transported materials (clay sheets) and represent areas that are elevated above current flood levels. Slopes are usually less than 1%, although some areas may be gently undulating with slopes between 1 and 3%.

  This group includes areas to the east and north-east of Goondiwindi, and further west around Bungunya North. It should not be confused with the flooded belah country associated with the Macintyre LRA (Kalanga soil).

- Level plains with cypress pine - mixed eucalypt forest: **Goodar LRA**

  These are level or gently undulating plains with cypress pine, narrow leaved ironbark and rusty gum forest. They are mostly developed on quartzose and deeply weathered sedimentary rocks, or less commonly transported material (relict alluvia). Slopes are usually 1 to 2%. They occur mainly in the eastern margins of the shire, and are closely associated with forestry leases around Bendidee, Kerimbilla and north-east of Yelarbon.

- Gently undulating lowlands with brigalow - belah forest: **Commoron and Bungunya North LRAs**

  These include gently undulating or occasionally undulating plains, rises, scarp footslopes and broad valleys, with brigalow-belah forest. These form the lower landscape components of the dissected uplands, and are closely associated with jumpup areas in the north of the shire. They are developed mainly on labile sedimentary rocks, although around Bungunya North some areas are developed on transported material (clay sheets). Most slopes are 1 to 3%, but occasionally range up to 8% in steeper areas. Areas east of the

Weir River usually have significant melonhole microrelief, while west of the Weir River this may vary.

- Gently undulating lowlands with belah forest: **Billa Billa LRA**

  These are gently undulating rises with belah forest that are widespread across the centre of the shire. They are mostly developed on labile sedimentary rocks. Slopes are usually 1 to 3%, but occasionally may be up to 8%. Microrelief is either only minor or absent.

- Gently undulating lowlands with poplar box woodland or bull oak - mixed eucalypt forest: **Geralda and Boondandilla LRAs**

  These are level or gently undulating plains and occasional rises that are developed mainly on transported material and deeply weathered sedimentary rocks in the eastern and western margins of the shire. Vegetation is usually characteristic and consists of: poplar box woodlands in the south-west between Talwood and Mungindi; and bull oak - mixed eucalypt forests in the eastern margins of the shire, between Wyaga and Yelarbon.

  These grade to uplands in the north, that are otherwise similar.

- Undulating lowlands with open downs: **Lundavra LRA**

  This unit is restricted to minor occurrences around the properties of Tarewinnabar, Te Apiti and Lundavra, where it is closely associated with outcropping calcareous labile sandstones and siltstones. It occurs on undulating rises, that resemble the gently rolling downs, which are common further north around Inglestone and Surat. A distinct catena is usually developed, in which soil type and vegetation vary markedly with landscape position.

1.2.3 Uplands

This region comprises the highest landscapes in the shire, all of which have undergone some degree of dissection or wearing down. The more strongly dissected uplands commonly occur as a series of disconnected longitudinal scarps (*jumpups)*, rises and low hills. The gently dissected uplands, in contrast are broad, gently undulating plateaus that lie above, and often adjacent to scarps. Dissected areas are characterised by a local relief of 30 to 90 m with most slopes between 5 to 25%; while the gently dissected plateaus have a local relief of only 10 to 30 m and slopes usually between 1 and 5%.

The uplands are developed mainly on deeply weathered sedimentary rocks and occur in a disjointed belt that runs from east to west across the north of the shire.

- Gently dissected uplands with poplar box woodland: **Geralda LRA**

  This unit includes gently undulating and undulating plains, rises and occasional low hills that occur as extensive plateau-like areas in the north-west of the shire (particularly north of Talwood and Weengallon). It grades to gently undulating lowlands in the south-west, that are otherwise similar. Soils and vegetation are relatively uniform throughout. Both upland and lowland areas are developed on transported material and deeply weathered sedimentary rocks.

- Gently dissected uplands with bull oak-mixed eucalypt forest: **Boondandilla LRA**

  This unit includes gently undulating plains and rises that occur mainly in the north-east of the shire as broad plateaus that lie above, and usually adjacent to, the dissected *jumpups*. They are widespread in areas north of the *jumpups*, east of the Weir River. Along the eastern margins of the shire, dissection of these uplands has left lowland areas between Wyaga and Yelarbon, that are otherwise similar. Both upland and lowland areas are developed mainly on deeply weathered sedimentary rocks.

- Gently dissected uplands with ironbark-poplar box woodland: **Westmar LRA**

  This unit is restricted to minor occurrences around Westmar. It occurs as gently undulating plains and rises with interspersed undulating low hills. Its distribution is closely associated with outcropping quartzose sandstones, that may be partially weathered. Soils and vegetation vary significantly with landscape position.

Soil profile sampling with an auger

- Dissected uplands: **Jumpup LRA**

These include undulating or rolling rises and low hills; often as continuous scarps or *jumpups*; or occasionally as flat-topped, isolated hills. The dissected uplands run in a discontinuous belt across the north of the shire. They represent resistant features that remain from the dissection, downwearing and subsequent northerly retreat of the deeply weathered land surface that once covered much of the area. The underlying, deeply weathered rock types on which the scarps have developed vary from east to west. Soils and vegetation may differ significantly as a result.

2. SOILS

2.1 Introduction

A *major soil* represents either the dominant soil or one of the typical soils within a land resource area. Each major soil is associated with a specific geology, landform, and vegetation association. Where an LRA comprises more than one of these associations further major soils are described. Variability within the more complex LRAs usually relates to differences in:

- landscape position (for example, Tarewinnabar and Tarewinnabar shallow);
- substrate material (for example, Kurumbul and Mt. Carmel);
- vegetation type (for example, Kalanga and Undabri); and
- profile morphology (for example, Moruya and Mt. Carmel).

The relationships between the major soils and the land resource areas are detailed in the map reference. The important characteristics of each association are also listed. A key to aid in the identification of the major soils is presented in Part B of this manual along with the photo-description cards.

Each major soil has been assessed for a range of landscape and soil related properties, and detailed laboratory analysis undertaken. Representative pit sites for each soil were established for soil descriptions, sampling and photography. Detailed site and soil profile descriptions with comprehensive laboratory analyses are presented in Appendix I for each major soil. Interpreted data are summarised in Tables II.1 to II.5 of Appendix II.

2.2 Soil properties and characteristics important to land management

Many soil properties and characteristics significantly affect agricultural production, either through reduced productivity or by requiring inputs to prevent land degradation. In Waggamba Shire, moisture availability is the major soil property limiting optimal production in the short-term. Other properties associated with declining fertility, surface soil characteristics, subsoil chemistry, susceptibility to erosion, and microrelief have had varying effects on productivity to date. Such factors, while usually slow to develop and difficult to recognise, represent the most significant risk to increasing land degradation.

An understanding of these properties is essential if management requirements and appropriate strategies are to be developed for the range of soils within the shire.

2.2.1 Moisture availability

All land within the shire is subject to some degree of limited moisture availability. Moisture availability is determined by climate, mainly rainfall and evaporation, and the plant available water capacity of the soil (PAWC). Whilst variation in climate is significant within the shire, particularly decreasing summer rainfall from east to west, agricultural production is most limited by the ability of the soil to store moisture.

PAWC (measured in millimetres of water) represents the average amount of water stored in a soil that is available for use by plants. It is calculated as the difference between the maximum and minimum level of stored soil water over the effective root depth of the soil (the long-term depth of wetting).

Soil properties that affect PAWC include:

- *the ability of the soil to retain moisture* - determined by clay content, soil structure, and the size and quantity of soil pores; the amount of deep drainage and surface evaporation are also important;

- *the effective root depth* - an estimate of the long-term depth of wetting within a soil. It is measured as the depth to which salts have been leached. This is usually where the salt content in a soil reaches a maximum. It may also represent the depth to severe physical or chemical barriers that restrict root growth, such as dense gravel or stone, impermeable and impenetrable sodic clay subsoil, or acid and saline clay subsoils;

- *surface soil characteristics that reduce infiltration and increase runoff* - structureless or poorly structured surface soils which have high levels of fine sand, silt or dispersible clay and low levels of organic matter are usually prone to surface sealing after rain; they may also set hard or crust on drying; and

- *landscape position* - steep slopes increase runoff and drainage, decreasing infiltration and subsequent water storage; in flat, poorly drained or flooded areas, water supply may exceed PAWC making soils waterlogged.

2.2.2 Declining fertility

Most soils used for cropping in Waggamba Shire are considered fertile, having been cropped successfully for 20 to 30 years without the addition of fertilisers. However, evidence from areas where the history of cropping goes back further than this, for example northern NSW and the Darling Downs, suggests that fertility rundown is inevitable.

As nutrient levels run down, nitrogen and phosphorus inputs will be required if optimal levels of production are to be maintained. Of the other nutrients (potassium, sulphur and the micronutrients) it is unclear which, if any, will become limiting in the future.

Nitrogen inputs may come from fertilisers or legume rotations, while phosphorus inputs will require fertiliser application. Management strategies aimed at slowing fertility decline are discussed in Chapter 9.

2.2.3 Seedbed condition

Seedbed condition refers to the physical condition of the surface soil, usually after tillage. It mainly affects seedling emergence and crop establishment, but can also influence surface infiltration, runoff, erodibility and the success of surface management systems such as zero tillage.

Where seedbed conditions are poor, for example, crusted, hard setting, sandy or a coarse self-mulch, crop establishment may be limited through physical restrictions to emergence, restricted seed-soil contact or rapid drying. In addition, soils may be physically difficult to cultivate, may require frequent tillage or may be abrasive to machinery.

Factors affecting seedbed conditions usually relate to inherent surface soil properties and disturbance caused by tillage. Most soils have a characteristic surface condition when dry and undisturbed. This may range from loose, soft or firm to hard setting, crusting or a self-mulching condition It is affected by:

- thickness of surface horizons;
- level of organic matter;
- clay content;
- level of fine sand or silt;
- presence or absence of structure;
- grade (weak to strong) and fineness of structure;
- strength and stability of soil aggregates, where structured;
- pH, the level of calcium and presence or absence of calcium carbonate in clay surface soils; and
- dispersibility of clay surface soils, including sodicity levels and clay type.

Tillage usually affects the surface condition of a soil through the breakdown of soil structure, destruction of organic matter, or the incorporation of soil material from below. While the surface condition of most soils will usually be restored following wetting and drying cycles, such as after good rains, regular tillage will inevitably cause seedbed condition to degrade.

Most soils within Waggamba Shire have one of the following characteristic seedbed conditions:

- *Shallow, gravelly or stony seedbed:* pulverises readily with tillage; seals during rain and sets hard after rain; dries rapidly.

- *Coarse, sandy seedbed:* loose and easily tilled; dries rapidly; abrasive to machinery.

- *Fine sandy seedbed:* pulverises readily with tillage; seals during rain and sets hard if organic matter is removed; dries rapidly; may be wind erodible.

- *Loamy seedbed:* initially cloddy but pulverises with excessive tillage; seals during rain and sets hard after rain; occasionally may crust or dry rapidly; sometimes gravelly.

- *Silty seedbed:* pulverises very easily with tillage; sets hard with severe surface sealing and crusting; usually wind erodible and prone to scalding. Additional comments:

  - Surface soils that are not friable are usually structureless, and degrade rapidly with tillage. Physical disturbance and the destruction of organic matter are the main causes. Organic matter acts to bind structureless soil particles together making the surface soil less dense and more permeable. The surface soils tend to break down and disperse once organic matter is removed.

  - It is difficult to replace or improve organic matter in a semiarid environment. It can only be achieved practicably through long-term pasture rotations - in excess of three to five years - that are productive and well managed. Pastures must be thought of as a tool for the rejuvenation of seedbed conditions, as well as a source of forage.

- *Friable seedbed, after tillage:* friable; usually seals but does not set hard after rain; may crust after deep tillage. Additional comments:

  - These soils may initially benefit from the effects of tillage, producing a friable seedbed. Many of the 'belah' soils such as Kurumbul, Mt. Carmel, Wynhari and Tandawanna, have shallow clay loam surface horizons (less than 5 cm) that overlie well-structured heavy clays. During tillage, clay from the upper subsoil is incorporated with the poorly structured clay loam surface soil, improving the overall structure and friability of the seedbed. Problems can develop with these soils if deep tillage (below 20 to 30 cm) brings up sodic clay which is dispersible. This increases problems with sealing and crusting. Where deep tillage is contemplated, soil tests to check the level of sodicity in the upper subsoil should be undertaken.

• *Fine, friable clay seedbed:* very friable; relatively stable with tillage. Additional comments:

- The soils that are least affected by tillage are the structured clays that develop a strong, fine self-mulch (a fine, friable, clay seedbed), for example Wondalli, Arden, Kalanga. These soils are characterised by high clay content, shrink-swell clay types, high surface pH and $CaCO_3$ (calcium carbonate) in the surface soil. They aggregate strongly after wetting and drying. This makes them relatively resilient to the degrading effects of tillage.

• *Coarse, friable clay seedbed:* friable; relatively stable with tillage; may seal after rain. Additional comments:

- Clay soils that are not self-mulching, because of lower clay content, non shrink-swell clay types or lower surface pH (for example Undabri, Tarewinnabar shallow) are usually still well structured in the surface soil and form a coarse, friable, clay seedbed. These soils are relatively stable with tillage, but are difficult to manage because of the strength and coarseness of soil aggregates. Seedbeds are friable but are coarse. This limits seed-soil contact and adversely affects crop establishment, particularly where small seeded crops or pastures are involved.

Successful management of surface soils to improve seedbed conditions involves some basic principles:

- surface cover should be maximised; either through cover crops and pastures or through the maintenance of high levels of crop residues (stubble);

- organic matter levels, reduced by cropping and tillage, need to be replaced through long-term, productive pasture phases (three to five years duration);

- reductions in the frequency and aggressiveness of tillage are necessary to minimise disturbance and the breakdown of soil structure; tined equipment should be used where possible, while the adoption of minimum or zero tillage systems and the implementation of rotational cropping and ley pastures, are essential;

- traffic and tillage under wet conditions should be minimised;

- application of gypsum on dispersible clay surface soils that are a result of high levels of sodicity; usually only justified where problems with sealing and crusting are extreme; and

- deep tillage to improve the structure, clay content and friability in the seedbed; only applicable, where A horizons are shallow (less than 10 cm) and upper subsoils are well-structured, non-sodic clays.

2.2.4 Subsoil properties

Many soils have chemical or physical properties in their subsoils that limit root growth. They may also present problems when exposed, for example after severe erosion, after levelling operations, or from the construction of dams and erosion control structures. In Waggamba Shire many soils have subsoils that are either sodic, saline or strongly acid at depth.

Sodicity

Sodicity is usually associated with clay subsoils and is caused by a dominance of free sodium. In clays that are well-structured and permeable, calcium is usually the dominant cation. Calcium causes particles to attract each other when moist and form soil aggregates. Where sodium is dominant however, clay particles tend to repel each other making clays dispersible when wet. The dispersed clay fills in the pores and spaces in a soil that allow drainage and aeration making it impermeable and dense. Examples of this are the subsoils of the Bendidee, Uranilla or Bengalla Soils.

The subsoils of many of the brigalow or belah soils are also sodic, though these soils are usually alkaline in their upper subsoils with high levels of calcium present in addition to the sodium. This makes them well structured and permeable while undisturbed, but prone to dispersion when exposed.

Sodic clay, when brought to the surface, will readily disperse because it is no longer confined by the compact soil around it. It tends to slake (breakdown) with wetting, and seal, and crust on drying.

Most duplex soils in the shire have shallow surface horizons that overlie sodic clays in their upper subsoils. Deep tillage on these soils is not recommended as the incorporation of sodic clay into surface horizons will inevitably increase sealing and crusting problems.

Salinity

Salinity refers to the presence of soluble salts in soils, either as a natural feature of the soil profile, usually in the subsoil, or as secondary salinity associated with shallow groundwater effects from agricultural development. Plant growth is affected by high levels of soluble salts due mainly to induced water stress as well as specific element toxicities and nutrient disorders.

Effects such as these usually result from high levels of salt in the surface soil, something normally associated only with *secondary* salinity. Outbreaks of secondary salinity have not been recorded in the Waggamba Shire to date; the reason is probably the abundance of impermeable soils, either clay or sodic duplex soils, in the recharge areas (areas of water entry in the landscape) in the north of the shire. Many soils in the shire have high levels of inherent salinity in their subsoils, usually below about 0.5 to 1.0 m. The origin of this salt is probably the parent material.

Problems for dryland agriculture are associated mainly with subsoil salinity and involve reduced water availability from subsoils. This is particularly important during dry seasons.

Should water tables rise because of irrigation it is likely the salt present at depth in many of these soils could move closer to the surface. Water table monitoring will be required to keep a check on salt movements as irrigated cropping expands.

Acidity

Most plants tolerate a range in pH conditions from moderately acid to moderately alkaline (pH 5.5 to 8.5). As acidity or alkalinity increases specific element toxicities or nutrient deficiencies, particularly with micronutrients, may develop.

Most soils within Waggamba Shire have a surface soil pH between 5.5 and 8.5. Soils developed on alluvium usually have subsoils that are alkaline throughout (pH 8.0 to 10.0) while soils that have developed over clay sheets or sedimentary rocks have alkaline upper subsoils (pH 8.0 to 10.0) over lower subsoils that are acid (pH 4.0 to 6.0).

Alkalinity in the upper subsoil is usually not regarded as a limitation to plant growth, except for extreme alkalinity, although the availability of some micronutrients may be more limited than they would be at a lower pH.

Problems with acid subsoils (particularly many brigalow or belah soils) usually only occur where these are exposed after the levelling of melonholes or during the construction of earthworks.

It is difficult to ascertain the effect the acidity has on plant growth as this is complicated by sodicity and salinity effects. The combination of marked sodicity and salinity with acidity is common in most acid subsoils and makes any sort of plant growth on these materials difficult after exposure. It is recommended, wherever possible, that the subsoils of most brigalow or belah soils, below 0.5 to 1.0 m, be left undisturbed.

2.2.5 Soil erosion

Sheet, rill and gully erosion have been a continual problem on cropping areas within Waggamba Shire since development began 20 to 30 years ago.

Most agricultural land uses increase the potential for soil loss from water erosion through increasing the volume and velocity of runoff. Decreased protection of the soil surface because of reduced cover and the absence of perennial plants also contributes. Accelerated soil loss within any one area is a product of climate, landform, soil properties, vegetative cover and management practices.

A number of specific factors affect the susceptibility of soils to water erosion:

- *inherent erodibility of the surface soil* - surface soil types included here are listed from least to most susceptible to erosion:
  - self-mulching or hard setting, structured clays;
  - hard setting loamy surfaced soils;
  - firm to hard setting, fine sandy surfaced soils;
  - loose or soft, coarse sandy surfaced soils;
- *slope* - as slopes become steeper, greater runoff velocities increase the rate of erosion through the tendency for channelling;
- *length of slope* - long gentle slopes may be just as erosion prone as short steep slopes; long slopes are usually associated with large catchments where runoff is usually slow but has

time to concentrate into channels, the resultant surface flow can often be more damaging than that occurring on short, steep slopes; and

- *level of surface soil cover* - low levels of surface cover allow higher surface flow velocities and easier detachment of soil particles.

The management of water erosion is discussed in Chapter 11 of this manual.

The occurrence of wind erosion within the shire is mainly restricted to the Yelarbon Desert. The combination of highly sodic, impermeable, silty soils and inappropriate management are the most probable causes of the extreme wind erosion and scalding that is evident today. Little can be done to rehabilitate the area whilst grazing continues.

2.2.6 Microrelief

Microrelief refers to uneven topography of up to a few metres from the plane of the land surface. In Waggamba Shire it occurs predominantly as melonhole or crabhole gilgai and is restricted to brigalow and belah soils.

- Melonhole gilgai, usually up to 1 m deep and from 5 to 15 m across, are associated with the brigalow soils of the Commoron and Bungunya North LRAs or, less commonly, on areas within the Macintyre LRA. They cause uneven conditions for tillage, planting and harvesting, and impede the trafficability of large machinery. The density of microrelief is often important as small, closely spaced melonholes can impede operations far more than occasional, very large melonholes. Ponding in depressions and the exposure of high levels of salt or acid clays after levelling are problems that are commonly associated with these gilgai.

- Crabhole gilgai, usually 10 to 30 cm deep and from 5 to 15 m across, are associated with the belah soils of the Billa Billa and Bungunya North LRAs or, less commonly, on areas within the Macintyre LRA. Crabhole gilgai have little effect on land management other than causing minor ponding and soil variability between mounds and depressions. Conventional tillage is usually adequate for levelling. Subsoil effects are less pronounced than for melonholes.

3. DISTINGUISHING CHARACTERISTICS OF THE SOILS IN WAGGAMBA SHIRE

KEETAH SOIL (1)*

One of two soils (the other is Bengalla) identified within the narrow alluvial plains of the **Dumaresq LRA.** Associated soils include Bengalla and Oonavale and some unnamed dark or grey non-cracking clays and prairie soils.

The Keetah soil is a firm to hard setting, brown alluvial soil, earthy sand or uniform loam over buried clay layers. It may also resemble solodized solonetz or solodic soils. Surface horizons are dominated by fine sand.

It is restricted to the gently undulating low terraces and levees that occur close to major river and stream channels. It is most widespread in the upper reaches of the Macintyre and Dumaresq Rivers east of Goondiwindi, and the Weir River north of Yarrill Creek. In areas immediately east and west of Goondiwindi, around Kildonan and along Callandoon Creek, prairie soils and hard setting, non-cracking clays are associated with these landforms, and take the place of the Keetah Soil. Similar unnamed soils are also developed along the Weir River, north of Goodar.

The soil is relatively young and in many areas it may still be actively aggrading from material being deposited by floodwaters. Evidence for this is the presence of layering or buried horizons within many profiles, and a high content of fine sand and silt.

- Management of this soil is affected largely by low PAWC, unfavourable seedbed conditions and a potentially high erosion risk. Seedbeds are fine sandy and tend to seal, set hard and dry out quickly after rain, particularly as organic matter levels decline with tillage. Lower lying areas are prone to regular flooding.

BENGALLA SOIL (2)

One of two soils (the other is Keetah) identified within the narrow alluvial plains of the **Dumaresq LRA.** Associated soils include Keetah, Oonavale, Yambocully and some unnamed dark or grey non-cracking clays and solodic soils.

* Indicates the soil number in the summary cards in Part B of this manual.

The Bengalla soil is a hard setting, silty surfaced, soloth, solodized solonetz or solodic soil.

It is restricted to the level, high terraces that are common in the upper reaches of the Macintyre and and Dumaresq Rivers, east of Goondiwindi and includes narrow-ridged levees that occur adjacent to main river channels. Better drained versions of the soil are developed on similar high terraces along the Macintyre Brook to the east of the shire.

Immediately east and west of Goondiwindi, around Kildonan and along Callandoon Creek, dark or grey non-cracking clays and solodic soils are associated with these landforms, and take the place of the Bengalla soil.

- Management of this soil is affected by very low PAWC, unfavourable seedbed conditions, poorly structured and impermeable subsoils, and a high wind erosion risk. The silty surface soil is very powdery. It limits infiltration and crop establishment because it seals and crusts severely. Subsoils are poorly drained, strongly sodic and very dispersible.

UNDABRI SOIL (3)

One of two soils (the other is Kalanga) identified as typical of the wide, level alluvial plains of the **Macintyre LRA**. Associated soils include Kalanga, Oonavale, and Yambocully.

The Undabri soil is a hard setting to weakly self-mulching, dark or grey cracking clay with a coarsely structured surface.

It occurs on extensive open clay plains which are low lying and flood prone, and represent either active or inactive floodplains of the Macintyre and Weir Rivers. These areas are characterised by complex drainage. It is typically less flood-prone than the associated Kalanga soil and is more common in the eastern half of the alluvial plains of the lower Macintyre and Weir Rivers. It occurs mainly east of Toobeah.

- Management of this soil is aided by high PAWC, well structured upper subsoil and a low erosion risk. Seedbeds are coarsely structured therefore limiting seed-soil contact and plant establishment. Lower subsoils may be sodic and have high levels of salinity. Lower lying areas present problems with temporary waterlogging and restricted trafficability because of regular flooding.

KALANGA SOIL (4)

One of two soils (the other is Undabri) identified as typical of the wide, level alluvial plains of the **Macintyre LRA**. Associated soils include Undabri, Yambocully and Oonavale.

The Kalanga soil is a moderately to strongly self-mulching, dark or grey cracking clay with a finely structured surface.

It occurs on extensive, open clay plains similar to the Undabri soil, but is usually lower lying and more flood prone, with thicker vegetation and more regrowth. It is more common in the western half of the alluvial plains of the lower Macintyre - Weir Rivers. It occurs mainly west of Toobeah.

- Management of this soil is aided by high PAWC, fine, friable seedbed, well structured upper subsoil and low erosion risk. However, lower lying areas are prone to regular flooding causing temporary waterlogging problems, restricted trafficability and woody weed invasion. Lower subsoils are usually strongly sodic with high levels of salinity occurring at depth.

MURRA CUL CUL SOIL (5)

One of three soils identified as typical of the **Serpentine LRA**. The other two soils, Yambocully and Oonavale, occur on different landforms and are not closely associated with the Murra Cul Cul soil. Soils that may be associated include Undabri, Wondalli, Kurumbul, Marella and Bendidee.

The Murra Cul Cul soil is a hard setting, loamy surfaced solodic soil occurring mainly on narrow, alluvial plains associated with major creeks, east of the Weir River. These are usually level or gently undulating drainage floors that traverse the lowlands in the east of the shire, and may be frequently or occasionally flooded.

- Management of this soil is affected by unfavourable seedbed and subsoil conditions. After tillage seedbeds are either loamy, tending to seal and set hard, or are coarsely structured, sodic clays that are prone to severe crusting.

Subsoils are usually strongly sodic and have high levels of salinity. They may also become acid at depth. Erosion risk depends on slope length and angle.

YAMBOCULLY SOIL (6)

One of three soils (the others are Murra Cul Cul and Oonavale) identified as typical of the **Serpentine LRA**. Soils that are associated include Oonavale, Undabri and Kalanga. As a group these represent the dominant soils of the wide alluvial plains of the lower Macintyre and Weir Rivers.

The Yambocully soil is a hard setting, loamy surfaced solodic soil occurring mainly on elevated, alluvial landforms within these plains. These include levees, terraces, prior streams and point bar deposits most of which are no longer active. The landforms are usually level or very gently undulating and occur in close association with current or past floodplain streams. Soil distribution is often quite complex. The Yambocully soil occurs throughout the alluvial plains of the lower Macintyre and Weir Rivers, but is more common west of Toobeah.

- Management of this soil is affected by unfavourable seedbed and subsoil conditions. Seedbeds are loamy, often with high levels of silt, tending to seal during rain, set hard and crust after rain. Subsoils are well structured but may have high levels of salinity at depth. There is a moderate risk of wind erosion.

OONAVALE SOIL (7)

One of three soils (the others are Murra Cul Cul and Yambocully) identified as typical of the **Serpentine LRA**. Soils that are associated include Yambocully, Undabri, Kalanga and Wondoogle.

The Oonavale soil is a hard setting, loamy surfaced, solodic soil occurring on similar landforms to the Yambocully soil. These are usually level to very gently undulating and occur in close association with current or past floodplain streams. Soil distribution is often quite complex. The Oonavale soil occurs throughout the alluvial plains of the lower Macintyre and Weir Rivers, but is more common east of Toobeah.

- Management of this soil is affected by unfavourable seedbed and subsoil conditions. Seedbeds are loamy, often with high levels of fine sand, tending to seal during rain and set hard after rain. Subsoils are strongly sodic and very dispersible, with high levels of salinity at depth.

JINDABYNE SOIL (8)

This is the only soil identified within the **Boogara LRA** and is considered typical. Associated soils include Tandawanna, Arden and Weengallon soils.

The Jindabyne Soil is a hard setting, loamy surfaced, red-brown earth or solodic soil.

It occurs mainly on narrow alluvial plains associated with the major creeks west of the Weir River. These are usually level or gently undulating drainage floors that traverse the lowlands in the west of the shire and may be frequently or occasionally flooded.

- Management of this soil is affected by low PAWC, and unfavourable seedbed and subsoil conditions. Seedbeds are loamy, often with high levels of fine sand, tending to seal during rain and set hard after rain. Subsoils are strongly sodic and very dispersible with high levels of salinity at depth. Erosion risk depends on slope length and angle.

WONDOOGLE SOIL (9)

One of two soils (the other is Wai Wai) identified within the **Broomfield LRA**. Associated soils include Wai Wai, Oonavale and Marella.

The Wondoogle Soil is a soft surfaced, brown, siliceous sand or earthy sand occurring on very low, broad, sandy rises mostly within the wide, alluvial plains of the lower Macintyre and Weir Rivers. These are elevated above the general level of the plain, with a local relief of about 5 m. They are usually level over most of their area, but may be gently undulating along their margins, with sideslopes between 1 and 2%. They probably represent relict alluvial deposits. Isolated occurrences elsewhere in the shire are probably associated with prior stream activity.

- Management of this soil is affected by low PAWC, low fertility, unfavourable seedbed conditions and a high wind erosion risk. Seedbeds are loose, coarse and sandy, and dry out quickly due to rapid drainage and evaporation. Wind erosion is likely where this soil is left unprotected after clearing or disturbance.

WAI WAI SOIL (10)

One of two soils (the other is Wondoogle) identified within the **Broomfield LRA**. Associated soils include Wondoogle, Oonavale and Marella.

The Wai Wai Soil is a loose surfaced siliceous sand occurring on low, elongated, distinctly dune-like sand ridges, mostly within the wide, alluvial plains of the lower Macintyre and Weir Rivers. They are usually gently undulating and elevated well above the general level of the plain, with a local relief of between 5 and 9 m and slopes between 1 and 3%. They probably represent relict alluvial deposits that have been affected by subsequent aeolian (windblown) action. Isolated occurrences elsewhere in the shire are probably associated with prior stream activity.

- Management of this soil is affected by very low PAWC, very low fertility, unfavourable seedbed conditions, and an extreme wind erosion risk. Seedbeds are loose, coarse and sandy and dry out very quickly due to rapid drainage and evaporation. Severe wind erosion is likely where this soil is left unprotected after clearing or disturbance.

MARELLA SOIL (11)

One of two soils (the other is Bendidee) identified as typical of the **Goodar LRA**. Associated soils include Oonavale and Wondoogle.

The Marella soil is a soft to firm, fine sandy surfaced solodic soil or, less commonly, solodized solonetz soil.

It occurs mainly on extensive, elevated level or occasionally very gently undulating sandy plains; these are mainly associated with areas surrounding the Umbercollie State Forest, west of the Weir River. These plains are probably relict alluvial landforms, for example fan or terrace deposits, that have been laid down where the alluvial plains of the lower Macintyre and Weir Rivers combine. Relict features such as old levees or stream channels are common.

The Marella soil also occurs on similar deposits that lie within the current alluvial plain of the upper Weir River. These are usually elevated and appear to represent high terraces.

- Management of this soil is affected by low PAWC, low fertility and unfavourable seedbed conditions. Seedbeds are fine sandy, and tend to seal during rain, and set hard and dry out quickly after rain, particularly as organic matter levels decline with tillage. Management of woody weed regrowth is difficult because control measures are usually not cost effective.

BENDIDEE SOIL (12)

One of two soils (the other is Marella) identified as typical of the **Goodar LRA.** Associated soils include Uranilla and Murra Cul Cul.

The Bendidee soil is a soft to firm, coarse sandy surfaced solodized solonetz or, less commonly, a solodic soil.

It occurs on elevated level or gently undulating, sandy plains that are associated with the lowlands in the eastern margins of the shire. It is generally not developed on alluvium. The most significant areas occur in the forestry leases around Bendidee, Kerimbilla and to the north-east and south-east of Yelarbon.

- Management of this soil is affected mostly by very low PAWC, very low fertility, unfavourable seedbed and subsoil conditions, and a high erosion risk. Seedbeds are loose, coarse and sandy, and dry out quickly at the surface due to high evaporation. Subsoils are strongly sodic and very dispersible, and can have high levels of salinity at depth. Erosion risk is high because of the sandy surface soil, dispersible nature of the subsoil, and slopes ranging between 1 and 3%. Management of woody weed regrowth is difficult, because of the unstable nature of this soil when cleared or disturbed, and low cost effectiveness.

YELARBON SOIL (13)

The Yelarbon Soil is the only one identified within the **Desert LRA,** and is considered typical of the area known as the Yelarbon Desert. Associated with this soil are some unnamed solodized solonetz that are somewhat similar to the Uranilla or Bengalla soils.

The Yelarbon soil is a hard setting, eroded, silty surfaced solonetz soil. It occurs on a level, relict alluvial plain, most probably a stranded terrace, associated with the confluence of the Macintyre Brook and Dumaresq Rivers. It is elevated above current alluvial plains but is still barely active and floods irregularly from the Macintyre Brook. It is restricted to an area of about 7000 ha surrounding the township of Yelarbon. It has a characteristic claypan appearance due to extensive wind erosion and scalding. Vegetation is stunted and impoverished and ground cover is either absent or very sparse.

- Management of this soil is affected by very low PAWC, very low fertility, unfavourable seedbed and subsoil conditions, extreme alkalinity and sodicity throughout, and an extreme wind erosion risk. The silty surface soil is very powdery and limits infiltration and plant establishment due to severe surface sealing and crusting. Where eroded and scalded, strongly sodic subsoils are often exposed, which are both impermeable and impenetrable to roots. Subsoils are poorly drained, very dispersible and have high levels of salinity at depth. Lower lying areas may be ponded and waterlogged after rain.

WONDALLI SOIL (14)

One of two soils (the other is Calingunee) identified as typical of the **Commoron LRA**.

Associated soils are Kurumbul, Murra Cul Cul and Bendidee.

The Wondalli Soil is a melonholed, moderately to strongly self-mulching, dark or grey cracking clay that has a finely structured surface. It occurs mainly on elevated, level, melonholed plains with brigalow-belah forest that lie east and north-east of Goondiwindi, and in the far north of the shire around Moonie. These grade to gently undulating areas along the eastern margins of the shire. These plains generally lie above the level of current floodplains.

Melonhole microrelief is usually well developed, often up to 1 m deep and 5 to 15 m across. Apart from difficulties with uneven relief, variability in surface condition and the depth to subsoil, problems with sodicity, salinity or acidity near the surface may also occur. Surface structure is usually more friable on mounds, whereas subsoil problems usually occur deeper in the profile under depressions.

- Management of this soil is aided by high PAWC fine, friable seedbed, well structured upper subsoil, and a low erosion risk. The presence of melonholes restricts tillage and trafficability and causes localised ponding and waterlogging. Where they are very large or closely spaced, regrowth can be difficult to control. Subsoils under mounds are usually strongly sodic and very dispersible with high levels of salinity at depth. They also become acid below about 1 m. Where mounds are levelled, subsoil exposure can cause problems for plant growth.

CALINGUNEE SOIL (15)

One of two soils (the other is Wondalli) identified as typical of the **Commoron LRA**. Associated soils are Mt Carmel, Wynhari, Uranilla and Flinton.

The Calingunee soil is a melonholed, firm to strongly self-mulching, dark or grey cracking clay that has a finely structured surface.

It occurs with brigalow-belah forest on gently undulating rises, scarp footslopes and broad valleys. These form the lower landscape components of the dissected uplands, in the north-east of the shire. As such, it is widespread amongst the *jumpup* country that occurs in areas around Lundavra and Minnabilla west of the Weir River, east to the Wyaga district and north around Booroondoo and Keggabilla.

Melonhole microrelief is usually well developed, often up to 1 m deep and 5 to 15 m across. Apart from difficulties with uneven relief, variability in surface condition and the depth to subsoil, problems with sodicity, salinity or acidity near the surface may also occur. Surface structure is usually more friable on mounds, whereas subsoil problems usually occur deeper in the profile under depressions.

- Management of this soil is aided by high PAWC, fine, friable seedbed and well structured upper subsoil. The melonhole microrelief, unfavourable subsoil conditions and a moderate to high erosion risk increase management requirements. The presence of melonholes restricts tillage and trafficability and causes localised ponding and waterlogging. Where melonholes are very large or closely spaced, regrowth can be difficult to control. Lower subsoils are strongly sodic and very dispersible with high levels of salinity. They also become acid below about 60 cm. Where mounds are levelled, subsoil exposure can cause problems for plant growth.

KURUMBUL SOIL (16)

One of four soils (the others are Mt. Carmel, Moruya and Wynhari) identified as typical of the **Billa Billa LRA.** Associated soils are Murra Cul Cul, Wondalli and Bendidee.

The Kurumbul Soil is a firm to hard setting, friable, solodic soil with a shallow, clay loam surface.

It occurs on elevated, level plains with belah forest east and north-east of Goondiwindi. These plains generally lie above the level of current floodplains. It is particularly common in the Kurumbul-Wondalli area and along Yarrill and Wyaga Creeks in the north-east.

This soil should not be confused with the Kalanga soil which occurs on flooded belah-coolibah country associated with the Macintyre LRA to the west of Goondiwindi.

Crabhole microrelief is often developed, but is usually only 10 to 30 cm deep and 5 to 15 m across. As such, it has little effect on surface relief or soil profile characteristics, other than causing variation in the depth of A horizons. Typically, mounds have shallower A horizons than the depressions. Where A horizons are less than 2 to 3 cm deep, mound profiles effectively become uniform, non-cracking clays after tillage. Some variation in the surface condition is usually present between mounds, shelves and depressions.

- Management of this soil is aided by high PAWC, friable seedbed after tillage, well structured upper subsoil and low erosion risk. During tillage, well structured clay from the upper subsoil is often incorporated with shallow surface layers improving clay content and structure. As a result, seedbeds are friable and tend to seal but not set hard. Deep tillage can cause problems with dispersibility and crusting where sodic clay from below 20 to 30 cm is brought to the surface. Soil tests prior to deep ripping are advised. Subsoils below about 30 cm are strongly sodic and very dispersible with high levels of salinity. They become acid below about 90 cm.

MT. CARMEL SOIL (17)

One of four soils (the others are Kurumbul, Moruya and Wynhari) identified as typical of the **Billa Billa LRA.** Associated soils include Moruya, Wynhari, Calingunee and Murra Cul Cul.

The Mt. Carmel Soil is a firm or hard setting, friable, solodic soil with a shallow clay loam surface.

It occurs on the gently undulating rises with belah forest in the north-east of the shire. It is common in the Billa Billa area and further east in the Yagaburne, Wyaga and Kindon districts. It does not occur much west of the Leichhardt Highway.

Crabhole microrelief is often developed, but is usually only 10 to 30 cm deep and 5 to 15 m across. As such, it has little effect on surface relief or soil profile characteristics, other than causing variation in the depth of A horizons. Typically mounds have shallower A horizons than the depressions. Where A horizons are less than 2 to 3 cm deep, mound profiles effectively become uniform, non-cracking clays after tillage. Some variation in the surface condition is usually present between mounds, shelves and depressions.

- Management of this soil is aided by high PAWC, friable seedbed after tillage and well structured upper subsoil. During tillage, well structured clay from the upper subsoil is often incorporated with shallow surface layers, improving clay content and structure. As a result, seedbeds are friable and tend to seal but not set hard. Deep tillage can cause problems with dispersibility and crusting where sodic clay from below 20 to 30 cm is brought to the surface. Soil tests prior to deep ripping are advised. Subsoils below about 20 to 30 cm, are strongly sodic and very dispersible, with high levels of salinity. They become acid below about 60 cm. The erosion risk is increased because of long slopes between 1 and 3% and large catchments.

MORUYA SOIL (18)

One of four soils (the others are Kurumbul, Mt. Carmel and Wynhari) identified as typical of the **Billa Billa LRA.** Associated soils include Mt. Carmel, Wynhari, Calingunee and Murra Cul Cul.

The Moruya soil is a hard setting, loamy surfaced red-brown earth or solodic soil.

It occurs on the gently undulating rises with belah forest in the north-east of the shire. It is not a widespread soil and usually occurs as isolated patches within more widespread areas of the Mt. Carmel or Wynhari Soils. In this association it occurs throughout the gently undulating rises from Kioma east to Kindon.

Crabhole microrelief may be present, but is only very weakly developed. It has little effect on surface relief or soil profile characteristics. Variability in the depth of A horizons is usually insignificant.

- Management of this soil is affected by having unfavourable seedbed and lower subsoil conditions and a moderate to high erosion risk. Seedbeds are loamy (often with high levels of fine sand) and tend to seal during rain and set hard after rain. Lower subsoils are usually strongly sodic and very dispersible with high levels of salinity. They become acid below about 1 m. A high erosion risk may exist because of the erodibility of the surface soil, long slopes between 1 and 3%, and large catchment size.

WYNHARI SOIL (19)

One of four soils (the others are Kurumbul, Mt. Carmel and Moruya) identified as typical of the **Billa Billa LRA.** Associated soils include Mt. Carmel, Calingunee, Murra Cul Cul, and Moruya.

The Wynhari soil is a firm or hard setting to moderately self-mulching, dark or brown, non-cracking clay.

It occurs on the gently undulating rises with belah forest in the north-east of the shire. It is common in the Billa Billa area and further west in areas around Tarewinnabar, Lundavra, Coorangy and Kioma. It rarely occurs east of the Leichhardt Highway.

Crabhole microrelief is often developed, but is usually only 10 to 30 cm deep and 5 to 15 m across. As such, it has little effect on surface relief or soil profile characteristics, other than causing variation in the depth of A horizons. Typically, mounds have shallower A horizons than the depressions. Where A horizons are less than 2 to 3 cm deep, mound profiles effectively become uniform, non-cracking clays after tillage. Some variation in the surface condition is usually present between mounds, shelves and depressions.

These soils characteristically overlie soft, labile siltstone and sandstone between 1 and 2 m depth.

- Management of this soil is aided by high PAWC, friable seedbed after tillage, and well structured upper subsoil. During tillage, well structured clay from the upper subsoil is often incorporated with shallow surface layers, improving clay content and structure. As a result, seedbeds are friable and tend to seal but not set hard. Deep tillage can cause problems with dispersibility and crusting where sodic clay from below 20 to 30 cm is brought to the surface. Soil tests prior to deep ripping are advised. Subsoils below 20 to 30 cm are strongly sodic and dispersible, with high levels of salinity at depth. Long slopes (1 to 3% gradient) and large catchment size increase the erosion risk.

TANDAWANNA SOIL (20)

One of two soils (the other is Arden) identified as typical of the **Bungunya North LRA.** Associated soils include Arden and Jindabyne.

The Tandawanna soil can occur either as a firm to weakly self-mulching, red or brown, non-cracking clay; or as a firm or hard setting, friable, solodic soil with a shallow, clay loam surface.

It occurs on elevated, level or occasionally gently undulating plains with belah forest that are common in the Bungunya North area and further west and south-west towards Mungindi. It does not occur east of the Weir River. These plains generally lie above the level of current floodplains.

This soil should not be confused with the Kalanga soil which occurs on flooded belah-coolibah country associated with the Macintyre LRA, to the west of Goondiwindi.

Crabhole microrelief is often developed, but is usually only 10 to 30 cm deep and 5 to 15 m across. As such, it has little effect on surface relief or soil profile characteristics, other than causing variation in the depth of A horizons. Typically mounds have shallower A horizons than the depressions. Where A horizons are less than 2 to 3 cm deep mound profiles effectively become uniform, non-cracking clays after tillage. Some variation in the surface condition is usually present between mounds, shelves and depressions.

- Management of this soil is aided by high PAWC, friable seedbed after tillage, well structured upper subsoil and low erosion risk. During tillage, well structured clay from the upper subsoil is often incorporated with shallow surface layers improving clay content and structure. As a result, seedbeds are friable and tend to seal but not set hard. Deep tillage can cause problems with dispersibility and crusting where sodic clay from below 20 to 30 cm is brought to the surface. Soil tests prior to deep ripping are advised. Subsoils below 20 to 30 cm are strongly sodic and become very dispersible below about 50 cm. They have high levels of salinity at depth and become acid below about 80 cm.

ARDEN SOIL (21)

One of two soils (the other is Tandawanna) identified as typical of the **Bungunya North LRA**. Associated soils include Tandawanna and Jindabyne.

The Arden soil is a weakly gilgaied, moderately to strongly self-mulching, red or brown cracking clay with a finely structured surface.

It occurs mainly on gently undulating plains and rises with brigalow-belah forest that are common in the Bungunya North area, west of Kioma. It also occurs on scarp footslopes and broad valleys associated with *jumpups* in the area. It is less common in areas west of Talwood and does not occur east of the Bungunya North area.

Crabhole or weakly to moderately developed normal gilgai are often present. These are usually between 10 and 60 cm deep and 5 to 15 m across. Where moderately developed, some variation in profile characteristics and surface condition may be seen. The depth to carbonate layers and acid subsoils is usually greater in depressions than on mounds. Surface structure is more friable on mounds than in depressions.

- Management of this soil is aided by high PAWC, a fine, friable seedbed and well structured upper subsoil. Lower subsoils are strongly sodic with high levels of salinity. They also become acid below about 60 cm. Problems with erosion occur because of long slopes between 1 and 3%, and large catchment size.

TAREWINNABAR SOIL (22)

One of two soils (the other is Tarewinnabar shallow) identified as typical of the **Lundavra LRA**. Associated soils include Wynhari and Tarewinnabar shallow.

The Tarewinnabar soil is a weakly gilgaied, moderately deep, moderately to strongly self-mulching, dark cracking clay, with a finely structured surface.

It is restricted to lower and mid-slopes or valley flats with an open downs appearance, that form part of the undulating rises around Tarewinnabar, Te Apiti and Lundavra. It is closely associated with the Tarewinnabar shallow soil and represents part of a well developed catena in which soil and vegetation occur in a predictable pattern with landscape position.

Linear gilgai are well developed but have little effect on soil profile characteristics other than minor variation in surface condition and the depth to carbonate layers. They are usually 10 to 30 cm deep and 5 to 10 m across, running the length of the slope. Mounds are typically strongly self-mulching with calcium carbonate on the surface, while depressions are more coarsely structured and only moderately self-mulching.

These soils characteristically overlie soft, labile sandstone and siltstone at 1 to 2 m depth.

- Management of this soil is aided by high PAWC, a fine, friable seedbed, and very favourable subsoil conditions. A moderate erosion risk (slope gradients of 1 to 5%) and shallow depth in some areas may increase management requirements.

TAREWINNABAR SHALLOW SOIL (23)

One of two soils (the other is Tarewinnabar) identified as typical of the **Lundavra LRA**. Associated soils include Wynhari and Tarewinnabar.

The Tarewinnabar shallow soil is a shallow, hard setting red or brown cracking clay with a relatively coarsely structured surface.

It is restricted to upper slopes and crests with an open downs appearance, that form part of the undulating rises around Tarewinnabar, Te Apiti and Lundavra. It is closely associated with the Tarewinnabar soil and forms part of a well developed catena.

These soils characteristically overlie soft, labile sandstone and siltstone at less than 1.0 m depth.

- Management of this soil is affected by low PAWC, low fertility, shallow soil depth, seedbed conditions that are less than optimal, and a high erosion risk. Seedbeds are naturally hard setting, but are coarse and friable after tillage. They tend to seal during rain. Soil depth is usually less than 60 cm over weathered rock. A high erosion risk can exist because of slopes up to 5%.

WEENGALLON SOIL (24)

One of two soils (the other is Flinton) identified as typical of the **Geralda LRA**. Associated soils include Flinton and Jindabyne.

The Weengallon soil is a hard setting, loamy surfaced, structured red earth or solodic soil.

It is widespread throughout the gently dissected uplands and lowlands in the north-west and south-west of the shire. It occurs mainly on gently undulating plains and rises in lower lying or less undulating upland areas, particularly north of Talwood and Weengallon. It also occurs on similar landforms in lowland areas between Talwood, Weengallon and Mungindi in the south-west. The Flinton soil is closely associated with, and often replaces, the Weengallon soil in the higher parts of the landscape.

- Management of this soil is affected by low PAWC, low fertility, seedbed conditions that are less than optimal and a high erosion risk. Seedbeds are loamy, often with high amounts of fine sand, and tend to seal, set hard and dry out quickly after rain. Problems with soil erosion occur because of the high erodibility of the surface soil and slopes up to 5%. Management of woody weed regrowth is difficult because control measures are usually not cost effective.

FLINTON SOIL (25)

One of two soils (the other is Weengallon) identified as typical of the **Geralda LRA**. Associated soils include Flinton shallow and Weengallon.

The Flinton soil is a hard setting, loamy surfaced, massive red earth.

It is widespread throughout the gently dissected uplands and lowlands in the north-west and south-west of the shire. It occurs mainly on undulating rises and low hills in the higher or more undulating upland areas, particularly north of Talwood and Weengallon. It is less common on the gently undulating plains and rises of the lowlands between Talwood, Weengallon and Mungindi. The Weengallon soil is closely associated with, and often replaces, the Flinton soil in the lower parts of the landscape.

- Management of this soil is affected by low PAWC, low fertility, seedbed conditions and a high erosion risk. Seedbeds are loamy and tend to seal during rain, set hard and dry out quickly after rain. Problems with soil erosion occur because of the high erodibility of the surface soil and slopes between 2 and 5%, occasionally up to 8%. Management of woody weed regrowth is difficult because control measures are usually not cost effective.

URANILLA SOIL (26)

This is the only soil identified within the **Boondandilla LRA**, and is considered typical. Associated soils include Bendidee, Flinton, and Flinton shallow.

The Uranilla soil is a hard setting, loamy surfaced solodized solonetz soil.

It is widespread throughout the gently dissected uplands and lowlands in the north-east of the shire, and on the gently dissected lowlands along its eastern margins. It occurs mainly on gently undulating plains and rises that form broad plateau-like areas above the dissected *jumpups* in the north-east. It also occurs on similar landforms in lowland areas between Wyaga and Yelarbon.

- Management of this soil is affected by very low PAWC, very low fertility, poor seedbed and subsoil conditions, and a high erosion risk. Seedbeds are loamy, sometimes coarse sandy, and pulverise readily with tillage. They seal, set hard and dry quickly after rain, and are often gravelly. Subsoils are strongly sodic and very dispersible with high levels of salinity at depth. They are usually impermeable and impenetrable to roots. Problems with erosion occur because of the high erodibility of the surface soil, the dispersible nature of the subsoil, and slopes between 1 and 3%. Management of woody weed regrowth is difficult, not only because of the unstable nature of this soil when cleared or disturbed but also it is usually not cost effective.

WESTMAR SOIL (Solodic form only) (27)

This represents an unnamed soil that is considered typical of the **Westmar LRA**. It is similar in many respects to the Bendidee soil of the Goodar LRA. Associated soils include unnamed soils similar to Wai Wai, Flinton and Flinton shallow.

The Westmar soil is a soft to hard setting, coarse sandy surfaced solodic soil, or less commonly solodized solonetz soil.

The Westmar soil is restricted to the gently undulating plains, rises and occasional low hills developed on quartzose sandstones around Westmar. It occurs mainly on mid to lower slopes and valley floors. Deep, siliceous sands, similar to the Wai Wai soil, are often associated in the more gently undulating areas, while shallow gravelly soils, similar to Flinton shallow usually occur on crests and upper slopes.

It is restricted to minor occurrences around Westmar, as well as further east along the Moonie Highway and south-west around Ula Ula Creek.

The information for this soil has been interpreted from data presented for the sandy solodic soil association (group 12) in Isbell (1957). This soil is the dominant soil of that association. Minor soils that also occur include shallow lithosols, lateritic red earths and earthy sands. No information is available for the minor soils.

- Management of this soil is affected by very low PAWC, very low fertility, unfavourable seedbed conditions, poorly structured impermeable subsoils and a high erosion risk. Seedbeds are loose, coarse and sandy, and dry out quickly at the surface due to rapid evaporation. Subsoils are strongly sodic and very dispersible. The high erosion risk is due to the highly erodible surface soil, the dispersible subsoil, and slopes between 1 and 3%. Management of woody weed regrowth is difficult, not only because of the unstable nature of this soil when cleared or disturbed but also it is not usually cost effective.

FLINTON SHALLOW SOIL (28)

One of two soils (the other is Karbullah) identified as typical of the **Jumpup LRA**. Associated soils include Karbullah, Flinton and Uranilla.

The Flinton shallow soil is a very shallow, hard setting, gravelly lithosol or red earth.

It is restricted to the undulating or rolling rises and low hills that characterise the dissected uplands in the north of the shire. It occurs mainly on crests and upper slopes of *jumpups* and residuals. It is common in the west of the shire, but also occurs in eastern areas.

- Management of this soil is affected by very low PAWC, very low fertility, unfavourable seedbed conditions, shallow soil depth, high amounts of gravel and a high erosion risk. Seedbeds are shallow, loamy and very gravelly. They pulverise readily and tend to seal during rain and set hard and dry out quickly after rain. The high erosion risk exists because of the highly erodible surface soil and very steep slopes usually between 5 and 25%. Management of woody weed regrowth is difficult not only because of the unstable nature of this soil when cleared or disturbed but also it is usually not cost effective.

KARBULLAH SOIL (29)

One of two soils (the other is Flinton shallow) identified as typical of the **Jumpup LRA**.

Associated soils include Flinton shallow, Flinton and Uranilla.

The Karbullah soil is a very shallow, firm to hard setting, dark or brown, stony, lithosol.

It is restricted to the undulating or rolling rises and low hills that characterise the dissected uplands, in the north of the shire. It occurs mainly on crests and upper slopes of *jumpups* and residuals in the eastern half of the shire.

- Management of this soil is affected by very low PAWC, very low fertility, unfavourable seedbed conditions, shallow soil depth, stoniness and a high erosion risk. Seedbeds are shallow, loamy and stony. They pulverise readily and tend to seal, set hard and dry out quickly after rain. A high erosion risk exists because of the high erodibility of the surface soil and very steep slopes, usually between 5 and 25%. Management of woody weed regrowth is difficult not only because of the unstable nature of this soil when cleared or disturbed but also it is usually not cost effective.

Chapter 8

LAND EVALUATION

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SUMMARY

* The soils of Waggamba Shire have been assessed for suitability for the following land uses:

- irrigation
  - flood irrigated cropping
  - spray irrigated cropping, flood or spray irrigated pastures
  - trickle irrigated cropping

- long-term dryland cropping
- short-term dryland cropping
- sown pastures (long-term, introduced pastures)
- native pastures

* The soils are grouped into five suitability classes to rate their performance for each of the land uses.

* On the basis of these ratings soils are grouped into recommended land uses according to management requirements. Soils within each group are of similar agronomic potential and require similar management for long-term productivity with minimal land degradation.

1. INTRODUCTION

Seven major land uses were identified for land suitability assessment from the variety of cropping and grazing enterprises that exist in Waggamba Shire. Dryland and irrigated land uses may be ranked in order of the level of agronomic and land management requirements necessary to achieve optimal production.

- Irrigated agriculture
  - flood irrigated cropping
  - spray irrigated cropping; flood or spray irrigated pastures
  - trickle irrigated cropping

- Dryland agriculture
  - long-term cropping with short-term forage or pasture rotations
  - short-term cropping with long-term forage and pasture rotations
  - sown pastures (long-term introduced pastures)
  - native pastures

The soils associated with each of these groups are listed in Tables 8.1 and 8.2. Within each group, it is assumed the requirements of the relevant crops and pastures are equivalent, although the inputs necessary to achieve optimal production will vary. Suitable crops and pasture types for each land use group are given in the summary pages in Part B of this manual for each soil.

Table 8.1. Soils recommended for irrigated cropping or pastures

Agricultural system	Soils
Irrigated cropping or pastures	
- flood (cropping only)	Undabri, Kalanga, Kurumbul, Tandawanna
- spray (cropping), and flood or spray (pastures)	Yambocully, Oonavale, Jindabyne, Wondalli, Keetah, Marella
- trickle (cropping only)	Wondoogle, Wai Wai, Bengalla

Table 8.2. Soils recommended for dryland cropping, sown pastures and native pastures

Agricultural system	Soils
Long-term dryland cropping	Kurumbul, Tandawanna, Arden, Wynhari, Mt Carmel, Tarewinnabar, Kalanga, Undabri, Wondalli, Calingunee
Short-term dryland cropping	Moruya, Murra Cul Cul, Yambocully, Oonavale
Sown pastures	Tarewinnabar shallow, Jindabyne, Weengallon, Flinton, Keetah
Native pastures - may be suitable for development for spray and trickle irrigation	Bengalla, Marella, Wondoogle, Wai Wai
Native pastures - unsuitable for development	Bendidee, Uranilla, Westmar, Flinton shallow, Karbullah, Yelarbon

Management requirements and recommendations for each group are summarised in Part B of this manual.

Irrigated land uses are generally restricted to soils that are adjacent to, or within acceptable pumping distance of a reliable water supply. As a result, suitability assessments for irrigated land uses have been restricted to soils that occur close to current water sources. These assessments are outlined in Section 4.1. Those soils not assessed for irrigation suitability may become suitable for irrigated agriculture should a potential water supply become available.

2. THE LAND SUITABILITY CLASSIFICATION

The agricultural potential of the soils in Waggamba Shire has been assessed for the major land uses currently being practised. Separate suitability ratings have been developed for each land use for this purpose. The land suitability classification allocates soils to one of five classes based on their potential for optimum productivity with minimal long-term land degradation. The five class classification is based on the standard used by the Queensland Department of Primary Industries, (Land Resources Branch Staff, 1990) and is summarised here:

Class 1	Suitable land with negligible limitations
Class 2	Suitable land with minor limitations
Class 3	Suitable land with moderate limitations
Class 4	Marginal land which is presently considered unsuitable owing to severe limitations
Class 5	Unsuitable land with extreme limitations that preclude its use

Land is considered less suitable as the severity of limitations for a particular land use increase. Increasing limitations may reflect one, or a combination, of the following:

- increased inputs required to prevent land degradation;
- increased inputs to achieve an acceptable level of production; or
- reduced potential for production.

Further explanation of the suitability classification and the limitations for each agricultural system is given in Appendix III.

2.1 The classes

Under this classification:

- Classes 1 to 3 are considered suitable for a specified land use as the benefits from using the land for that use should outweigh the inputs required to initiate and maintain production. No Class 1 land for dryland agriculture was identified within Waggamba Shire as all soils have some form of limitation to maximum productivity.
- The benefits from using Class 4 land may be cancelled out by the inputs required. Therefore its long-term suitability for the specified land use is doubtful and it is consequently called *marginal* land. In contrast, there is no doubt regarding the long-term suitability of land classed 1 to 3 or the unsuitability of Class 5 land.
- Class 5 land has limitations that altogether are so severe that the benefits would not justify the inputs required to initiate and maintain production (Land Resources Branch Staff, 1990).

The ratings are appropriate for existing technology and if this changes then the rating could alter.

2.2 Limitations

Fourteen limitations were identified as important to dryland and irrigated crop and pasture production in the Waggamba Shire. These are listed in Table 8.3 with a brief explanation of the basis on which they were assessed.

Table 8.3. Limitations to land use considered in the land suitability evaluation

Limitation	Description
• water availability	predicted PAWC (plant available water capacity and summer rainfall variability)
• nutrient deficiency	surface soil fertility based on inherent levels of nitrogen and phosphorus
• salinity	a comparison of average salinity within the root zone to plant tolerance data to gauge potential productivity losses due to salinity
• wetness	susceptibility to waterlogging; based on site and profile drainage
• flooding	susceptibility to flooding based on estimated flood frequencies and nature of flooding
• vegetation	regrowth potential and the range of options available for regrowth control; determined for sown and native pastures only
• rockiness	the presence of rock outcrops and stone in the plough zone; of minor importance for Waggamba Shire
• soil complexity	management difficulties associated with soils of limited or complex distribution, assessed for irrigation soils only

· microrelief	based on restrictions to tillage and the trafficability of machinery relating to the size and density of microrelief; requirement for levelling for flood irrigated cropping
· physical surface condition	effect of soil surface structure and seedbed condition on crop establishment
· soil workability	likely tillage problems associated with high soil strength, narrow tillage window or abrasiveness to machinery
· furrow infiltration	the efficiency of furrow irrigation; surface soil morphology is used to assess relative infiltration characteristics; the effect of local topography is also considered; determined for flood irrigated soils only
· water erosion	susceptibility to accelerated soil erosion due to surface runoff; based on slope angle, slope length and inherent surface soil erodibility
· wind erosion	susceptibility to wind erosion based on inherent surface soil erodibility and the form of the landscape

3. LAND SUITABILITY

Results of the land suitability assessments are tabulated in Appendix III. Each table represents a particular land use and presents the limitations, degree of hazard and suitability class for each soil. Individual assessments for spray irrigated cropping and pastures and trickle irrigated cropping have not been undertaken.

Suitability classes for each soil are presented in Tables 8.4 and 8.5 for all irrigated and dryland land uses.

These tables show that the suitability rating for each soil changes for different land uses. This reflects the ability of a soil to meet the agronomic and land management requirements for a particular crop or land use. For example, where the requirements of dryland cropping are relatively high, such as for dryland cotton, only the more highly rated soils capable of meeting such requirements are classed as suitable. Where land uses with lower requirements are considered, such as sown pastures, a much wider range of soils may be classed as suitable.

The requirements for flood irrigated cropping are usually more demanding than those for spray or trickle irrigated crops, or for irrigated pastures. Therefore, soils that are considered marginal or of low suitability for flood irrigation may be suited to spray or trickle irrigated cropping or for irrigated pasture production.

4. RECOMMENDED LAND USE

The suitability ratings in Tables 8.4 and 8.5 outline the particular land uses each soil is most suited to. They do not, however, consider how each soil should be best managed to achieve sustainable production in the long-term.

To clarify such management requirements, the soils have been finally grouped from the suitability assessment on the basis of *recommended* land use. The soils in each group are outlined in Tables 8.1 and 8.2. The land use recommended for each soil represents the most suitable land use to achieve optimal production with minimal land degradation. Soils in the same group have similar limitations and, therefore, possess common management requirements.

The limitations and hazards common to each group are discussed in the following section. Management requirements and recommendations that aim to overcome these problems and promote sustained productivity are detailed in Chapter 9 and summarised in Part B of this manual.

4.1 Irrigated agriculture

Several soils are suited to irrigated agriculture, where they occur within reach of an adequate water supply. Table 8.4 shows the results of the suitability assessment for those soils and the recommended irrigated land management system. This recommended land management system represents the most intensive production to which a soil is suited, based on soil limitations, to achieve optimal production with minimal land degradation in the long-term.

Table 8.4. Suitability class[1] and recommended land use for irrigated agriculture

Soil (No.)	Irrigation system: Flood	Spray	Trickle	Recommended land use
Undabri (3)	2	1	1	flood irrigated cropping and pastures
Kalanga (4)	2	1	1	
Kurumbul (16)	2	1	1	
Tandawanna (20)	2	1	1	
Yambocully (6)	3	2	1	flood or spray irrigated pastures; spray irrigated cropping
Oonavale (7)	3	2	1	
Jindabyne (8)	3	2	1	
Wondalli (14)	4	3	2	spray irrigated cropping and pastures
Keetah (1)	4	3	2	
Marella (11)	4	3	2	
Wondoogle (9)	5	4	2	trickle irrigated cropping
Wai Wai (10)	5	4	2	
Bengalla (2)	5	4	2	

[1] Suitability classification:
- Classes 1 to 3 are suitable, with increasing limitations
- Class 4 is marginal
- Class 5 is unsuitable

4.1.1 Flood irrigation

Suitable soils: **Kalanga, Undabri, Kurumbul, Tandawanna**

These soils represent the best of the irrigation soils for flood irrigated crops and pastures. They are also suitable for spray and trickle irrigated uses.

The following characteristics make these soils suitable for the high level of requirements demanded by flood irrigated cropping:

- High plant available water capacity means the soils require less frequent irrigation.
- High clay content in both surface soil and subsoil makes these soils suitable for earthwork construction.
- These soils occur on topography with slopes less than 1% and are therefore suitable for levelling and graded falls.
- Microrelief is usually either minor or absent, requiring only minimal levelling.

- The soils occur as extensive uniform areas. Development is usually not restricted by the soil distribution or soil complexity.

- Structured clay surface soil, once tilled; often self-mulching; therefore able to withstand the rigour of flood irrigated cropping.

- Suitable for long furrows; allowing increased efficiency in irrigation design and management.

Hazards or limitations that reduce the suitability of these soils for flood irrigated cropping include:

- Subject to regular flooding (1 in 1 up to 1 in 10 year floods), therefore requiring the construction of extensive levee banks around irrigation developments.

- High salinity levels in the subsoil which may represent a potential hazard should water tables rise.

4.1.2 Spray Irrigation

These soils are best suited to spray irrigated cropping. They are also suitable for either flood or spray irrigated pastures, depending on surface soil texture.

Suitable soils exist in three distinct groups:

- deep, fine sandy surfaced, duplex soils: **Keetah, Marella**

- fine sandy or silty, clay loam surfaced, duplex soils: **Yambocully, Oonavale, Jindabyne**

- gilgaied clay soils: **Wondalli**

The following characteristics make these soils less suitable or marginal for flood irrigated cropping and more suitable for spray irrigated land uses:

Deep, fine sandy surfaced, duplex soils - **Keetah, Marella**

- Low plant available water capacity and the sandy nature of the deep surface soil mean these soils require frequent irrigation and would be restricted to very short furrows if flood irrigated.

- Clay content is too low in the top 50 to 60 cm for earthwork construction.

- Poor seedbed conditions because of high levels of fine sand. Seedbeds usually pulverise readily with tillage and set hard after watering.

- Complex soil distribution; small and irregular areas and slopes of 1 to 3% make irrigation designs complicated and difficult to manage.

- Prone to regular flooding.

Fine sandy or silty, clay loam surfaced, duplex soils - **Yambocully, Oonavale, Jindabyne**

- Surface soil has relatively high levels of fine sand or silt. Seedbeds are usually hard setting and cloddy and tend to pulverise with excessive tillage as well as seal during watering and crust afterwards. Deep ripping may improve seedbed conditions by incorporating subsoil clay and improving texture and structure. This should only be contemplated where subsoils are not sodic. Where subsoils are sodic, large applications of gypsum are required. Soil testing prior to deep ripping is advised.

- Surface soil dries out relatively quickly compared to the flood irrigated soils; requiring more frequent irrigation and shorter furrows.

- Problems with soil complexity associated with existing or former streams; these soils occur in small areas and are less uniform in texture than the clay soils suitable for flood irrigation.

- High levels of subsoil salinity may be a potential hazard if water tables rise.

Gilgaied clay soils - **Wondalli**

- Melonhole microrelief causes problems with uneven topography and waterlogging. They usually require major levelling.

- High levels of salinity may be exposed in subsoils following levelling for land preparation.

4.1.3 Trickle Irrigation

These soils are best suited to trickle irrigated cropping. They are marginal for spray irrigated cropping and pastures and are unsuitable for flood irrigation.

Two distinct groups of suitable soils exist:

- deep sands: **Wondoogle, Wai Wai**
- deep, silty surfaced, duplex soils: **Bengalla**

The following characteristics make these soils unsuitable or marginal for flood or spray irrigated cropping and pastures and more suited to trickle irrigation:

Deep sands - **Wondoogle, Wai Wai**

- Low plant available water capacity and high permeability mean these soils require very frequent irrigation. They are usually unsuitable for furrow or spray irrigation because of high water usage and nutrient leaching.

- Clay content is extremely low throughout and soils are therefore unsuitable for earthwork construction.

- Seedbeds are usually loose and sandy, and dry out rapidly.

- Problems with small, irregular areas and slopes between 1 and 3% make irrigation design for flood or spray inefficient and difficult to manage.

Deep, silty surfaced, duplex soil - **Bengalla**

- Very low plant available water capacity, very slow infiltration rates and highly impermeable subsoil. This soil is suitable only for very frequent, low volume water application. It is difficult to manage under flood or spray systems because surface soils become waterlogged as a result of poor drainage.

- Surface soil has high levels of silt. Seedbeds are usually hard setting and pulverise readily with tillage. Surface soil is very powdery and tends to slake and seal during watering. It sets hard and crusts strongly as it dries. Problems with crop emergence and establishment usually occur owing to severe physical restrictions.

- Problems with high soil strength, a narrow tillage window and powdery seedbeds make this soil difficult to work.

4.2 Dryland agriculture

Most soils are suited to some form of dryland development as shown by the results of the suitability assessment in Table 8.5. The recommended land use in the table represents the most intensive production to which a soil is suited, based on soil limitations, to achieve optimal production with minimal land degradation in the long-term.

4.2.1 Long-term cropping soils

Suitable soils: **Kurumbul, Tandawanna, Arden, Wynhari, Mt. Carmel, Tarewinnabar, Kalanga, Undabri, Wondalli, Calingunee**

These predominantly clay soils represent the most suitable for dryland cropping within the shire. They are also suitable for forages, sown pastures and native pasture. Where they lie adjacent to, or within acceptable pumping distance of an adequate water supply, most soils are suited to irrigation (See Section 4.1).

The following characteristics make these soils suitable for the relatively high level of requirements associated with dryland cropping:

- High plant available water capacity and moderate to high fertility which gives these soils better yield potential.

- Good seedbed conditions: usually well structured clays or shallow clay loam surfaced soils that are incorporated during tillage. Seedbeds are usually fine and friable, often self-mulching and slow to dry out. Good seed - soil contact and lack of physical restrictions ensures reliable crop establishment.

- Good soil workability; associated with low soil strength and a wide tillage window. Surface soils are usually well structured and relatively resilient to the degrading effects of tillage.

- Low inherent, surface soil erodibilty (both wind and water erosion) because of structured clay surface soils.

Table 8.5. Suitability class[1] and recommended land uses for dryland agriculture

Soil (No.)	Dryland cropping	Annual forage	Perennial forage	Sown pasture	Native pasture[2]	Recommended land use
Kurumbul (16)	2	2	2	2	2	
Tandawanna (20)	2	2	2	2	2	
Arden (21)	2	2	2	2	2	
Wynhari (19)	2	2	2	2	2	
Mt. Carmel (17)	2	2	2	2	2	long-term
Tarewinnabar (22)	2	2	2	2	2	cropping
Kalanga (4)	2-3	2-3	2	2	2	
Undabri (3)	2-3	2-3	2	3	2	
Wondalli (14)	2-3	2-3	2	2-3	2-3	
Calingunee (15)	2-3	2-3	2	2-3	2-3	
Moruya (18)	3	3	3	3	2	
Murra Cul Cul (5)	3	3	3	3	2	short-term
Yambocully (6)	3	3	3	3	2	cropping
Oonavale (7)	3	3	3	3	2	
Tarewinnabar shallow (23)	4	4	4	3	2	
Jindabyne (8)	4	4	4	3	3	
Weengallon (24)	4	4	4	3	3	sown pastures
Flinton (25)	4	4	4	3	3	
Keetah (1)	4	4	4	3	3	
Bengalla (2)	5	5	5	4	3	
Marella (11)	5	5	5	4	3	
Wondoogle (9)	5	5	5	5	4	
Wai Wai (10)	5	5	5	5	4	native pasture,
Bendidee (12)	5	5	5	5	4	unsuitable for
Uranilla (26)	5	5	5	5	4	dryland
Westmar (27)	5	5	5	5	4	development
Flinton shallow (28)	5	5	5	5	4	
Karbullah (29)	5	5	5	5	4	
Yelarbon (13)	5	5	5	5	4	

[1] Suitability classification
- Classes 1 to 3 are suitable, with increasing limitations
- Class 4 is marginal
- Class 5 is unsuitable

[2] following development

Note • The intergrade class 2-3 arises because of the large variation within the soil unit brought about by the limited resolution of the mapping.

Hazards or limitations that may reduce the suitability of these soils for dryland cropping include:

- Flooding, causing prolonged waterlogging and planting delays on some soils.
- Melonhole microrelief, causing problems with uneven topography and waterlogging thereby reducing tillage efficiency, trafficability and crop growth. Levelling may expose subsoils that are saline, sodic or acidic.
- Slopes exceeding 1% are common for many of these soils and require planned erosion control structures, for example, contour banks and waterways, to minimise water erosion.

4.2.2 Short-term cropping soils

Suitable soils: **Moruya, Murra Cul Cul, Yambocully, Oonavale**

These are mainly duplex soils that are more suited to crop rotational systems incorporating short-term cropping and ley pastures. They are suitable for crop and forage production in short spells only. Regular rotation with ley pastures is recommended. They are also suitable for sown and native pasture. These soils are suitable to some forms of irrigation where they lie adjacent to, or within acceptable pumping distance of an adequate water supply (see Section 4.1). They are less suitable for dryland cropping than the clay soils of the previous group because of problems with surface soil characteristics, seedbed condition and lower plant water availability.

The following characteristics make these soils more suited to a rotational system of short-term cropping and ley pastures:

- The surface soil characteristics limit plant available water capacity as a result of lower infiltration rates and increased runoff.

- Seedbeds are poorly structured with high levels of fine sand or silt. They are usually cloddy and tend to pulverise with excessive tillage. They seal, set hard and sometimes crust after rain, and dry out more quickly than the clay soils. Physical restrictions to emergence and poorer seed-soil contact can reduce crop establishment.

- The soil is usually difficult to work. A hard setting surface that is quick to dry out narrows the tillage window. They are prone to surface soil instability with continuous tillage, and display less resilience than the clay soils to tillage.

- These soils possess a higher, inherent surface soil erodibility for both wind and water erosion than the previous group.

4.2.3 Sown pasture soils

These soils are suitable for long-term sown pastures but are marginal for dryland cropping and rotational systems. Opportunity cropping for two or three seasons during land development is recommended to control woody weed regrowth.

Suitable soils exist in three distinct groups:

- clay loam surfaced, duplex soils and earths: **Jindabyne, Weengallon, Flinton**
- deep, fine sandy surfaced, duplex soils: **Keetah**
- shallow, hard setting clays: **Tarewinnabar shallow**

The following characteristics make these soils marginal for long and short-term dryland cropping and ley pastures, and more suited to long-term sown pastures:

Clay loam surfaced, duplex soils and earths - **Jindabyne, Weengallon, Flinton**

- Plant available water capacity is low. In addition, these soils experience lower and more variable summer rainfall as they occur generally to the west of the 350 mm summer rainfall isohyet (Climatic Zone B: Map 2, Part B).

- Inherent fertility is often low.

- Hard setting, clay loam surface soils with relatively high levels of fine sand mean seedbeds are cloddy and tend to pulverise with excessive tillage. The surface soil often seals during rain, sets hard and crusts after rain, and dries out quickly. It also becomes unstable with tillage. Physical restrictions to emergence, and poor seed - soil contact, where cloddy, can reduce crop establishment.

- Poor workability because of a hard setting surface and high soil strength.

- Highly erodible when cultivated, requiring vegetative cover or erosion control structures for slopes over 1%. Erosion control structures may be inappropriate because of the marginality of these soils for cropping.

- Surface soils are prone to wind erosion where disturbed, and where vegetative cover is low.

- Physical or chemical control measures are often required to control woody weed regrowth because of the lack of regular tillage.

Deep, fine sandy surfaced, duplex soils - **Keetah**

- Low plant available water capacity because of the deep, sandy surface soil that is well drained and prone to rapid drying.

- The fine, sandy seedbed pulverises with tillage, sets hard after rain and is prone to rapid drying. Physical restrictions may limit emergence and reduce crop establishment.

- The land may be prone to regular flooding.

- Erodible when cultivated, requiring vegetative cover to minimise erosion. Erosion control structures are of limited application because of the fine sandy nature of the deep surface horizon.

Shallow hard setting clays - **Tarewinnabar shallow**

- Plant available water capacity is low because of shallow soil depth.

- Natural fertility is low due to the nutrient-poor parent material from which these soils have weathered (sandstones and siltstones).

- Seedbed condition is coarsely structured and hard setting, with poor seed-soil contact; establishment problems with small seeds can occur.

- High soil strength and a narrow tillage window make these soils difficult to cultivate to achieve a fine tilth.

- Rocks and stones within the surface soil may impede tillage.

- Inherent soil erodibility is low but undulating terrain, with slopes between 1 and 5%, makes this soil prone to water erosion when cultivated. Vegetative cover is required for erosion control. Erosion control structures may be inappropriate because of the marginality of this soil for cropping.

4.2.4 Native pasture soils; unsuitable for development

These soils are suitable for use only as native pasture. They are unsuited to any sort of dryland development and should be left for light grazing or forestry. Standing timber should be retained wherever possible and soil disturbance minimised.

Suitable soils exits in three distinct groups:

- deep, silty surfaced, duplex soils: **Bengalla, Yelarbon**

- deep sands and deep, sandy surfaced, duplex soils: **Wondoogle, Wai Wai, Marella, Bendidee, Uranilla, Westmar**

- shallow, stony and gravelly soils: **Flinton shallow, Karbullah**

Deep, silty surfaced, duplex soils - **Bengalla** and **Yelarbon**

Note: Development is not recommended for these soils as the risk of land degradation is very high.

- Very low plant available water capacity because of shallow effective root depth. Physical and chemical conditions in the subsoil are usually very poor for root growth.

- Poor seedbed condition owing to high levels of silt in the surface soil. They are usually hard setting, dry out rapidly, and pulverise readily with tillage. Surface soils are very powdery and tend to slake and seal with rain. They also set hard and crust strongly as they dry.

- Poor workability because of high soil strength, a narrow tillage window and poorly structured, extremely powdery surface soils.

- Both surface soils and subsoils are highly impermeable. Surface soils dry out rapidly while subsoils often remain waterlogged; in lower lying areas water may pond for long periods.

- Subsoils are strongly sodic, therefore very dispersible, and often saline at depth.

- Prone to severe wind erosion where disturbed or where vegetative cover is reduced.

Deep sands and deep, sandy surfaced, duplex soils - **Wondoogle, Wai Wai, Marella, Bendidee, Uranilla, Westmar**

Note: Development is not recommended for these soils as the risk of land degradation is very high.

- Seedbed is either coarse, loose and sandy or it is fine and powdery. Surface soils are prone to rapid drying and sometimes set hard. Poor seed - soil contact and rapid drying severely limit crop establishment.

- Poor soil workability; where surface soil is coarse and sandy. It may be abrasive to machinery.

- Low or very low plant available water capacity. The deep, sandy surface soils drain and dry out rapidly while subsoils are usually unsuitable for root growth.

- Inherent fertility is usually low.

- Soil erosion risk is usually high because the soils occur on gently undulating terrain, with slopes between 1 and 3%. They are highly erodible where disturbed. Wind erosion may occur where vegetative cover is removed, with clearing, cultivation or heavy grazing.

- Waterlogging may occur with the coarse, sandy surface soils because of impermeable clay subsoils; water accumulation in the sandy surface soil makes them *spewy*.

- Regrowth is difficult to control because of lack of regular tillage. Physical control methods, for example, pulling, raking or blade ploughing, may lead to severe erosion. Control measures are restricted to chemical methods.

Shallow, stony and gravelly soils - **Karbullah, Flinton shallow,** some **Westmar soils**

Note: Development is not recommended for these soils as the risk of land degradation is very high.

- Very low plant available water capacity because of shallow soil depth and high stone or gravel content.

- Very low fertility associated with the highly weathered landscapes.

- Physical limitations such as steep slopes, rockiness and shallow soil depth severely restrict tillage.

- High erosion risk; especially on steep slopes of the *jumpups* (slopes of 5 to 25%). Extreme water erosion is likely where vegetative cover is removed.

- Regrowth control is difficult: physical control methods are unsuitable therefore control is limited to chemical methods.

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Chapter 9

AGRICULTURAL SYSTEMS

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Summary

* Enterprise selection should be based on land suitability. Long-term dryland cropping and irrigated cropping are best suited to those soils recommended for cropping. Short-term dryland cropping, sown pasture and native pasture soils are better suited to grazing.

* On soils recommended for cropping, long-term productivity is best maintained with rotation of crops to alternative crops, grain legume or grass and legume ley pastures. On soils recommended for ley and sown pastures, productivity is best maintained with rotation of pastures to a short-term farming phase.

* Irrigation systems can be used to reduce the impact of climatic risk on grazing and farming profitability where a suitable water supply is available.

* Development of land for sown pastures or for improved grazing production from native pastures requires careful attention to clearing strategies and management of regrowth and woody weeds.

1. INTRODUCTION

The main issues facing dryland and irrigated crop producers in Waggamba Shire are the need to prevent soil erosion, and maintain soil structure and fertility, particularly nitrogen fertility. Erosion losses under conventional farming techniques are of the order of 6 tonnes/hectare/annum and up to 50 kg N/ha are removed for every 2 t/ha of wheat grain at 15% protein. Continuous farming causes soil structural decline, particularly on the 'lighter', coarse textured soils.

The main long-term problems for the pastoral industry are woody weed regrowth, sown pasture productivity decline and the loss of palatable native pasture species. Animal production on sown pastures can decline to similar levels as on native pastures within 5 to 10 years of sowing on soils with low to moderate nitrogen levels, while large areas of mitchell grass and Queensland bluegrass have been degraded through overgrazing.

Diversification into both livestock and cropping enterprises effectively spreads the risk of variable returns due to unpredictable rainfall. Where suitable water supplies are available, irrigated crops, forages and pastures are effective ways to reduce the impact of drought on dryland crop and pasture production.

This chapter sets out for the soils of Waggamba Shire:

- suitable irrigated and dryland crop, forage and pasture species;
- crop, pasture and livestock management techniques for sustainable production; and
- the reasons for the recommended management practices given in Part B of this manual.

2. AGRICULTURAL SYSTEMS

Sustainable production requires that land use is effectively matched to land type (soil and site characteristics) with the flexibility to allow change as technology and economics change. The recommended land uses for Waggamba Shire are based on allocating soils for their optimum sustainable use for one of the following *agricultural systems*:

- Irrigated cropping or pasture
- Long-term dryland cropping
- Short-term dryland cropping
- Sown pastures
- Native pastures

The allocation of the soils to these agricultural systems is based on an evaluation of their physical and chemical properties, site conditions and other factors that influence land management for sustainable production. The reasons for these recommendations are discussed in Chapter 8. The soils most suited for irrigated cropping or pasture are given in Table 9.1. The soils suited for dryland cropping, sown pastures and native pastures are given in Table 9.2. Table 9.2 shows the optimum recommended land use for each soil but this does not preclude the use of the soils for other uses which are less intensive. For example, all soils are suitable for use as native pasture soils and only those ones identified as *native pasture - unsuitable for development* are unsuitable for any more intensive use such as sown pastures or dryland cropping. Also all soils suitable for dryland cropping are suitable for sown pastures, but those shown as *sown pasture* soils are not suitable for dryland cropping.

Table 9.1. Soils recommended for irrigated cropping or pastures

Agricultural system	Soils
Irrigated cropping or pastures	
- flood (cropping only)	Undabri, Kalanga, Kurumbul, Tandawanna
- spray (cropping), and flood or spray (pastures)	Yambocully, Oonavale, Jindabyne, Wondalli, Keetah, Marella
- trickle (cropping only)	Wondoogle, Wai Wai, Bengalla

Table 9.2. Soils recommended for dryland cropping, sown pastures and native pastures

Agricultural system	Soils
Long-term dryland cropping	Kurumbul, Tandawanna, Arden, Wynhari, Mt. Carmel, Tarewinnabar, Kalanga, Undabri, Wondalli, Calingunee
Short-term dryland cropping	Moruya, Murra Cul Cul, Yambocully, Oonavale
Sown pastures	Tarewinnabar shallow, Jindabyne, Weengallon, Flinton, Keetah
Native pastures - may be suitable for development for spray and trickle irrigation	Bengalla, Marella, Wondoogle, Wai Wai
Native pastures - unsuitable for development	Bendidee, Uranilla, Westmar, Flinton shallow, Karbullah, Yelarbon

Though irrigated agriculture is increasing in Waggamba Shire, the majority of the production is still based on dryland systems and is likely to remain so. Some soils are suited to a range of production systems provided management practices change to take account of the different land use requirements.

The management requirements of the soils, suitable crop and pasture species, tillage techniques, and agronomic and soil conservation management practices are discussed in terms of irrigated and dryland agriculture with reference to the five agricultural systems.

3. IRRIGATED AGRICULTURE *Des McGarry, David Venz and David Blacket*

Major irrigation expansion, primarily for cotton production, is occurring west of Goondiwindi to Mungindi along the Macintyre River, and in the associated Yambocully and Callandoon schemes, predominantly on the Undabri and Kalanga soils.

Expansion to the east of Goondiwindi is mainly on the Kurumbul soils. Some irrigated forage crops are also grown for livestock fattening and drought mitigation though this does not compare favourably with cotton in terms of profitability.

Some of the Yambocully and Oonavale soils west of Goondiwindi are being developed mainly for irrigation of lucerne, soybean, cotton and forage crops.

Flood, spray and trickle irrigation techniques are all used and are discussed in section 3.2.

3.1 Irrigated crop and pasture suitability

The crops, including forage crops, and pastures listed below are suitable for irrigated production. They are discussed in terms of soil and management requirements. Irrigated forage crops are grown for fattening, drought mitigation, maintenance of high value stud stock and greenlotting. Pastures can be irrigated for seed production, fattening and drought feeding. In comparison with crops, profitability is generally lower due to the costs of high nitrogen inputs and irrigation.

Crops

Cotton

- best suited to flood irrigation soils using furrow irrigation techniques
- capital intensive
- requires specialist management for establishment, nutrition, weed and insect control, irrigation scheduling, harvesting and marketing - the use of crop consultants is recommended
- ideal planting time is early October
- technical information is available in McCollum (in prep.), Daniels and Larson (1990) for management, and objective pest management advice from SIRATAC (a computer program available from the SIRATAC users group: Graham Sutton, Seed and Grain Sales, Moree)

Lucerne

- best suited to well drained soils of light to medium texture (such as Keetah, Kalanga, Kurumbul and Tandawanna) with pH 6.0 to 8.0
- susceptible to waterlogging
- best suited to spray irrigation but can be grown under flood irrigation
- further information is available in Thompson (1985) and Anonymous (1989)

Soybean

- best suited to flood irrigation soils but will grow elsewhere
- minor summer crop only in the district
- grown in rotation with cotton
- requires specialist management for planting, weed and insect control, irrigation scheduling and harvesting but easier to manage than cotton
- ideal planting time is December

Sorghum grain	-	suited to a wide range of soils
	-	easy to manage
	-	profitability low compared to other crops in most years
Mungbean/chickpea	-	suitable for the district but rarely grown
	-	susceptible to waterlogging

Note: Winter cereals are mainly grown on the flood irrigation soils with the purpose of drying out the soil profile following irrigated crops. They help to ameliorate subsurface structural problems caused by tillage and trafficking on wet soils.

Forage crops

Oats	-	the major irrigated forage crop in the district
	-	grows on a range of soils under both flood and spray irrigation
	-	requires nitrogen for best production
Ryegrass	-	suited to a wide range of soils under both flood and spray irrigation
	-	produces more forage than oats in most seasons
	-	requires more nitrogen than oats as well as better irrigation management
	-	both oats and ryegrass are often sown in mixtures with Haifa white clover, lucerne, medics, fescue or phalaris
Sorghum	-	best suited to flood irrigation
	-	high productivity requires high rates of nitrogen for production and improved protein levels
	-	suitable for greenlotting
	-	efficient grazing requires high stocking rates
Maize	-	suitable for flood irrigation
	-	suitable for greenlotting in association with feedlots
	-	maximum production requires high levels of nitrogen

Further information on the management of irrigated forage crops is available in McCollum (in prep.).

Pastures

Bambatsi panic	-	suited to flood irrigation soils
	-	suitable for both seed and forage production
Silk sorghum	-	suitable for flood irrigation soils using both furrow and border check systems
	-	suitable for spray irrigation on Yambocully, Oonavale and Jindabyne soils
Purple pigeon grass	-	as for Silk sorghum
Katambora rhodes grass	-	suitable for spray irrigation on Yambocully, Oonavale and Jindabyne soils
Perennial ryegrasses	-	persist for 2 to 3 years under flood and spray irrigation
	-	high nitrogen requirement
	-	produce best in winter and spring
	-	other suitable temperate species include phalaris, prairie and cocksfoot

Lucerne/medics
- suitable for flood and spray irrigation soils
- produce well in combination with grasses
- susceptible to waterlogging

Clovers
- suitable species are Haifa white, Clare subclover, Redquin and Persian clover
- suitable for winter spray irrigation

3.2 Flood irrigation

3.2.1 Suitable soils

Undabri, Kalanga, Kurumbul, Tandawanna

These soils occur on low sloping land and all have a high clay content. They have high water holding capacity with low rates of loss through deep percolation making them more efficient soils for flood irrigation than lighter textured, sandy soils. Management of these soils for sustainable production requires:

. effective land development including laser levelling and adequate water storage and reticulation;
. maintaining a suitable physical and chemical soil environment for optimum plant growth through the use of proper tillage techniques and application of soil amendments where necessary;
. minimising the risk of erosion and flood damage to crops; and
. applying sound agronomic management practices for crop production.

3.2.2 Irrigation techniques

Two techniques are suitable for Waggamba Shire:

. Furrow - requires land levelling to achieve effective drainage within the field and to permit excess water to be drained away; and

. Border check - requires intensive land levelling to ensure even grades with negligible sidefall which can lead to ponding. This system is used mainly for pastures and sometimes for forage crops. The grade should be steeper than for furrow irrigation as the dense pasture cover impedes water movement down the bay.

3.3 Spray irrigation

3.3.1 Suitable soils

Yambocully, Oonavale, Jindabyne, Wondalli, Keetah, Marella

These soils are marginal to unsuitable for flood irrigation due to soil and site characteristics. They are suitable for trickle irrigation. They are lighter textured soils than those suitable for flood irrigation except for Wondalli which is marginal for flood irrigation due to melonhole gilgai.

3.3.2 Irrigation techniques

The following techniques are suitable for Waggamba Shire:

. Centre pivot
. Lateral move

These both require land levelling to avoid ponding and to facilitate travel by the irrigator

. Fixed lines - Suitable for orchards and horticultural crops only

Spray irrigation should be applied as follows:

. low flow rates (7 to 9 mm/hour) to ensure maximum infiltration and reduce surface sealing due to drop impact (this also reduces a crust developing as the soil dries out after each irrigation cycle);
. maximum single applications of 30 to 40 mm for annual crops to reduce the risk of surface ponding and runoff. Applications of up to 100 mm are possible on lucerne and other pastures depending on the spray technique used; and
. use small droplet sizes through low to medium pressure sprinklers (170 to 350 kPa), preferably at night, to avoid winddrift and reduce evaporation loss.

3.4 Trickle irrigation

3.4.1 Suitable soils

Wondoogle, Wai Wai, Bengalla

These soils are all associated with major streams and are therefore close to reliable water supplies. Their lighter textures (sandy in the cases of Wondoogle and Wai Wai) make them ideally suitable for low volume trickle applications.

3.4.2 Irrigation techniques

Trickle systems can be semi-permanent, as in the case of orchards, and reusable, as for horticultural small crops. They can also be temporary, using cheaper forms of watering lasting only the life of the crop, as for high value crops like cotton.

They are expensive to install and maintain and have a high labour requirement.

3.5 Management practices for irrigated soils

Irrigated agriculture is a more intensive form of land use and often problems associated with soil limitations are more strongly expressed under irrigated than under dryland cropping conditions. Nevertheless, many management practices for the irrigated soils apply equally to management under dryland conditions as they relate to managing soil properties rather than managing the agricultural system itself. The major problems requiring attention are changes in surface soil condition and the development of subsurface compaction layers through using improper tillage or agronomic practices.

3.5.1 Structural damage

Wet clay soils have very low strength and can be readily compacted and sheared by using heavy machinery or tilling soil when it is too wet. This problem is most common on those soils recommended for flood irrigation. Damage can result as one or a combination of the following three processes:

. Compaction - soil is compressed, all of the large pore spaces are destroyed and infiltration capacity is reduced making conditions unfavourable for root growth.

. Remoulding - the shape of the soil is changed leaving a disturbed soil structure, few pores, poor infiltration and unfavourable rooting conditions. This happens when the soil is too wet.

. Smearing - remoulding creating a smooth surface occurs with the resulting smeared surface being impermeable to water.

Damage to soil structure by wet trafficking or tillage produces one or a combination of:

. cloddy seedbeds;
. platy or massive layers in the soil;
. smeared layers from tillage tools; or
. loss of the natural shiny faces on the soil structural units.

These effects on soil structure often show up as one or more of the following symptoms in the plants:

. L shaped or stumpy roots;
. yellow (waterlogged) plants after rain or irrigation;
. small, stunted plants; or
. thirsty plants requiring frequent irrigation.

Structural damage in cracking clay soils repairs itself up to a point as the soil dries out and cracks. The compacted layers are disrupted by deep cracks on drying and the blocks shatter when tilled. It is necessary to dry out the soil layers below 10 cm by growing a crop, provided the crop roots can penetrate below the compacted layer. If the crop has a 'dry finish' and successfully dries out the deeper soil layers, subsequent tillage will shatter the compacted layer.

To prevent structural damage on cracking clay soils;

- traffic and till when they are not too wet. (To tell if soil is too wet, take a handful of soil and knead it into a golf ball sized sphere using firm pressure. Roll out a 3 mm diameter rod of this soil on a flat surface. If the soil crumbles before a 3 mm rod forms, then the soil is safe to till. If a 3 mm or less rod forms, then the soil is too wet and needs to dry further before tillage occurs, or if further drying is not possible, then keep tillage to a minimum.

Note: This test must be done with separate samples down the soil profile to below the depth of tillage.)

- minimise tillage;
- control weeds with herbicides; and
- apply fertiliser by banding into hills when soil is relatively dry.

Where structural damage is inevitable, an alternative management approach is to contain the area of impact by retaining hills and *tramlining*. This restricts traffic to constant areas and, combined with minimal tillage practices, permits maintenance of good soil structure in the area between the tramlines.

3.5.2 Surface crusting

Surface crusting is a condition that develops when soils dry following surface sealing caused by drop impact by rain or irrigation on susceptible soils. This problem is most common on those soils recommended for spray irrigation. Improving organic matter content and protecting the soil surface against drop impact with cover (crop or stubble) help reduce this effect and maintain a good infiltration rate. A three to four year pasture phase will provide a short-term (3 to 4 years) solution using pastures recommended for these soils. The cropping phase should incorporate the following management practices:

. retention of crop stubble for as long as possible;
. double cropping when required;
. following harvest, primary tillage with chisel ploughs to enhance infiltration, followed by minimal tillage prior to planting the subsequent crop (use disc ploughs only to reduce stubble or avoid spreading nutgrass; use Lillistons to break surface crusts);
. tillage at optimum soil moisture levels;
. use of herbicides instead of secondary tillage for weed control;
. use of minimal disturbance disc planters or tined planters with narrow points when planting into moist soils;
. plant on the contour on sloping lands to reduce erosion;
. use of fertilisers to increase yield and improve stubble levels; and
. minimal number of inter-row cultivations.

3.5.3 Seedbed condition

Many of the soils in Waggamba Shire have dispersible subsoils at relatively shallow depth. These dispersible clays are due to high levels of exchangeable sodium. Deep tillage or excessive disc tillage, together with erosion can bring this dispersible clay to the surface where it has an adverse effect on seedbed conditions and plant growth.

Dispersible clay can also be incorporated in the surface soil through extensive land levelling, particularly of gilgaied soils.

Soil amendments such as gypsum can improve soil surface condition by replacing the sodium with calcium and improving soil structure. Only the soils recommended for flood irrigation have shown a response to treatment with gypsum.

4. DRYLAND AGRICULTURE

The majority of cropping in Waggamba Shire is dryland production. Rainfall, both amount and variability, is the major limitation to production. Therefore, the clay soils with a higher water holding capacity are best suited for minimising the impact of dry seasons on dryland crop and forage production. The impact of soil erosion, soil structural decline and decrease in soil nitrogen fertility on dryland crop production are the main long-term management problems.

Proper management of dryland soils thus requires managing the fallow period to maximise soil water storage, applying surface management practices that maintain soil structure, preventing soil erosion, and maintaining soil nitrogen fertility.

This section sets out the limitations and management requirements for the *long-term dryland cropping* and *short-term dryland cropping* agricultural systems. Soils suitable for use with each of these agricultural systems are given in Table 9.2.

4.1 Dryland crop and forage suitability

Crop suitability is discussed in terms of major and minor winter and summer crops of the district.

Although decisions on which crop to plant are often based on economics (grain prices), seasonal conditions and farmer preference, the suitability of crops and forages are considered in terms of soil and site characteristics below.

Major winter crops

Wheat
- best suited for long-term cropping soils and less suited for short-term cropping soils
- highest yield from early planting but the frost risk is high
- lower yield from later planting but risk of heat stress at maturation
- compromise is to plant varieties that flower in mid-August to mid-September
- plant fast maturing varieties late in the season on lighter textured soils
- high stubble yield provides good erosion protection

Note:
. Lower frost risk areas are the gently undulating country in the Weengallon, Daymar, Talwood, Tarawera, Lundavra, Billa Billa, Wyaga and Moonie districts; plant Mid-April to mid-May. Higher frost risk areas are the level alluvial plains associated with major rivers and creeks and the melonhole plains in the Moonie, Yelarbon and Wyaga districts, plant in May
. Detailed information on wheat planting times and nutrition is contained in WHEATMAN (1989)

Barley
- suitable for long-term cropping soils
- also suitable for short-term cropping soils where it generally yields better than wheat
- more frost tolerant than wheat
- plant in mid-April to mid-May
- suppresses winter weeds more effectively than wheat
- high soil nitrogen levels mostly prevent production of malting barley

Minor winter crops

Chickpea
- suitable only for long-term cropping soils
- requires moisture probe penetration to at least 90 cm
- as they are a low-growing crop, select areas free of sticks, stones and melonholes
- susceptible to *Phytophthora* root rot if waterlogged
- at present no registered herbicides for broadleaf weed control
- best yields from late-April to mid-May plantings and when zero tilled into winter cereal or sorghum stubble
- moderately frost tolerant
- require more intensive management for weed and insect control, and in harvesting than cereals

Grain oats
- best suited to long-term cropping soils but will grow on short-term cropping soils
- produced for seed and feed
- shedding can be a problem at harvest

Triticale/lupin
- better suited to acid soils of which there are few in the shire but will grow on long-term cropping soils
- yields highly variable; low yield with dry finish

Canola
- best suited to long-term cropping soils
- difficult to establish in coarse seedbed soils
- no registered herbicides for broadleaf weed control

Safflower
- suited to long-term cropping soils
- slower maturing than wheat and has higher water requirements
- plant mid-April to mid-May
- slow early growth affected by broadleaf weeds
- no registered herbicides for broadleaf weed control

Canary
- suited for long-term cropping soils
- needs moisture probe penetration to at least 90 cm
- long growing season
- difficult to establish in coarse seedbed soils

Other minor crops include linseed, rye, faba bean, field pea, fenugreek and lentil.

Major summer crops

Grain sorghum
- only recommended for long-term cropping soils
- needs moisture probe penetration to at least 90 cm which generally requires a long fallow
- plant in October in areas where there is a high frost risk and in September where there is a low frost risk
- yield potential is highest with spring plantings
- two to three seasons with chemical weed control help control winter weeds and crop diseases
- drought tolerant and more reliable than other summer crops
- provides valuable grazing of stubble and failed crops

Minor summer crops

Cotton
- suited to long-term cropping soils only where free from sticks, stones and melonholes
- needs moisture probe penetration to at least 90 cm; generally requires a long fallow from previous winter crop
- zero till into cereal stubble to reduce erosion risk
- best planted mid-September to October (but never later than mid-December)
- a crop consultant, harvesting contractor and marketing arrangements should be finalised before planting

Grain millets
- suited to long-term cropping soils only
- need moisture probe penetration to at least 90 cm
- difficult to establish in coarse seedbed soils
- less drought tolerant than sorghum as they are shallow rooted
- no registered herbicides for grass weed control
- plant in spring
- provide good summer ground cover for erosion protection

Sunflower
- best suited to long-term cropping soils
- opportunity crop for August-September planting
- moderate frost tolerance in seedling stage
- problems with establishment, plough pans, pest damage, weed control and drought
- poor protection against soil erosion so should be zero tilled into cereal stubble
- no grazing value

Mung bean
- suited to long-term cropping soils only
- plant in December-January
- select sites free of sticks, stones and melonholes
- need moisture probe penetration to at least 90 cm
- zero till into cereal or sorghum stubble to reduce erosion risk

- requires specialist management for insect control, harvesting and grain handling
- limited options for broadleaf weed control

Pigeon pea/maize
- both suited to long-term cropping soils
- Pigeon pea susceptible to *Heliothis* damage
- maize as an opportunity crop in August but has poor yield reliability

Winter forage crops

Oats
- suited for short-term cropping soils but also well suited to long-term cropping soils
- major winter forage in the district and the most reliable crop for fattening
- often grown as pioneer crop on newly developed land
- requires 4 to 8 kg/ha of phosphorus at planting for maximum production
- good regrowth after first grazing
- vetch combines well with oats to improve feed quality

Snail medic
- suited to both long-term and short-term cropping soils
- plant Kelson and Sava mixture at 5 to 10 kg/ha with oats to improve feed quality and compensate for quality decline if oats become rusted
- west of Talwood, replace at least one-third of mixture with barrel medics
- plant shallow

Barley/triticale/wheat
- suited to both long-term and short-term cropping soils
- similar forage quality to oats for first grazing but regrowth potential is poorer
- wastage with awned varieties
- slower maturing types produce more forage than faster types, but they are slower to first grazing

Summer forage crops

Forage sorghum
- suited to both long-term and short-term cropping soils
- higher forage yields and more drought tolerant than other summer crops
- may not properly finish livestock

Forage millet
- suited to long-term cropping soils only
- higher quality forage than sorghum but lower yields
- lower drought tolerance than sorghum
- difficult to establish in coarse seedbed soils
- popular with sheep and lamb producers
- hybrid *Pennisetum* types (Nutrifeed, Supermill and Feedmill) are unpalatable if moisture stressed and are less suitable for the district than the *Echinochloa* millets (Japanese, Shirohie and Siberian)

Lab lab
- suited to long-term and short-term cropping soils
- plant October to November to allow grazing before winter
- regrowth potential is good but slow to first grazing
- zero till into cereal stubble on a full soil moisture profile

Cowpea
- suited to both long-term and short-term cropping soils
- quicker to first grazing than lab lab but produces less dry matter and has poorer recovery

4.2 Management of dryland cropping soils

Effective soil management requires the land user to recognise those soil properties which affect crop and animal production, both directly and indirectly, and develop management strategies for sustainable production which minimise land degradation.

The main limitations to production in Waggamba Shire are plant available water, soil structure and fertility decline, particularly soil nitrogen decline and soil erosion. These limitations are discussed and appropriate management practices to overcome them are recommended.

4.2.1 Soil water

Successful cropping of both long-term cropping soils and short-term cropping soils requires strategies that maximise the storage of soil water and minimise losses through evaporation. The long-term cropping soils are capable of storing more soil water than the short-term soils as they have higher clay content. Planting a crop into a moist soil profile where the moisture probe will penetrate to at least 90 cm ensures a greater chance of successful crop production with normal rainfall. A comparison of the effect of differing amounts of soil water on yield for both long-term and short-term cropping soils is given in Table 9.3 based on simulations using WHEATMAN (1989). The amount of stored soil water is subjectively estimated by the depth to which a 1 m steel moisture probe can be pushed into the soil.

On average, only 25% of rainfall received during the fallow period is retained in the soil. More than 60% is lost through evaporation and the remainder is lost as runoff. An efficient fallow that maximises storage while minimising evaporation and runoff losses can best be achieved by:

- retaining post-harvest crop stubble for as long as possible to improve infiltration and reduce runoff;
- reducing or eliminating tillage during the fallow to minimise evaporation loss; and
- timely control of weeds, volunteer and crop regrowth to reduce evapo-transpiration losses.

4.2.2 Soil fertility

Soil fertility in the district is variable but some generalisations can be made about the major cropping soils based on their native vegetation community. The Kurumbul, Tandawanna, Arden, Wynhari, Mt. Carmel, Tarewinnabar, Wondalli, Calingunee, Moruya and Murra Cul Cul soils, which are associated with brigalow or belah communities, are naturally high in nitrogen. After 20 to 30 years of continuous cropping, however, these soils are likely to respond to legumes or the application of nitrogen fertiliser, particularly in wet seasons. They are low in phosphorus and an application of 4 to 8 kgP/ha (20 to 40 kg/ha of MAP or DAP) with grain and forage crops at planting is recommended. Under dryland cropping conditions, economic responses to the application of other nutrients is unlikely.

Table 9.3. A comparison of the effect of different levels of stored soil moisture on wheat yield for four dryland cropping soils in Waggamba Shire

Probe penetration in moist soil (cm)	Yield potential (t/ha)*			
	Long-term cropping soils		Short-term cropping soils	
	Undabri	Arden	Moruya	Oonavale
30	1.38	1.35	1.25	1.22
60	1.88	1.82	1.63	1.57
90	2.39	2.29	2.01	1.91

* Unfrosted yield potential for Hartog wheat in 80% of seasons, planted 15 May at Goondiwindi with no limits to crop nutrition

The Kalanga and Undabri soils (associated with coolibah vegetation), and the Yambocully and Oonavale soils have moderate to high phosphorus levels. Economic responses to applied phosphate on these soils are, therefore, less likely. In contrast, these soils are inherently low in nitrogen. Grain crops may respond to legume or nitrogen fertiliser input, particularly in wetter seasons. Zinc deficiency is possible on these soils where pH exceeds 8.0. Nevertheless, zinc deficiency is not a widespread problem in dryland cropping in the district.

Continuous cropping leads to rundown in the organic matter status of all soils in the district, but particularly with cropping of the short-term cropping soils. The use of pasture phases and cropping systems that retain maximum amounts of stubble to restore organic matter will help reduce the impact of the decline. The additional benefits include soil structure improvement and increased infiltration.

4.2.3 Surface management techniques

There has been a widespread trend to zero and minimum tillage in recent years owing to the proven benefits of soil conservation, moisture storage, weed control and timeliness of planting.

Soil erosion risk and soil structural decline increase with increased frequency of tillage. Reduced tillage is recommended to minimise these effects, particularly on the short-term cropping soils. The various benefits of the different tillage systems are discussed below.

Zero tillage (no-tillage). Tillage is limited to crop planting, and post-harvest stubble is retained. Weeds are controlled with herbicides and by grazing with sheep. Zero tillage reduces the risk of soil erosion in cropping systems.

Zero tillage is most suited on the long-term cropping soils where surface sealing and crusting are not problems and infiltration is reasonable provided sufficient stubble remains. Weeds are not a problem except for perennial vine weeds on the Kalanga and Undabri soils.

Minimum tillage or reduced tillage. This involves one or two tillage operations at some stage in the fallow combined with grazing or herbicides to control weeds instead of tillage. It is recommended on the short-term cropping soils and is also suitable on the long-term cropping soils. Minimum tillage is preferable to zero tillage where *urochloa*, barnyard grass and vine weeds are major weed problems. Grass weeds are generally a greater problem on the short-term cropping soils.

The short-term cropping soils generally produce lower stubble levels than the long-term cropping soils and have hard setting and surface sealing characteristics which lead to high runoff under zero or conventional tillage. Under these conditions, minimum tillage with one or two workings early in the fallow is likely to store more moisture.

Conventional tillage. This typically involves two primary workings with a chisel plough and one or two secondary tillage operations with a scarifier or cultivator. Post-harvest stubble burning is now rarely practiced.

Conventional tillage is only recommended when:

- developing new land for farming;
- rotating from ley pastures to crop;
- livestock have compacted the surface during wet conditions; and
- weed control is too difficult or expensive using herbicides or sheep.

Although conventional tillage can be used on all soils in Waggamba Shire, it increases the rate of soil structural degradation, exposes soil to higher erosion risk and is less efficient at storing fallow rainfall than minimum or zero tillage.

4.2.4 Crop/pasture rotations

Crop rotation with different crops or ley pastures benefits the crop, the pasture and the soil. Though rotations improve productivity there may be a short-term decline in production from the paddock during the changeover. This effect can be minimised by rotating the paddocks in stages. The type of rotation and its duration depend on the soil type. Other factors such as soil nitrogen status, soil structure, erosion risk, economic circumstances and the incidence of weed and disease problems also influence the type and duration of the rotation. The most common forms in the district are:

Long-term cropping soils

- cereal crops rotated with alternative grain and legume crops; or
- 2 to 3 years under pasture legume ley.

Short-term cropping soils

- cereal crops rotated with 2 to 3 years of forages; or

- 3 to 5 years under a grass and pasture legume ley.

Examples of rotations suitable for the long-term and short-term cropping soils are given in Table 9.4, and for the sown pasture and dryland cropping soils in Table 9.5.

Rotation options. A long fallow (eight months or longer) into and/or out of summer crop will be necessary in most seasons to accumulate sufficient stored soil water to ensure reliable yields. In particular, a long fallow will be necessary in most years when rotating from winter crop to grain sorghum, mungbean and dryland cotton (rotations 1, 2, 4, 5 and 6). A long fallow will also be necessary in many years when rotating from summer crop to winter crop or when the summer crop is planted in summer instead of spring (rotations 1, 3 and 7).

If soil water is quickly replenished through rainfall, double cropping (crop planted within three months of the previous crop harvest) is worth considering, such as in rotations 2, 3, 4, 5, 6, 7 and 8. This will help maintain an average frequency of one crop/year.

Grain and forage crop yields are more reliable if crops are zero tilled into the stubble of alternative crops (rotations 1, 2, 3, 4, 5, 6, 7 and 8). This can be on a long or short fallow, depending on soil moisture levels. When grain or forage sorghum is double cropped into cereal stubble on a stored soil moisture profile where probe penetration is more than 90 cm, nitrogen fertiliser is normally required to maximise yield (rotations 3 and 7).

Lab lab is a summer forage legume which should be planted separately to other forages to make grazing management easier (rotations 7 and 8).

Pure lucerne leys are particularly suited for sheep enterprises (rotations 5, 12, 13 and 14). Bloat risk in cattle can be minimised by planting a grass with lucerne (rotation 15). Lucerne establishment is generally successful when undersown with winter cereals (rotations 12 and 13). The main attraction of this method is the income from the grain crop, while the lucerne is establishing. Lucerne sown in autumn will generally establish more reliably, is a stronger weed competitor and will persist longer than lucerne undersown with cereals (rotations 5 and 14).

When rotating from lucerne to crop, a long fallow of 10 to 12 months duration is normally necessary to replenish soil water (rotations 5, 12, 13, 14 and 15).

Snail medic is recommended with oats to extend the duration of grazing in spring, provide insurance against rusted oats and provide nitrogen input (rotations 8 and 10). Snail medic can also be grown as a pure legume pasture ley for grazing and nitrogen input (rotations 5 and 11). The disadvantage of a pure medic stand is that, although nutritionally better, it cannot produce the same quantity of dry matter as oats under equal growing conditions. Snail medic will provide reliable production when grown on fallowed country where weed competition is low.

After three years or longer out of snail medic, re-seeding may be necessary where medic seed reserves have declined below the recommended 8 to 10 kg/ha of soft germinable seed.

Barrel and snail medics are recommended with grass pastures to improve the quality of the grazing diet in winter and spring and provide nitrogen input (rotation 16). Annual medics have variable production when grown with pastures due to variable winter rain and competition from summer grasses. Barrel medic persists longer than snail medic in this situation. Medics are ideally undersown with winter cereals prior to rotation to pastures or forages (rotations 10 and 16). Medics and lucerne are better undersown with winter cereals than with oats.

If country is being returned to longer term pastures, medics should be included in a mixture with lucerne. However, lucerne suppresses medics due to its competitiveness for soil moisture and as a result, provides the majority of forage yield in the short-term.

Better stands of purple pigeon grass are likely from January-February plantings such as in rotations 15 and 16, compared with those resulting from undersowing with winter crop or from planting in spring.

Soil erosion protection. Soil erosion risk is lower under pastures (rotations 12, 13, 14, 15 and 16) compared with crops.

Table 9.4. **(facing page)** a) Examples of crop rotations for long-term dryland cropping soils only (Rotations 1 to 6)
b) Examples of crop rotations for short-term and long-term dryland cropping soils (Rotations 7 to 16)

Note: Pastures and forages in italics means 'undersown with ...'

During the cropping phase, erosion can be minimised by retaining crop stubble in combination with soil conservation structures on sloping land. Zero tillage techniques maximise stubble cover. Winter cereals provide more stubble protection than other crops. Dryland cotton, mungbean and chickpea leave little surface stubble cover following harvest (rotations 1, 2, 3, 4 and 6).

In sequence, these crops leave country exposed for a longer period. Consequently in option 6, chickpea is recommended after wheat rather than after dryland cotton to minimise soil erosion risks. Country will also be exposed to higher erosion risks when forages, chickpea and grain sorghum stubble are grazed and fallowed back to crop.

Zero tillage of chickpea, summer crops and forages into wheat or barley stubble will reduce soil erosion risks. When soil water profiles permit, double cropping will also reduce exposure to soil erosion (rotations 2, 3, 4, 5, 6, 7 and 8). Avoid grazing chickpea stubble whenever possible.

Soil surface condition. The surface soil structure of short-term cropping soils can be maintained or improved by organic matter provided from at least 5 years of grass pastures (rotation 16). This will be reflected in an improvement in surface soil tilth and by a reduction in the surface sealing characteristics of the soil.

Lucerne, medics, grain legumes and crop stubble provide little benefit to surface soil structure compared with grasses but subsurface compaction layers can be reduced with pastures such as lucerne.

Weeds. Wheat monoculture has been a common practice in Waggamba Shire. This practice has led to high weed populations with heavy reliance on herbicides for control.

The cheapest form of weed control in cropping systems is by alternating sequences of winter and summer crop, and controlling weeds during fallows with herbicides, tillage or grazing instead of relying on the more expensive in-crop herbicides (for example the selective grass weed herbicides).

To adequately reduce weed seed levels and reliance on expensive in-crop herbicides, at least three consecutive winters fallowed out of winter or summer crop are necessary (rotations 1, 3, 13, 14, 15 and 16). Shorter durations will not normally control high weed levels without some use of herbicides (rotations 2, 4, 5, 6, 7 and 8). As weed seed levels decline, the duration of summer and winter crop sequences can be reduced accordingly.

There are limited herbicide options for controlling broadleaf weeds in grain legumes. Sheep can be used to graze weeds in chickpeas when chickpeas are young but if grain legumes are planted after a summer crop phase rather than before, less weed problems are likely (rotations 2 and 4).

In forage systems, forage crop rotations can provide reliable control of weeds, provided weeds are prevented from seeding (rotations 7, 8, 9, 10 and 11). Sheep will provide more effective weed control than cattle.

Ley pastures provide cheap and effective weed control, once established, through competition for moisture and grazing (rotations 5, 12, 13, 14, 15 and 16). The longer the pasture phase, the better the weed control. Established lucerne, purple pigeon grass and Silk sorghum are the best competitors against weeds.

A major problem with controlling weeds with ley pastures can be during the interchange phase from crop to pasture when pastures are establishing. Legume and grass pastures are poor weed competitors during this period and if weeds are not controlled a large weed seed set will occur. Consequently, when ley pastures are returned to cropping, weed seed levels will still be high, thus negating one of the fundamental aims of crop rotation. A more productive and competitive pasture generally results where weeds are controlled by herbicides during the establishment phase. This, combined with grazing after establishment, can reduce weed seed populations to manageable levels over a period of seasons.

Although lucerne is usually undersown with winter cereals such as in rotations 12 and 13, weeds are usually easier to manage if the lucerne is sown by itself (rotations 5 and 14). Grass and legume pastures can become weeds in the subsequent crop phase, for example medics, but these can be controlled with herbicides.

Nitrogen input. Pasture and grain legumes are the most economic way of restoring or maintaining soil nitrogen. Although fertiliser nitrogen improves grain yield and protein, economic responses are dependent on good seasons.

Nitrogen input from grain or pasture legumes or fertilisers eventually becomes essential in all farming systems, but it becomes necessary sooner with zero tillage than with minimum or conventional tillage. This is because higher yields remove more nitrogen when water storage is improved and the absence of tillage during the fallow reduces mineralisation of organic matter to provide available mineral nitrogen.

Legumes provide the most effective method of restoring or maintaining soil nitrogen on soils with low mineral nitrogen levels. Where soil nitrogen levels are high, legumes will use the available nitrogen for their own use, rather than fix atmospheric nitrogen. Nitrogen input from legumes is proportional to their dry matter production and in a dry season with low production levels, legumes will fix little nitrogen. Although nitrogen fertiliser will also provide nitrogen inputs, yield and protein responses are dependent on good seasons.

Lucerne as a pasture ley is normally the most effective legume for rebuilding soil nitrogen levels (rotations 5, 12, 13 and 14). Lucerne can fix 70 to 100 kg N/ha/annum on soils with low nitrogen levels. Increased wheat yields of 0.5 t/ha or more have been measured for 4 to 7 years after a 3.5 year lucerne ley on nitrogen deficient soils.

The duration of lucerne necessary to restore nitrogen to levels that will consistently produce wheat with prime hard protein, depends on the initial soil nitrogen levels. For example, if soil nitrogen is only moderately depleted, 18 months of good lucerne production should restore soil nitrogen (rotations 5 and 12). This will allow faster cycling of paddocks to crops compared with rotations 13 and 14.

Nitrogen input from medics is approximately equivalent to 1% of dry matter yield, which can range from 0 to 100 kg N/ha, depending on moisture availability and competition from other plants.

When snail medic is grown as a ley on fallowed country, either as a pure stand (rotations 5 and 11) or with oats (rotations 8 and 10), forage yield and nitrogen input are more reliable. Nitrogen input from a pure snail medic stand grown on fallowed country is typically in the order of 50 to 80 kg N/ha. When grown with pastures, medic production and nitrogen input are more variable and are typically in the order of 20 to 40 kg N/ha/annum (rotation 16).

Grain legumes such as chickpea and mungbean also fix atmospheric nitrogen but as nitrogen is removed in grain, they are unlikely to rebuild soil nitrogen levels to the extent of lucerne or medics. Winter grain legumes will normally provide more reliable production and consequently nitrogen input than summer grain legumes.

Diseases. Disease cycles generally increase under monoculture cropping. Rotation to alternative crops or ley pastures will minimise the potential for disease to reduce crop yields. This is particularly important in zero tillage programmes where stubble-borne diseases such as yellow spot can reduce wheat yields in wet seasons.

Some diseases can be transferred between different crop species. For example, barley hosts common root rot and crown rot which affect wheat. Wheat should not be planted for at least two years on country infected with these diseases. Medics and lucerne host *Phytophthora* root rot which can infect subsequent chickpea crops.

Chickpea should not be planted for four years on country which previously grew chickpeas, lucerne or medics. Medics and lucerne do not host winter cereal crop diseases such as yellow spot, common root rot, crown rot and the rusts.

5. SOWN PASTURES

Introduced grass or legume pastures will grow best on the long-term cropping soils but are also suited to the short-term cropping and sown pasture soils. They are sown after land development or following scrub pulling and burning where the ash creates a favourable seedbed. They are sown instead of the native pastures as they have the following advantages:

- Better production response in the early years while the extra nutrients mobilised through tillage or from the burnt timber remain available. Without additional fertiliser application, annual production eventually declines to levels similar to that of native pastures.
- Longer feed availability, better quality and more standover feed in autumn and winter than native pastures. This helps with drought management. When combined with winter legumes, introduced pastures provide higher weight gains in winter and spring.
- Better persistence under higher grazing pressures.

- Generally improved palatability.

- Availability of seed and generally cheaper seed costs than for native pastures.

- Less wool contamination; for example, when replacing speargrass or wiregrass with buffel grass.

If none of these benefits are likely, there is no reason to replace existing native pastures with introduced species. Pastures can be difficult and expensive to establish and can tie-up country for 12 months or longer before grazing is possible.

5.1 Soil suitability

The soils suitable for sown pasture production under dryland conditions are:

> **Tarewinnabar shallow, Jindabyne, Weengallon, Flinton and Keetah** (plus all the long-term and short-term dryland cropping soils);

and those suitable for irrigated pasture production include:

> **Yambocully, Oonavale, Jindabyne, Wondalli, Keetah and Marella** (plus flood and spray irrigated soils).

5.2 Suitable pasture species

The selection of the best pasture species requires matching the characteristics of the species available with soil type and the needs of the agricultural system proposed. Key points to consider include:

. *The dominant soil type and fertility level.* The suitability of introduced grass and legume species to the soils of Waggamba Shire is given below and summarised on the soil summary cards in Part B.

. *The need for a ley pasture of two to four years duration, or a longer term pasture.* Persistence will be modified by nitrogen availability, grazing pressure and drought. When grown on suitable soils at recommended stocking rates, pastures normally persist in a productive state as follows:

Pasture type	Persistence
Lucerne, Silk sorghum, snail medic	2 to 4 years
Rhodes grass, green panic	4 to 6 years
Purple pigeon grass	5 to 10 years
Bambatsi panic, Premier digit grass	10 to 20 years
Native pastures, buffel grass, creeping bluegrass, barrel medic, serradella	more than 20 years

. *The effects of drought and waterlogging.* Buffel grass and Bambatsi panic tolerate drought best. Bambatsi panic is the only drought tolerant species that will also survive prolonged waterlogging in flooded areas, swamps and melonholes.

. *Expected establishment problems.* Silk sorghum, purple pigeon grass and lucerne are recommended for clay soils with coarse structure such as Undabri and hard setting soils such as Murra Cul Cul and Yambocully.

. *Erosion risk.* Katambora rhodes grass or Silk sorghum provide the most rapid cover and soil protection in erosion prone areas for all soils although rhodes grass can be difficult to establish on coarse structured clay soils such as Undabri.

. *The need for a pasture mixture.* Pasture mixes are only suggested in the following situations:

  - to minimise bloat risk in cattle, sow Silk sorghum or purple pigeon grass with lucerne;
  - when establishing new grass pastures, include medics;
  - in gilgaied areas (Wondalli and Calingunee soils) sow Bambatsi panic and purple pigeon grass as Bambatsi panic grows well in the depressions and purple pigeon grass colonises the mounds; and
  - where clay soils and lighter textured soils occur together, a mixture of buffel grass with either Bambatsi panic or purple pigeon grass may suit.

5.2.1 Tropical pastures

Tropical grasses are better adapted to the climate in Waggamba Shire than temperate grasses. They produce feed in the warmer months of spring, summer and autumn when rainfall probability is highest. Tropical legumes such as leucaena and stylos are difficult to establish and will not persist because of drought and frost.

Buffel grass is the main introduced pasture species grown in the western half of the Shire. It is most suited to loamy soils associated with poplar box vegetation. It will also grow well on long-term dryland cropping soils such as Kurumbul, Tandawanna, Arden, Wynhari and Mt. Carmel. It will grow on sandy loam soils such as Marella, Wondoogle, Wai Wai and Bendidee where rehabilitation is necessary, but will not persist on clay soils such as Tarewinnabar, Kalanga, Undabri, Wondalli and Calingunee.

Bambatsi panic is well suited as a longer term species on the Tarewinnabar, Kalanga and Undabri soils, but establishment problems may occur. It will establish with greater reliability on the Kurumbul, Tandawanna, Arden, Wynhari, Mt. Carmel, Wondalli and Calingunee soils. It will also grow on loamy soils such as the Moruya and Weengallon soils but will not persist as well as buffel grass. Bambatsi panic will survive prolonged waterlogging. It has the best frost tolerance of the tropical grasses and is second only to buffel grass in drought tolerance. Being slow to establish, it is a poor weed competitor during the establishment phase.

Bambatsi panic can cause photosensitisation in sheep and goats. This is mostly likely in young animals and when the panic is reshooting.

Purple pigeon grass is best suited on the Undabri and Kalanga soils with coarse structured surfaces which cause establishment problems with other grasses. It will persist for up to 10 years in the eastern half of the Shire on the clay soils with good moisture holding capacity. It will also grow on the short-term dryland cropping soils but does not persist as long. It is susceptible to drought on the lighter textured soils.

Purple pigeon grass has been recommended for undersowing with winter crops, but summer sowings are more successful. It competes well with weeds during the establishment phase.

Silk sorghum is a short-term perennial sorghum most suited to the long-term dryland cropping soils. It will also grow on the short-term cropping soils where production is less and persistence shorter. It provides faster grazing and surface protection than other grasses though productivity declines after its first full year of production. The rate of decline will depend on nitrogen fertility and grazing pressure. It will not survive summer droughts, but can regenerate from self-sown seed.

Rhodes grass is suited on hard setting, short-term cropping soils such as Murra Cul Cul, Yambocully and Oonavale. Rhodes grass will also grow on the long-term cropping soils but it is difficult to establish on clay soils with a coarse surface structure such as Undabri. Katambora rhodes grass is recommended on these soils. Pioneer rhodes grass is suited on the Keetah soil and can be used to rehabilitate the Bengalla, Marella and Bendidee soils. Rhodes grass can persist for up to 6 years but it will not survive drought conditions. Its creeping stems make Rhodes grass the best grass for soil stabilisation, and Katambora is used as a waterway grass.

Creeping bluegrass and **Premier digit grass** are suited to low fertility sandy soils such as Keetah, and can be used to rehabilitate Marella, Wondoogle, Wai Wai, Bendidee and Uranilla soils. They are susceptible to drought and only moderately suitable on long-term and short-term cropping soils. They will die out during droughts.

Green panic requires fertile soils, high summer rainfall and moderate grazing pressures for persistence. It is suitable for cropping soils such as Kurumbul, Wynhari, Mt. Carmel, Wondalli and Calingunee, but normally only persists for 4 to 5 years, except under shade trees. Green panic survives well under shade trees on Keetah, Marella, Wondoogle, Bendidee and Uranilla soils where it has potential as an understorey pasture component of reafforestation programmes.

African star grass is well suited for stabilising waterways on clay soils, but must be planted from runners.

5.2.2 Temperate pastures

Temperate grasses such as ryegrass, phalaris, prairie, Demeter fescue and cocksfoot are only moderately suitable except under irrigation. They need an average rainfall greater than 750 mm/year with a high winter component. Temperate legumes are better adapted to Waggamba Shire than tropical legumes. They consist of both perennial and annual regenerating species. Serradella and vetch are the only species in this group that will not cause bloat in cattle.

Lucerne is a short-term perennial ley pasture legume best suited to the neutral to alkaline dryland cropping soils that are not subjected to flooding or waterlogging. It is only moderately suited to the loamy short-term cropping soils and the Keetah soil. Lucerne will not persist under continuous stocking or drought. It must be planted shallow. Detailed information on lucerne agronomy can be found in Thompson (1985) and Anonymous (1989).

Medics are annual regenerating legumes which are productive in winter and spring. The barrel medics Paraggio, Cyprus, Jemalong and Sephi are best suited in combination with longer term grass pastures. The snail medic varieties Sava and Kelson are best suited as annual forages in combination with oats or in rotation with grain crops. Medics will produce best on the neutral to alkaline (pH 6.5 to 8.0), clay, long-term dryland cropping soils not subjected to flooding and waterlogging. A mixture of Paraggio, Sephi, Jemalong and Snail medic are recommended on these soils. On the loamy short-term cropping soils and sown pasture soils, a mixture of Paraggio and Cyprus is most suited.

Medics are best undersown with the winter crop preceding rotation to pastures. They are difficult to establish by oversowing into established pasture stands. Once hard seed is set, medics will persist for many years. They respond well following tillage. Medic production is low in dry winters, unless grown on a fallow. They will die if waterlogged. High levels of summer grass pasture growth will also suppress medic production. Detailed information on medics can be found in Weston *et al.*(1989).

Serradellas are annual regenerating legumes which are productive in winter and spring. They are suited on sandy soils of neutral to acid pH with a rainfall requirement in excess of 650 mm/year. They will not tolerate waterlogging. At present they are considered only to have limited suitability in the shire. They are more likely to persist in the eastern half of the shire because of higher winter rainfall. The serradella mixture should comprise 70% of the variety Madeira and 30% of the variety Slender. They should be surface sown in autumn.

Clover species will not persist except under irrigation.

5.3 Pasture management

Seed must be allowed to set before grazing newly established pastures. Annuals, such as medics, should be spelled at flowering to allow seed set. As Silk sorghum, purple pigeon grass and lucerne establish more reliably, they can normally be lightly grazed within the first year of establishment provided growth is satisfactory.

Grazing management subsequent to establishment is the first major factor determining pasture persistence. The long-term survival of pastures depends on the replacement of older plants with regenerating seedlings. Pastures must be allowed to seed periodically to achieve this. Heavy continuous stocking will inhibit this cycle and lead to deterioration of the stand. Heavy grazing during dry and drought periods will further accelerate pasture thinning.

As an alternative to set stocking, rotationally graze or spell pastures every one or two years to allow seeding and replenishment of root reserves. A six week spell in early summer, after rainfall, is ideal for summer grass pastures while autumn is the best time to spell lucerne. In practice, it is best to graze native pastures earlier in summer and use the introduced grasses later as introduced grasses hold their quality longer and provide more standover feed than native pastures. Stocking rate guidelines are listed in part B of this manual and discussed in Chapter 10.

Nitrogen availability is the second major factor affecting productivity and persistence of pastures. The inherent soil nitrogen levels will determine initial pasture production levels. For example, higher pasture productivity can be expected for a longer period from a fertile long-term dryland cropping soil such as Arden compared to a less fertile sown pasture soil such as Weengallon.

Rainfall and soil moisture availability are the third group of major factors affecting pasture productivity and persistence.

Pasture renovation. During development of long-term and short-term cropping soils and sown pasture soils, burning, stick raking and tillage stimulate mineralisation of nitrogen. The resulting 'runup' in plant available mineral nitrogen contributes to better grass pasture growth and livestock weight gains (Figure 9.1).

This is followed by a 'rundown' in pasture and animal production as nitrogen becomes immobilised (N tie-up) in grass root organic matter (Figure 9.1). This is recognised by thinning of the stand, poor growth after rain, and reduced seed production. After several years, an equilibrium is reached where available nitrogen, rather than water, limits animal production to similar levels to that from native pastures.

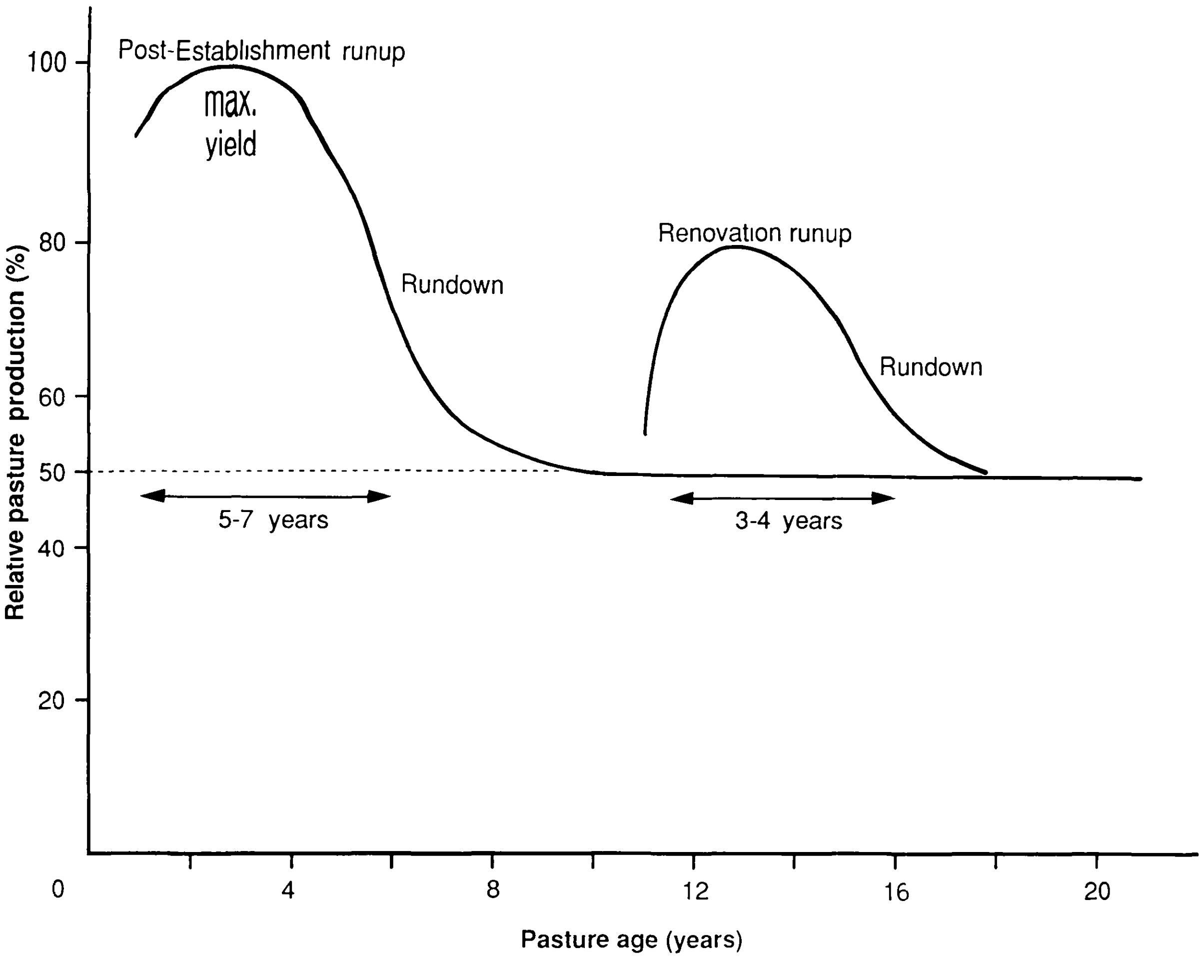

Figure 9.1. A typical pasture production response from ageing buffel grass growing on a moderately fertile soil (T.W.G.Graham, Pasture Management Branch, Roma, personal communication, 1990)

The following options can be used to improve pasture growth rather than accept the lower production equilibrium:

- **Pasture legumes** - the use of legumes such as medics will slow the rate of decline and slightly increase the eventual equilibrium level of pasture production but they will not provide sufficient nitrogen to maintain sown pastures at their initial runup levels of production.

- **Nitrogen fertiliser** - nitrogen applied at high rates can maintain grass and seed production at high levels but the expense can only be justified on irrigated pastures or seed plots.

- **Tillage** - A single tillage operation can improve feed quality for a short period but it rarely provides lasting benefits to grass production.

- **Short fallow** - A short fallow involving severe mechanical disturbance is the only way to significantly accelerate root decomposition and fully release nitrogen. A three month fallow can increase grass yield by up to 80% maximum yield over a 3 to 4 year period (Figure 9.1).

A fallow involving at least three workings commencing with a heavy disc or chisel ploughing is necessary to effectively renovate pastures and control woody weeds (Table 9.5 rotation 17). Renovation can be undertaken during winter and spring, prior to summer pasture growth. If pastures are allowed to set seed during the autumn preceding renovation, re-seeding should not be necessary following renovation. A renovation in summer is likely to release more nitrogen than winter renovations.

Pasture renovation frequency will depend on the rate of rundown and woody weed invasion. For example, on more fertile soils, a mechanical renovation may only be necessary every 10 years. On older or less fertile pasture country a mechanical renovation may be necessary every five years to maintain pastures at higher levels of production. With wattle invasion, a farming phase may also be necessary every five years.

Table 9.5. Examples of pasture rotations on sown pasture soils and dryland cropping soils

Year	1	2	:	8		9		10	11	
Season	Winter	Summer		Winter	Summer	Winter	Summer	Winter	Summer	Winter
Rotations 17	oats and *medic*	grass and medic ——→		fallow	repeat pasture					
Rotations 18	oats and *medic*	grass and medic ——→	——→	——→	——→	——→	fallow	oats		[REPEAT]

The duration of the renovation period will depend on the severity of woody weed invasion, soil erosion risks and forage requirements. Other methods of woody weed control using weedicides, burning and stick raking do not stimulate nitrogen release.

Additional information on pasture renovation is given in Cavaye *et al.*(1989).

Pasture rotation. Examples of pasture rotations suitable on sown pasture soils and cropping soils are given in Table 9.5.

6. NATIVE PASTURES *Richard Silcock*

Most of the grazing in the shire is on native pastures. The best native species are rarely out-produced in the long-term by unfertilised introduced pastures but unpalatable species inevitably increase under continuous grazing in the absence of other factors such as herbicides, fire and flood. Heavy stocking removes the option of fire and increases the bad effects of droughts.

6.1 Pasture plant types

The plants in native pasture can be classed into three major groups:

- woody trees and shrubs;
- perennial grasses and herbs; and
- annual grasses and herbs.

Tree management needs long-term planning. Trees must be managed sensibly; complete removal can sometimes be catastrophic in its implications. Timber management is discussed in the following section and in Chapter 11.

Perennial grasses are the key to productive and stable native pastures and they will respond to good management.

Annual grasses and herbs are difficult to manage predictably because their germination and growth are controlled strongly by climate.

Grasses differ fundamentally from shrubs, herbs and legumes in their root structure and chemical composition. Legumes behave like other herbs except that they can fix atmospheric nitrogen and hence may have higher protein content on less fertile soils.

6.2 Native pasture management

Points to remember when managing native pastures:

- Native pastures produce over 80% of their annual yield during summer;
- Grasses respond best to summer rain;
- Late summer rain promotes prolific grass seeding;
- Winter rainfall will not break summer pasture droughts;
- Winter rains favour woody weeds, burrs and medics;
- At least two consecutive good seasons are necessary to renovate a thin pasture stand;
- Dense timber cover reduces grass growth;
- Vigorous grass growth suppresses tree and shrub seedlings;
- Cattle and kangaroos prefer grass to herbs;

- Only hot fires suppress regrowth of trees and shrubs, and insufficient use of fire in pasture grazing programs will contribute to timber regrowth problems; and

- To grow sufficient fuel for hot fire do not graze for one productive grass growing season before burning.

Note: Each March/April, the following steps should be taken for effective pasture management for the coming year:

- Aim to promote perennial grasses;

- Do not burn in spring if restoring perennial grasses;

- If young regrowth is visible, spell to encourage grass growth and burn in early summer; and

- Allow grasses to seed after clearing, burning or severe drought before rebuilding stock numbers. A six week spell following summer rain is usually long enough. This is particularly important on poorly grassed paddocks.

6.3 Native pasture condition

Climate and soil broadly determine the sort of pasture growing in Waggamba Shire. The major factors that determine the condition of the pasture are:

. basal cover;
. dry matter yield; and
. relative abundance of key species.

Appendix IV lists the key species currently found in each of the LRAs in the shire and gives a guide to what constitutes good, fair or poor pasture condition. Other notes about weeds and plant cover are included.

6.4 Native pasture composition

Native pastures are a mixture of grasses, woody plants and non-grass herbs. The proportions fluctuate with seasonal conditions and with disturbance. A grazier's task is to keep those fluctuations within acceptable bounds so that his stock, his pastures and his country are healthy. Healthy native pastures contain many species and are well buffered against dramatic changes in composition caused by grazing.

The pristine or 'original' state of native pastures is not necessarily the best for animal production. Appendix IV gives guidelines on what a good native pasture stand should contain on the major soils in the shire, and what constitutes good, fair and poor pasture condition.

Pasture composition can vary significantly without detriment to its condition or animal production. Grass is grass provided it is green and eaten. For example, leaf of windmill grass is just as good as buffel grass leaf. Similarly, rhynchosia pea leaf is of similar feed value to lucerne leaf and is not known to cause bloating. Agronomically, though, there are big differences between the species quoted which makes the value of sown pasture species very different. But in an existing mix they are all valuable to stock.

The big differences in feed value lie between:

- grasses and non-grasses;
- green grass and dead grass; and
- grass leaf and grass stem.

Composition becomes important when pastures differ widely in either the proportion or the total amount of each. Wiregrasses have a notoriously low proportion of leaf to stem. Stem is much less digestible. Frosted or senescent grass leaf has less than half the digestibility of green leaf while differences between comparable species in fresh green leaf digestibility are normally of the order of only 5 to 10% (spinifex and irongrass excepted).

Grazing management to encourage leafiness, or more legumes as opposed to grasses, is thus a more potent tool in influencing animal nutrition than management aimed at replacing 10% of mitchell grass with, say, Bambatsi panic. Most potent by far, are the effects of rainfall and frosts. Nevertheless, a pasture consisting of 90% whitespear or wiregrasses is greatly inferior to one of 90% mitchell grass because intake of digestible dry matter (palatability x digestibility) would probably be 50% less.

7. CLEARING AND MANAGING WOODY PLANTS

7.1 Property planning for clearing

Timber must be cleared when developing country to allow crops to be planted and pastures established, or to open up densely timbered native pasture areas to facilitate stock management and improve grazing potential. Many of the areas of arable soils in Waggamba Shire have already been cleared for cropping and pastures though not necessarily appropriately, given the present state of knowledge with regard to land degradation. In some areas, replanting and rehabilitation are required where clearing has caused erosion or other damage. Where clearing has not occurred, the following principles should be considered when preparing a property development plan to avoid unwise clearing that could lead to land degradation:

- prepare a map of the area to be cleared identifying land resources, drainage lines, infrastructure and other impediments to development such as rock outcrops;

- identify the areas to be cleared for cropping or pastures in relation to the distribution of suitable soils as recommended in Tables 9.1 and 9.2;

- incorporate shadelines in the property plan, laid out according to wind direction and of a width sufficient to ensure their survival through natural regeneration. These shadelines can function as wildlife corridors through the property when properly laid out. They can also act as shade for stock and assist in stock movement when located adjacent to but separated from fencelines.

- do not clear on a face, ignoring areas that should not be cleared, as this will cause management problems in the future. This may require marking out of areas that are to be left; and

- do not clear timber along streams and retain belts at least 20 m wide either side of the stream.

Timber clearing guidelines are outlined in Chapter 11 and Chapter 12 with additional information available in Burrows *et al.* (1988).

Initial clearing is only the first step in the process of developing land for farming or introduced pastures, and management should incorporate strategies to deal with the subsequent regrowth problems that inevitably arise. The following sections discuss effective means for clearing and managing regrowth without causing further degradation.

7.2 Initial development of country

Clearing timber and development of land is a prerequisite for farming or for the planting of introduced pastures. Clearing and development typically involves scrub pulling, stick raking, pin wheel raking, and heavy discing. Alternatively, introduced grass and legume pastures can be sown after burning of pulled timber on long-term cropping soils, short-term cropping soils and sown pasture soils (Table 9.2). This typically involves scrub pulling and aerial seeding.

Clearing or selective thinning is necessary for introduced pasture development on long-term cropping soils, short-term cropping soils and sown pasture soils. Most native pasture soils (Table 9.2) are unsuitable for development and should not be cleared. Several important points need to be considered when clearing and developing timbered country:

- Develop the best soil first. These soils have the highest productivity and will provide the fastest return on your clearing investment.

- Do not clear more than can be adequately managed. There is no substitute for properly developing long-term cropping soils and short-term cropping soils with a three year farming phase, to facilitate subsequent cropping, pasture production, pasture renovation and mustering. Pioneer forages, such as Silk sorghum, and annual forages such as oats, are often planted in the initial years of development but grain crops generally provide the fastest return on development costs.

- The initial costs of scrub pulling and burning are low compared to the subsequent costs of development for farming, regrowth control and erosion control.

- When considering clearing techniques on soils designated for pastures, also consider regrowth consequences. For example, pulling will usually promote severe regrowth. In contrast, selective clearing of open timber with chemical treatment or ring barking will stimulate less regrowth.

7.3 Timber regrowth control

Woody weed regrowth is a perpetual and costly problem following clearing of the original community. Species that commonly cause regrowth problems are listed in Tables 9.6 and 9.7.

Key considerations in regrowth control involve:

- Early recognition of the problem. Chemical or mechanical control are more effective when woody weeds are 0.2 m high compared with 2 m high. Unfortunately control is usually left until woody weeds are large.

Table 9.6. Potential regrowth on cropping and sown pasture soils

Soil	Major potential regrowth
Kurumbul, Tandawanna, Arden, Wynhari, Mt Carmel, Wondalli, Calingunee, Moruya	- brigalow, limebush, false sandalwood, belah
Kalanga, Undabri	- coolibah, river red gum, myall, belah
Tarewinnabar, Tarewinnabar shallow	- minor or no regrowth
Murra Cul Cul, Yambocully, Oonavale, Jindabyne	- poplar box, false sandalwood, wilga
Weengallon, Flinton	- poplar box, false sandalwood, silver leaved ironbark, wattle, shrubby acacias, cassias
Keetah	- poplar box, silver leaved ironbark, river red gum, carbeen

(Source: J. Burgess, QDPI, Goondiwindi, personal communication, 1990)

Table 9.7. Potential regrowth on native pasture soils unsuitable for development

Soil	Major potential regrowth
Bengalla*	- poplar box, silver leaved ironbark, river red gum
Marella, Wondoogle, Wai Wai	- poplar box, cypress pine, river red gum, carbeen
Bendidee, Uranilla, Westmar soils, Karbullah	- bull oak, cypress pine, wattles, rusty gum, narrow leaved ironbark
Flinton Shallow	- poplar box, false sandalwood, silver leaved ironbark, wattle, shrubby acacias, cassias
Yelarbon	- minor regrowth of bull oak and tea-tree

* Selective clearing using chemicals or ring barking possible
(Source: J. Burgess, QDPI, Goondiwindi, personal communication, 1990)

- Maintenance of a vigorous summer pasture. This will reduce establishment from seed and growth rate of woody weed seedlings, and enable burning of untreated regrowth in the first two years of regrowth establishment. Summer grass growth provides more competition against woody weeds than autumn growing pastures.

- Removal or killing of regenerative parts of woody weeds. For example, three years of farming or a heavy duty blade ploughing are the best methods of removing the lignotubers of false sandalwood and eucalypts, and the roots of brigalow and limebush.

Dry summers and wet autumns are ideal for woody weed establishment. Another consequence of dry summers is that they produce insufficient fuel for good regrowth control through burning. Where cattle replace sheep, regrowth of more palatable woody weed species also increases.

7.3.1 Methods of timber control

Appropriate methods of controlling particular species are outlined in Pressland *et al.* (in prep.) and the normal methods of timber control are discussed briefly below.

Non-chemical control

- Scrub pulling is used in virgin timber or older regrowth on long-term and short-term cropping soils and sown pasture soils. It is most effective when trees are large and the soil is wet. If the ground is dry, trees will break off, resulting in more severe regrowth. It is important to ride with or ride ahead of bulldozers to ensure shade lines and shade trees are left standing. Re-pulling is used to control 2 to 4 m high regrowth though this will only delay the problem for a short period and must be followed with more effective control measures. It is preferable to control regrowth with other techniques before it becomes necessary to re-pull.

- Stick raking is used primarily to relocate pulled timber into windrows for burning or to relocate residual burnt timber into piles for further burning. False sandalwood regrowth can be controlled with light stick raking if done under moist soil conditions. Stick raking provides poor control of most species, as they break off below ground level and regrow.

- A three year farming phase on long-term and short-term cropping soils and sown pasture soils is the most reliable method of controlling regrowth after initial clearing. Primary tillage should be deep enough to kill roots and lignotubers. A farming phase is the most reliable way to introduce sown pastures.

  Further farming phases in pasture country will be necessary every ten years or so, to control subsequent woody weed regrowth. The frequency of farming intervals will depend on the rate of woody weed invasion and pasture renovation requirements, as described in section 5.3. The rate of woody weed invasion will depend on the degree of initial control, species, seasonal patterns, how often fire is used and grazing management strategies.

- Heavy duty blade ploughs with root lifters are capable of controlling regrowth up to 4 m high with a single 20 to 30 cm depth pass. They are the most effective implement for killing roots and lignotubers and removing stumps. Blade ploughs are more efficient where melonholes are not common.

- Heavy duty offset discs can control regrowth less than 2 m high, provided country has been previously stick raked though they are usually less effective than blade ploughs. Two passes at 15 to 20 cm depth are generally required for effective regrowth control.

  Pioneer grasses such as Silk sorghum can be directly seeded behind blade and offset disc ploughs. Because these implements leave the soil in an extremely rough condition and the country has not been fallowed to store rainfall, there is a higher risk of pasture establishment failure. The surface is difficult to muster or travel on for 12 months after deep ploughing. A scrub pulling chain dragged over the surface after blade ploughing can reduce this problem.

- Fire reduces woody weed regrowth. Though fire does not kill the root systems or lignotubers of woody weeds, it destroys the above ground plant and allows short-term pasture regeneration and competition. Fire stimulates wattle regeneration. It is most effective when regrowth is less than 0.5 m high and can be used in conjunction with woody weedicide applications. Following fire, young regrowth is more susceptible to chemicals than mature regrowth and better coverage of foliage is possible.

  The effectiveness of fire is often limited because of insufficient grass fuel to carry a hot burn during the summer months. To generate sufficient grass fuel, country must be destocked for at least 12 months during a good grass producing season.

- Heavy grazing with goats can suppress regrowth of unpalatable species such as brigalow, wattle and coolibah. High stocking rates are required and goats should be spelled on alternative pastures for equal periods of time to regain condition. Grazing with goats is more effective following a hot burn where the tips of saplings are burnt and where regrowth height is less than 1.5 m. More effective regrowth control is likely if goats are used in combination with other regrowth control measures.

- Heavy grazing with merino wethers will also only suppress regrowth of unpalatable species. The suckers must be heavily stocked as soon as they appear after burning or cropping. The sheep must be moved to good quality forage to regain lost condition. The costs include a loss of wool production, labour, subdivisional fencing and degradation of pasture species. An alternative system is to stock at lower rates and supplement with protein. Grazing woody weeds with sheep merely delays the problem and should be followed with more effective control measures.

Over a period of time, goats and sheep at lower stocking rates will effectively suppress regrowth of palatable species.

- Slashing is occasionally used to delay regrowth though very few species are killed by this method.

- Ringbarking provides individual treatment of virgin timber or older regrowth. It is an option in lower density communities where the cost does not exceed that of pulling and burning. Some species such as poplar box will require sucker treatment after ringbarking. Ringbarking does not allow the introduction of improved pastures unless followed by development. It is often difficult to obtain suitable labour for ringbarking.

Chemical control

Chemicals provide effective control of many species and are particularly useful where mechanical control of woody weeds will expose soil to excessive erosion or degradation. Woody weedicides do not assist in the establishment of introduced pastures unless treatment is followed by development.

The main methods of chemical treatment are:

- overall spraying - high and low volume;
- basal bark treatment;
- cut stump treatment;
- stem injection; and
- soil treatment - overall or spot spraying.

The most suitable method of application will depend on factors such as:

- available equipment;
- the area requiring treatment;
- weed growth stage;
- the type of chemical to be applied; and
- proximity to crops and homesteads.

Overall treatment using sprays or pellets, applied by aircraft or ground rig, is appropriate where regrowth density makes individual treatment or spot spraying uneconomical.

Chemical treatment of individual trees or small patches of trees and regrowth using basal bark, cut stump, stem injection or soil spot treatments are useful options where timber density is relatively low. Chemical treatment is most effective following rainfall after a burn when suckers are actively growing, and on suckers less than 0.5 m high. Ideal conditions are more likely in summer and autumn. A follow-up spraying within 12 months of the initial application of non-residual chemicals can give complete regrowth control.

Detailed information on chemical control of individual species can be found in Inkata Press (1987) and Pressland *et al.* (in prep.).

7.4 Noxious weed control

Poor summer grass competition resulting either from dry summers or high stocking pressures combined with wet autumns and winters is ideal for the germination and spread of noxious weeds such as saffron thistle, variegated thistle, noogoora burr, bathurst burr, African boxthorn, prickly acacia and thornapple.

Most of these weeds can be controlled with herbicides, but this can be expensive and is not always practicable. A competitive grass pasture which may require a farming phase for establishment and maintenance, is the best long-term method of control. Biological control is also relevant for some species.

Thirty-five plant species are declared noxious in Queensland under the Rural Lands Protection Act, 1985. Declaration is made within various categories, each requiring a different level of control.

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Chapter 10

LIVESTOCK MANAGEMENT

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1. BEEF CATTLE *John Bertram*

1.1 Introduction

The relative importance of beef cattle production to the sheep and cropping systems on a property often reveals the quality of management involved in the cattle enterprise. Much of the area supporting native pastures is unsuitable for cropping. Little pasture improvement beyond the brigalow lands has occurred because of the high cost and unknown returns associated with pasture improvement. Between 60% and 70% of the average annual rainfall falls from October to March with animal production in the region dependent on summer rains and subsequent pasture growth.

1.2 Stocking rate

Grazing experiments have indicated that heavy grazing produces maximum returns for a few years whereas light stocking rates usually give maximum gain per animal but are not often economic. Good management strikes a balance between these two whilst maintaining productive pastures.

A light stocking rate tends to allow:

- a more uniform continuous income to the producer;
- less effect by seasonal conditions; and
- decreased expenditure in times of drought.

Greenhalgh, *et al.* (1976) found that by harvesting pasture and feeding cattle in pens there was a 20% increase in live weight gains for each animal for every hectare, compared to field grazing at the same stocking rate. However, they suggested that if the stocking rate of field grazing were reduced, the production for each animal may be as high as harvesting forage and pen feeding animals. This response is mainly owing to:

- wastage of herbage by trampling;
- energy requirements of grazing animals may be under estimated; and
- the energy value of herbage may be over-estimated.

Coaldrake *et al.* (1969) found at Tarewinnabar, in the brigalow region north of Goondiwindi, that native pastures are not inferior to sown pastures for feed. They also indicated that native pastures could have been stocked more heavily than 1 steer/1.86 ha without seriously reducing the weight gain for a steer. They did not relate animal liveweight gain and sustainability of pasture species.

This carrying capacity is in stark contrast to the results of a survey by Cavaye *et al.* (1989*b*) who found that livestock gross margins peaked at approximately one adult equivalent (AE)[1] per 2 ha and livestock variable costs limited profitability at high stocking rates of 1.0 AE/1 to 1.8 ha.

The normally accepted stocking rate for native pasture in the brigalow lands of the Western Darling Downs is 1 AE/4 to 6 ha.

Trials at Remilton, in brigalow country south of Westmar, showed a greater pasture yield in kilograms of dry matter per hectare from the higher stocking rate of 1 AE/5.7 ha compared to the lower stocking rate of 1 AE/8 ha in first two years. They

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[1] Whilst 1 AE (a 450 kg live weight non-lacating bovine) is generally equated with 8 Dry Sheep Equivalents (DSE), the species composition of the pastures and the maturity of the plants will have significant effects on this conversion rate

suggest there is little prospect of increasing returns by exceeding 1 AE/2.3 ha owing to added risks and more frequent feed shortages.

There appears to be no relationship between size of property and intensity of stocking rate. Fluctuations in rainfall and seasonal response may make the practice of using stocking pressure and relating available feed to the number of animals the more appropriate method of assessment. Rotational grazing of pastures makes best use of the relationship between available pastures, production per unit area, the requirements of the class of the cattle grazed and the stage of maturity of the pastures.

Recommended stocking rates for livestock in Waggamba Shire are given for each soil in Part B of this manual, and for each LRA in Table 10.1

Note: The stocking rate which maximises profit per unit area will be less than that which maximises beef production per unit area. This rate will also be somewhere short of the maximum attainable stocking rate (Figure 10.1). This is based on the premise that production per animal diminishes as stocking rate increases, with the consequence that total production per unit area initially increases at a diminishing rate and then declines as stocking rate increases.

Table 10.1. Recommended stocking rates for cattle and sheep in Waggamba Shire

	Stocking rate (cattle - ha/AE; sheep - ha/DSE)					
LRA	Sown pastures		Uncleared native pasture		Cleared native pasture	
	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep
Macintyre	2.5	0.2	3.7-5.0	0.4	3.7	0.4
Lundavra	2.4-4.0	0.2-0.3	9-14	0.5-1.2	3.7-7.0	0.4-0.8
Commoron	2.5	0.2	18-23	2.8	3.7	0.4
Billa Billa	2.5	0.2-0.4	18-23	2.8	5.5-7.5	0.6-0.8
Bungunya North	2.5	0.2	18-23	2.8	3.7-5.5	0.4-0.6
Dumaresq	2.5	0.2	5.5-7.0	1.2-1.6	4.0-5.5	0.4-0.6
Serpentine	2.5	0.2	7-14	1.4-2.4	5.5	0.6
Boogara	2.5	0.3	11	2.4	5.5	0.6
Geralda	4.0-4.5	0.4	14-21	2.8-3.2	7.5-10.5	0.8-1.2
Broomfield	*n.a.*	*n.a.*	9-11	1.6	*n.r.*	*n.r.*
Goodar	*n.a.*	*n.a.*	9-23	2.5-4.0	*n.r.*	*n.r.*
Desert	*n.a.*	*n.a.*	9-11	2.5	*n.r.*	*n.r.*
Boondandilla	*n.a.*	*n.a.*	23-28	6	*n.r.*	*n.r.*
Westmar	*n.a.*	*n.a.*	23-28	6	*n.r.*	*n.r.*
Jumpup	*n.a.*	*n.a.*	18-23	4	*n.r.*	*n.r.*

n.a.: not applicable; *n.r.*: not recommended

The inference from this model is that there is a greater tolerance of change in stocking rate before a significant change in farm income. In each case, stocking rate is closely linked with the financial return per head or financial return per hectare with virtually no measurement of changes in species composition and associated environmental changes. In a survey based on a narrow range of stocking rates and conducted in the Blackall district the maximum profit was approximately 1 AE/8 ha. This is very similar to the long standing Lands Department rated carrying capacity for that area.

Rotational grazing gives higher animal liveweight gains (474 kg/ha) and is less detrimental to pasture production and species persistance than continuous grazing (330 kg/ha) (Lowe *et al.* (1978)).

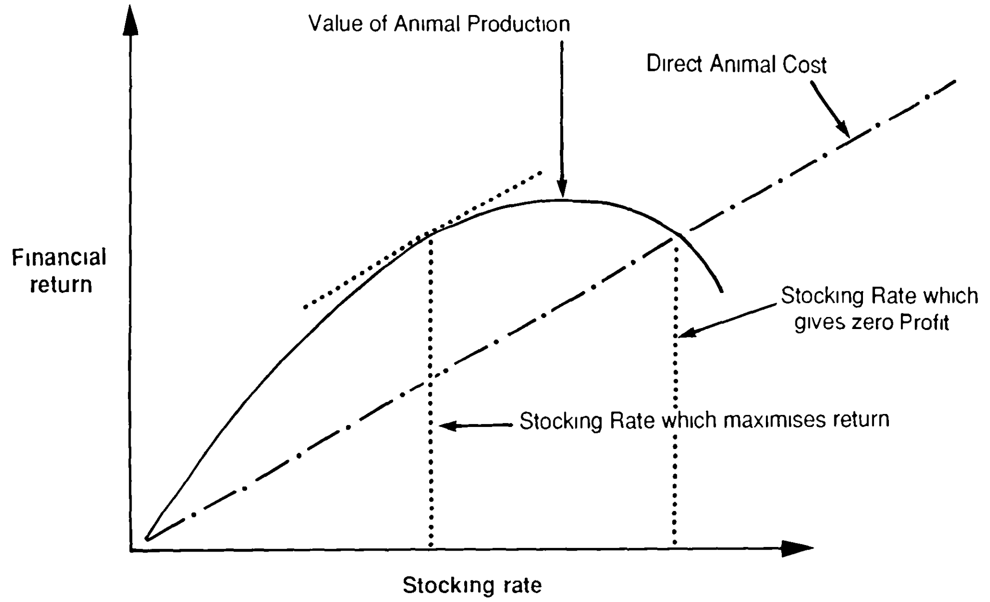

Figure 10.1. Theoretical model relating financial return to short-term stocking rate

The choice of enterprise in areas suited to both sheep and cattle is basically one of economics, and personal preference. Land improvements, particularly the stock water supply, yards and fences have a significant influence on species choice. Sheep also can thrive on saline waters which are unsuitable for cattle, particularly lactating cows. The mixes of these enterprises can also be economically assessed using herd and economic models, for example, Rangepak.

1.3 Drought

Droughts throughout the district are often divided into seasonal and long-term droughts. Several droughts have affected the entire area in recent times: in 1965, 1967 and 1980-1. Seasonal feed shortages particularly in winter and spring regularly occur because of the limited range of pastures used. Increasing use of medic species in pasture, summer forages and winter oats have helped reduce shortfalls in pasture production.

Producers operating with carrying capacities slightly lower than average have reported the ability to sustain longer short-term droughts with decreased expenditure when returns from cattle are normally reduced.

The increased growth of the feedlot industry has helped absorb large numbers of 'turnoff' animals for both the local and export trade. Feedlots are either opportunity feedlots, for example, occurring on properties as a drought mitigation measure, or large commercial feedlots, purchasing steers from properties throughout the district. In a 1975 survey of producers feeding supplements on a regular basis during drought it was indicated that:

- 61% use molasses-urea mixes;
- 31% use commercial lick preparations;
- 16% supplement with grain; and
- 12% supplement with hay.

There is currently an increased use of whole cotton seed for supplementing the weaners and breeding herd, whilst a number of grain and cattle producers operate an opportunity feedlot on property to finish their sale animals during times of drought or low grain prices.

Note: As dry conditions approach, reduction of stocking pressure by sale or agistment of various classes of stock, including feedlotting of steers is the preferred first option.

2. SHEEP AND GOATS *Lloyd Dunlop*

2.1 Introduction

Wool has been the major industry in Waggamba Shire since it was settled. The shire produces 3 491 000 kg or 5.4% of the State's wool. Increased cropping areas and the trend towards cattle grazing after the 1960s led to a relative decline in importance of the wool industry. Since the late 1970s sheep numbers have steadily risen until the 1990 crisis created by the drop in the wool floor price and increase in the levy. Cattle numbers have been far more volatile than sheep as shown in Figure 2.1 in Chapter 2.

Flooding of whole properties, except for small patches of high ground, is a problem between the Macintyre and Weir rivers west of Goondiwindi. For this reason few sheep properties are found south of the Barwon highway.

2.2 Sheep enterprise

2.1.1 Breeding

Merino breeding and wool production is the most profitable sheep enterprise in the shire. It is a low cost, high income, complex pastoral pursuit which integrates, with little difficulty, with cattle and cropping enterprises.

The average area for a holding in the shire is 3745 ha but an average sheep holding area would be in excess of this. Sixty-three per cent of the shire's holdings have facilities to shear sheep. There are five merino studs representing Saxon, Peppin and South Australian blood lines.

Lambings average 83%, flock woolcuts average 4.62 kg with weaners averaging 2.5 to 3.0 kg, ewes 5.2 kg, wethers 5.9 kg and rams 8.0 kg.

Wool types of the respective classes of sheep are:

- lambs and weaners 19.5 to 21.5μ;
- ewes 21.6 to 23.5μ;
- wethers 22.6 to 24.5μ; and
- rams shorn twice per annum will produce a 'French combing' line of 22.6 to 24.5μ. These figures are for AAAM wools. (μ = micron)

These wool types are stronger than visual qualities suggest because of the better nutrition for sheep provided by the shire's fertile soils and generally favourable rainfall compared to the northern and western shires of the state. Improved pastures result in an increase of about 1 micron in fibre diameter and a lift of about 0.5 kg in wool weight for sheep on the same soil type.

Overstocking is a chronic problem in the shire with many graziers believing the country can sustain 2.5 DSE/ha on native pastures indefinitely. This figure could be sustained with spelling but would be nearer to 2.0 DSE/ha with continuous stocking.

Future opportunities include the introduction of improved pastures, which allow the increase in stocking rates and wool cuts, the further integration of sheep with cropping, forages; weed control on fallows; dealing; and the growing and shearing of western sheep on either an opportunist or regular basis.

2.2.2 Wethers

Wethers have come into prominence in recent years for weed control on zero till wheat fallows. Numbers have increased rapidly since 1986 to approximately 130 000 wethers on the 1989-90 fallow.

Wethers account for approximately 30% of the sheep in the shire compared to 40% in western shires.

With the introduction of legume and grass pasture rotations, wheat growers keep wethers for more than one shearing.

2.2.3 Dealing

Waggamba Shire is ideally located for producers to indulge in dealing. It is relatively close to the major pastoral areas of Queensland from where graziers can gain access to large lines of sheep. High quality forages and improved pastures can be grown in the shire and it is on the periphery of districts to the east and south from where young sheep are sought on a regular basis.

The most common practice has been to buy woolly wether weaners, place them on summer forages with lucerne or oats for winter and achieve stocking rates of 25/ha on hybrid pearl millets in the summer and 15/ha on oats until shorn and sold in the winter or spring.

2.2.4 Prime lambs

This is a small scale industry because of limitations introduced by transport, distance, low and unpredictable prices, poor guidelines on carcass specifications, seasonal lambings, and unpredictable pastures on which to finish lambs.

The main lamb breeds in the shire are Merino ewes crossed by Border Leicester rams and Border merino ewes crossed by Poll Dorset rams.

2.3 Regrowth control

2.3.1 Goats and merino wethers for scrub regrowth control

Goats are often perceived by graziers as a panacea to all their woody weed problems. Under certain controlled circumstances they will be very effective for controlling scrub but it sometimes requires high stocking rates, cheap goats, highly intensified management and the introduction of other control agents. Relying on goats alone will be only partially successful because of the intensity of management necessary.

Goats can be run with other animal species at low stocking rates to modify a persistant regrowth problem over time, so long as the plant species to be controlled is within their appetite range. This range may change with time.

Merino wethers should also be considered, even for brigalow regrowth control. They are numerous, cheap and grow a fleece, though of lowered quality and weight, through the regrowth control period.

2.3.2 Goats

Goats are browsers by nature and fit in well with other grazing species such as cattle and sheep providing little competition. As a rule of thumb, goat societies suggest an add-on stocking rate of goats to cattle and sheep of 30% of paddock DSEs before they compete.

Goats prefer flowers, seeds, leaves, grasses and bark which is a fibre dominant diet. They dislike soft highly digestible pastures such as medics. They are extemely sensitive to shock, changes in weather, parasitism and predation of their young.

Feral goats are the preferred animal for regrowth control. They are available in large numbers from western Queensland where they are considered a pest. It is advisable to draft off the males (55% of the feral mobs) sell them for meat and retain the females. Wether goats are ideal for scrub control and are available, in small numbers from Cashmere or Angora flocks.

Most western graziers attempting regrowth control with goats, will attempt a 'grading up' program to either cashmere or mohair, buying bucks from one of the many stud producers in Queensland. Also, a combination of merino wethers and goats may be warranted because of current low cashmere and mohair returns.

Limitations

Large numbers of goats (or merino wethers) are needed for woody weed control. They should be spelled on good pastures for equal periods of time in a two mob rotational system if control of highly unpalatable woody weeds is to be successful.

The paddock will generally be pulled, raked and burnt and sown with an improved pasture species. In some cases burning will be delayed until the sown pasture has provided sufficient fuel for a burn. Ideally goats should be introduced following a hot burn in which the apex of each juvenile tree is burnt. Therefore, to achieve a total clearance of woody weeds from a paddock goats, as well as a combination of agents (mechanical, fire or chemical) are necessary.

Goats can only reach to a height of 1.5 to 2 m. So if the apex of the vegetation they are required to control is higher than this it will survive their attention, unless they strip its bark. Mechanical intervention is therefore necessary.

If the plants to be controlled are palatable the stocking pressure can be greatly reduced. In addition, if the goats carry a valuable fleece, steps can be taken to conserve the offending vegetation as a continued food supply.

Poisonous plants can be a hazard, but, most acacias and eucalypts are not in this category.

Animal selection

Ferals are the cheapest, most numerous and readily available for regrowth control. Cashmere and Angora wethers are less numerous, are more costly but will yield a fleece during the control period.

2.3.3 Examples of control

Species effect

Mechanical clearing can increase shrub seedling establishment four-fold. Introducing goats offers an answer to the problem because of their selectivity between shrub species. Significant reductions in shrub populations will only be achieved at high goat stocking rates.

Work on the control of woody weeds by goats was done in 1986 on coolibah (75%) eucalypt (15%) and sandy ridge (10%) flood country south of Dirranbandi at Clyde by the QDPI. A 161 ha paddock at Clyde was pulled and stocked progressively over a period of two years with feral cashmere goats at the rate of 1/10 ha up to 3.75/ha.

Despite the low initial stocking rates it was found that heavy grazing pressure from goats completely eliminated problem weeds such as cypress pine, brigalow, sandlewood and galvanised burr. Effective control over coolibah and box was achieved nearest the watering point after three years but was patchy and incomplete elsewhere.

The paddock was not burnt and insufficient goats were used to achieve the desired browsing pressure. Two years were required to gain control over brigalow sucker regrowth at Woodlands in Tara Shire using merino wethers at heavy stocking rates.

Costs and savings

Among the costs is the postponement of farming production from the paddock for two years, the depreciation on the wethers, the loss in wool production of 1 kg/hd, lower yielding (lower micron) wool, labour costs and subdivisional fencing.

On the positive side is a substantial saving on fuel, oil, repairs, maintenance, tractor life and an income from the wool or cashmere of up to $150/ha at 1990 returns and prices. The tractor or chemical savings could be as high as $100/ha assuming one pass of a blade plough or one application of residual pellets is saved.

Annual cropping for at least three years followed by an aggressive pasture grass is required to further control regrowth according to work done at Meandarra. This fits a rotational control system where country development, grain farming and livestock will integrate well.

Despite the best efforts of sucker control by cultivation and farming, brigalow regrowth will continue to appear many years later. In these cases a small mob of goats are needed to run with cattle or sheep in well pastured paddocks to maintain sucker control.

Chapter 11

SOIL CONSERVATION MANAGEMENT AND PLANNING

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QDPI, Goondiwindi

1. INTRODUCTION

Properties should be managed in such a way that the principles of correct land use for the long-term productivity of the land can be achieved and maintained. In order to achieve this, careful soil conservation planning, implementation and maintenance must be undertaken.

The property plan can be implemented over many years provided that the first decisions allow for long-term flexibility in enterprise changes.

- The primary role of property plans should be to allow consideration of soil type limitations, clearing limits and slope limits.

- On land with slopes greater than 0.5%, soil conservation structural works form an essential framework around which further soil conservation practices can be built.

Cropping land will require intensive structures, contour banks, for example, whilst pasture land will require basic structures, such as waterways, particularly in the improved pasture establishment phase.

- On cropping land, soil erosion will be best minimised by the maintainance of crop stubble for as long as possible during the fallow, combined with earthwork structures on sloping land.

- On all land developed for farming or grazing, cover provided by grass pastures will best minimise soil erosion and maintain or improve soil surface structural stability.

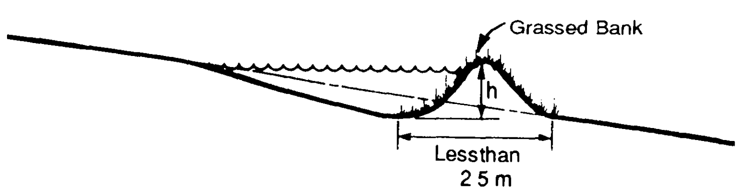
2. RUNOFF CONTROL STRUCTURES

2.1 Contour Banks

The contour bank type selected depends on the depth of the soil and whether the soil cracks. Two types are recommended for this district:

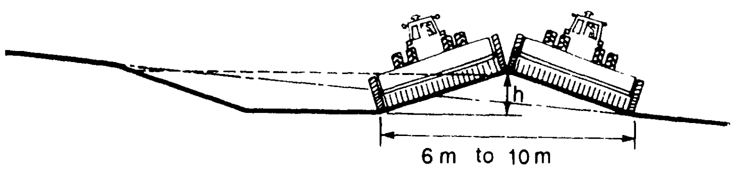
Narrow-based (NB) banks have the following features:

- Cultivated channel, grassed bank;
- Suitable on shallow soils and non-cracking soils;
- Relatively cheap to construct;
- Relatively low maintenance costs;
- Potential weed problem;
- Some loss of cultivation;
- Unsuitable for cracking soils;
- Settled height h of 600 mm up to 6% slope; and
  750 mm over 6% slope.



Broad-base cultivated (BB) banks have the following features:

- Channel and banks are cultivated;
- Suitable for cracking soils;
- No loss of cultivation;
- Batter width constructed to suit planter;
- Relatively expensive to construct;
- High maintenance costs as cultivation reduces bank height;
- Not recommended over slopes of 5%;
- Settled height **h** of 600 mm.

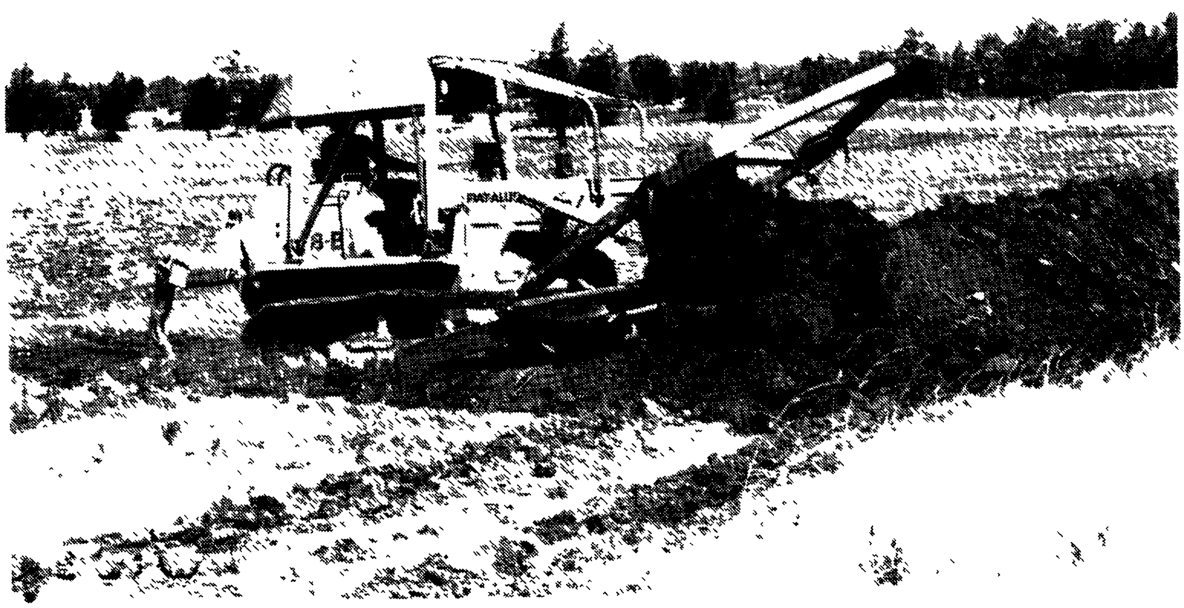


Examples of contour bank selection:

Arden: A strongly self-mulching, deep cracking soil where a broad-based or an oversized narrow-based bank would be required.

Calingunee: A moderately self-mulching soil where oversized narrow-based banks are effective but broad-based banks on slopes up to 5% are usually recommended.

Murra Cul Cul: Effective soil depth is 40 to 80 cm and it has a largely impermeable B horizon so a narrow-based bank is recommended.

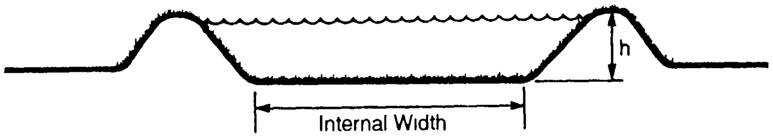


Constructing contour banks

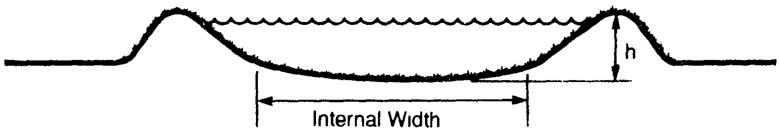
2.2 Constructed Waterways

Three types are usually recommended:

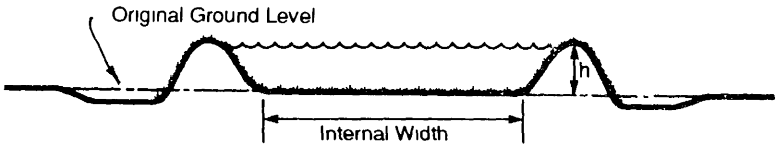
WWA: Flat bottom
- Used on shallow soils or slopes of 5% or steeper
- A level bottom spreads flows and avoids concentrations.



WWB: Dished bottom
- Used for most situations on slopes of less than 5%.
- Dish shape reduces meandering.
- Maximum depth of dish is 0.15 metres.



WWD: Waterway banks
- pushed from outside
- Used where suitable stabilising vegetation exists and runoff requires confining, or where excavation will expose dispersible subsoils that are difficult to vegetate.



Waterway type WWD is recommended for the poorer soil types such as Flinton. Excavation from the inside would expose subsoil of very low fertility, and is generally difficult to establish grass.

Only a WWD type waterway should be used for any soil with a dispersible subsoil.

2.2.1 Waterway construction

The construction technique for WWD waterways on low sloping land (less than 1.5%) can result in the floor of the waterway being higher than the land outside the waterway. This will occur when banks or spur banks are constructed leading into the waterway and have channel floors lower than the waterway floor. This results in ponding at best, or a bank breakage at worst.

- Waterway types WWA and WWB are normally recommended on low sloping land.

- If there is a suspicion of highly dispersible subsoils the best option would be not to build waterways and consider returning the area to grass.

- If grass establishment is likely to be a problem owing to exposure of poor subsoil, for example with Marella, Murra Cul Cul and Bendidee soils stockpiling of the topsoil during construction and topdressing the waterway with the topsoil after its completion is recommended.

2.2.2 Waterway grass type selection

Rhodes grass is suitable for most situations except for some of the poorer soils in the western areas, for example, Flinton and Jindabyne where buffel grass is recommended, and some of the poorer soil types, for example, Marella and Bendidee which are also more suited to buffel grass. For more details see Chapter 8.

Whilst it is recognised that buffel grass is clumpy, not sending out runners like rhodes grass, buffel appears to have a record of survival. In these situations any grass is far better than no grass at all.

African star grass is regarded as one of the best waterway grasses available owing to its ability to send out runners and cover the ground quickly. It does not grow excessively high and has a good record for surviving in harsh environments. However, it has to be planted in turfs and watered until the first worthwhile fall of rain. This makes it very labour intensive and as such cannot be seriously recommended for establishment in large waterways.

African star grass is most suitable in fertile clay soil types. In critical locations, for example, dam bywashes or poor soils, it can be successfully used provided it is fertilised and watered. It is the recommended grass species for valuable or critical areas such as dam bywashes and gully cutbacks.

2.2.3 Planting waterway grasses

Rates: The rule is the higher the planting rate the better. A minimum of 3 kg/ha and up to 5 kg/ha is recommended for both rhodes and buffel grasses.

Time: Any time except winter can be considered for successful waterway grass planting but the situation must be considered individually. Spring plantings should be avoided in areas known to be heavily infested with mintweed and urochloa grasses as they will choke out grass seedlings. The usual heatwave period in December should also be avoided unless there is good subsoil moisture present. Late autumn plantings could pose a risk due to frost. Cover crops can help to prevent this.

Undersowing waterway grasses with cover crops: Undersowing can be successful providing the cover crop planting rate is reduced from the normal planting rate by a third. This method has been successfully used for sowing rhodes grass under a winter cereal crop in late autumn into fertile friable soil types such as Arden and Calingunee. It appears that the cover crop offers frost protection to the grass seedlings.

In all situations grass seed should be treated for ant control. This is vitally important when sowing or broadcasting seed into a dry seedbed in readiness for anticipated rain.

By using ant control, seed can be sown or broadcast dry at any time and the seed will strike at a time best suited to itself.

Establishment of rhodes and buffel grass: The establishment technique used can depend on many factors including soil type, and whether the waterway is 'live' or not.

A 'live' waterway is one which will carry water from the day it is built; that is, it is not posssible to divert the water away from the waterway to a temporary location. In this situation it is essential to establish a cover crop quickly and plan to establish the permanent pasture at a later stage.

2.2.4 Cover crops

Suitable cover crops are winter cereals suitable for autumn to winter plantings and summer grazing forage crops, including small seeded crops such as millets, for spring to summer plantings.

The cover crop can be allowed to mature and a zero-till seedbed prepared for the pasture or the cover crop can be sprayed out in the growing stage. The pasture seed is then broadcasted into the cover crop residue at the appropriate time.

This technique is also suitable for soil types prone to hard setting, surface sealing or cloddiness, for example, Moruya, Wynhari, and Murra Cul Cul soils.

If water can be excluded from the waterway, the seedbed can be prepared in a conventional manner obtaining a fine clean seed bed with subsoil moisture accumulated. Soil types well suited to this are Tarewinnabar, Calingunee and Arden soils.

2.2.3 Waterway maintenance

Fencing and grazing: Grasses cannot be effectively established and maintained in waterways if livestock are allowed unrestricted grazing. If stock cannot be excluded from the paddock where the waterway is located, the waterway should be fenced. Electric or permanent fencing can be used.

Permanent fencing has the advantage that stock can be either kept in or out of the waterway. Crash grazing is the best method for controlling growth in established waterways as it prevents the development of stock tracks leading to watering points which will invariably wash out.

Burning and slashing: For a waterway to function effectively grass length should be kept to less than 0.3 m. This can be difficult for rhodes grass waterways. Regular slashing in good seasons is recommended but it can be time consuming in large waterways. Some landholders have successfully made hay from waterways.

Burning the waterways in August is an excellent management tool to maintain grass length of less than 0.3 m. The grass is scorched whilst the surrounding winter crops are still green, and a cool controlled burn can be achieved. A cool burn will not harm established grasses as the butts soon shoot again.

Weed control: Apart from competing with the grass for moisture and nutrients, weeds in waterways are a source of seed for further reinfestation of all areas downstream. Weeds can be controlled by the large range of herbicides now available. Controlled grazing, slashing and burning will also restrict weed growth.

Fertilising: The frequency and amount of fertiliser needed will vary greatly depending on soil type and grazing management. Poorer soil types such as Bendidee and Marella will benefit greatly from fertilising. Other more fertile soils may not require the same treatment and specialist advice should be sought for each situation.

General maintenance: Any sediment deposits should be removed. Scours should be immediately filled, preferably with topsoil, and revegetated. Machinery crossings should be periodically built up.

3. PASTURES AND STUBBLE FOR SOIL PROTECTION

3.1 Pastures

On all land developed for farming or grazing, cover provided by grass pastures will best minimise soil erosion losses and maintain, or even improve, soil surface structural stability.

For example, average annual soil loss (1983-7) on sloping brigalow country at the Brigalow Research Station, Theodore was reduced from 1.7 t/ha on a conventionally farmed catchment to 0.3 t/ha on a buffel grass pasture catchment. This compares with 0.1 t/ha on an uncleared brigalow catchment.

Pasture legumes such as lucerne will best restore nitrogen fertility on rundown soils. However, they will not significantly improve soil surface structural stability.

3.2 Crop stubble

On cropping land, soil erosion is minimised by growing a crop followed by maintenance of crop stubble for as long as possible during the fallow, combined with earthwork structures on sloping land. Research at Fairlands, Wallumbilla showed that by protecting soil with crop stubble, the annual cost of producing a 680 g loaf of bread was reduced by 0.3 to 1.0 kg of topsoil compared with 3 to 5 kg of topsoil using conventional fallowing techniques which left no stubble protection.

Maintenance of sufficient stubble protection is best achieved in most years by not tilling country. Weeds are controlled instead by herbicides or sheep.

Crop stubble itself will not significantly improve soil surface structural stability. However, elimination of mechanical tillage in the fallow will significantly reduce the rate of soil surface structural decline.

On all ley pasture and on the steeper sloping cropping soils, 3 to 5 year ley pasture - crop rotation sequences are considered necessary for stable land use; in addition to stubble maintenance during the farming phase and earthwork structures.

4. PROPERTY PLANNING

4.1 Clearing guidelines

When planning to clear areas keep in mind the possibility of future change in enterprises.

If clearing areas where regrowth will occur, clear only enough area that can be handled. Whilst pulling an area may be easy at the time, follow-up work such as stick-raking and ploughing may be slower, with the result that suckers soon take over.

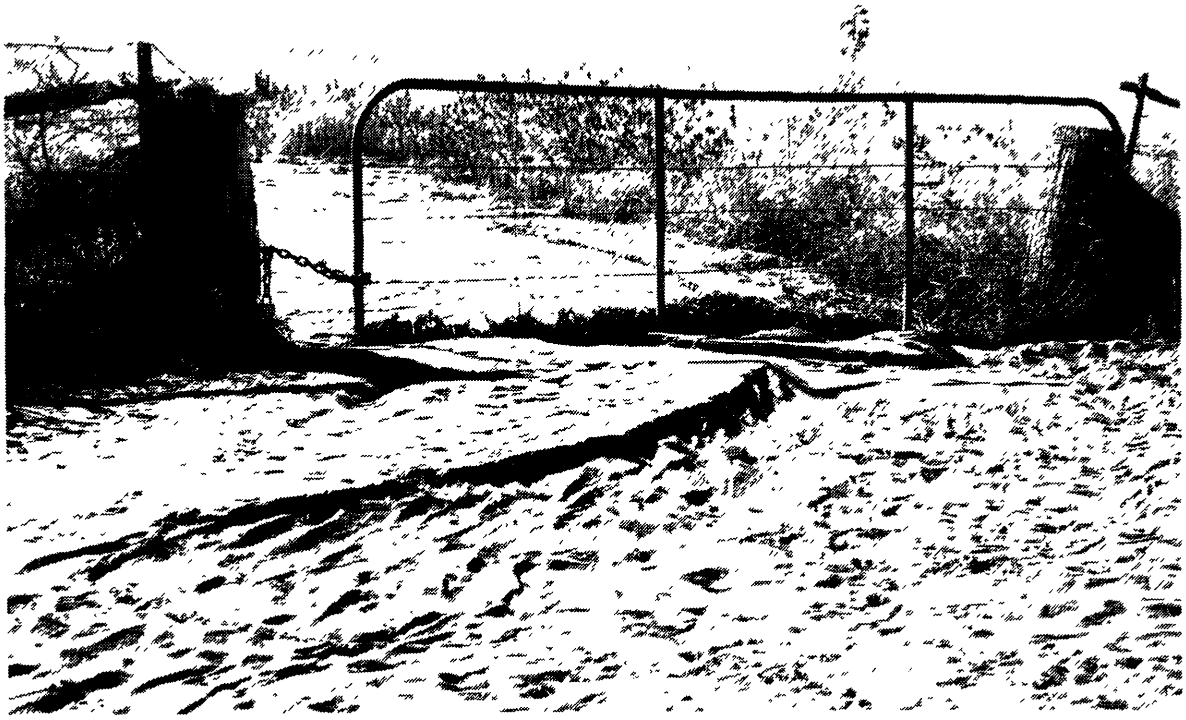
Dead timber and rubbish should not be dozed into drainage lines as this creates erosion problems and reduces channel capacity.

Timber clearing limits are determined by slope and soil type and are described below.

4.1.1 Slope limits

Slopes greater than 8% should not be cleared under any circumstances.

Timber regrowth and woody weeds on 8% slopes should be controlled chemically so that there is no soil disturbance.



Sediment accumulation from excessive surface erosion

Slopes of 6 to 8% should only be cleared for pasture development if diversion and contour banks are installed.

4.1.2 Soil type limits

Soils within Waggamba Shire can be grouped into the broad units outlined in Chapters 8 and 9 for developing and managing within a property plan.

- Soils suitable for irrigation (flood, spray and trickle).
- Soils suitable for long-term dryland cropping.
- Soils suitable for short-term dryland cropping and pasture rotations. Slope or other restrictions, such as melonholes, may be the determining factor.
- Soils only suitable for sown pastures, for example any soil type over 6% slope.
- Soils not suitable for any development at all.

A more comprehensive guide for land use groupings of soil types can be found in Chapter 8.

4.1.3 Trees

Ideally, approximately 20% of the property should be left timbered, either in clumps of 10 ha or greater or in shadelines of no less than 100 m wide. The 20% area retained should be in strategically located strips, clumps, or both and not as single, scattered trees or in one large group.

In brigalow areas, past clearing mistakes can be corrected by allowing areas of brigalow suckers to regenerate in the desired locations and with the appropriate density.

Belah is very susceptible to wind damage so narrow belah shadelines are not recommended.

Fodder. Any known suitable fodder trees should be retained as a source of stock fodder during drought. Wilga, kurrajong, mulga and belah are examples of trees that should be retained for this purpose.

Windbreaks. Planning of windbreaks should involve the retention of such lines to break up the westerly winds over large tracts of cultivation. Also, research in the 1960s suggested that windbreaks running north-south are the most effective in this area.

4.1.4 Drainage lines

Natural timber adjacent to watercourses such as oaks and river red gum should be retained. Heavy stands of brigalow suckers in drainage lines restrict grass growth, leading to gully erosion. Selected thinning or clearing of this timber is necessary to allow the growth of a stabilising grass cover to occur.

Trees, particularly brigalow, are not recommended in constructed waterways as they restrict grass growth and alter the velocity of the water flow. Trees in waterways also encourage livestock to camp in the waterway which creates an erosion hazard.

4.1.5 Clearing non-arable areas

Removal of trees on stony ridges, 'jumpups', bendee covered ridges and unstable solodic soils, for example Uranilla, should not be undertaken.

The increased potential erosion risk and potential regrowth problems and possible future salinity and salting problems are the main reasons not to clear non-arable areas.

The benefits of timber thinning in native pasture for improved carrying capacity must be balanced with the potential problems outlined above.

4.2 Minimising erosion

4.2.1 Access tracks

Poorly located tracks can lead to severe gully erosion. Tracks should be located on ridges, on the contour, or at right angles to the contour. In the latter case spur drains or low banks may be necessary to remove runoff from the access track. Avoid using drainage lines or constructed waterways for access.

4.2.2 Fencing

Fencing should be designed to separate the different management units. Potential erosion problems can be avoided by siting fences on ridges, on the contour and always out of drainage lines. The following points should be considered when planning fencing layout:

- Electric fencing is suitable for subdividing cultivation areas when there is a reason not to have permanent fences.

Surface and gully erosion after clearing

- Where possible, gateways located at the higher end of a fenceline avoid stock pads and tracks eroding due to concentration or channelling of running water.

- Laneways should not be narrow, otherwise overgrazing and erosion may result. Wide laneways, if managed correctly, can act as temporary holding paddocks and are less likely to erode. The width of the laneway would depend on the number of stock on the property.

4.2.3 Watering points

Sufficient, strategically-placed watering points are necessary to encourage stock to graze all the paddock.

- Many water points are located in drainage lines on the lower end of a paddock because of catchment considerations and underground aquifer locations. Stock pads and watering points are susceptible to erosion in this location. Sedimentation and reduced life of the water supply or bogging of stock often result.

- Troughs should therefore be located on higher country. There is a definite advantage in fencing off dams and installing tanks and troughing, particularly if it is an important water supply watering large numbers of stock. Dam bywashes should be fenced off from stock to prevent erosion.

- Watering large numbers of stock in creek and river waterholes can result in bank erosion.

- Shade camps should be located away from, and downstream from a dam.

Further information

Bourne (1986) (see References, p. 189)

French (1990) (see References, p.189)

Soil Conservation Services Branch (1990), *Planning your property. How to get started in grazing lands*, Queensland Department of Primary Industries Leaflet QL 90016.

Chapter 12

NATURE CONSERVATION ON RURAL PROPERTIES

Alan Don
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1. INTRODUCTION

Australia has a unique and diverse wildlife of which Queensland has the greatest diversity. More than three-quarters of the families and genera of Australian plants and almost two-thirds of terrestrial animal species occur in Queensland. The bird and mammal fauna are particularly rich, having 73% and 67% of Australian species respectively.

National parks and other conservation reserves aim to protect viable samples of this diversity, and in particular to preserve genetic variation. These reserves alone cannot successfully conserve our native plants and animals. In Queensland they cover about 2% of the state, and sample only 55% of the vegetation communities. This has taken 80 years to achieve, the first Queensland national parks being declared in 1908.

The Truss Report on *An Agricultural Policy for Queensland* recommended that 'Conservation in rural areas should aim at a balance of achieving a managed ecosystem in which native flora and fauna species are maintained along with the long-term productivity of the land'.

In rural areas, conservation (the wise use of resources for present and future generations) applies to soil, water, pasture, forests, and wildlife. Farmers and graziers can play a role in nature conservation on their properties, and some general guidelines for management practices are given in the following sections.

2. WHY CONSERVE WILDLIFE ON RURAL PROPERTIES?

Adequate conservation of the state's wildlife needs more than islands of habitat as parks. It is clearly impractical to reserve, let alone manage, all areas of land that contribute to nature conservation. Parks and reserves can only succeed when they function in conjunction with the surrounding landscape, with its remnants and corridors of natural vegetation, its partially cleared pastoral lands, and its highly modified agricultural areas. Integration of nature conservation practices into all forms of land management is required.

About 90% of Queensland's rural lands is controlled directly by private individuals. The contribution to nature conservation of this land is significant, and includes its habitat value to plants and animals, and as corridors which allow dispersal of species from one area to another.

The conservation of our fauna heritage and maintenance of sustainable productivity from rural lands are generally compatible, and provide good reason for the consideration of nature conservation in property management.

2.1 Benefits of nature conservation

How does a landholder benefit from nature conservation on his property? The benefits are direct as well as more subtle, and stem from both the native animals and the vegetation forming their habitats. The stability of natural systems is the most important, yet intangible, advantage of nature conservation. All plants and animals depend on each other for survival. Plants rely on insects and birds for pollination, animals feed on plants and in turn are food for other animals, including man. Many organisms are involved in breakdown of organic matter, an essential step in recycling nutrients in biological systems. Agriculture utilises these natural systems, compensating for changes by inputs of fertiliser, pest control and new farming techniques. Where the natural systems can be maintained to some degree, through on-farm conservation, the long-term prospects for stable agricultural systems are enhanced.

Natural vegetation can play a significant role in maintaining sustainable agricultural and pastoral productivity. Vegetation can be retained as shelterbelts or shade for crops and livestock. Research shows that windbreaks can increase crop yields markedly, while shade and shelter may improve animal production and breeding success. Trees kept in suitable parts of the landscape can prevent salting problems by the regulation of water balances. With careful management, forest areas and woodlots can be a continuing source of timber for fencing and farm structures. Trees also help to stabilise slopes and drainage lines.

Trees and shrubs, natural or planted, beautify the property landscape and increase its amenity and resale value. The lifestyle benefits of a pleasant living and working environment enhanced by native trees and shrubs cannot be underestimated. The economic benefits of native animals are more difficult to quantify. Many species of birds eat large quantities of insect pests. Magpies take thousands of scarab larvae per hectare each year. An ibis feeds on 200 g of insects a day, including caterpillars, grubs, beetles and grasshoppers, and moths as well. In healthy eucalypt woodlands, birds may eat about half of the insects produced (about 30 kg/ha/year), while small mammals and predatory insects and spiders take a significant proportion of the rest. Some of the larger predators play a role in controlling populations of pest species such as rats and mice, rabbits and hares. Dingoes may be more important than previously thought in controlling the number of pigs, wallabies and kangaroos in some areas.

2.2 Pests

A few native animals have had their habitats so enhanced by agricultural and pastoral development that they may become economic pests. Planning for nature conservation on properties must account for this possibility, and appropriate controls taken when necessary. Native fauna in most states is protected, although open seasons are declared on some species. Local national parks and wildlife officers can give advice on suitable techniques for minimising fauna problems, and on laws or regulations which may apply.

3. BASIC PRINCIPLES

Before examining techniques for rural nature conservation, a review of the biological principles involved in wildlife habitat management is helpful. These include succession, shape and size of habitat, diversity of features, and dispersal of animal populations.

3.1 Succession

Succession is the process whereby plant and animal communities develop through a series of stages to a final, mature community called the *climax community*. As the plant species and the structure of the habitat change so does the associated fauna, and generally each new stage is more diverse in both fauna and flora than its predecessor. The succession can be held at a stage, or pushed back down the stages, by a series of factors. In an agricultural environment, fire, grazing by livestock, clearing of vegetation, and introduction of exotic plants and animals all affect the succession.

Many Australian plants have evolved with fire, and have specific adaptations to take advantage of fire effects, such as, the seeds of many wattles and the shrubby hakeas, and the lignotubers of eucalypts. If a grassland area is fenced off to allow trees to regenerate, a fire may be needed to stimulate tree growth if the exclusion of grazing has not been sufficient.

The frequency and intensity of fire can affect the succession. Frequent, low intensity fires in woodlands and forests generally maintain a grassland understorey, while intermittent, hotter fires encourage a shrubby understorey. Each provides habitat for a different range of fauna, particularly birds. The fire system should aim to leave a mosaic of burned and unburned patches of differing ages to maximise the diversity of habitats for wildlife. This must, of course, fit in with the burning strategies adopted for pasture management if required.

Introduced plants and animals, both domestic and pests, also influence the successional cycle. Where regeneration of plant communities is desired, management of these factors will be necessary.

3.2 Shape, size and proximity

The size, shape, and proximity of a habitat area to other wildlife habitats will influence its value for nature conservation.

Shape is important as, for a given area, the shape with the smallest perimeter length is least susceptible to disturbance from outside influences. The closer a habitat area is to a square or circle, the better its chances of long-term survival. Long narrow strips are frequently damaged by fires, wind exposure or tree dieback.

A pleasant, shaded creek on a rural property, but there is no regrowth to replace the mature trees in the future.

A larger *size* of habitat supports not only more of a particular species, but often a greater range of species as well.

The proximity of a habitat area to other areas of natural vegetation is important for conserving the diversity and genetic strength of fauna and flora. Many species require continuous or near-continuous habitat for ready dispersal or repopulation. This is critical to smaller animals such as frogs, lizards, and small mammals which are highly vulnerable to predation in exposed situations. Isolated populations in small remnants of vegetation are susceptible to severe depletion or even extinction through effects of drought, fire, or other natural or human disturbances to their habitat.

Where an area of habitat adjoins other similar areas, vulnerable species can spread and reproduce quickly. If corridors and links of vegetation, such as shadelines, road verges, stock routes and along watercourses, are retained between habitat areas, the species can still disperse successfully, though more slowly. Planting trees and shrubs, especially on smaller properties, can simulate these links. The connections also effectively increase the size of each habitat remnant, improving its potential for nature conservation. Corridors are particularly valuable as they play a dual role of providing useful habitat in themselves while allowing effective dispersal of wildlife.

3.3 Diversity

Diversity of habitat is the most important principle. A range of habitat types on a property will meet the needs of a greater variety of plants and animals. Vegetation changes related to soil types, slope variations or drainage can support a diversity of species. Even small changes, such as a seepage in sandstone country, are sufficient to provide habitats for a whole new range of species. Diversity can be created, for example, by varying burning or grazing regimes so that several stages are present in the one community.

Within a habitat, certain features may encourage a greater diversity of species. These include the presence and permanence of water, rock outcrops, mature trees with hollow limbs, logs on the ground, and differing depths of water in dams.

Diversity between and within habitats should be a deciding factor in assessing which of several potential areas will be most suitable for nature conservation. Although the natural tendency is to avoid prime productive areas, these should be considered if the greatest diversity of habitats is to be achieved.

3.4 Dispersal

Animal populations will fluctuate from season to season and from year to year. Some bird species are migratory, and are seen only seasonally. The species composition of particular areas will vary in response to other, more irregular factors, such as fluctuating abundance of food, or changing density of understorey for protective cover as a vegetation community moves through its stages. The presence of a predator will depend on whether the habitat area supports a viable population of prey.

Many fauna species are nomadic in response to Australia's unpredictable rainfall patterns. Nectar feeders follow the flowering of food plants, while waterbirds congregate or disperse according to available water bodies. Remnants and corridors of vegetation, farm dams, parkland and house yards are beneficial to such species which need to be able to move over large areas. The corridors are also used by young animals to move into new territories, avoiding overcrowding of existing habitats, while recolonising sites where animals have died.

4. CONSERVATION GUIDELINES

There are many ways in which nature conservation can be integrated into management and development of properties. The key element is the retention or creation of suitable habitat, in most cases native vegetation. The following guidelines cover basic conservation techniques which can be adapted for particular needs. Suggested areas or widths of retained vegetation are guides only, and are not necessarily appropriate or attainable. A good rule of thumb is to retain or regenerate as much as is possible, bearing in mind the primary purpose of the property.

4.1 Property management

- *Plan the property* with regard to neighbouring properties, and the total catchment area it is in. Locate corridors to connect with vegetation on adjacent farms or reserves. Assess the habitat types on the property in relation to those conserved in the locality, and consider protecting those poorly represented elsewhere. Encourage neighbours to consider nature conservation on their properties, and encourage local authorities to manage road verges, reserves and parkland for habitat as well as public utility. A significant number of native grasses and ground covers are now only represented on road reserves and other areas where domestic stock are excluded.

- *Windbreaks or shadelines* in cropping and horticultural areas protect crops from wind, and provide useful habitat and corridors for plants and animals. They can be established by retaining native vegetation when the land is cleared, or by replanting with native species. Experience in Queensland has shown that a shadeline should be about 100 metres wide to withstand exposure effects and be able to regenerate successfully, although narrower strips may suffice if land is not available. To reduce competition for crop moisture, locate access lanes between windbreaks and the crop, and periodically deep rip along the edge of the windbreak.

- *Shelterbelts and shade clumps* provide shade, shelter and protection for livestock, and wildlife habitat. Again, these are best created by leaving strips and clumps of vegetation when the paddock is being cleared. The QDPI recommends retaining 20% of the original tree population on land which is suitable for clearing. Clumps rather than individual trees minimise suckering and seeding and maximise shade, wildlife habitat, and resistance to damage from storms or fires. Clump size will vary with circumstances, but a minimum size of 10 ha is desirable. Shelterbelts along fencelines act as wildlife corridors as well. These can connect vegetation along creeklines or on less productive land with adjacent vegetation on road verges or reserves. Isolated trees should not be left as they are most susceptible to dieback, and are unlikely to be replaced by natural regeneration.

- *Creeks and rivers* are generally the most diverse wildlife areas. Vegetation should be retained along banks for as great a width as possible, aiming for at least 50 metres each side. This will assist with bank stability while providing habitat and movement corridors for a range of wildlife. These drainage lines should be linked with other retained blocks for maximum value. Do not use creeks as convenient dumps for garden rubbish - they soon become choked with weeds and garden plants, and act as seed sources for these plants far downstream. *Swamps and marshes* are also valuable habitat areas. Avoid draining runoff waters into these areas, as it may adversely change water levels and vegetation communities.

- *Farm dams* can be habitats for a range of wildlife. Numerous species of birds use dams, including ducks, ibis, herons and egret. If the dam is designed with variations in water depth and shoreline, a wider variety of birds will be attracted. Plant a mixture of native trees and shrubs to create a mosaic of individual trees and shrubby thickets, and introduce appropriate native water plants. Leave a clear flight path off the dam for ducks. Islands in larger dams act as wave breaks, and provide protected habitats where birds can safely feed and nest. If possible, exclude stock from the dam and most of the shoreline to protect plants and dam edges.

- *Amenity plantings* around homesteads and buildings make the property more attractive, and encourage many interesting native animals to your doorstep. Plant native species which will provide food or shelter for birds and small mammals. Flowering plants attract honeyeaters, lorikeets and possums, while some denser prickly shrubs will give protection for wrens and finches. Plant a variety of flowering plants, so nectar is available all year. This will attract insects too, which will in turn be food for insectivorous birds. Judicious additional feeding may encourage desirable species, but avoid making them dependent on handouts - natural food sources are by far the best.

4.2 Farm reserves for nature conservation

Farm reserves are the most significant contribution to conservation on a property. Although these areas may be used occasionally for minor purposes such as cutting fenceposts, their conservation value is high because they conserve the whole habitat in a relatively unaltered state. Many of these farm reserves protect samples of vegetation types extensively cleared for agriculture, such as softwood scrubs, which are not well represented in national parks or conservation reserves. Frequently landholders set aside these areas as examples of 'what the country used to be like', or for the diversity of plants and animals they have observed in the area. Even small patches of this kind are important.

Farm reserves do not necessarily mean foregoing production. Parts of many properties are unsuitable for development, being steep, rocky, poor soils, or prone to erosion. These areas are often well suited to nature conservation, as they have the diversity of features which supports a diversity of wildlife. If left under native vegetation, or allowed to regenerate, these 'problem' areas have a purpose in the overall property management plan, and may well be an asset to the property value.

- *Old and dead trees with hollows* are especially valuable for many species. One in five Australian bird species nests in hollows, and many arboreal mammals such as possums and gliders need hollows for survival. Avoid clearing all these trees as it may take 70 years or more for hollows to develop in young trees. Fallen trees and logs also provide refuges for ground dwelling animals. In recently planted areas where mature trees with hollows may be absent, it is possible to place nesting boxes in trees for birds and possums to supply the nesting and living spaces.

- *Retaining native vegetation* is by far the best and cheapest way to establish shade, shelter, windbreaks and habitat on any property. Before any clearing is done, consider all these requirements and how they can be satisfied through vegetation retention.

- *Revegetating cleared areas* can sometimes be achieved by fencing off the area and allowing natural regeneration to occur. If relying on seedfall from existing trees, some preparation to reduce grass and weed competition will be beneficial. Consider also the prevailing wind and seed drift in locating protective fencing. Where regeneration relies on seed and suckers in the soil, success will decrease the longer since initial clearing.

- *Planting trees and shrubs* is expensive in time and materials, so the purpose for and selection of species, and site preparation, are critical. The greatest value to wildlife is achieved by using those species which occur naturally in the district on similar soils and LRAs. As these are adapted to local conditions, they should establish well. Propagating seedlings from local seed is strongly recommended for the same reason, and will also save costs. Using local genetic material helps to conserve the local flora, establishes a habitat which local fauna is used to, and maintains the natural character of the district's landscape.

  Use a diversity of species when replanting. Ideally this should include a range of plant forms from ground covers to trees, creating a varied habitat and bringing stability to the planting as losses from insect attack and disease will be reduced.

5. CONCLUSION

Nature conservation in Queensland is not a simple task. The combination of an extremely diverse natural environment and the broad range of primary industries presents many challenges to successful wildlife conservation.

Adequate conservation of the State's wildlife, especially fauna, cannot be achieved through conservation reserves alone. The Queensland National Parks and Wildlife Service recognises that wildlife conservation and sustainable primary production can coexist successfully on lands outside the reserve system. This, coupled with a demand from the rural community, has highlighted the need for a means of long-term protection of nature conservation areas on private land.

Appendix I

SOIL PROFILE ANALYSIS DATA

Standard site description and laboratory analysis data is presented for each of the Waggamba soils.

The site and profile information refer specifically to the type site identified on the Land Resource Area map (in back map pocket of Part B).

No data is provided for Westmar (28) and Flinton shallow (29) soils.

1. KEETAH

LAND RESOURCE AREA. Dumaresq
SOIL TYPE: Keetah
SITE NO: 5
A M.G. REFERENCE. 277 100 mE 6 829 600 mN ZONE 56
GREAT SOIL GROUP: Alluvial soil (affinities with earthy sands or solodized solonetz)
PRINCIPLE PROFILE FORM: Uc3.21

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: No coarse fragments

SUBSTRATE MATERIAL: Fine sandy alluvium
SLOPE: 0.5 %
LANDFORM ELEMENT TYPE: Levee
LANDFORM PATTERN TYPE: Gently undulating alluvial plain; includes narrow levees and lower terraces of the major rivers.
CHARACTERISTIC VEGETATION:
Tall open forest of river red gum, poplar box, silver leaved ironbark; with occasional carbeen or coolibah.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Firm to hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to .42 m	Dull yellowish brown (10YR4/3) moist; loamy sand; massive; moist very weak; common fine roots. Gradual to-
A2sb	.42 to .69 m	Dull yellowish brown (10YR5/3) moist, dull yellowish orange (10YR7/2) dry, dry sporadically bleached; sandy loam; massive; moist moderately weak, few fine roots. Abrupt to-
2B21tn	.69 to 1 08 m	Brown (7 5YR4/3) moist; few medium distinct grey mottles; light clay; weak 100-200mm columnar secondary, parting to moderate 10-20mm angular blocky primary, with 5-10mm cast, dry very firm; few fine manganiferous veins; few fine roots. Gradual to-
2B22n	1.08 to 1.50 m	Brown (7.5YR4/4) moist; few medium distinct grey mottles; sandy clay loam,fine sandy; moderate 10-20mm angular blocky with 5-10mm cast; dry very firm; few fine manganiferous veins, few fine roots.

Depth metres	1:5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch. Cations m.eq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp.Ratio R1	R2
Bulk .10	6.4	.06	.001																	
.10	6.5	.04	.001	21	50	19	13	8	2.9	1.2	.13	76	.053	2.42	.015	0.6		5	.69	
.30	7.0	.03	.001	24	44	18	15	7	2.9	1.4	.05	.60	.037	2.47	013	0.6		5	76	
.60	7.3	.02	.001	15	43	26	20	7	3.2	1 9	.13	.26	.025	2.30	.007	0.6		5	.85	
.90	8.1	.06	.001	11	37	24	30	13	6.5	3.7	.77	.22	.036	2.20	.009	1.1		10	.80	
1.20	8.5	.13	.011	9	40	25	28	12	6.3	3.4	.93	.23	.029	2.22	.010	1.0				

Depth metres	Org.C (W&B) % @ 105C	Tot.N % @ 105C	Extr. Phosphorus ppm @ 105C Acid	Bicarb.	Rep. K m.eq% @105C	DTPA-extr. ppm @ 105C Fe	Mn	Cu	Zn
Bulk .10	1.0	.09	76	45	.86	43	23	0.5	3.4

2. BENGALLA

LAND RESOURCE AREA: Dumaresq
SOIL TYPE: Bengalla
SITE NO: 4
A M.G. REFERENCE 269 900 mE 6 827 600 mN ZONE 56
GREAT SOIL GROUP: Solodized solonetz (affinities with soloths)
PRINCIPLE PROFILE FORM. Dr2.42
TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS No coarse fragments

SUBSTRATE MATERIAL: Silty alluvium
SLOPE: 0.5 %
LANDFORM ELEMENT TYPE: Plain
LANDFORM PATTERN TYPE: Level alluvial plain; mainly high terraces of the upper Macintyre and Dumaresq Rivers
CHARACTERISTIC VEGETATION:
Tall woodland of silver leaved ironbark and poplar box with occasional roughbarked apple.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to 15 m	Dark brown (10YR3/4) moist, silt loam; weak 20-50mm angular blocky secondary, parting to moderate 2-5mm polyhedral primary; dry moderately weak; common fine roots. Clear to-
A21	.15 to 40 m	Brown (10YR4/6) moist; silty clay loam; massive parting to weak 10-20mm angular blocky, dry moderately weak; few medium roots. Abrupt to-
A22cb	.40 to .52 m	Brown (10YR4/6) moist, dull orange (7.5YR7/3) dry, silty clay loam; massive with 5-10mm cast, dry moderately firm; few fine roots. Abrupt to-
B21tn	.52 to .95 m	Reddish brown (5YR4/6) moist; light medium clay, strong 100-200mm columnar secondary, parting to moderate 10-20mm angular blocky primary, with 5-10mm cast, dry moderately strong, few fine manganiferous veins; few coarse roots. Gradual to-
B22n	.95 to 1 50 m	Bright reddish brown (5YR5/6) moist, silty clay; moderate 10-20mm angular blocky with 5-10mm cast, dry moderately strong, few fine manganiferous veins.

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	% @105C	% @ 105C				m.eq/100g @ 105C					% @ 80C			% @ 105C				
Bulk 10	5.5	.03	.001																	
10	5 6	04	.001	4	34	40	25	13	2.6	1.4	.08	.65	077	2.26	021	1.0		9	.66	
.30	6.1	02	.002	4	34	40	26	8	2.1	1 5	.21	.17	042	2.25	.010	0.9		7	.72	
60	6.5	.11	.013	<1	27	32	43	17	4 9	5.7	2.2	.24	047	2 13	011	1.6		15	.96	
90	6 9	.23	030	<1	30	37	35	14	4.5	5.0	2.4	.20	033	2 24	.008	1.5		13	.94	
1.20	7 3	.21	.029	<1	26	42	32	13	4.8	4.9	2.3	19	027	2.26	.008	1.4				

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus		Rep.	DTPA-extr.			
			Acid	Bicarb.	K	Fe	Mn	Cu	Zn
metres	% @ 105C	% @ 105C	ppm @ 105C		m.eq% @105C	ppm @ 105C			
Bulk 10	0.9	.08	48	40	.42	88	84	0.8	1 2

3. UNDABRI

LAND RESOURCE AREA: Macintyre
SOIL TYPE: Undabri
SITE NO: 13
A.M.G. REFERENCE. 224 400 mE 6 850 600 mN ZONE 56
GREAT SOIL GROUP. Grey clay (affinities with black earths)
PRINCIPLE PROFILE FORM: Ug5.16
TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: No coarse fragments

SUBSTRATE MATERIAL: Clay alluvium
SLOPE: 0.0 %
LANDFORM ELEMENT TYPE: Plain
LANDFORM PATTERN TYPE: Level alluvial plain; occurs as extensive, flooded, open clay plain of the lower Macintyre and Weir Rivers
CHARACTERISTIC VEGETATION:
Vegetation is variable and ranges from a tussock grassland of curly mitchell grass and Queensland bluegrass with occasional coolibah to a mid high open woodland of coolibah.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Periodic cracking; hardsetting or weakly self mulching with a weak surface flake after rain

HORIZON	DEPTH	DESCRIPTION
A11	0 to .01 m	Brownish black (10YR3/2) moist; heavy clay; strong 5-10mm angular blocky primary; dry very weak.
A12	.01 to .10 m	Brownish black (10YR3/2) moist; heavy clay, strong 50-100mm angular blocky, dry very strong, common fine roots Clear to-
B21	.10 to .70 m	Greyish yellow-brown (10YR4/2) moist; heavy clay; moderate 20-50mm lenticular secondary, parting to moderate 10-20mm lenticular primary; moist moderately firm; few fine roots. Clear wavy to-
B22k	.70 to 1.05 m	Greyish yellow-brown (10YR4/2) moist, heavy clay; moderate 20-50mm polyhedral secondary, parting to moderate 10-20mm polyhedral primary; dry very strong; very few medium carbonate soft segregations. Gradual wavy to-
B23k	1.05 to 1 50 m	Dull yellowish brown (10YR4/3) moist, heavy clay, moderate 20-50mm polyhedral secondary, parting to moderate 10-20mm polyhedral primary; dry moderately strong; very few medium carbonate soft segregations.

Depth metres	1 5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch. Cations m.eq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp Ratio R1	R2
Bulk .10	7 2	08	.001																	
.10	7.6	.06	.001	1	8	23	67	45	21	15	1.2	1.1	.025	1.30	.017	3 8		21	.60	
.30	8.3	.07	.001	1	8	24	67	46	23	16	2.5	.62	020	1.26	014	3 9		22	64	
.60	8 6	10	.003	1	8	23	69	47	23	16	3.0	.59	.019	1 25	013	3.7		21	.67	
.90	8.6	.35	035	1	6	23	70	45	23	17	4.5	.61	.019	1.29	.020	3.4		20	.77	
1.20	8.4	39	.046	1	10	23	64	41	18	14	3.5	.20	.026	1 53	.012	3 2				

Depth metres	Org.C (W&B) % @ 105C	Tot.N % @ 105C	Extr. Phosphorus ppm @ 105C Acid	Bicarb.	Rep. K m.eq% @105C	DTPA-extr. ppm @ 105C Fe	Mn	Cu	Zn
Bulk .10	0.9	.08	15	12	1.1	43	43	1.5	0.5

4. KALANGA

LAND RESOURCE AREA: Macintyre
SOIL TYPE: Kalanga
SITE NO: 24
A.M G. REFERENCE: 761 100 mE 6 842 000 mN ZONE 55
GREAT SOIL GROUP: Grey clay (affinities with black earths)
PRINCIPAL PROFILE FORM: Ug5 24
TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: No coarse fragments

SUBSTRATE MATERIAL: Clay alluvium
SLOPE: 0.0 %
LANDFORM ELEMENT TYPE Plain
LANDFORM PATTERN TYPE Level alluvial plain, occurs as extensive, flooded, open, clay plains of the lower Macintyre and Weir Rivers.
CHARACTERISTIC VEGETATION:
Vegetation is variable and ranges from a mid high to tall woodland of belah with myall and coolibah to a low shrubland of myall and boonaree.

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Periodic cracking,moderately to strongly self mulching with a weak surface flake after rain

HORIZON	DEPTH	DESCRIPTION
A	0 to .02 m	Brownish black (10YR3/1) dry; medium heavy clay, strong 2-5mm granular secondary, parting to strong <2mm granular primary; dry moderately firm Clear to-
A12	02 to 20 m	Brownish grey (10YR4/1) moist; medium heavy clay, moderate 20-50mm angular blocky secondary; dry moderately strong. Clear to-
B22	.20 to .80 m	Brownish grey (10YR4/1) moist; medium heavy clay; strong 20-50mm lenticular; dry very strong Gradual to-
B23k	.80 to 1.20 m	Grey (5Y4/1) moist, medium heavy clay; strong 50-100mm lenticular secondary, parting to strong 10-20mm lenticular primary; moderately moist very strong, common medium carbonate nodules Clear to-
B24k	1.20 to 1 40 m	Dark greyish yellow (2.5Y4/2) moist; medium heavy clay; strong 20-50mm lenticular secondary, parting to strong 2-5mm lenticular primary; moderately moist moderately strong; common medium carbonate nodules.

Depth metres	1:5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch. Cations m.eq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp.Ratio R1	R2
Bulk .10	8 2	.13	.001																	
.10	8.2	.10	002	7	17	17	57	49	28	11	.85	2.6	.038	1.42	029	4.2		18	.40	
.30	9.0	.21	.006	5	15	17	64	47	27	15	3.0	0.6	.025	1 24	024	5.7		20	.54	
60	8 9	52	045	5	15	15	65	46	22	17	6.0	58	.022	1 22	.028	5 3		21	.78	
.90	8.5	1 4	.185	4	14	14	67	47	18	16	8.6	.48	.018	1 21	039	5.9		21	.75	
1.20	8.4	1 5	186	5	14	16	66	47	18	17	8.2	1.6	.017	1.25	.034	6 1				

Depth metres	Org.C (W&B) % @ 105C	Tot N % @ 105C	Extr Phosphorus ppm @ 105C Acid	Bicarb.	Rep. K m.eq% @105C	DTPA-extr. ppm @ 105C Fe	Mn	Cu	Zn
Bulk .10	1.0	.08	24	16	1.7	11	18	1.4	0.3

5. MURRA CUL CUL

LAND RESOURCE AREA: Serpentine
SOIL TYPE: Murra Cul Cul
SITE NO: 17
A.M.G. REFERENCE: 234 200 mE 6 886 900 mN ZONE 56
GREAT SOIL GROUP: Solodic soil
PRINCIPAL PROFILE FORM: Dd1.43

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: Very few coarse pebbles

SUBSTRATE MATERIAL: Fine sandy and clay alluvia.
SLOPE: 1.5 %
LANDFORM ELEMENT TYPE: Lower slope
LANDFORM PATTERN TYPE: Level to gently undulating alluvial plains; mainly as narrow drainage floors of major creeks east of the Weir River
CHARACTERISTIC VEGETATION:
Tall open woodland of poplar box with occasional myall or belah and an understorey of shrubs.

PROFILE MORPHOLOGY

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to .05 m	Dark brown (10YR3/3) moist; sandy clay loam,fine sandy; very few coarse pebbles, rounded unspecified coarse fragments, strong, dispersed; massive; dry very firm; few fine roots. Abrupt to-
A2cb	.05 to .08 m	Greyish yellow-brown (10YR5/2) moist, dull yellowish orange (10YR7/2) dry; sandy clay loam,fine sandy, massive, dry very firm; few fine roots. Sharp to-
B21t	.08 to .27 m	Brownish black (10YR3/2) moist; heavy clay; weak 50-100mm prismatic secondary, parting to moderate 10-20mm angular blocky primary; dry moderately strong; few medium roots. Clear to-
B22tk	.27 to 62 m	Brown (7.5YR4/3) moist, heavy clay; very few coarse pebbles, rounded unspecified coarse fragments, strong, dispersed, moderate 20-50mm polyhedral; dry moderately strong, very few medium carbonate soft segregations, very few medium carbonate nodules. Gradual to-
B23yn	.62 to 87 m	Dull brown (7 5YR5/4) moist; few medium faint grey mottles, medium clay, very few coarse pebbles, rounded unspecified coarse fragments, strong, dispersed; moderate 2-5mm polyhedral, dry very strong; many coarse gypseous crystals, very few coarse manganiferous veins. Clear wavy to-
BC?	87 to 1.50 m	Bright brown (7.5YR5/6) moist; many coarse distinct grey mottles, few medium prominent orange mottles, light medium clay, few medium pebbles, angular tabular sandstone, moderate, undisturbed, moderate 5-10mm polyhedral; wet moderately weak.

Depth	1 5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	%		%				m eq/100g					%			%			
			@105C		@ 105C				@ 105C					@ 80C			@ 105C			
Bulk .10	6.9	.13	.007																	
10	7 2	.05	003	4	59	17	19	15	6.8	3.3	50	48	.017	.506	.018	1.0		6	.69	
.30	7.9	.92	.116	2	30	11	57	46	16	19	7.2	.54	.022	.574	.060	2.9		24	75	
.60	8 5	1.6	167	2	34	12	53	40	13	17	8 3	.50	.016	.540	.099	2 9		21	78	
.90	7.5	.38	.068	7	20	7	57	34	15	15	8.0	.49	016	.511	3.25	5.0		22	.97	
1.20	5.8	.24	.007	1	35	14	48	39	11	14	7.5	.54	020	1.07	.059	2.7				

Depth	Org.C (W&B)	Tot N	Extr. Phosphorus		Rep.	DTPA-extr			
			Acid	Bicarb.	K	Fe	Mn	Cu	Zn
metres	%	%	ppm		m.eq%	ppm			
	@ 105C	@ 105C	@ 105C		@105C	@ 105C			
Bulk .10	1.8	.13	22	15	.71	47	21	0 5	0 9

6. YAMBOCULLY

LAND RESOURCE AREA Serpentine
SOIL TYPE: Yambocully
SITE NO: 8
A M G REFERENCE. 773 200 mE 6 842 900 mN ZONE 55
GREAT SOIL GROUP Solodic soil
PRINCIPAL PROFILE FORM. Db1 43

TYPE OF MICRORELIEF No microrelief
SURFACE COARSE FRAGMENTS. No coarse fragments

SUBSTRATE MATERIAL: Fine sandy and clay alluvia
SLOPE: 0.5 %
LANDFORM ELEMENT TYPE: Levee or scroll
LANDFORM PATTERN TYPE. Level to very gently undulating alluvial plain, includes slightly elevated landforms associated with current and former floodplain streams of the wide alluvial plains of the lower Macintyre and Weir Rivers
CHARACTERISTIC VEGETATION:
Tall open woodland of poplar box with occasional belah or supplejack and an understorey of shrubs.

PROFILE MORPHOLOGY

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY Hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to 10 m	Dark brown (7 5YR3/4) moist, silty clay loam; weak 10-20mm angular blocky, moderately moist moderately firm, common fine roots Abrupt to-
A2cb	10 to 13 m	Brown (7 5YR4/3) moist, dull orange (7.5YR7/3) dry, clay loam, weak 10-20mm angular blocky parting to massive;moderately moist moderately firm, common very fine roots. Sharp to-
B21t	13 to 26 m	Dark reddish brown (5YR3/3) moist, medium heavy clay, weak 50-100mm prismatic secondary, parting to strong 20-50mm angular blocky primary; moist moderately firm; few very fine roots. Clear smooth to-
B22t	26 to 47 m	Brown (7 5YR4/3) moist, medium heavy clay, moderate 20-50mm lenticular secondary, parting to moderate 10-20mm lenticular primary, moist moderately firm, very few medium carbonate nodules, few very fine roots. Clear wavy to-
B23k	.47 to 83 m	Brown (7 5YR4/3) moist, medium clay; weak 20-50mm prismatic secondary, parting to strong 10-20mm angular blocky primary, dry moderately strong, few coarse carbonate soft segregations, very few medium carbonate nodules, common very fine roots Clear wavy to-
Dn	83 to 1.50 m	Dull yellowish brown (10YR5/3) moist, light medium clay, strong 20-50mm prismatic secondary, parting to strong 5-10mm polyhedral primary, with 5-10mm cast; dry moderately strong, very few coarse carbonate soft segregations, many medium manganiferous veins.

Depth metres	1 5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch. Cations m.eq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp Ratio R1	R2
Bulk 10	7.0	.05	002																	
.10	6 8	04	001	12	37	32	22	17	6 2	2 5	.08	1 1	053	1.85	017	1 5		8	.62	
30	7.9	.11	011	4	26	23	48	31	14	10	2.0	.52	024	1 57	.014	3.2		18	.68	
60	8.7	.96	131	4	39	20	39	24	11	11	2.7	40	.026	1.73	.031	2 7		15	.50	
90	8 5	1 0	123	2	52	17	31	20	8 7	9 1	2 7	.44	029	1.93	.034	2.4		13	55	
1.20	8.5	1.0	.125	1	47	18	34	23	9.5	9.4	3.1	.48	.029	1.77	025	2 5				

Depth metres	Org.C (W&B) % @ 105C	Tot N % @ 105C	Extr Phosphorus ppm @ 105C Acid	Bicarb.	Rep. K m.eq% @105C	DTPA-extr. ppm @ 105C Fe	Mn	Cu	Zn
Bulk 10	1.1	08	88	45	1 2	35	63	1 0	0 9

8. JINDABYNE

LAND RESOURCE AREA: Boogara
SOIL TYPE: Jindabyne
SITE NO: 10
A.M.G. REFERENCE: 759 800 mE 6 865 700 mN ZONE 55
GREAT SOIL GROUP: Red brown earth (affinities with solodic soils)
PRINCIPLE PROFILE FORM. Dr2.43

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: No coarse fragments

SUBSTRATE MATERIAL: Fine sandy and clay alluvia
SLOPE: 0.0 %
LANDFORM ELEMENT TYPE: Plain
LANDFORM PATTERN TYPE: Level to gently undulating alluvial plain; mainly as narrow drainage floors of major creeks, west of the Weir River.
CHARACTERISTIC VEGETATION:
Tall open woodland of poplar box with occasional belah or brigalow and an understorey of shrubs

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to .12 m	Dark reddish brown (5YR3/4) moist; sandy clay loam,fine sandy; massive; dry very weak; few fine roots. Sharp to-
A2cb	.12 to .13 m	Dark reddish brown (5YR3/4) moist, dull orange (5YR6/4) dry; loam, fine sandy, massive; dry moderately firm; few fine roots. Sharp to-
B21t	.13 to .32 m	Dark reddish brown (2.5YR3/4) moist; heavy clay; weak 20-50mm prismatic secondary, parting to strong 10-20mm angular blocky primary; dry moderately strong, few coarse roots Clear to-
B22tk	.32 to 96 m	Dark reddish brown (5YR3/6) moist; heavy clay; moderate 50-100mm angular blocky secondary, parting to moderate 10-20mm angular blocky primary, with 5-10mm cast; dry moderately strong; common very coarse carbonate soft segregations, very few medium carbonate concretions; few fine roots. Diffuse to-
B23n	.96 to 1.50 m	Dark reddish brown (5YR3/6) moist, medium heavy clay; moderate 10-20mm polyhedral with 5-10mm cast, dry very strong; few coarse carbonate concretions, many coarse manganiferous veins.

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	% @105C	% @ 105C				m.eq/100g @ 105C					% @ 80C			% @ 105C				
Bulk .10	6.9	.06	.002																	
.10	6.6	.03	.001	9	56	17	20	16	5.4	2.7	17	.76	060	.577	.021	1.2		7	.52	
.30	8.8	.50	054	4	37	10	49	28	10	10	4 6	.79	028	.639	.018	2.4		18	.91	
.60	9.0	.96	.103	5	38	14	45	25	7.9	10	6.1	79	023	633	.039	1.7		18	.87	
.90	9.1	1 0	.102	5	38	13	44	24	7.3	9.8	7.0	.77	022	.618	041	1.7		18	89	
1.20	9.1	.97	.096	4	39	14	42	25	7.2	9.7	7.5	.74	019	.590	.040	1.6				

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus		Rep.	DTPA-extr.			
			Acid	Bicarb.	K	Fe	Mn	Cu	Zn
metres	% @ 105C	% @ 105C	ppm @ 105C		m.eq% @105C	ppm @ 105C			
Bulk .10	1.3	.11	29	20	1.2	28	89	1.4	0.9

9. WONDOOGLE

LAND RESOURCE AREA. Broomfield
SOIL TYPE: Wondoogle
SITE NO· 21
A.M.G. REFERENCE. 776 700 mE 6 843 100 mN ZONE 55
GREAT SOIL GROUP. Siliceous sand (affinities with earthy sands)
PRINCIPLE PROFILE FORM: Uc1.23

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS. No coarse fragments

SUBSTRATE MATERIAL: Sand deposits mainly overlying clay alluvium
SLOPE: 1.0 %
LANDFORM ELEMENT TYPE: Scroll, point bar deposit or relict dune
LANDFORM PATTERN TYPE: Level alluvial plain, occurs as very low, broad sand rises within the wide alluvial plains of the lower Macintyre and Weir Rivers.
CHARACTERISTIC VEGETATION:
Tall woodland or open forest of tumbledown gum, river red gum and carbeen, with occasional poplar box, cypress pine, ironwood and long fruited bloodwood; understorey usually absent.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY Loose or soft

HORIZON	DEPTH	DESCRIPTION
A11	0 to .05 m	Brownish black (10YR2/3) moist; loamy sand; massive; moist moderately weak, common fine roots. Abrupt smooth to-
A12	.05 to .85 m	Dark brown (10YR3/4) moist; loamy sand; massive; moist very weak; few fine roots Diffuse wavy to-
D	.85 to 1.50 m	Dull yellowish brown (10YR5/4) moist; very few fine faint grey mottles, sand; massive, moist very weak, very few fine manganiferous soft segregations, many extremely coarse argillaceous soft segregations with sandy clay loam texture.

Depth metres	1:5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch. Cations m.eq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp.Ratio R1	R2
Bulk .10	7.1	.03	.001																	
.10	7.2	.06	.001	69	15	7	8	8	4.4	1.3	.15	2.0	.042	1.89	.028	0.7		4	.61	
.30	7.5	.01	.001	69	19	8	6	4	1.1	1.0	.32	1.3	.020	1.92	.006	0.4		3	58	
.60	7.4	.01	.001	67	22	5	5	3	.89	.80	.17	.84	.019	2.14	.008	0.3		2	.60	
.90	7.4	.01	.001	67	24	7	2	3	.73	.60	05	.44	.012	2.06	.005	0.3		2	.60	
1.20	7.3	02	.001	52	23	7	16	8	3.2	2.7	.05	.46	.021	2.09	.005	0.8				

Depth metres	Org.C (W&B) % @ 105C	Tot.N % @ 105C	Extr. Phosphorus ppm @ 105C Acid	Bicarb.	Rep. K m.eq% @105C	DTPA-extr. ppm @ 105C Fe	Mn	Cu	Zn
Bulk .10	0 5	03	44	27	.40	17	29	0.4	0.7

10. WAI WAI

LAND RESOURCE AREA: Broomfield
SOIL TYPE: Wai Wai #
SITE NO: 28
AMG REFERENCE: 211 800 mE 6 842 400 mN ZONE 56
GREAT SOIL GROUP: Siliceous sand
PRINCIPAL PROFILE FORM. Uc4.21

TYPE OF MICRORELIEF No microrelief
SURFACE COARSE FRAGMENTS. No coarse fragments

SUBSTRATE MATERIAL: Sand deposits mainly overlying clay alluvium
SLOPE: 3.0 %
LANDFORM ELEMENT TYPE: Relict dune or sand ridge
LANDFORM PATTERN TYPE. Level alluvial plain; occurs as elevated, slightly elongated, dune like sand ridges within the wide alluvial plains of the lower Macintyre and Weir Rivers.
CHARACTERISTIC VEGETATION.
Tall open forest of cypress pine with occasional pink bloodwood or supplejack and an understorey of river wattle, wilga and bitterbark.

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY Loose

HORIZON	DEPTH	DESCRIPTION
A11	0 to .10 m	Brownish black (7.5YR3/2) moist, sand, single grain; moist loose. Clear to-
A12	.10 to .40 m	Brownish black (7.5YR2/2) moist, sand; massive; moist very weak. Gradual to-
A2	.40 to .70 m	Bright reddish brown (5YR5/6) moist; sand, massive; moist very weak. Diffuse to-
A3	.70 to 1 00 m	Orange (5YR6/6) moist, sand; massive; moist very weak. Diffuse to-
B2	1 00 to 1.50 m	Bright reddish brown (5YR5/8) moist; sand, massive; moist very weak.

Depth	1 5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	% @105C	% @ 105C				m eq/100g @ 105C					% @ 80C			% @ 105C				
.10	6.7	01	001	93	3	1	1	2	.80	26	05	15	012	1 22	004	0.2		2	.99	
30	5.6	01	.001	86	7	2	1	4	.34	.10	05	.15	.017	1.36	005	0.4		2	.99	
.60	6.0	01	.001	87	8	2	1	2	.30	28	.05	.13	010	1.24	0	0.2		2	.12	
.90	6 0	01	.001	86	7	2	1	3	30	.05	.05	.08	008	1.43	0	0.1		1	000	
1.20	5 9	01	.001	86	7	2	1	2	.55	05	.05	.13	.010	1 46	003	0 2				

Depth	Org C (W&B)	Tot n	Extr. Phosphorus		Rep.	DTPA-extr.			
			Acid	Bicarb.	K	Fe	Mn	Cu	Zn
metres	% @ 105C	% @ 105C	ppm @ 105C		m.eq% @105C	ppm @ 105C			
.10	0.3	.03	17	13	0.3	12	8	0.1	0.4

Described by B.Slater from 'Soils of the Callandoon Creek Area, South Queensland'. (unpub)

11. MARELLA

LAND RESOURCE AREA: Goodar
SOIL TYPE: Marella
SITE NO: 22
A.M G. REFERENCE: 210 300 mE 6 867 800 mN ZONE 56
GREAT SOIL GROUP: Solodic soil
PRINCIPAL PROFILE FORM. Db3 33

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS. No coarse fragments

SUBSTRATE MATERIAL: Fine sandy alluvium and other transported material (relict alluvia)
SLOPE: 0.5 %
LANDFORM ELEMENT TYPE. Mid slope
LANDFORM PATTERN TYPE: Level plains; elevated relict alluvial plains (fan or terrace deposits) associated with the upper Weir River
CHARACTERISTIC VEGETATION:
Tall open forest of cypress pine and poplar box with occasional silver leaved ironbark and roughbarked apple, and an understorey of shrubs.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Soft to firm

HORIZON	DEPTH	DESCRIPTION
A1	0 to .35 m	Brownish black (7.5YR3/2) moist; fine sandy loam; massive; moist moderately weak; common fine roots. Clear smooth to-
A2sb	.35 to 55 m	Dark brown (7.5YR3/4) moist, dry sporadically bleached; light sandy clay loam fine sandy; massive; moist moderately weak; few fine roots. Abrupt smooth to-
B21t	.55 to .84 m	Brown (7.5YR4/4) moist, fine sandy clay; moderate 20-50mm prismatic secondary, parting to moderate 10-20mm angular blocky primary; moderately moist moderately firm. Abrupt smooth to-
2B2n?	.84 to 1 20 m	Brown (7.5YR4/3) moist, dull yellowish orange (10YR6/4) dry; sandy clay loam, fine sandy; weak 20-50mm prismatic secondary, parting to strong 10-20mm angular blocky primary, with 5-10mm cast; moderately moist very firm, few fine manganiferous veins, few fine roots Clear wavy to-
Dk	1.20 to 1 50 m	Brown (7.5YR4/4) moist, dull yellowish orange (10YR7/4) dry; sandy clay loam, fine sandy; weak 20-50mm prismatic secondary, parting to moderate 10-20mm polyhedral primary; dry very firm, very few medium carbonate soft segregations.

Depth metres	1:5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch Cations m.eq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp Ratio R1	R2
Bulk .10	7.6	.11	.001																	
.10	7.3	.03	.001	16	59	13	13	10	6.8	1.4	.56	.79	067	.682	.013	0.7		5	.56	
.30	7.6	.02	001	16	58	11	14	10	5.9	1.7	1.3	.26	.032	.660	.012	0.6		6	.68	
.60	8.0	.02	.001	16	51	10	22	14	8.3	2.8	1.6	44	.018	.635	.009	0.8		9	.72	
.90	8 5	02	.001	12	50	12	25	16	10	4.3	1.0	.54	.020	.647	009	1.2		10	.40	
1.20	8.9	.11	.001	6	59	13	19	15	8.4	4 3	04	50	017	.672	.010	1.0				

Depth metres	Org.C (W&B) % @ 105C	Tot N % @ 105C	Extr Phosphorus ppm @ 105C Acid	Bicarb.	Rep. K m.eq% @105C	DTPA-extr. ppm @ 105C Fe	Mn	Cu	Zn
Bulk .10	1.2	.09	129	63	.77	17	50	0.4	0 9

12. BENDIDEE

LAND RESOURCE AREA: Goodar
SOIL TYPE: Bendidee
SITE NO: 7
A.M.G. REFERENCE: 290 600 mE 6 841 900 mN ZONE 56
GREAT SOIL GROUP: Solodized solonetz
PRINCIPAL PROFILE FORM: Dy5.43

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: No coarse fragments

SUBSTRATE MATERIAL: Quartzose and deeply weathered sedimentary rocks; less commonly transported material (relict alluvia)
SLOPE: 1.5 %
LANDFORM ELEMENT TYPE: Mid slope
LANDFORM PATTERN TYPE: Level to gently undulating plains; occurs as extensive elevated sandy plains of the lowlands along the eastern margins of the shire.
CHARACTERISTIC VEGETATION:
Tall open forest of cypress pine, narrow leaved ironbark and rusty gum with occasional tumbledown gum; an understorey of bulloak and wattles often present.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Soft to firm

HORIZON	DEPTH	DESCRIPTION
A1	0 to .10 m	Dark brown (10YR3/3) moist; loamy sand; massive; moist loose; common fine roots. Clear wavy to-
A21	.10 to .42 m	Dull orange (7.5YR6/4) moist; clayey sand; massive; moist loose; common fine roots. Clear smooth to-
A22cb	.42 to .45 m	Dull orange (7.5YR7/3) moist, dry conspicuously bleached; clayey sand, few small pebbles, subangular quartz, strong; massive; moist loose; very few medium ferromanganiferous nodules; few medium roots. Sharp gammate to-
B21t	.45 to .75 m	Dull yellowish orange (10YR6/3) moist; many medium distinct orange mottles, very few medium prominent red mottles; medium heavy clay; strong 200-500mm columnar secondary, parting to moderate 10-20mm angular blocky primary; dry moderately strong; very few medium carbonate soft segregations; few fine roots. Clear smooth to-
B22t	.75 to 1.00 m	Dull yellowish orange (10YR6/3) moist; very few medium prominent red mottles; light medium clay; moderate 10-20mm angular blocky; dry moderately strong; very few medium carbonate soft segregations; few fine roots. Abrupt gammate to-
2A2cbb	1.00 to 1.02 m	Dull yellowish orange (10YR7/3) moist, dry conspicuously bleached; sandy clay loam,coarse sandy; massive; dry moderately strong. Abrupt gammate to-
2B21tb	1.02 to 1.50 m	Yellowish brown (10YR5/8) moist; few medium distinct grey mottles, very few medium prominent red mottles; sandy clay; strong 100-200mm columnar secondary, parting to moderate 10-20mm angular blocky primary; dry moderately strong; very few medium manganiferous veins, very few medium carbonate soft segregations.

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	% @105C	% @ 105C				m.eq/100g @ 105C					% @ 80C			% @ 105C				
Bulk .10	6.0	.02	.001																	
.10	5.6	.01	.001	59	29	8	5	5	0.2	0.3	.13	.07	.009	.177	.010	0.3		2	.52	
.30	5.7	.01	.001	51	37	9	5	3	.05	.20	.05	.03	.004	.192	.008	0.2		1	.59	
.60	6.2	.34	.051	31	17	4	46	17	.05	8.9	3.3	.26	.011	.361	.018	2.1		14	.96	
.90	8.2	.31	.045	39	21	3	33	13	0.1	7.7	3.3	.30	.010	.337	.018	1.6		11	.98	
1.20	8.5	.39	.055	39	22	5	34	14	0.2	7.6	3.3	.40	.011	.313	.020	1.4				

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus		Rep. K	DTPA-extr.			
			Acid	Bicarb.		Fe	Mn	Cu	Zn
metres	% @ 105C	% @ 105C	ppm @ 105C		m.eq% @105C	ppm @ 105C			
Bulk .10	0.8	.03	4	3	.07	86	8	0.1	0.3

13. YELARBON

LAND RESOURCE AREA: Desert
SOIL TYPE: Yelarbon
SITE NO: 6
A.M.G. REFERENCE: 282 100 mE 6 833 200 mN ZONE 56
GREAT SOIL GROUP: Solonetz
PRINCIPLE PROFILE FORM: Dy2.43

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: No course fragments

SUBSTRATE MATERIAL: Transported material (relict alluvia)
SLOPE: 0.0 %
LANDFORM ELEMENT TYPE: Plain
LANDFORM PATTERN TYPE: Level plain; represents an elevated relict alluvial plain associated with the confluence of the Macintyre Brook and Dumaresq River near Yelarbon.
CHARACTERISTIC VEGETATION:
Stunted teatree and bulloak with a sparse ground cover of spinifex and windmill grasses; large areas as bare scalded clay pans.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A2cb	0 to .07 m	Greyish yellow (2.5Y7/2) dry; silty clay loam; massive; moderately moist very weak; common fine roots. Abrupt gammate to
B21t	.07 to .30 m	Greyish yellow-brown (10YR5/2) moist; light medium clay; moderate 200-500mm prismatic secondary, parting to strong 5-10mm angular blocky primary; moist moderately weak; very few medium carbonate soft segregations; few fine roots. Clear to-
2A2cb	.30 to .40 m	Dull yellowish orange (10YR6/4) moist, dry conspicuously bleached; light medium clay; weak 2-5mm platy; dry moderately firm; very few medium carbonate soft segregations, very few fine manganiferous veins; few fine roots. Clear gammate to-
2B21bk	.40 to .90 m	Brown (7.5YR4/4) moist, dull orange (7.5YR6/4) dry; light clay; strong 10-20mm angular blocky; dry moderately strong; few medium carbonate nodules, very few fine manganiferous veins; few very fine roots. Gradual to-
D1k	.90 to 1.20 m	Dull yellowish orange (10YR6/4) moist; fine sandy loam; moderate 20-50mm polyhedral; dry moderately strong; few medium carbonate nodules, very few fine manganiferous veins. Gradual to-
D2	1.20 to 1.50 m	Yellowish brown (10YR5/6) moist; clayey sand; massive; moist very firm; very few fine manganiferous veins.

Depth metres	1:5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch. Cations m.eq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp.Ratio R1	R2
Bulk .10	9.1	.15	.007																	
.10	9.5	.13	.002	8	22	41	30	15	8.0	1.7	4.5	.25	.013	1.47	.013	1.2		8	.82	
.30	10	.46	.006	8	16	33	46	25	6.6	2.6	15	.36	.028	1.59	.014	2.2		23	.98	
.60	9.8	.48	.005	34	22	21	24	31	5.3	1.5	22	.31	.034	1.55	.007	2.0		15	.36	
.90	9.7	.81	.108	8	42	25	25	26	4.7	.82	20	.27	.038	1.57	.007	2.1		15	.59	
1.20	11	.31	.003	43	34	13	10	10	0.2	0.1	9.2	.13	.008	1.28	.005	0.9				

Depth metres	Org.C (W&B) % @ 105C	Tot.N % @ 105C	Extr. Phosphorus ppm @ 105C Acid	Bicarb.	Rep. K m.eq% @105C	DTPA-extr. ppm @ 105C Fe	Mn	Cu	Zn
Bulk .10	0.8	.05	22	8	.21	8	16	0.5	0.3

14. WONDALLI

LAND RESOURCE AREA: Commoron
SOIL TYPE: Wondalli
SITE NO: 1
A.M.G. REFERENCE: 267 500 mE 6 843 600 mN ZONE 56
GREAT SOIL GROUP: Grey clay
PRINCIPAL PROFILE FORM: Ug5.24
TYPE OF MICRORELIEF: Melonhole gilgai
VERTICAL INTERVAL: 0.80 m
HORIZONTAL INTERVAL: 15m
COMPONENT OF MICRORELIEF SAMPLED: Mound
SURFACE COARSE FRAGMENTS. No coarse fragments

SUBSTRATE MATERIAL: Transported material (clay sheets)
SLOPE: 0.0%
LANDFORM ELEMENT TYPE: Plain
LANDFORM PATTERN TYPE: Level to very gently undulating plain; occurs as elevated melonholed plains east and north east of Goondiwindi.
CHARACTERISTIC VEGETATION:
Tall open forest of brigalow with belah and an understorey of shrubs; occasional poplar box and gum topped box.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY· Periodic cracking, moderately to strongly self mulching on mounds and in depressions, with a weak surface flake after rain; firm to hardsetting where water ponds

HORIZON	DEPTH	DESCRIPTION
A1	0 to .07 m	Greyish brown (7.5YR4/2) moist; light medium clay; strong 2-5mm granular primary, moderately moist moderately weak; few medium carbonate concretions; common medium roots Abrupt to-
B21	.07 to 43 m	Greyish yellow-brown (10YR5/2) moist; heavy clay; moderate 10-20mm angular blocky primary; moderately moist very firm; very few medium carbonate concretions, very few medium gypseous soft segregations; common medium roots. Clear to-
B22y	.43 to .70 m	Greyish yellow-brown (10YR5/2) moist, heavy clay; strong 50-100mm lenticular primary, dry very strong, very few medium carbonate nodules, few coarse gypseous soft segregations; few medium roots. Gradual to-
B23	.70 to 1 50 m	Greyish yellow-brown (10YR5/2) moist; heavy clay; strong 50-100mm lenticular primary; dry very strong, few medium roots.

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	% @105C	% @ 105C				m.eq/100g @ 105C					% @ 80C			% @ 105C				
Bulk .10	8.2	.18	.002																	
.10	9.0	.16	.001	10	24	16	52	37	25	8.1	1.8	1.2	.015	656	.024	2.6		19	.51	
.30	9.1	.44	.026	8	23	15	56	34	16	11	6.2	.81	011	.645	.028	2.7		23	.90	
.60	8 0	1.8	.103	7	23	17	58	32	13	11	9.3	.72	008	.640	.137	2.4		22	.85	
.90	7.4	1.4	.175	8	23	14	56	32	11	10	8.6	.71	.007	.622	.047	2.2		21	.96	
1.20	7.4	1.3	.168	8	24	16	54	32	10	10	8.5	.76	.008	.626	.038	2.6				

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus		Rep.	DTPA-extr.			
			Acid	Bicarb.	K	Fe	Mn	Cu	Zn
metres	% @ 105C	% @ 105C	ppm @ 105C		m.eq% @105C	ppm @ 105C			
Bulk .10	1.1	.10	17	11	1.1	15	27	1.0	0.4

15. CALINGUNEE

LAND RESOURCE AREA: Commoron
SOIL TYPE: Calingunee
SITE NO: 20
A.M.G. REFERENCE: 257 200 mE 6 894 500 mN ZONE 56
GREAT SOIL GROUP: Grey clay
PRINCIPAL PROFILE FORM: Ug5.16
TYPE OF MICRORELIEF: Melonhole gilgai
VERTICAL INTERVAL: 0.60 m
HORIZONTAL INTERVAL: 10 m
COMPONENT OF MICRORELIEF SAMPLED: Shelf
SURFACE COARSE FRAGMENTS: Few coarse pebbles

SUBSTRATE MATERIAL: Labile sedimentary rocks
SLOPE: 2.0 %
LANDFORM ELEMENT TYPE: Mid slope
LANDFORM PATTERN TYPE: Gently undulating to undulating rises, scarp footslopes and broad valleys; occurs as sloping lowlands associated with the northern jump-ups; particularly in the north east.
CHARACTERISTIC VEGETATION:
Tall open forest of brigalow with belan and occasional poplar box, with an understorey of shrubs.

PROFILE MORPHOLOGY

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY. Periodic cracking; weakly to moderately self mulching on mounds and in depressions with a weak surface flake after rain; firm to hardsetting where water ponds

HORIZON	DEPTH	DESCRIPTION
A11	0 to 05 m	Brownish black (10YR3/2) moist; medium clay, strong 2-5mm angular blocky secondary, parting to strong <2mm granular primary; dry moderately weak; common fine roots. Abrupt to-
A12	.05 to 20 m	Brownish black (10YR3/1) moist; medium heavy clay; few coarse pebbles, angular quartz, very strong, dispersed, very few coarse pebbles, angular sandstone, strong, dispersed; strong 20-50mm angular blocky; moist moderately weak; common medium roots Clear to-
B21k	.20 to 60 m	Greyish yellow-brown (10YR4/2) moist; medium heavy clay; few coarse pebbles, angular quartz, very strong, dispersed; strong 20-50mm angular blocky , dry moderately firm; common medium carbonate soft segregations, few fine roots Diffuse gammate to-
B22	.60 to 1 50 m	Brown (7.5YR4/3) moist, medium heavy clay; very few coarse pebbles, angular quartz, very strong, dispersed; moderate 100-200mm lenticular tertiary, parting to moderate 50-100mm polyhedral secondary, parting to moderate 10-20mm lenticular primary; dry very firm; few fine roots.

Depth metres	1:5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch. Cations m.eq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp.Ratio R1	R2
Bulk 10	7 4	.08	.002																	
.10	6.9	.07	.001	30	24	12	33	29	17	4.4	.24	.45	.065	.571	.050	1.7		13	.32	
.30	9.1	.30	.007	21	20	8	50	35	24	11	.03	.73	.033	.388	026	1.8		20	.80	
.60	8.9	.54	.048	21	18	8	50	30	12	11	7.6	.33	.023	370	.023	1.5		20	.94	
.90	5.4	.88	.139	17	17	9	56	33	6.8	9 2	8.4	.30	021	370	.018	2 0		20	94	
1.20	4.9	.80	.128	21	19	11	49	30	4.6	8.1	7.2	34	018	.377	013	1.9				

Depth metres	Org.C (W&B) % @ 105C	Tot.N % @ 105C	Extr Phosphorus ppm @ 105C Acid	Bicarb.	Rep. K m.eq% @105C	DTPA-extr. ppm @ 105C Fe	Mn	Cu	Zn
Bulk .10	1.7	.18	26	18	.82	33	31	1.0	1.0

16. KURUMBUL

LAND RESOURCE AREA. Billa Billa
SOIL TYPE: Kurumbul
SITE NO: 3
A M.G. REFERENCE: 263 400 mE 6 831 700 mN ZONE 56
GREAT SOIL GROUP: No suitable group (affinities with solodic soils or grey clays)
PRINCIPLE PROFILE FORM: Dy2.33
TYPE OF MICRORELIEF: Normal gilgai
VERTICAL INTERVAL. 0.20 m
HORIZONTAL INTERVAL. 15 m
COMPONENT OF MICRORELIEF SAMPLED: Mound
SURFACE COARSE FRAGMENTS: No coarse fragments

SUBSTRATE MATERIAL: Transported material (clay sheets)
SLOPE: 0.0 %
LANDFORM ELEMENT TYPE: Plain
LANDFORM PATTERN TYPE: Level plain; occurs as elevated plains east and north east of Goondiwindi.
CHARACTERISTIC VEGETATION:
Tall open forest of belah with an understorey of shrubs; occasional brigalow, poplar box or gum topped box.

PROFILE MORPHOLOGY

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Occasional periodic cracking; hardsetting

HORIZON	DEPTH	DESCRIPTION
A1	0 to .06 m	Dark brown (10YR3/3) moist; clay loam; very few small pebbles, subangular quartz, very strong, dispersed; weak 20-50mm angular blocky secondary, parting to moderate 2-5mm granular primary; dry moderately weak; common fine roots. Sharp to-
A2sb	.06 to 07 m	As above but sporadically bleached Sharp to-
B21	.07 to 15 m	Brownish black (10YR3/2) moist; heavy clay; very few small pebbles, subangular quartz, very strong, dispersed; moderate 20-50mm angular blocky, dry moderately strong; common fine roots Abrupt to-
B22k	15 to 30 m	Greyish yellow-brown (10YR4/2) moist; heavy clay; few small pebbles, subangular quartz, very strong, dispersed; strong 20-50mm angular blocky; dry very strong, few medium carbonate soft segregations; few medium roots. Clear to-
B23k	.30 to .60 m	Greyish yellow-brown (10YR4/2) moist, heavy clay; very few small pebbles, subangular quartz, very strong, dispersed; strong 20-50mm prismatic; dry very strong; few coarse carbonate soft segregations; few very fine roots. Clear to-
B24ky	.60 to 82 m	Greyish yellow-brown (10YR5/2) moist; heavy clay; very few small pebbles, subangular quartz, very strong, dispersed; strong 50-100mm angular blocky secondary, parting to moderate 10-20mm angular blocky primary, dry very strong; many medium gypseous crystals, few medium carbonate soft segregations Abrupt to-
B25ny	.82 to .87 m	Greyish yellow-brown (10YR6/2) moist; heavy clay; very few small pebbles, subangular quartz, very strong, dispersed; strong 50-100mm angular blocky; dry very strong; many medium manganiferous soft segregations, few medium gypseous crystals. Abrupt to-
B26	.87 to 1.50 m	Greyish yellow-brown (10YR6/2) moist; heavy clay; very few small pebbles, subangular quartz, very strong, dispersed; moderate 200-500mm prismatic, moderate 100-200mm lenticular; dry very strong; very few medium gypseous crystals.

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	% @105C	% @ 105C				m.eq/100g @ 105C					% @ 80C			% @ 105C				
Bulk .10	7.4	.15	.004																	
.10	7.1	.12	.001	22	37	16	25	22	14	3.3	.23	1.2	.042	.590	.048	1.8		11	.54	
.30	9.3	.32	.013	16	28	14	42	31	14	11	3.8	.72	014	.460	.028	2.8		17	.73	
.60	9.1	.87	.055	16	25	16	44	32	11	14	7.1	.57	.011	.410	.049	2.4		18	.87	
.90	8.1	1.8	.067	13	23	16	46	33	10	15	7.8	.38	.008	.454	.168	2.8		19	.87	
1.20	5 9	1.4	.061	13	23	16	47	31	9.1	13	7.2	.27	007	.464	.131	2.8				

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus		Rep. K	DTPA-extr.			
			Acid	Bicarb.		Fe	Mn	Cu	Zn
metres	% @ 105C	% @ 105C	ppm @ 105C		m.eq% @105C	ppm @ 105C			
Bulk .10	1.5	.11	19	13	1.1	27	65	0.8	0.6

18. MORUYA

LAND RESOURCE AREA. Billa Billa
SOIL TYPE: Moruya
SITE NO: 18
A.M.G. REFERENCE: 224 800 mE 6 879 800 mN ZONE 56
GREAT SOIL GROUP: Red brown earth (affinities with solodic soils)
PRINCIPAL PROFILE FORM: Dr2.43
TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: No coarse fragments

SUBSTRATEMATERIAL: Labile sedimentary rocks
SLOPE: 2.0 %
LANDFORM ELEMENT TYPE: Upper slope
LANDFORM PATTERN TYPE: Gently undulating rises; associated with sloping lowlands in the north east.
CHARACTERISTIC VEGETATION:
Tall open forest of belah with occasional brigalow and an understorey of shrubs.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to 07 m	- Dark brown (7.5YR3/3) moist; loam, fine sandy; massive; dry moderately weak; common very fine roots. Abrupt to-
A2cb	.07 to 14 m	Dull reddish brown (5YR4/4) moist, dull orange (5YR7/4) dry; clay loam,fine sandy; massive; dry moderately firm, common fine roots. Sharp to-
B21t	.14 to .50 m	Dark reddish brown (5YR3/4) moist; medium clay; moderate 100-200mm prismatic secondary, parting to strong 20-50mm angular blocky primary; dry moderately strong; very few medium carbonate soft segregations; few fine roots. Clear to-
B22tk	.50 to 80 m	Reddish brown (5YR4/6) moist; medium clay; moderate 20-50mm angular blocky secondary, parting to moderate 5-10mm polyhedral primary; dry very firm; very few medium carbonate nodules, common medium carbonate soft segregations. Clear to-
B23n	.80 to 1.50 m	Dull reddish brown (5YR5/4) moist, very few fine distinct red mottles, very few fine distinct grey mottles; light medium clay; moderate 10-20mm polyhedral secondary, parting to moderate 5-10mm polyhedral primary, with 5-10mm cast; dry moderately strong, very few medium manganiferous veins

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	% @105C	% @ 105C				m eq/100g @ 105C					% @ 80C			% @ 105C				
Bulk .10	8.1	.11	.001																	
.10	8.0	10	.001	10	56	17	18	15	10	1 0	.07	.80	.029	.219	.038	1.1		6	56	
.30	8 8	.13	.001	5	41	13	40	24	15	4.9	1.4	65	014	.210	.036	1 8		15	.53	
.60	9.4	.23	.003	4	42	13	41	27	12	7.3	5.0	.56	.013	.197	.021	2.0		17	.87	
90	9.0	.25	.036	4	41	13	40	29	10	7.6	8.6	.37	.012	.167	.035	2.2		17	1.0	
1.20	5.6	92	.118	4	41	14	41	22	7.3	6.0	7.9	.01	.009	.125	.071	1.9				

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus		Rep	DTPA-extr.			
			Acid	Bicarb.	K	Fe	Mn	Cu	Zn
metres	% @ 105C	% @ 105C	ppm @ 105C		m.eq% @105C	ppm @ 105C			
Bulk .10	1.3	.11	15	7	.89	10	23	0.5	0.6

19. WYNHARI

LAND RESOURCE AREA: Billa Billa
SOIL TYPE: Wynhari
SITE NO: 14
A.M.G. REFERENCE: 218 900 mE 6 878 300 mN ZONE 56
GREAT SOIL GROUP: Brown clay
PRINCIPAL PROFILE FORM: Ug5.32 (Uf6.31)?
TYPE OF MICRORELIEF: Crabhole gilgai
VERTICAL INTERVAL: 0.15 m
HORIZONTAL INTERVAL: 9 m
COMPONENT OF MICRORELIEF SAMPLED: Shelf
SURFACE COARSE FRAGMENTS: No coarse fragments

SUBSTRATE MATERIAL: Labile sedimentary rocks
SLOPE: 0.5 %
LANDFORM ELEMENT TYPE: Crest
LANDFORM PATTERN TYPE: Gently undulating rises; associated with sloping lowlands in the north east.
CHARACTERISTIC VEGETATION
Tall open forest of belah with occasional brigalow and an understorey of shrubs.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Variable according to microrelief; occasional periodic cracking; shelves (70% of area) firm to hardsetting; mounds and depressions (30% of area) weakly to moderately self mulching with a weak surface flake after rain

HORIZON	DEPTH	DESCRIPTION
A1	0 to .05 m	Dark brown (10YR3/3) moist; light medium clay; moderate 10-20mm angular blocky secondary, parting to moderate <2mm granular primary; moderately moist moderately firm; common fine roots. Abrupt to-
B21t	.05 to .36 m	Dark brown (10YR3/3) moist, medium heavy clay; strong 20-50mm angular blocky secondary, parting to moderate 10-20mm angular blocky primary; moist moderately firm, few medium carbonate nodules; few coarse roots. Clear to-
B22tk	.36 to .98 m	Dull yellowish brown (10YR5/3) moist; few medium faint grey mottles; medium heavy clay; strong 200-500mm lenticular secondary, parting to moderate 20-50mm angular blocky primary, moderately moist very firm; many coarse carbonate soft segregations, common medium carbonate nodules, few fine roots. Abrupt to-
BCk	.98 to 1 23 m	Soft weathered sandstone and siltstone, 'ghost rock' structure evident, very few coarse carbonate soft segregations. Gradual to-
C	1.23+	Weathering sandstone and siltstone, underlain by hard rock at depth (2-6m).

Depth metres	1:5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch. Cations m.eq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp.Ratio R1	R2
Bulk .10	8.2	.16	.002																	
.10	8.4	.13	.001	9	40	16	37	40	30	4.4	.49	1.1	.029	420	.030	2.8		15	.39	
.30	9 2	.41	014	6	35	14	47	43	26	8.8	7.3	.54	.015	.337	043	3.3		21	79	
.60	8 8	82	.055	7	33	15	45	44	24	9.8	9.0	48	.013	.331	.062	3.0		20	.74	
90	8.7	1.0	079	3	28	14	52	49	25	10	10	.50	.009	.386	.049	3 6		23	93	

Depth metres	Org.C (W&B) % @ 105C	Tot.N % @ 105C	Extr Phosphorus ppm @ 105C Acid	Bicarb.	Rep. K m.eq% @105C	DTPA-extr. ppm @ 105C Fe	Mn	Cu	Zn
Bulk .10	1.2	.11	15	9	.86	17	23	0.8	0.4

20. TANDAWANNA

LAND RESOURCE AREA: Bungunya north
SOIL TYPE: Tandawanna
SITE NO: 9
A.M G REFERENCE. 760 100 mE 6 861 400 mN ZONE 55
GREAT SOIL GROUP. No suitable group (affinities with solodic soils or red clays)
PRINCIPLE PROFILE FORM: Dr2.33 (Uf3/Uf6.31)?
TYPE OF MICRORELIEF. Normal gilgai
VERTICAL INTERVAL: 0.15 m
HORIZONTAL INTERVAL: 8 m
COMPONENT OF MICRORELIEF SAMPLED. Mound
SURFACE COARSE FRAGMENTS. No coarse fragments

SUBSTRATE MATERIAL. Clay alluvium and other transported material (clay sheets)
SLOPE: 0.0 %
LANDFORM ELEMENT TYPE: Plain
LANDFORM PATTERN TYPE: Level to gently undulating plains; occurs as elevated plains around Bungunya north and further west.
CHARACTERISTIC VEGETATION:
Tall open forest of belah with occasional brigalow and an understorey of shrubs.

PROFILE MORPHOLOGY.

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Occasional periodic cracking, shelves and depressions hardset, mounds firm to weakly self mulching

HORIZON	DEPTH	DESCRIPTION
A1	0 to 06 m	Dark reddish brown (5YR3/4) moist; light clay; moderate 5-10mm platy secondary, parting to moderate 2-5mm granular primary; dry moderately weak; few fine roots. Sharp to-
A2sb	06 to .06	As above but sporadically bleached Sharp to-
B21	.06 to 68 m	Dark reddish brown (5YR3/3) moist; medium heavy clay, moderate 20-50mm prismatic tertiary, parting to strong 20-50mm angular blocky secondary, parting to moderate 10-20mm angular blocky primary, dry moderately strong; few medium roots. Abrupt to-
B22kn	68 to .80 m	Reddish brown (5YR4/8) moist, common medium distinct red mottles, many coarse prominent grey mottles, heavy clay, moderate 20-50mm polyhedral, dry moderately strong, very few medium carbonate nodules, common medium manganiferous veins. Clear to-
B23	.80 to 1.50 m	Reddish brown (5YR4/8) moist; many coarse prominent grey mottles, common medium distinct red mottles, heavy clay; moderate 20-50mm polyhedral; dry moderately strong; very few medium manganiferous veins.

Depth	1:5 Soil/Water			Particle Size				Exch Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	%	%				m.eq/100g					%			%				
			@105C	@ 105C				@ 105C					@ 80C			@ 105C				
Bulk .10	8 2	.16	.003																	
.10	7.0	.03	.001	6	40	25	30	20	6.8	3.7	.39	1 4	.057	.548	021	1.7		10	.54	
.30	8.4	.47	.059	2	21	18	62	35	15	10	5.3	.83	026	.521	.018	3.2		22	57	
.60	8 2	.95	.131	2	24	19	55	31	11	10	7.0	.58	.020	.495	.031	2.3		20	.87	
.90	5.7	1.3	.166	1	23	19	57	30	7.2	8.6	6.6	.41	.019	.468	046	2.5		20	.89	
1.20	4 9	1.5	.196	<1	20	20	58	29	6.0	8.0	6.5	.36	019	.460	.054	2.8				

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus		Rep.	DTPA-extr.			
			Acid	Bicarb.	K	Fe	Mn	Cu	Zn
metres	%	%	ppm		m.eq%	ppm			
	@ 105C	@ 105C	@ 105C		@105C	@ 105C			
Bulk .10	1.4	.14	43	29	2.0	18	54	1.8	1.5

21. ARDEN

LAND RESOURCE AREA: Bungunya north
SOIL TYPE: Arden
SITE NO: 11
A.M.G. REFERENCE: 750 200 mE 6 873 100 mN ZONE 55
GREAT SOIL GROUP: Red clay
PRINCIPAL PROFILE FORM: Ug5.38
TYPE OF MICRORELIEF: Normal gilgai
VERTICAL INTERVAL: 0.15 m
HORIZONTAL INTERVAL: 8 m
COMPONENT OF MICRORELIEF SAMPLED: Mound
SURFACE COARSE FRAGMENTS: Very few medium pebbles

SUBSTRATE MATERIAL: Labile sedimentary rocks and transported material (clay sheets)
SLOPE: 2.0 %
LANDFORM ELEMENT TYPE: Mid slope
LANDFORM PATTERN TYPE: Gently undulating plains and rises; occurs as sloping lowlands around Bungunya north and further west.
CHARACTERISTIC VEGETATION:
Tall open forest of brigalow and belah with an understorey of shrubs; occasional poplar box or yapunyah.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Periodic cracking; moderately to strongly self mulching with a weak surface flake after rain

HORIZON	DEPTH	DESCRIPTION
A1	0 to .04 m	Dark brown (7.5YR3/4) moist; medium clay; strong 2-5mm granular; dry moderately firm; few medium carbonate nodules; few medium roots. Abrupt to-
B21	.04 to 28 m	Dark reddish brown (5YR3/3) moist; heavy clay, very few small pebbles, rounded tabular unspecified coarse fragments, strong, dispersed; strong 20-50mm angular blocky; dry moderately strong; common medium roots. Clear to-
B22k	.28 to .71 m	Dark reddish brown (5YR3/4) moist; heavy clay, very few small pebbles, rounded tabular unspecified coarse fragments, strong, dispersed; strong 50-100mm angular blocky secondary, parting to moderate 10-20mm angular blocky primary; dry very strong, few medium carbonate soft segregations, few medium carbonate nodules; few coarse roots. Clear to-
B23yn	.71 to .90 m	Reddish brown (5YR4/6) moist, heavy clay; moderate 50-100mm lenticular; dry very strong; very few medium carbonate nodules, few medium manganiferous veins, very few medium gypseous crystals; few medium roots. Gradual to-
B24	.90 to 1.50 m	Reddish brown (5YR4/8) moist; heavy clay, strong 100-200mm lenticular secondary, parting to moderate 10-20mm lenticular primary; dry moderately strong; few very fine roots.

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	% @105C	% @ 105C				m.eq/100g @ 105C					% @ 80C			% @ 105C				
Bulk .10	7.5	.19	.006																	
.10	7.4	.08	.001	8	45	15	34	27	13	5.6	.45	2.2	.049	.686	.039	1.8		13	.51	
.30	8.6	.56	055	3	30	12	54	43	25	12	4.4	1.4	.034	.660	.046	2.5		22	51	
.60	8.3	1.6	.239	3	31	15	53	41	17	14	7.7	.58	.017	.506	063	2.9		21	.61	
.90	5.3	1.8	.248	1	30	16	55	40	13	11	7.5	.49	.013	.469	.077	2.5		22	.64	
1.20	4.8	1.7	.243	1	29	16	56	39	12	11	8.2	.46	.011	.451	.055	3.0				

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus		Rep.	DTPA-extr.			
			Acid	Bicarb.	K	Fe	Mn	Cu	Zn
metres	% @ 105C	% @ 105C	ppm @ 105C		m.eq% @105C	ppm @ 105C			
Bulk .10	1.8	.19	21	17	1.8	22	58	2.3	1.1

22. TAREWINNABAR

LAND RESOURCE AREA: Lundavra
SOIL TYPE: Tarewinnabar
SITE NO: 15
A.M.G. REFERENCE: 221 300 mE 6 890 000 mN ZONE 56
GREAT SOIL GROUP: Black earth
PRINCIPAL PROFILE FORM: Ug5.12
TYPE OF MICRORELIEF: Linear gilgai
VERTICAL INTERVAL: .15 m
HORIZONTAL INTERVAL: 8 m
COMPONENT OF MICRORELIEF SAMPLED: Mound
SURFACE COARSE FRAGMENTS: Very few stones

SUBSTRATE MATERIAL: Labile sedimentary rocks
SLOPE: 3.0 %
LANDFORM ELEMENT TYPE: Lower slope
LANDFORM PATTERN TYPE: Gently undulating to undulating rises; includes mid to lower slopes and valley flats of the resticted 'open downs' around 'Tarewinnabar', 'Te Apiti" and 'Lundavra'.
CHARACTERISTIC VEGETATION:
Tussock grassland of Queensland bluegrass to mid-high open woodland of myall and coolibah.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Periodic cracking; moderately to strongly self mulching with a weak surface flake after rain

HORIZON	DEPTH	DESCRIPTION
A11	0 to .02 m	Brownish black (10YR3/2) moist; medium heavy clay; strong 5-10mm granular secondary, parting to strong 2-5mm granular primary; dry moderately weak; few fine roots. Abrupt to-
A12	.02 to .06 m	Brownish black (10YR3/2) moist, medium heavy clay; moderate 20-50mm angular blocky; moist moderately weak, common fine roots Clear to-
B21	.06 to .45 m	Brownish black (10YR3/1) moist; heavy clay, strong 20-50mm angular blocky; moist moderately weak; very few medium carbonate nodules; common fine roots. Gradual to-
B22k	.45 to 92 m	Brownish black (10YR3/1) moist; heavy clay, strong 50-100mm lenticular secondary, parting to moderate 10-20mm lenticular primary; dry moderately strong; common medium carbonate nodules, common fine roots. Gradual to-
BC	.92 to 1.01 m	Soft weathered sandstone and siltstone, 'ghost rock' structure evident as moderate 5-10 mm angular blocky primary, few coarse carbonate soft segregations, gradual to-
Ck	1.01+	Weathering sandstone and siltstone with common coarse carbonate laminae; underlain by hard rock at depth (2-4m)

Depth	1.5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	% @105C	% @ 105C				m.eq/100g @ 105C					% @ 80C			% @ 105C				
Bulk .10	8.2	.11	.001																	
10	7.7	.07	.001	7	36	11	46	52	38	6.8	30	1.1	.028	.562	.030	4.2		21	.39	
30	8.6	.09	.001	5	32	13	52	58	45	6.9	1.3	.52	.018	.494	.020	4.3		24	.40	
.60	8.7	.18	.006	4	29	12	54	62	45	8.8	2.8	.57	.015	.515	.019	4.7		26	.53	
.90	8.6	27	.017	4	25	12	57	64	45	10	3.4	.62	.016	.539	.018	5.3		27	.56	

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus		Rep. K	DTPA-extr.			
			Acid	Bicarb.		Fe	Mn	Cu	Zn
metres	% @ 105C	% @ 105C	ppm @ 105C		m.eq% @105C	ppm @ 105C			
Bulk .10	0.9	.07	24	3	.71	16	11	0.6	0.3

23. TAREWINNABAR SHALLOW

LAND RESOURCE AREA: Lundavra
SOIL TYPE: Tarewinnabar shallow
SITE NO: 16
A.M.G. REFERENCE: 221 500 mE 6 889 700 mN ZONE 56
GREAT SOIL GROUP: Red clay (affinities with brown clays)
PRINCIPAL PROFILE FORM: Ug5.37

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS. Very few stones

SUBSTRATE MATERIAL: Labile sedimentary rocks
SLOPE: 3.0 %
LANDFORM ELEMENT TYPE: Upper slope
LANDFORM PATTERN TYPE: Gently undulating to undulating rises; crests and upper slopes of the restricted areas of 'open downs' around 'Tarewinnabar', 'Te Apiti' and 'Lundavra'.
CHARACTERISTIC VEGETATION:
Tall open woodland of silver leaved ironbark and poplar box.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Periodic cracking; hardsetting

HORIZON	DEPTH	DESCRIPTION
A1	0 to 10 m	Dark brown (7.5YR3/3) moist; light medium clay; moderate 20-50mm angular blocky; moderately moist moderately firm, common fine roots Clear to-
B21	.10 to .35 m	Dark reddish brown (5YR3/4) moist; medium clay; moderate to strong 10-20mm angular blocky; moist moderately firm, common very fine roots. Clear to-
B22k	.35 to .60 m	Dark brown (10YR3/3) moist; medium clay; moderate to strong 10-20mm angular blocky, moist moderately weak; common medium carbonate nodules. Clear to-
BC	.60 to .71 m	Soft, weathered sandstone and siltstone with 'ghost rock' structure evident as moderate 5-10 mm angular blocky; few extremely coarse carbonate soft segregations; gradual to-
Ck	.71+	Weathering sandstone and siltstone with few extremely coarse carbonate soft segregations, few coarse carbonate laminae; underlain by hard rock at depth (1-2m)

Depth metres	1 5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size CS % @ 105C	FS	S	C	Exch. Cations CEC m.eq/100g @ 105C	Ca	Mg	Na	K	Total Elements P % @ 80C	K	S	Moistures ADM % @ 105C	1/3b	15b	Disp Ratio R1	R2
Bulk 10	7 1	.04	001																	
.10	7.0	.04	.001	11	46	11	31	31	16	7.0	.32	82	.027	.697	.030	2.5		14	.45	
.30	7 4	.03	001	6	37	10	48	40	25	9.4	.60	.50	.023	.592	029	3.8		21	.35	
60	8.1	.06	.002	8	34	10	48	49	32	13	.78	40	.026	.602	024	4.4		21	33	

Depth metres	Org.C (W&B) % @ 105C	Tot.N % @ 105C	Extr Phosphorus Acid ppm @ 105C	Bicarb.	Rep. K m.eq% @105C	DTPA-extr. Fe ppm @ 105C	Mn	Cu	Zn
Bulk .10	1.5	.13	7	5	.77	22	47	0 6	0.4

24. WEENGALLON

LAND RESOURCE AREA: Geralda
SOIL TYPE: Weengallon
SITE NO: 25
A.M.G. REFERENCE: 742 100 mE 6 886 300 mN ZONE 55
GREAT SOIL GROUP: Solodic soil (affinities with red earths)
PRINCIPAL PROFILE FORM: Dr2.13
TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: No coarse fragments

SUBSTRATE MATERIAL: Transported material and deeply weathered sedimentary rocks
SLOPE: 1.5 %
LANDFORM ELEMENT TYPE: Mid slope
LANDFORM PATTERN TYPE. Gently undulating plains and rises; associated with the extensive uplands and lowlands in the west.
CHARACTERISTIC VEGETATION: Tall woodland or open woodland of poplar box with an understorey of shrubs.

PROFILE MORPHOLOGY:

CONDITION OF SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A11	0 to .05 m	Dark reddish brown (5YR3/3) moist, clay loam; few small pebbles, rounded gravel, moderate, dispersed; weak 10-20mm platy secondary, parting to massive; dry moderately weak. Abrupt to-
A12	.05 to .25 m	Dark reddish brown (2.5YR3/4) moist; clay loam, common medium pebbles, rounded gravel, moderate, dispersed; weak 10-20mm angular blocky parting to massive; dry moderately firm Clear to-
B2	25 to .43 m	Dark reddish brown (2.5YR3/6) moist; light medium clay; common medium pebbles, rounded gravel, moderate, stratified, common coarse pebbles, rounded gravel, moderate 5-10mm polyhedral secondary, parting to moderate 2-5mm polyhedral primary, dry very firm Clear to-
2B21	.43 to 85 m	Dark reddish brown (2.5YR3/6) moist; medium clay, common small pebbles, subrounded gravel, moderate, dispersed; moderate 20-50mm prismatic tertiary, parting to moderate 10-20mm lenticular secondary, parting to strong 2-5mm lenticular parting to strong 5-10mm polyhedral, dry moderately strong. Gradual to-
2B22k	.85 to 1.30 m	Brown (7.5YR4/6) moist, few medium faint red mottles; medium clay, few medium pebbles, subrounded gravel, moderate, dispersed, weak 20-50mm prismatic tertiary, parting to moderate 10-20mm lenticular secondary, parting to moderate 5-10mm lenticular primary, dry very firm, common very coarse carbonate soft segregations, few medium carbonate nodules, very few fine manganiferous soft segregations Clear to-
D	1 30 to 1 40 m	Brown (7.5YR4/6) moist; common medium distinct pale mottles, common medium distinct orange mottles, fine sandy light medium clay, common small pebbles, subrounded gravel, moderate, dispersed; moderate 5-10mm angular blocky, dry moderately strong, few medium manganiferous soft segregations

Depth metres	1 5 Soil/Water pH	EC mS/cm	Cl % @105C	Particle Size % @ 105C CS	FS	S	C	Exch. Cations m eq/100g @ 105C CEC	Ca	Mg	Na	K	Total Elements % @ 80C P	K	S	Moistures % @ 105C ADM	1/3b	15b	Disp.Ratio R1	R2
Bulk 10	6.6	.05	.002																	
.10	6.8	.05	.001	13	36	20	31	29	12	3 9	.08	1.5	.067	.509	.044	2.6		12	39	
.30	6.6	.02	.001	11	40	17	34	22	7.3	3 1	10	1.1	.041	.460	.018	2 5		11	.37	
.60	7.4	.04	.003	10	31	10	50	24	7.8	4 9	1.3	.88	.027	.396	.013	3.0		15	56	
90	8 0	16	.013	7	26	10	58	31	14	9 2	2.2	.92	.017	335	016	4 6		18		
1.20	8 6	.45	030	10	25	10	55	34	14	11	2.8	.74	.013	.260	.029	5.0				

Depth metres	Org.C (W&B) % @ 105C	Tot N % @ 105C	Extr. Phosphorus ppm @ 105C Acid	Bicarb.	Rep K m.eq% @105C	DTPA-extr ppm @ 105C Fe	Mn	Cu	Zn
Bulk .10	2.5	.16	15	9	1 3	18	64	0.8	0.7

25. FLINTON

LAND RESOURCE AREA: Geralda
SOIL TYPE: Flinton
SITE NO: 12
A.M.G. REFERENCE: 745 100 mE 6 882 300 mN ZONE 55
GREAT SOIL GROUP: Red earth
PRINCIPAL PROFILE FORM: Gn2.11

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS: Very few small pebbles

SUBSTRATE MATERIAL: Deeply weathered sedimentary rocks
SLOPE: 1.0 %
LANDFORM ELEMENT TYPE: Mid slope
LANDFORM PATTERN TYPE: Gently undulating rises and undulating low hills; mainly associated with the extensive uplands in the west
CHARACTERISTIC VEGETATION:
Tall woodland or open woodland of silver leaved ironbark and poplar box with occasional cypress pine, kurrajong, mulga or bendee and an understorey of shrubs.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to .08 m	Dark reddish brown (5YR3/4) moist; loam; massive; dry very weak; few very fine roots. Clear to-
B21	.08 to .45 m	Dark reddish brown (2.5YR3/6) moist; clay loam, few medium pebbles, subrounded platy unspecified coarse fragments, strong, dispersed; massive; dry moderately weak; few medium roots Gradual to-
B22	.45 to 1.05 m	Dark reddish brown (2.5YR3/6) moist; clay loam, many coarse pebbles, subrounded platy unspecified coarse fragments, strong, dispersed; massive; dry moderately weak; few fine roots Diffuse to-
C1b	1.05 to 1.25 m	Greyish brown (7.5YR5/2) moist; many coarse prominent red mottles; sandy clay; few medium pebbles, subrounded platy unspecified coarse fragments, strong, dispersed; strong 10-20mm angular blocky; dry moderately strong.

Depth	1 5 Soil/Water			Particle Size				Exch Cations					Total Elements			Moistures			Disp Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	%	%				m.eq/100g					%			%				
			@105C	@ 105C				@ 105C					@ 80C			@ 105C				
Bulk .10	5.8	.02	.001																	
.10	5.3	.02	.001	8	45	14	34	17	2.1	0.5	.07	.80	.049	.406	.023	1.3		9	.32	
.30	4 7	.03	001	7	45	13	38	13	1.3	.05	.05	.28	.033	.357	.016	1.1		9	.24	
.60	4.7	.02	.001	8	41	12	41	13	0.7	1.0	.05	.19	.031	.326	.017	1.1		10	.21	
.90	5.0	.02	.001	8	40	11	43	12	0.2	2.3	.11	.17	.029	.314	.013	1.1		11	.24	
1.20	5.0	.04	.003	9	36	13	43	14	1.5	3.9	.34	.19	.018	.282	.013	1.4				

Depth	Org.C (W&B)	Tot.N	Extr. Phosphorus		Rep. K	DTPA-extr.			
			Acid	Bicarb.		Fe	Mn	Cu	Zn
metres	%	%	ppm		m.eq%	ppm			
	@ 105C	@ 105C	@ 105C		@105C	@ 105C			
Bulk .10	1.1	.09	5	4	.80	16	40	0.8	0.4

26. URANILLA

LAND RESOURCE AREA: Boondandilla
SOIL TYPE: Uranilla
SITE NO: 19
A.M.G. REFERENCE: 258 300 mE 6 899 400 mN ZONE 56
GREAT SOIL GROUP: Solodized solonetz
PRINCIPAL PROFILE FORM: Dy2.43

TYPE OF MICRORELIEF. No microrelief
SURFACE COARSE FRAGMENTS: No coarse fragments

SUBSTRATE MATERIAL: Deeply weathered sedimentary rocks
SLOPE: 1.0 %
LANDFORM ELEMENT TYPE: Mid slope
LANDFORM PATTERN TYPE: Gently undulating plains and rises; associated with gently dissected uplands and lowlands in the north east and eastern margins of the shire.
CHARACTERISTIC VEGETATION:
Mid high open forest of bulloak, with cypress pine and emergent trees of narrow leaved ironbark, poplar box, gum topped box and rusty gum.

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Hard setting

HORIZON	DEPTH	DESCRIPTION
A1	0 to 10 m	Dark brown (7 5YR3/3) moist; sandy loam; massive; dry moderately firm; very few medium ferromanganiferous nodules; few fine roots. Clear to-
A2cbn	.10 to .20 m	Dull reddish brown (5YR4/3) moist, dull orange (5YR7/3) dry; loamy sand; common small pebbles, subangular unspecified coarse fragments, weak, dispersed; massive; dry moderately firm; many very coarse ferromanganiferous nodules; few fine roots. Sharp to-
B21tn	.20 to .52 m	Dull reddish brown (5YR5/4) moist; light medium clay; strong 200-500mm columnar secondary, parting to moderate 20-50mm angular blocky primary; dry moderately strong; few medium ferromanganiferous nodules, few fine roots. Gradual to-
B22t	.52 to 1 05 m	Brown (7.5YR4/4) moist, few fine faint orange mottles; medium clay; moderate 10-20mm polyhedral; dry moderately strong; very few medium ferromanganiferous nodules; few fine roots. Clear to-
B23tg	1.05 to 1.30 m	Greyish yellow-brown (10YR5/2) moist; few fine prominent red mottles, medium clay; moderate 10-20mm polyhedral, dry very strong; few fine roots.

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp.Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	% @105C	% @ 105C				m.eq/100g @ 105C					% @ 80C			% @ 105C				
Bulk .10	5 7	03	.002																	
.10	5.3	.05	004	35	43	6	14	12	0.6	1.5	.17	.15	023	104	.021	0.6		4	.48	
.30	5.5	.02	.001	24	33	10	37	14	0.2	7 3	3 5	.08	.008	.100	.022	1.1		12	.88	
.60	6.7	34	.040	22	34	9	37	15	0.3	7.9	4.6	.15	.006	.107	.023	1.2		13	94	
.90	8.2	.47	.062	20	34	10	37	15	0.4	8.7	4.9	.34	.005	111	.018	1.1		14	.95	
1.20	7.9	.50	.069	18	41	11	29	13	0.2	6 7	4.0	.18	.003	.108	.017	0.7				

Depth	Org.C (W&B)	Tot N	Extr. Phosphorus		Rep. K	DTPA-extr.			
			Acid	Bicarb.		Fe	Mn	Cu	Zn
metres	% @ 105C	% @ 105C	ppm @ 105C		m.eq% @105C	ppm @ 105C			
Bulk .10	0.9	.05	5	3	.10	95	4	0.1	0.4

29. KARBULLAH

LAND RESOURCE AREA: Jump-up
SOIL TYPE: Karbullah
SITE NO: 23
A.M G REFERENCE: 246 600 mE 6 890 800 mN ZONE 56
GREAT SOIL GROUP: Lithosol
PRINCIPAL PROFILE FORM: Uc1 24

TYPE OF MICRORELIEF: No microrelief
SURFACE COARSE FRAGMENTS. Many cobbles

SUBSTRATE MATERIAL: Deeply weathered sedimentary rocks
SLOPE: 15.0 %
LANDFORM ELEMENT TYPE. Hillcrest
LANDFORM PATTERN TYPE: Undulating to rolling rises and low hills; occurs as scarps and dissected residuals associated with the northern jump-ups, mainly in the north east.
CHARACTERISTIC VEGETATION:
Tall woodland of silver leaved ironbark, narrow leaved ironbark, poplar box and cypress pine, with an understorey of shrubs

PROFILE MORPHOLOGY:

CONDITION OF UNDISTURBED SURFACE SOIL WHEN DRY: Firm to hardsetting

HORIZON	DEPTH	DESCRIPTION
A11	0 to .12 m	Brownish black (10YR2/2) moist; sandy loam; abundant cobbles, subangular sandstone, moderate, undisturbed; massive; dry moderately weak, few very fine roots Clear smooth to-
A12	12 to 35 m	Brownish black (10YR2/3) moist, brownish grey (10YR6/1) dry, loamy sand; abundant cobbles, subangular sandstone, moderate, undisturbed, massive; dry moderately firm. Abrupt smooth to-
C	.35 to .45 m	Weathered sandstone and siltstone, gradual smooth to-
R	.45+	Silicified sandstone and siltstone

Depth	1:5 Soil/Water			Particle Size				Exch. Cations					Total Elements			Moistures			Disp Ratio	
	pH	EC	Cl	CS	FS	S	C	CEC	Ca	Mg	Na	K	P	K	S	ADM	1/3b	15b	R1	R2
metres		mS/cm	%		%				m.eq/100g					%			%			
			@105C		@ 105C				@ 105C					@ 80C			@ 105C			
.10	6.3	.02	.001	20	62	3	10	8	3.5	.84	05	.31	016	141	.023	0.4		4	.34	
.30	6.6	.03	.001	29	52	7	10	6	2.6	.87	.06	35	.008	.092	.018	0.3		4	62	

Appendix II

SUMMARY SOIL AND SITE INFORMATION

Table II.1. Distinguishing morphological characteristics of the major soils

Soil[1] (No.)	Colour[2]	Texture[2]	Structure[2]	Other profile characteristics[2,3]
Keetah (1)				
Surface soil	brown or red-brown; occasionally grey or yellow-brown	loamy sand, sandy loam or loam	massive	very thick, sporadically or conspicuously bleached subsurface layer between 30 and 60 cm
Upper subsoil	brown or red-brown, occasionally yellow-brown or grey-brown	sandy loam to light clay	weak, coarse, columnar or prismatic to moderate medium angular blocky, faunal casts	minor mottling, minor to common soft manganese
Lower subsoil	brown or yellow-brown; occasionally grey	sandy clay loam, fine sandy or light clay	massive to moderate, medium, angular blocky, faunal casts	minor mottling, minor to common soft manganese
Bengalla (2)				
Surface soil	grey or brown; occasionally dark	silt loam or silty clay loam, loam to light clay	massive or weak, medium (20 to 50 mm) angular blocky to fine (2 to 5 mm) polyhedral	very thick, conspicuously bleached subsurface layer between 30 and 60 cm
Upper subsoil	yellow- brown, brown or red-brown; also grey or dark	clay loam to light medium clay	strong, coarse columnar to moderate medium angular blocky, faunal casts	minor to common soft manganese segregations
Lower subsoil	as for upper subsoil	silty clay, clay loam to light clay	massive to moderate, medium angular blocky, faunal casts	minor to common soft manganese segregations
Undabri (3)				
Surface soil	dark or grey	medium to heavy clay	weak, coarse (5 to 10 mm) angular blocky surface mulch over strong, coarse angular blocky	*n.a*
Upper subsoil	dark or grey	medium to heavy clay	moderate, medium lenticular	minor soft or nodular carbonate
Lower subsoil	grey or brown	medium to heavy clay	moderate, medium polyhedral	minor to common soft or nodular carbonate

Kalanga (4)				
Surface soil	dark or grey	medium to heavy clay	strong, fine (2 to 5 mm) granular surface mulch over moderate, medium, angular blocky	*n.a.*
Upper subsoil	dark or grey	medium to heavy clay	strong, medium lenticular	minor, soft or nodular carbonate
Lower subsoil	grey or brown	medium to heavy clay	strong, medium or coarse lenticular	common, soft or nodular carbonate
Murra Cul Cul (5)				
Surface soil	brown, occasionally grey or red-brown	sandy clay loam, fine sandy to clay loam	massive	minor, coarse gravels; moderately thick conspicuously bleached subsurface layer between the surface and 20 cm
Upper subsoil	dark, brown or red-brown; occasionally grey	medium to heavy clay	weak or moderate, coarse prismatic to moderate or strong medium angular blocky	minor to common soft and nodular carbonate, minor coarse gravels
Lower subsoil	brown or yellow-brown; occasionally grey or grey-brown	fine sandy clay to medium clay	moderate, fine to medium polyhedral	minor to abundant mottling, minor to common, soft manganese; common to abundant crystalline gypsum; minor to common coarse gravels; acid clays developed below 1 m
Yambocully (6)				
Surface soil	dark or brown; occasionally grey or red-brown	clay loam; occasionally loam, fine sandy, sandy clay loam, fine sandy or silty clay loam	massive to weak, medium (10 to 20 mm) angular blocky	thin to moderately thick, conspicuously bleached subsurface layer between the surface and 20 cm
Upper subsoil	dark, brown or red-brown	light medium to heavy clay	weak, medium or coarse prismatic to strong, medium angular blocky; may grade to moderate medium, lenticular	minor to common, soft and nodular carbonate
Lower subsoil	brown or yellow-brown; occasionally grey or grey-brown	sandy clay loam, fine sandy to medium clay	moderate to strong, medium prismatic or angular blocky to fine, polyhedral, faunal casts	minor, soft or nodular carbonate; common to abundant, soft manganese

Table II.1. cont.

Soil[1]	Colour[2]	Texture[2]	Structure[2]	Other profile characteristics[2,3]
Oonavale (7)				
Surface soil	brown; occasionally dark	fine sandy loam to sandy clay loam, fine sandy	massive or weak, medium (10 to 20 mm) angular blocky	thick to very thick, conspicuously bleached subsurface layer between 10 and 40 cm
Upper subsoil	brown; occasionally dark or red-brown	fine sandy clay to medium clay	moderate, medium prismatic to strong, medium or fine angular blocky, occasionally coarse	minor mottling; minor to abundant soft and nodular carbonate
Lower subsoil	brown or yellow-brown	sandy clay loam, fine sandy to light medium clay	massive or weak to strong medium, angular blocky	minor to abundant, soft and nodular carbonate; minor to common soft manganese
Jindabyne (8)				
Surface soil	red-brown; occasionally brown or red	sandy clay loam, fine sandy or clay loam	massive	thin to moderately thick conspicuously bleached subsurface layer between the surface and 20 cm
Upper subsoil	red-brown or red, occasionally brown	medium to heavy clay	weak, medium prismatic to moderate or strong medium angular blocky	minor to abundant soft carbonate; minor nodular carbonate
Lower subsoil	red-brown; occasionally brown	medium clay	moderate, medium polyhedral; faunal casts	minor to common nodular carbonate; common to abundant soft manganese
Wondoogle (9)				
Surface soil	dark or brown, occasionally grey or yellow-brown	sand or loamy sand	massive	*n.a.*
Upper subsoil	brown or yellow-brown; occasionally grey	sand or loamy sand	massive	*n.a.*
Lower subsoil	brown or yellow-brown; occasionally grey	sand or loamy sand	massive	minor mottling; minor soft manganese; common to many, coarse clay segregations

Wai Wai (10)				
Surface soil	dark or brown; occasionally red-brown	sand or loamy sand	single grain or massive	*n.a.*
Upper subsoil	red-brown; occasionally brown	sand or loamy sand	massive	*n.a.*
Lower subsoil	red-brown; occasionally brown	sand or loamy sand	massive	*n.a.*
Marella (11)				
Surface soil	brown; occasionally dark, grey-brown or yellow-brown	loamy sand, sandy loam or light sandy clay loam	massive	thick to very thick, sporadically or conspicuously bleached subsurface layer between 30 and 50 cm
Upper subsoil	brown or yellow-brown, occasionally red-brown	sandy clay loam, fine sandy to light medium clay	moderate, medium prismatic or angular blocky; faunal casts	*n.a.*
Lower subsoil	brown or yellow-brown	fine sandy loam to fine sandy clay	moderate, medium polyhedral; faunal casts	minor, soft carbonate and manganese
Bendidee (12)				
Surface soil	brown; occasionally grey, grey-brown or yellow-brown	sand or loamy sand	massive	minor to common, fine or medium gravels; moderately thick to thick, conspicuously bleached subsurface layer between 30 and 50 cm
Upper subsoil	brown or yellow-brown; occasionally grey or grey-brown	sandy clay, light medium or medium clay	strong, coarse columnar to moderate, medium angular blocky	common to strong mottling; minor, soft and nodular carbonate; minor, fine or medium gravel
Lower subsoil	brown, yellow-brown or yellow	sandy clay loam to sandy clay	strong, coarse columnar to moderate, medium angular blocky	minor to common mottling; minor, soft carboate and manganese

Table II.1. cont.

Soil[1]	Colour[2]	Texture[2]	Structure[2]	Other profile characteristics[2,3]
Yelarbon (13)				
Surface soil	bleached or grey	silt loam to silty clay loam	massive	thick or very thick, conspicuously bleached surface or subsurface layer to 30 cm
Upper subsoil	grey, brown, or yellow-brown	silty clay, light medium or medium clay	moderate or strong, coarse, prismatic or columnar to strong, fine or medium angular blocky	minor to common soft carbonate, minor soft manganese; buried bleached layers occasionally present
Lower subsoil	brown or yellow-brown; occasionally grey or yellow	loamy, fine sand to fine, sandy loam, sandy clay loam, fine sandy or fine sandy clay	massive or weak to moderate, medium polyhedral	minor to common, occasionally abundant, soft or nodular carbonate; minor soft manganese; buried bleached layers occasionally present
Wondalli (14)				
Surface soil	dark, grey or grey-brown	medium to heavy clay	strong, fine (2 to 5 mm) granular surface mulch over moderate medium angular blocky	minor, nodular carbonate on surface of melonhole mounds
Upper subsoil	dark or grey	heavy clay	moderate, medium angular blocky	minor to common nodular carbonate and soft gypsum
Lower subsoil	grey or brown	heavy clay	strong, coarse lenticular	minor, soft gypsum; acid clays developed below 1 2 to 1 5 m
Calingunee (15)				
Surface soil	dark, grey or grey-brown	medium to heavy clay	moderate to strong, fine (2 to 5 mm) angular blocky or granular surface mulch over strong, medium, angular blocky	occasionally minor, nodular carbonate on surface of melonhole mounds; minor coarse gravels
Upper subsoil	dark or grey	medium heavy to heavy clay	strong, medium angular blocky	common, soft carbonate, minor coarse gravels
Lower subsoil	grey or brown	medium heavy to heavy clay	moderate, coarse polyhedral to moderate, medium lenticular	minor, coarse gravels; acid clays developed below 60 to 80 cm

Kurumbul (16)				
Surface soil	brown; occasionally grey or red-brown	clay loam	weak, medium (20 to 50 mm) angular blocky to moderate, fine (2 to 5 mm) granular	minor, fine gravels; thin, sporadically or conspicuously bleached subsurface layers between the surface and 10 cm
Upper subsoil	dark, grey or brown; occasionally red-brown	medium to heavy clay	moderate to strong, medium prismatic or angular blocky; occasionally coarse, angular blocky	minor to common soft carbonate; minor fine gravels
Lower subsoil	grey, brown or yellow-brown	medium to heavy clay	moderate, coarse prismatic or lenticular	common to abundant soft manganese, minor to abundant crystalline gypsum, minor, fine gravels; acid clays developed below about 90 cm
Mt. Carmel (17)				
Surface soil	brown; occasionally grey or red-brown	clay loam	massive to weak, medium (10 to 20 mm) angular blocky	thin sporadically or conspicuously bleached subsurface layer between the surface and 10 cm
Upper subsoil	dark, grey or brown; occasionally red-brown or yellow-brown	medium to heavy clay	strong, medium angular blocky to moderate or strong, fine angular blocky	minor to common, soft carbonate; minor medium gravels
Lower subsoil	grey, brown or yellow-brown	medium to heavy clay	weak to moderate, medium angular blocky or polyhedral	acid clays developed below 60 cm
Moruya (18)				
Surface soil	brown, occasionally red-brown	loam, fine sandy to clay loam, fine sandy	massive	moderately thick to thick, conspicuously bleached subsurface layer between the surface and 20 cm
Upper subsoil	brown or red-brown	light medium to medium clay	moderate, coarse prismatic to moderate or strong, medium angular blocky	minor to common, soft and nodular carbonate
Lower subsoil	brown, red-brown or yellow-brown	light medium to medium clay	moderate medium or fine polyhedral; faunal casts	minor, mottling and soft manganese, acid clays developed below 10 cm

Table II.1. cont.

Soil[1]	Colour[2]	Texture[2]	Structure[2]	Other profile characteristics[2,3]
Wynhari (19)				
Surface soil	brown; occasionally dark, grey or red-brown	light clay to light medium clay	moderate or strong, medium (10 to 20 mm) angular blocky to fine (>2 mm) granular	minor, nodular carbonate on surface of gilgai mounds; sometimes with a very thin sporadically bleached subsurface layer between the surface and 10 cm
Upper subsoil	dark or brown; occasionally grey, red-brown or yellow-brown	medium to heavy clay	moderate, medium angular blocky	common to abundant, soft and nodular carbonate
Lower subsoil	brown or yellow-brown	medium to heavy clay	moderate, medium polyhedral	minor mottling; abundant, soft and nodular carbonate; alkaline or acid subsoils may overlie weathering sandstone and siltstone
Tandawanna (20)				
Surface soil	brown or red-brown	clay loam to light clay	moderate, fine (2 to 5 mm), granular	very thin to thin sporadically bleached subsurface layer between the surface and 10 cm
Upper subsoil	red-brown; occasionally brown or red	medium clay to heavy clay	moderate, medium prismatic to strong, medium, angular blocky	minor to common soft or nodular carbonate
Lower subsoil	red-brown; occasionally brown	heavy clay	moderate medium polyhedral	common to strong mottling, minor to common soft manganese; acid clays developed below 80 cm

Arden (21)				
Surface soil	brown or red-brown	light to medium clay	moderate to strong, fine (2 to 5 mm) granular surface mulch	minor, nodular carbonate
Upper subsoil	red-brown, occasionally brown or red	heavy clay	strong, medium or coarse angular blocky	minor to common, soft and nodular carbonate; minor, fine gravels
Lower subsoil	red-brown; occasionally brown	heavy clay	strong, coarse lenticular to moderate, medium lenticular or polyhedral	minor to common, soft manganese and crystalline gypsum, acid clays developed below about 70 cm
Tarewinnabar (22) Surface soil	dark or grey	medium to heavy clay	strong, fine (2 to 5 mm) granular surface mulch over moderate, medium angular blocky	minor, nodular carbonate on surface of linear gilgai mounds
Upper subsoil	dark	heavy clay	moderate, medium angular blocky	minor, nodular carbonate
Lower subsoil	dark, brown or yellow-brown	medium to heavy clay	moderate, coarse to medium lenticular	common to abundant nodular carbonate; subsoil overlies weathering sandstone and siltstone with common, soft, carbonate layers
Tarewinnabar shallow (23) Surface soil	brown or red-brown; occasionally dark or red	light medium or medium clay	moderate, medium (2 to 5 mm) angular blocky	*n.a.*
Upper subsoil	brown or red-brown; occasionally dark	medium to heavy clay	moderate, medium angular blocky	*n.a.*
Lower subsoil	brown or yellow-brown; occasionally grey	light to medium clay	moderate, medium angular blocky	common, nodular carbonate; subsoil overlies weathering sandstone and siltstone; with coarse patches or layers of soft carbonate

Table II.1. cont.

Soil[1]	Colour[2]	Texture[2]	Structure[2]	Other profile characteristics[2,3]
Weengallon (24)				
Surface soil	red-brown, occasionally brown	clay loam	massive to weak fine (5 to 10 mm) or medium (10 to 20 mm) angular blocky; occasionally weak, medium platy	minor to common fine or medium gravels; sometimes with thin, sporadically bleached subsurface layers between the surface and 20 cm
Upper subsoil	red or red-brown	light clay to medium clay	moderate, fine polyhedral over moderate, medium prismatic or lenticular	common to abundant fine, medium or coarse gravels
Lower subsoil	brown, red-brown or red	light medium to medium clay	moderate, fine angular blocky	minor to abundant, soft and nodular carbonate; minor to common soft manganese and fine or medium gravels; subsoil often overlies strongly mottled, lateritic material
Flinton (25)				
Surface soil	red-brown; occasionally brown	loam to clay loam	massive	minor to common fine or medium gravels on surface
Upper subsoil	red, occasionally red-brown	clay loam to light clay	massive	minor to common, fine or medium gravels
Lower subsoil	red. occasionally red-brown. *brown or grey-brown*	light to light medium clay or *sandy clay*	massive over moderate to strong *angular blocky D or BC material*	common to abundant medium or *coarse gravel; subsoils overlie* strongly mottled, lateritic material

Uranilla (26)				
Surface soil	grey or brown; occasionally yellow-brown	sandy loam to clay loam	massive	common to abundant, fine or coarse gravels; thick to very thick, conspicuously bleached subsurface layer between the surface and 30 cm
Upper subsoil	grey, brown or yellow-brown	light medium to heavy clay	strong, coarse columnar to moderate, medium angular blocky or polyhedral	minor to common mottling; minor to common fine or medium gravels
Lower subsoil	grey, brown or yellow-brown	fine sandy clay, light medium or medium clay	massive or weak to moderate, medium polyhedral	minor to common mottling, minor to common fine or medium gravels
Westmar· (27)				
Major soil similar to Bendidee				
Surface soil	brown or yellow-brown	loamy sand to sandy clay loam	massive to weak medium, angular blocky	minor to common, fine or medium gravels; moderately thick to thick conspicuously bleached subsurface layer between 30 and 50 cm
Upper subsoil	grey, brown or yellow-brown	sandy clay to medium clay	moderate to strong coarse columnar or prismatic	minor to common mottling; minor soft carbonate and manganese, minor fine or medium gravels
Lower subsoil	brown or yellow-brown; occasionally grey	sandy clay to medium clay	massive or weak to moderate, medium angular blocky or polyhedral	minor to common mottling, minor soft carbonate and manganese
Westmar. (27)				
Associated soil similar to Wai Wai				
Surface soil	red; occasionally red-brown	sand or loamy sand	massive	occasionally minor, fine gravels
Upper subsoil	red; occasionally red-brown	sand or loamy sand	massive	occasionally minor or common fine gravels
Lower subsoil	red; occasionally red-brown	sand or loamy sand	massive	occasionally minor or common fine gravels

Table II.1. cont.

Soil[1]	Colour[2]	Texture[2]	Structure[2]	Other profile characteristics[2,3]
Westmar (27) **Associated soil similar to Flinton and Flinton Shallow**				
Surface soil	brown; occasionally grey-brown or yellow brown	sandy loam to sandy clay loam	massive	common or abundant, fine to medium gravels
Upper subsoil	red-brown, brown or yellow-brown	sandy clay loam	massive	common or abundant, fine to medium gravels; often overlying mottled, lateritic material or weathering sandstone
Lower subsoil	red-brown, brown or yellow-brown	sandy clay loam to sandy clay	massive	*n.a.*
Flinton shallow (28)				
Surface soil	red-brown; occasionally brown	sandy loam to clay loam	massive	common or abundant, fine to coarse gravels
Subsoil	red or red-brown; occasionally brown	loam, clay loam to light or clay	massive	common or abundant, fine to coarse gravels; overlying mottled, lateritic material
Karbullah (29)				
Surface soil	dark or brown	sandy loam to clay loam	massive or weak to moderate medium (10 to 20 mm) angular blocky	common to abundant, coarse gravels, cobbles and stones
Subsoil	dark or brown	sandy loam to light or medium clay	massive or weak to moderate, medium angular blocky	common or abundant, coarse gravels, cobbles and stones; overlies weathering sandstone and siltstone

Notes 1. See Glossary, under *Soil depth* for soil depth classes

2. See Glossary, under *Soil colour, Soil texture, Soil structure*, for definitions and explanation

3 Coarse fragments, segregations and bleaching are described according to McDonald *et al.* (1984); see Glossary for definition and explanation of terms used

NOTES FOR TABLES II.1 AND II.2

The following terms have been interpreted from McDonald *et al.* (1984);

Soil profile

- *uniform soil*: texture (clay content) stays relatively constant throughout the profile

- *gradational soil*: texture (clay content) gradually increases down the profile

- *duplex soil*: texture (clay content) increases rapidly from surface to subsoil (eg: Bendidee soil; clay content increases from 5 to 45% over less than 10cm)

- subsoil colours use the colour scheme of McDonald *et al.* (1984) and are defined in the Glossary of this manual under *Soil colour.*

Structure

- *moderately* and *well structured* (or *moderate* and *strong* grade structure) refer to subsoils with 30 to 60% (*moderately; moderate*) or greater than 60% (*well; strong*) of their mass being structured; structure may occur as *polyhedral* (many sided), *blocky* (block-like) or *lenticular* (lens-like)

- *poorly structured* refers to subsoils with less than 30% of their mass being structured (*weak* grade of polyhedral, blocky or lenticular); or subsoils that have *columnar* (column like) structure; indicating strongly sodic, impermeable clay.

- *structureless* refers to soils that have no structure (includes the grades *massive* or *single grain*)

Surface condition

- *hard setting* refers to a compact, hard, apparently structureless surface condition that forms on drying

- *self-mulching* refers to a highly structural, loose surface mulch that forms on drying

Microrelief

- *melonhole gilgai* are defined as gilgai with a vertical interval greater than 30 cm and a horizontal interval greater than 6 m

Surface texture

- surface soils have been qualified as *coarse sandy* where sand greater than 0.2 mm in diameter predominates[1]; *fine sandy* where sand between 0.02 to 0.2 mm in diameter predominates[2]; or *silty* meaning a predominance of particles between 0.002 to 0.02 mm in diameter predominate[3]

NB: [1] - individual grains can be felt
[2] - only general sandiness can be felt
[3] - generally silty to the touch

Landform

- see map reference for definitions and descriptions

Table II.2. Summary of important site characteristics within the soil profile

Soil (No.)	Soil depth (cm)[1]	Microrelief[2]	Surface characteristics	Subsoil characteristics
Keetah (1)	**Surface:** 70; variable (40 to >120) **Total** >120; buried layers often present	absent	**Dry condition:** firm to hard setting **Seedbed** structureless owing to high levels of fine sand (>50%), seedbed pulverises readily with tillage, seals and sets hard if organic matter decreases, dries rapidly	**Structure** poorly structured; weak, 100 to 200 mm, columnar **Drainage:** imperfect owing to high levels of fine sand and silt throughtout the profile, clay at depth
Bengalla (2)	**Surface:** 50 **Total** >120; buried layers sometimes present	absent	**Dry condition:** hard setting, powdery **Seedbed:** structureless and dense owing to high levels of silt (>40%); seedbed pulverises very easily with tillage, sets hard with to severe surface sealing and crusting after rain; subject to wind erosion and scalding	**Structure:** poorly structured; strong 100 to 200 mm, columnar **Drainage** poor owing to level topography, high levels of silt throughout the profile and strongly sodic clay at depth
Undabri (3)	**Surface:** 1 to 3 **Total:** > 120	occasionally very weakly developed normal gilgai **V I:** < 10 cm **H I:** 5 to 10 m	**Dry Condition** periodic cracking; hard setting or weakly self-mulching with a weak surface flake after rain **Seedbed** well structured due to high clay content (70%), seedbed friable but coarse with strong, 5 to 10 mm aggregates; relatively stable with tillage, may seal after rain	**Structure** moderately structured, moderate or strong 20 to 50 mm, lens **Drainage:** imperfect owing to low-lying position, level topography, high clay content and presence of sodic clay at depth
Kalanga (4)	**Surface:** 2 to 5 **Total:** > 120	occasionally weakly developed normal gilgai **V I.** 8 to 20 cm **H I:** 4 to 5 m	**Dry condition** periodic cracking, moderately to strongly self-mulching with a weak surface flake after rain **Seedbed:** self-mulching due to high clay content (60%) and presence of free calcium carbonate, seedbed very friable and fine with strong < 2 to 5 mm soil aggregates, relatively stable with tillage	**Structure** well structured; strong, 20 to 50 mm, lens **Drainage** imperfect owing to low-lying position, level topography, high clay content and presence of strongly sodic clay at depth
Murra Cul Cul (5)	**Surface** < 5 to 15 **Total:** > 120	absent	**Dry condition:** hard setting **Seedbed.** structureless in the virgin state owing to high levels of fine sand (>60%), surface soil > 10 cm; usually a coarse cloddy seedbed which tends to pulverise with excessive tillage, seals and sets hard after rain, surface soil < 10 cm, seedbed is usually a coarse, poorly structured clay, prone to severe crusting owing to the incorporation of strongly sodic clay from the upper subsoil (10 to 15 cm) during tillage	**Structure:** moderately structured; moderate 10 to 20 mm, blocky grading to polyhedral at depth **Drainage** imperfect owing to low-lying position, clay subsoil

Yambocully (6)	**Surface.** < 20 **Total** > 120	absent	**Dry Condition** hard setting **Seedbed** structureless to poorly structured owing to high levels of silt and fine sand (>60%), coarse cloddy seedbed which tends to pulverise with excessive tillage; seals and sets after rain, prone to crusting and wind *erosion*	**Structure:** well structured; strong, 20 to 50 mm, blocky or lenticular **Drainage:** moderately well drained owing to slightly elevated position and well structured upper subsoil
Oonavale (7)	**Surface:** < 35 **Total·** > 120	absent	**Dry condition:** hard setting **Seedbed** structureless owing to high levels of coarse and fine sand (>60%); seedbed pulverises readily with tillage; seals and sets hard after rain, especially where organic matter is removed, sometimes wind erodible	**Structure:** well structured; strong, 5 to 20 mm, blocky **Drainage:** moderately well drained owing to slightly elevated position and well structured upper subsoil
Jindabyne (8)	**Surface.** < 15 **Total** > 120	absent	**Dry condition** hard setting **Seedbed** structureless owing to high levels of fine sand (60%); cloddy seedbed which pulverises with excessive tillage; seals and sets hard after rain	**Structure:** well structured; strong, 10 to 20 mm, blocky **Drainage.** imperfect owing to low-lying position, level topography and strongly sodic clay subsoil
Woondoogle (9)	**Surface:** 5 to > 120, organic matter *accumulation* 5 to 10 **Total:** > 120	absent	**Dry condition** soft **Seedbed** structureless owing to high levels of *coarse sand (>70%), seedbed loose and easily* tilled; coarse sand may be abrasive to tillage equipment, dries rapidly	**Structure:** structureless, massive **Drainage:** well drained owing to slightly *elevated position, and high coarse sand* content throughout the subsoil
Wai Wai (10)	**Surface:** 5 to > 120; organic matter accumulation restricted to 5 to 10 **Total·** > 120	absent	**Dry condition** loose **Seedbed:** structureless owing to high levels of coarse sand (>90%); seedbed loose and easily tilled, coarse sand may be abrasive to tillage equipment; dries very rapidly	**Structure.** structureless, massive **Drainage:** rapid owing to slightly elevated position and very high coarse sand content throughout the subsoil
Marella (11)	**Surface:** 50 to 60; variable **Total** > 120	absent	**Dry condition:** soft to firm **Seedbed** structureless owing to high levels of fine sand (>60%); pulverises readily with tillage; seals and sets hard if organic matter is removed; may be wind erodible	**Structure:** moderately structured; moderate 10 to 20 mm, blocky **Drainage:** moderately well drained owing to slightly elevated position, low clay content and well structured upper subsoil

Table II.2. cont.

Soil	Soil Depth (m)[1]	Microrelief[2]	Surface Characteristics	Subsoil Characteristics
Bendidee (12)	**Surface:** 40 to 50, variable **Total** 60 to > 120; sometimes underlain by deeply weathered material	absent	**Dry condition** soft to firm **Seedbed:** *structureless owing to high levels of* coarse sand (>60%); seedbed loose and easily tilled; coarse sand may be abrasive to tillage equipment; dries rapidly	**Structure.** poorly structured, strong, 200 to 500 mm, columnar **Drainage** poor owing to impermeable, strongly sodic clay throughout the subsoil
Yelarbon (13)	**Surface:** < 10 **Total:** > 120	gilgai absent, some microrelief associated with scalding and wind erosion deposits	**Surface:** hard setting, powdery **Seedbed:** structureless and dense owing to high levels of silt (>40%) and strong sodicity at the surface; very powdery seedbed which pulverises very easily with tillage; prone to extreme surface sealing, crusting and scalding due to wind erosion, subsoils exposed following erosion are hard setting with coarse, columnar structure; these are both impermeable and inpenetrable	**Structure:** poorly structured, moderate 200 to 500 mm, prismatic or columnar **Drainage·** poor owing to low-lying position, level topography, high silt content and *strongly sodic subsoil; subject to shallow* groundwater fluctuations
Wondalli (14)				
mound	**Surface.** 5 to 10 **Total:** > 120	moderately to strongly developed melonhole gilgai **V I:** 80 cm **H I.** 15 m	**Dry condition** periodic cracking; moderately to strongly self-mulching with a weak surface flake after rain **Seedbed** self-mulching owing to high clay conten (>50%) and the presence of free calcium carbonate; seedbed very friable and fine with strong < 2 to 5 mm soil aggregates, relatively stable with tillage	**Structure:** well structured; strong 50 to 100 mm, lens **Drainage:** imperfect owing to level topography; high clay content and presence of strongly sodic clay at depth
depression	**Surface:** 5 to 10 **Total.** > 120	moderately to strongly developed melonhole gilgai **V I:** 80 cm **H I::** 15 m	**Dry condition:** periodic cracking and ponding; hard setting or moderately self-mulching with a weak surface flake after rain **Seedbed·** well structured owing to high clay content (60%), but not as friable as mounds owing to the effects of water ponding, relatively fine with 5 to 10 mm soil aggregates, relatively stable with tillage	**Structure** well structured; strong 50 to 100 mm, lens **Drainage:** poor owing to ponding by melonhole gilgai, level topography, high clay content and presence of strongly sodic clay at depth

Calingunee (15) mound	**Surface.** 5 **Total.** > 120	moderately to strongly developed melonhole gilgai **V I:** 60 cm **H I·** 10 m	**Dry condition** periodic cracking, firm to strongly self-mulching with a weak surface flake after rain **Seedbed:** well structured owing to moderate or high clay content (35 to 40%) and organic matter; self-mulching where clay content is high and free calcium carbonate is present mainly on mounds; seedbed very friable with fine strong < 2 to 5 mm soil aggregates, relatively stable with tillage	**Structure** well structured; strong 20 to 50 mm, blocky, over 100 to 200 mm, lens **Drainage·** imperfect owing to high clay content and presence of strongly sodic clay at depth; depressions similar but poorly drained owing to ponding by melonhole gilgai
Kurumbul (16)	**Surface.** < 5 to 10 **Total.** > 120	occasionally very weakly developed crabhole or normal gilgai **V I** 10 to 20 cm **H I** 15 m	**Surface** occasional periodic cracking, hard setting **Seedbed** structureless to poorly structured in the virgin state owing to significant levels of fine sand and silt (37% and 16%), seedbed usually friable and fine (2 to 5 mm), tillage below 5 to 10 cm increases clay content and improves seedbed friability; tends to seal but not set hard after rain, crusting may develop where sodic clay from below 30 cm is incorporated	**Structure.** well structured; strong 20 to 50 mm blocky, over 100 to 200 mm, lens **Drainage:** imperfect owing to level topography, ponding by crabhole gilgai high clay content and strong sodicity in the subsoil
Mt. Carmel (17)	**Surface:** < 5 to 10 **Total.** > 120	occasionally very weakly developed crabhole gilgai **V I** < 10 cm **H I:** 7 m	**Dry condition:** occasional periodic cracking; mounds usually soft to firm, shelves and depressions usually hard setting **Seedbed:** structureless to poorly structured in the virgin state owing to high levels of fine sand (50%); seedbed usually friable and fine (2 to 5 mm); tillage below 5 to 10 cm increases clay content and improves seedbed friability; tends to seal but not set hard after rain; crusting may develop where sodic clay from below 20 cm is incorporated	**Structure:** well structured; strong 20 to 50 mm, blocky **Drainage·** imperfectly to moderately well drained owing to elevated, sloping topography, ponding by crabhole gilgai and high clay content; and strong sodicity in the subsoil
Moruya (18)	**Surface:** < 15 **Total:** > 120	occasionally very weakly developed crabhole gilgai **V I·** < 10 cm **H I:** 7 to 10 m	**Dry condition·** hard setting **Seedbed·** structureless or poorly structured in the virgin state owing to high levels of fine sand (60%), cloddy seedbed which tends to pulverise with excessive tillage, seals and sets hard after rain; depth of surface soil usually too great for tillage to improve seedbed friability through the incorporation of clay from the upper subsoil	**Structure.** well structured; strong 20 to 50 mm, blocky **Drainage:** similar to Mt. Carmel but is moderately well drained owing to elevated position, sloping topography, and lower clay content, only strongly sodic at depth

Table II.2. cont.

Soil	Soil Depth (m)[1]	Microrelief[2]	Surface Characteristics	Subsoil Characteristics
Wynhari (19)	**Surface** < 5 **Total:** 90 to > 120, underlain by yellow sandstone and siltstone	weakly developed crabhole or linear gilgai **V I** < 20 cm **H I·** 9 m	**Dry condition:** occasional periodic cracking, mounds and depressions are weakly to moderately self- mulching with a weak surface flake after rain; shelves are usually firm to hard setting **Seedbed:** moderately to well structured, occasionally self- mulching, in the virgin state owing to moderate to high clay content (35 to 40%) and occasional free calcium carbonate; seedbed usually friable and fine (< 2 to 5 mm); tillage below 5 to 10 cm increases clay content and improves seedbed friability, tends to seal but not set hard after rain; crusting may develop where sodic clay from below 20 cm is incorporated	**Structure·** well structured; strong 20 to 50 mm, blocky **Drainage:** imperfectly to moderately well drained owing to elevated position, sloping topography, ponding by crabhole gilgai, high clay content and strong sodicity in the subsoil; underlain by permeable soft and hard sandstone and siltstone
Tandawanna (20)	**Surface** < 5 to 10 **Total** > 120	occasionally very weakly developed crabhole gilgai **V I:** 15 to 30 cm **H I::** 8 to 10 m	**Dry condition** occasional periodic cracking; where gilgaied, mounds may be firm to weakly self- mulching, shelves and depressions hard setting **Seedbed:** poorly or moderately structured in the virgin state with moderate levels of fine sand (40%) and silt (25%), and clay (30%), seedbed usually friable and fine with (2 to 5 mm) soil aggregates, mainly on mounds, tillage (below 5 to 10 cm) increases clay content and improves seedbed friability; tends to seal hard but not set hard after rain; crusting may develop where sodic clay from below 20 cm is incorporated	**Structure:** well structured, strong 20 to 50 mm, blocky **Drainage:** imperfect owing to level topography, ponding by crabhole gilgai and high clay content and strong sodicity in the subsoil
Arden (21)	**Surface:** < 5 **Total:** > 120; occasionally shallower where underlain by yellow sandstone and siltstone	weakly to moderately developed crabhole or normal gilgai **V I:** 15 to 30 cm **H I.:** 8 m	**Dry condition:** periodic cracking; moderately to strongly self- mulching with a weak surface flake after rain **Seedbed:** self mulching owing to moderate or high clay content (35 to 50%) and free calcium carbonate; seedbed very friable and fine with strong < 2 to 5 mm soil aggregates; relatively stable with tillage	**Structure:** well structured; strong 20 to 50 mm, blocky; over 50 to 200 mm, lens **Drainage:** imperfectly to moderately well drained owing to elevated position, sloping topography, ponding by crabhole gilgai and high clay content and strong sodicity in the subsoil

Tarewinnabar (22)	**Surface.** < 5 **Total.** 60 to > 120, underlain by yellow sandstone and siltstone	moderately to strongly developed linear gilgai **V I** < 20 cm **H I** · 8 m	**Dry condition.** periodic cracking; moderately to strongly self- mulching with a weak surface flake after rain **Seedbed:** self-mulching owing to high clay content (50%) and the presence of free calcium carbonate, seedbed very friable and fine with *strong < 2 to 5 mm soil aggregates, relatively* stable with tillage	**Structure** well structured, strong 20 to 50 mm, blocky; over 50 to 100 mm lens **Drainage:** imperfect owning to low-lying position and high clay content; underlain by permeable soft and hard sandstone and siltstone
Tarewinnabar (23) Shallow	**Surface**· 10 **Total** 30 to 60; underlain by yellow sandstone and siltstone	occasionally very weakly developed linear gilgai	**Dry condition** periodic cracking, hard setting **Seedbed**· moderately structured in the virgin state but with significant levels of fine sand (45%); seedbed usually friable but coarse (5 to 10 mm); tends to seal and set hard after rain, tillage below 10 cm increases clay content and improves seedbed friability	**Structure:** moderately to well structured; moderate to strong 10 to 20 mm, blocky **Drainage:** moderately well drained owing to elevated position, sloping topography and shallow depth to permeable soft and hard sandstone and siltstone
Weengallon (24)	**Surface:** 10 to 25 **Total:** 50 to > 120; sometimes underlain by deeply weathered material	absent	**Dry condition:** hard setting **Seedbed** structureless or poorly structured with a moderate clay content (30%); cloddy seedbed which tends to pulverise with excessive tillage; seals and sets hard after rain; sometimes gravelly, dries rapidly	**Structure:** moderately structured; moderate 20 to 50 mm, prismatic or polyhedral **Drainage** moderately well drained owing to sloping topography and low sodicity in the subsoil
***Flinton* (25)**	***Surface:*** < 10 **Total:** 50 to > 120; often underlain by deeply weathered material	*absent*	**Dry condition**· *hard setting* **Seedbed** structureless owing to high levels of coarse and fine sand (35% and 45%); cloddy seedbed, often gravelly, which pulverises with excessive tillage; seals and sets hard after rain; dries rapidly	***Structure.*** *structureless; massive* **Drainage.** well drained owing to elevated position, sloping topography, high sand and gravel content, and lack of an impermeable layer (structureless and non sodic)
Uranilla (26)	**Surface.** 10 to 30 **Total.** > 120: *occasionally* underlain by deeply weathered material	absent	**Dry condition**· hard setting **Seedbed.** structureless owing to high levels of *coarse and fine sand* (35% *to* 45%), *cloddy* seedbed, often gravelly, which pulverises readily with tillage, seals and sets hard after rain, dries rapidly	**Structure:** poorly structured; strong, 200 to 500 mm, columnar **Drainage.** *poor owing to impermeable,* strongly sodic clay subsoil
Westmar Soil (27)	**Surface**· 30 to 50 **Total:** >120	absent	**Dry condition**· soft to hardsetting **Seedbed:** loose or cloddy depending on texture of the surface soil; pulverises readily with tillage, dries rapidly; abrasive to tillage *equipment*	**Structure**· poorly structured; strong 200 to 500 mm columnar or prismatic **Drainage:** poor owing to impermeable clay subsoil

Table II.2. cont.

Soil	Soil Depth (m)[1]	Microrelief[2]	Surface Characteristics	Subsoil Characteristics
Flinton Shallow (28)	**Surface:** < 10 **Total·** 10 to 50, underlain by deeply weathered material	absent	**Dry condition·** hard setting **Seedbed:** structureless owing to high levels of fine sand (45%) and moderate clay content (30%), usually very shallow and gravelly, pulverises readily with tillage, seals and sets hard after rain, dries rapidly	**Structure:** structureless, massive **Drainage** well to rapidly drained owing to elevated position, sloping topography, high sand and gravel content, and lack of an impermeable layer (structureless and non sodic)
Karbullah (29)	**Surface** < 10 **Total·** 10 to 50, underlain by sandstone and siltstone	absent	**Dry condition:** firm to hard setting **Seedbed.** structureless owing to high levels of coarse and fine sand (20% and 60%), seedbed, usually very shallow and rocky, pulverises readily with tillage, dries rapidly	**Structure** structureless, massive **Drainage** well drained to rapidly drained owing to elevated position, sloping topography, high sand, and stone content, and shallow depth to permeable rock

Notes

[1] See Glossary under *Soil depth*
[2] VI vertical interval, HI· horizontal interval

- microrelief, surface condition and drainage (site drainage) are defined in McDonald *et al.* (1984)

- seedbed characteristics have been interpreted from particle size analysis data, surface condition and structure of the surface soil (A1 and A2 horizons); see Appendix I for detailed analyses

- subsoil structure has been interpreted from McDonald *et al.* (1984) using the following modifications.

	grade of structure	*description*
· surface soil	single grain/massive	structureless
	. weak	poorly structured
	moderate	moderately structured
	strong	well structured or self-mulching
subsoil	. single grain/massive	structureless
	weak or columnar of any grade	poorly structured
	moderate	moderately structured
	. strong	well structured
· structure type	columnar (columns with domed tops) prismatic (columns) blocky (mainly angular blocky) lenticular (lens-like) polyhedral (many faced)	
· structure size	in millimetres	

- sodicity is defined in the Glossary

Table II.3 Summary of important chemical characteristics within the soil profile

Soil[1] (No.)	Acidity[2] (pH)	Salinity[2] (EC 1:5)	Salinity[2] due to NaCl (%)	Sodicity[3]	Dispersibility[4]	Clay Content[5] (%)
Keetah (1)						
Surface	6.5-7.3	very low	*n.a.*	non sodic	*n.a.*	15-20
Upper subsoil	8 1	very low	*n.a.*	non sodic to slightly sodic	mod. to high	30-35
Lower subsoil	8.5	low	*n.a*	slightly sodic	mod. to high	25-30
Bengalla (2)						
Surface	5.6-6.1	very low	*n a.*	non sodic	mod.	25-30
Upper subsoil	6.5	very low to low	*n.a.*	sodic	very high	40-45
Lower subsoil	6 9-7 3	medium	*n a.*	strongly sodic to sodic	high	30-35
Undabri (3)						
Surface	7 6	very low	*n.a.*	non sodic	low to mod	65-70
Upper subsoil	8.3-8 6	very low	*n.a*	non sodic	mod.	65-70
Lower subsoil	8.6-8 4	low to medium	*n.a.*	slightly sodic to sodic	mod	65-70
Kalanga (4)						
Surface	8.2-8 8	very low to low	*n a.*	non sodic	low	55-60
Upper subsoil	8.9-9 0	low to medium	*n a.*	slightly sodic to sodic	low to mod.	60-65
Lower subsoil	8.4-8 5	high to very high	80-90	strongly sodic	mod.	65-70
Murra Cul Cul (5)						
Surface	7 2	very low to low	*n.a.*	non sodic	*n a.*	15-20
Upper subsoil	7 9-8.5	high to extreme	70-100	strongly sodic	mod	50-60
Lower subsoil	7 5-5 3	low to medium	*n.a.*	strongly sodic	very high	45-55
Yambocully (6)						
Surface	6 8	very low	*n a.*	non sodic	*n.a.*	20-25
Upper subsoil	7.9	very low to low	*n a*	non sodic to slightly sodic	mod.	45-50
Lower subsoil	8 7-8.5	very high	60-90	sodic	low	30-40
Oonavale (7)						
Surface	6.2-6.5	very low	*n.a.*	non sodic	*n.a.*	10-15
Upper subsoil	8 4-9 0	low	*n a.*	very strongly sodic	mod	20-25
Lower subsoil	9 9	very high	30-50	very strongly sodic	high	20-25
Jindabyne (8)						
Surface	6.6	very low	*n a.*	non sodic	*n.a.*	20-25
Upper subsoil	8.8	medium	*n a.*	strongly sodic	high	45-50
Lower subsoil	9 1-8 9	high to very high	70-80	strongly sodic	high	40-45
Wondoogle (9)						
Surface	7.2	very low to low	*n.a.*	non sodic	*n.a.*	5-10
Upper subsoil	7.5	very low	*n.a.*	non sodic	*n.a.*	5-10
Lower subsoil	7 3	very low	*n.a*	non sodic	*n.a.*	10-15
Wai Wai (10)						
Surface	6.7	very low	*n.a*	non sodic	*n a*	<5
Upper subsoil	5.6-6.0	very low	*n a*	non sodic	*n.a*	<5
Lower subsoil	6 0	very low	*n.a*	non sodic	*n.a.*	<5

Table II.3 cont.

Soil[1] (No.)	Acidity[2] (pH)	Salinity[2] (EC 1 5)	Salinity[2] due to NaCl (%)	Sodicity[3]	Dispersibility[4]	Clay Content[5] (%)
Marella (11)						
Surface	7 3-7.6	very low	*n.a.*	non sodic to	*n.a.*	10-15
Upper subsoil	8.0-8.5	very low	*n.a.*	slightly sodic to sodic	*n.a.*	20-25
Lower subsoil	8.9	low to medium	*n.a.*	non sodic to slightly sodic	*n.a.*	15-20
Bendidee (12)						
Surface	5 6	very low	*n.a.*	non sodic	*n.a.*	5-10
Upper subsoil	6.2-8.2	medium	*n.a.*	strongly sodic	very high	40-50
Lower subsoil	8.5-8 2	medium to high	90-100	strongly sodic	very high	30-35
Yelarbon (13)						
Surface	9 5	low	*n.a*	strongly sodic	high	30-35
Upper subsoil	9.8-10.0	medium	*n.a*	very strongly sodic	very high	40-50
Lower subsoil	11.0-10.0	high to very high	80-90	very strongly sodic	*n.a.*	10-25
Wondalli (14) (mound)						
Surface	8.2-9 0	low	*n.a.*	non sodic	low	50-55
Upper subsoil	9.1	medium	*n.a.*	strongly sodic	high	55-60
Lower subsoil	8.0-6 0	very high to extreme	35-90	strongly sodic	very high	55-60
(depression)						
Surface	8 6	low	*n a.*	non sodic	low	55-60
Upper subsoil	8 9-9.1	low	*n a.*	slightly sodic to sodic	mod.	50-55
Lower subsoil	8.3-6.6	high to extreme	30-50	strongly sodic	high	50-55
Calingunee (15)						
Surface	6.9-7 4	very low	*n.a*	non sodic	low	30-35
Upper subsoil	8.9-9 1	medium	*n.a.*	non sodic	high	50-55
Lower subsoil	5.4-4 9	high	90-100	strongly sodic	high	50-55
Kurumbul (16)						
Surface	7.1	low	*n a.*	non sodic	low	25-30
Upper subsoil	9 1-9 3	medium	*n a.*	sodic	mod.	40-45
Lower subsoil	8 1-4 9	high to extreme	30-40	strongly sodic	high	45-50
Mt Carmel (17)						
Surface	7.0-7.4	very low to low	*n a.*	non sodic to slightly sodic	low	25-30
Upper subsoil	8.7	high	>75	strongly sodic	mod	45-55
Lower subsoil	7.1-4 8	high	>75	strongly sodic	very high	50-55
Moruya (18)						
Surface	7.3-8 0	low	*n.a*	non sodic	low	15-20
Upper subsoil	8.8-9 4	low to medium	*n.a*	non sodic to strongly sodic	low to high	40-45
Lower subsoil	5.6	high to very high	80-100	stongly sodic to very strongly sodic	very high	40-45

Table II.3 cont.

Soil[1] (No.)	Acidity[2] (pH)	Salinity[2] (EC 1.5)	Salinity[2] due to NaCl (%)	Sodicity[3]	Dispersibility[4]	Clay Content[5] (%)
Wynhari (19)						
Surface	8 4	low	*n.a.*	non sodic	low	35-40
Upper subsoil	9.2	medium	*n a.*	strongly sodic	mod	45-50
Lower subsoil	8.7	high to very high	40-50	strongly sodic	mod to high	45-50
Tandawanna (20)						
Surface	7.0-8 2	very low	*n a.*	non sodic	low	30-35
Upper subsoil	8.2-8.4	medium	*n.a.*	strongly sodic	low	60-65
Lower subsoil	5.7-4.8	high to very high	80-90	strongly sodic	high	55-60
Arden (21)						
Surface	7.4	very low to low	*n.a.*	non sodic	low	30-35
Upper subsoil	8 3-8.6	medium	*n.a.*	slightly sodic to sodic	low	50-55
Lower subsoil	5.3-4 5	extreme	90-100	strongly sodic	mod	50-55
Tarewinnabar (22)						
Surface	7.7-8 2	very low	*n.a*	non sodic	low	45-50
Upper subsoil	8.7	very low to low	*n.a*	non sodic	low	50-55
Lower subsoil	8 6	medium	*n.a.*	non sodic	low	55-60
Tarewinnabar (23) shallow						
Surface	7 0	very low	*n.a.*	non sodic	low	30-35
Upper subsoil	7 4	very low	*n.a.*	non sodic	low	45-50
Lower subsoil	8 1	very low	*n.a.*	non sodic	low	45-50
Weengallon (24)						
Surface	6 6-6.8	very low	*n.a.*	non sodic	low	30-35
Upper subsoil	6.6-7.4	very low	*n.a.*	non sodic	low	35-50
Lower subsoil	8 0-8 6	low to medium	*n.a.*	slightly sodic	high	55-60
Flinton (25)						
Surface	5.3	very low	*n.a*	non sodic	low	30-35
Upper subsoil	4 7	very low	*n.a.*	non sodic	low	35-40
Lower subsoil	4 7-5 6	very low	*n a.*	non sodic	low	40-45
Uranilla (26)						
Surface	5 3	very low to low	*n.a.*	non sodic	*n a.*	10-15
Upper subsoil	5.5	very low	*n a.*	strongly sodic	high	35-40
Lower subsoil	6 7-8.2	medium to high	80-90	strongly sodic	very high	30-40
Westmar Soils (27)	*n.a*	*n a.*	*n a*	*n a*	*n.a.*	*n.a.*
Flinton shallow (28)						
Surface	5 5-6 0	very low	*n a.*	non sodic	*n.a.*	20-35
Upper subsoil	5 0-6 0	very low	*n a*	non sodic	*n.a.*	20-35
Karbullah (29)						
Surface	6 3	very low	*n.a.*	non sodic	*n.a.*	10-15
Upper subsoil	6 6	very low	*n.a.*	non sodic	*n.a*	10-15

Notes:

1. See Glossary under *Soil depth* for explanation of depths.

2. The pH and salinity properties are measured in a 1:5 soil:water suspension;

   - See Glossary under *pH* for acidity classes.
   - the EC (electrical conductivity) 1:5 measurement estimates the total salt content of the soil.
   - where the salinity levels are not high the percentage due to NaCl is not relevant and is entered as *n.a.*
   - the percentage of these salts as NaCl (sodium chloride or table salt) is calculated using the relationship EC due to Cl (chloride in salt) = 6.64 x Cl%. The methodology is described in Bruce and Rayment (1982).

3. Sodicity is calculated as the percentage of exchangeable sodium (ESP) (Bruce and Rayment, 1982).

4. Clay dispersibility, measured as a clay dispersion ratio, is described in Bruce and Rayment (1982); results from samples with a low clay content (<25%, or field texture of sandy clay loam to clay loam) can be misleading due to high levels of coarse or fine sand, and have not been recorded (*n.a.*); see Glossary, under *Dispersion*, for dispersivity ratings.

5. Clay content (%) is measured by particle size analysis as described in Bruce and Rayment (1982). It is relevant to the chemical activity and status of the soil.

6. See Appendix 1 for complete soil analyses and site descriptions.

Table II.4. Summary of surface soil fertility

Soil (No.)	Organic carbon	Total nitrogen	Extractable phosphorus	Replaceable potassium	Extractable zinc
Keetah (1)	low	low	high	high	medium
Bengalla (2)	low	low	medium to high	medium	medium
Undabri (3)	low	low	low	very high	low
Kalanga (4)	low	low	low	very high	very low
Murra Cul Cul (5)	medium	low	low	high	medium
Yambocully (6)	low	low	high	very high	medium
Oonavale (7)	low	low	high	high	low
Jindabyne (8)	low	low	low to medium	very high	medium
Wondoogle (9)	very low to low	very low	medium	medium	low to medium
Wai Wai (10)	very low	very low	low	medium	low
Marella (11)	low	low	high	high	low to medium
Bendidee (12)	low	very low	very low	very low	very low to low
Yelarbon (13)	low	very low to low	very low	low to medium	very low to low
Wondalli (14)					
. mound	low	low	low	very high	very low to low
depression	medium	low to medium	medium	very high	low to medium
Calingunee (15)	medium	medium	low	high	medium
Tandawanna (16)	low	low to medium	medium	very high	medium
Arden (17)	medium	medium	low	very high	medium
Kurumbul (18)	low to medium	low	low	very high	low
Mt. Carmel (19)	low to medium	low	very low	high	very low
Moruya (20)	low	low	very low	high	low
Wynhari (21)	low	low	very low	high	very low to low
Tarewinnabar (22)	low	low	very low	high	very low to low
Tarewinnabar shallow (23)	low to medium	low	very low	high	very low to low
Weengallon (24)	medium	medium	very low	very high	medium
Flinton (25)	low	low	very low	high	low
Uranilla (26)	low	very low to low	very low	high	low
Westmar Soil (27)	*n.a.*	*n.a*	*n.a*	*n a.*	*n a.*
Flinton (28) shallow	*n.a.*	*n.a*	*n.a*	*n a.*	*n.a.*
Karbullah (29)	*n.a.*	*n.a*	*n.a*	*n a.*	*n.a*

Notes:

- Analytical methods are described in Bruce and Rayment (1982)
- All analyses were carried out on bulked 0 to 10 cm samples
- Ratings used for classifying the analytical results are those used by Bruce and Rayment (1982) and are as follows.

Organic carbon (%)

- very low less than 0.5
- low 0.5 to 1 5
- medium 1.5 to 2 5
- high 2 5 to 5 0
- very high more than .50

Replaceable potassium (meq/100g soil)

- very low less than 0 1
- low 0.1 to 0.2
- medium 0.2 to 0.5
- high 0 5 to 1.0
- very high more than 1

Total Nitrogen (%)

- very low less than 0.05
- low 0.05 to 0.15
- medium 0.15 to 0.25
- high 0 25 to 0 50
- very high more than 0 5

Extractable zinc (μg/g)

- very low less than 0 3
- low 0 3 to 0 8
- medium 0 8 to 5 0
- high 5 0 to 15 0
- very high more than 15

Extractable phosphorus (μg/g)

- very low less than 10
- low 10 to 20
- medium 20 to 40
- high 40 to 100
- very high more than 100

Table II.5. Important agronomic characteristics of the soils (at type site only)

Soil (No.)	Effective root depth (cm) (100 cm max.)	Plant available water capacity[1] (mm)	Average root zone salinity in the top 1 m (dS/m)
Keetah (1)	70	95	very low (0 3)
Bengalla (2)	50	80	low (1 1)
Undabri (3)	100	145	low (1 2)
Kalanga (4)	80	120	medium (3 7)
Murra Cul Cul (5)	60	100	high (5.7)
Yambocully (6)	70	110	high (6.6)
Oonavale (7)	100	125	medium (2.7)
Jindabyne (8)	60	100	high (6 6)
Wondoogle (9)	100	105	very low (0 2)
Wai Wai (10)	100	100	very low (0 2)
Marella (11)	100	120	very low (0 2)
Bendidee (12)	50	70	medium (2.0)
Yelarbon (13)	30	60	high (6 3)
Wondalli (14)			
mound	90	130	high (7 0)
depression	100	140	medium to high (4.5)
Calingunee (15)	90	130	medium (4.0)
Tandawanna (16)	100	140	high (5.8)
Arden (17)	60	100	very high (8.7)
Kurumbul (18)	70	110	high (6.9)
Mt Carmel (19)	60	100	high (5 1)
Moruya (20)	100	135	low (1.6)
Wynhari (21)	100	140	high (5 2)
Tarewinnabar (22)	90	135	very low (0.9)
Tarewinnabar (23) shallow	60	100	very low (0 3)
Weengallon (24)	100	135	very low (0 4)
Flinton (25)	100	125	very low (0 6)
Uranilla (26)	20	40	medium (2 6)
Flinton shallow (27)	30	55	very low (0 2)
Karbullah (28)	30	55	very low (0.3)

[1] PAWC is recorded in millimetres of water which directly corresponds to rainfall and evaporation

Note • A maximum root depth of 1 0 m has been assumed for the purposes of this study, on some soils rooting depth may go deeper and PAWC could be expected to be higher, where soils are shallower than 1 0 m profile depth has been used

Appendix III

LAND SUITABILITY AND SOIL LIMITATIONS TO LAND USE

1. SUITABILITY CLASSES

Land is classified on the basis of a specified land use which allows optimum production with minimal degradation to the land resource in the long term.

Class 1

Suitable land, with negligible limitations: highly productive soils requiring only simple management practices to maintain their optimal productivity.

For example: under dryland cropping, soils may only require recommended stubble retention practices to reduce surface runoff but not soil structural protection. No class 1 land was identified for dryland agriculture within Waggamba Shire as all soils had some form of limitation.

Class 2

Suitable land with minor limitations which reduce soil productivity to below optimum or require more than simple management practices to maintain productivity.

For example: under dryland cropping, soils may require stubble retention to minimise soil erosion and require other soil erosion control measures or flood control earthworks. Such practices are usually in addition to those required for Class 1 land.

Class 3

Suitable land with moderate limitations which further lower productivity or require more than the management practices of Class 2 soils to maintain productivity.

For example: under dryland cropping, soils may require planned erosion control earthworks, such as waterways and broad or narrow based banks, levelling where melonholes restrict trafficability and tillage, or the addition of fertiliser. Such practices are usually in addition to those required of Class 1 and 2 soils.

Class 4

Marginal land which is presently considered unsuitable due to severe limitations. The long term significance of these limitations on the proposed land use is unknown. It is doubtful whether the benefits in the long term outweigh the inputs required to achieve and maintain productivity. The risk of land degradation is also greatly increased.

For example: for dryland cropping, soils may be classed as marginal because plant available moisture is too low to sustain a crop through to harvest, either because of soil type or lower rainfall; low fertility may require uneconomic fertiliser inputs; seedbed problems may severely restrict germination and crop establishment; the land may be prone to regular flooding, or it has a high erosion risk due to steep slopes or erodible surface soils. Management practices associated with Classes 1, 2 and 3 are of limited relevance because of the magnitude of the problems associated with these soils.

Class 5 *Unsuitable land with extreme limitations that preclude its use*: the benefits gained do not justify the inputs necessary to initiate and maintain production in the long term; production is usually uneconomic and the risk of land degradation is very high.

For example: for dryland cropping, soils may be classed as unsuitable because of very low plant available moisture, very poor seedbed characteristics, very low fertility, poor drainage, presence of large amounts of rock, or because of an extreme erosion risk associated with very steep slopes or fragile, highly erodible surface soils. Management practices used in lower classes are irrelevant here because of the magnitude of the problems associated with these soils.

2. SOIL LIMITATIONS TO LAND USE

Fourteen limitations were identified as important to dryland and irrigated crop and pasture production in Waggamba Shire. These are listed below with a brief explanation of the basis on which they were assessed.

- (m) water availability — on predicted PAWC (plant available water capacity: the amount of soil water stored for plant growth) and summer rainfall variability
- (nd) nutrient deficiency — surface soil fertility based on inherent levels of nitrogen and phosphorus
- (sa) salinity — a comparison of average salinity within the root zone with plant tolerance data to gauge potential productivity losses due to salinity
- (w) wetness — susceptibility to waterlogging; based on site and profile drainage
- (f) flooding — susceptibility to flooding based on estimated flood frequencies and the nature of flooding
- (v) vegetation — regrowth potential and the range of options available for regrowth control; determined for sown and native pastures only

• (r) rockiness	the presence of rock outcrops and stone in the plough zone; of minor importance for Waggamba Shire
• (xs) soil complexity	management difficulties associated with soils of limited or complex distribution; assessed for irrigation soils only
• (tm) microrelief	based on restrictions to tillage and the trafficability of machinery relating to the size and density of microrelief; requirement for levelling for flood irrigated cropping
• (ps) physical surface condition	effect of soil surface structure and seedbed condition on crop establishment
• (pm) soil workability	likely tillage problems associated with high soil strength, narrow tillage window or abrasiveness to machinery
• (i) furrow infiltration	the efficiency of furrow irrigation; surface soil morphology is used to assess infiltration characteristics; the effect of local topography is also considered; determined for flood irrigated soils only
• (e) water erosion	susceptibility to accelerated soil erosion due to surface runoff; based on slope angle, slope length and surface soil erodibility
• (a) wind erosion	susceptibility to wind erosion based on surface soil erodibility and the form of the landscape

Table III.1. Soil limitations for dryland cropping

Soil (No.)	Limitations	Class
Kurumbul (16)	cf_2 m_2 $sa_{1\text{-}2}$ w_2 $tm_{1\text{-}2}$ ps_2 $a_{1\text{-}2}$	2
Tandawanna (20)	cf_2 m_2 $sa_{1\text{-}2}$ w_2 $tm_{1\text{-}2}$ ps_2 $a_{1\text{-}2}$	2
Arden (21)	m_2 sa_2 $w_{1\text{-}2}$ e_2	2
Wynhari (19)	m_2 nd_2 $sa_{1\text{-}2}$ $w_{1\text{-}2}$ $r_{1\text{-}2}$ ps_2 $a_{1\text{-}2}$	2
Mt. Carmel (17)	m_2 nd_2 $sa_{1\text{-}2}$ $w_{1\text{-}2}$ ps_2 e_2	2
Tarewinnabar (22)	$cf_{1\text{-}2}$ m_2 nd_2 w_2 $r_{1\text{-}2}$ $tm_{1\text{-}2}$ e_2	2
Kalanga (4)	cf_2 m_2 nd_2 w_2 $f_{2\text{-}3}$	2-3
Undabri (3)	cf_2 m_2 nd_2 w_2 $f_{2\text{-}3}$	2-3
Wondalli (14)	cf_2 sa_2 $w_{2\text{-}3}$ $tm_{2\text{-}3}$	2-3
Calingunee (15)	$sa_{1\text{-}2}$ $w_{2\text{-}3}$ $tm_{2\text{-}3}$ $e_{2\text{-}3}$	2-3
Moruya (18)	$m_{2\text{-}3}$ nd_2 ps_3 pm_3 e_3 a_2	3
Murra Cul Cul (5)	cf_2 m_3 $sa_{1\text{-}2}$ w_2 $f_{1\text{-}2}$ ps_3 pm_3 $e_{1\text{-}2}$ a_2	3
Yambocully (6)	cf_2 $m_{2\text{-}3}$ nd_2 $sa_{1\text{-}2}$ $f_{1\text{-}2}$	3
Oonavale (7)	cf_2 m_3 nd_2 $f_{1\text{-}2}$ ps_3 pm_3 a_3	3
Tarewinnabar shallow (23)	m_4 nd_3 r_2 ps_2 pm_2 e_3	4
Jindabyne (8)	cf_2 m_4 $sa_{1\text{-}2}$ w_2 $f_{1\text{-}2}$ ps_3 pm_3 $e_{1\text{-}2}$ a_3	4
Weengallon (24)	m_4 nd_3 ps_3 pm_2 e_3 a_3	4
Flinton (25)	m_4 nd_4 ps_3 pm_2 e_4 a_3	4
Keetah (1)	cf_2 m_4 nd_2 $w_{1\text{-}2}$ $f_{2\text{-}4}$ ps_4 pm_2 e_3 a_4	4
Bengalla (2)	cf_2 m_5 nd_2 w_5 ps_4 pm_4 a_4	5
Marella (11)	cf_2 m_5 nd_2 ps_4 pm_2 a_3	5
Wondoogle (9)	cf_2 m_5 nd_4 ps_5 pm_2 e_2 a_4	5
Wai Wai (10)	cf_2 m_5 nd_4 ps_5 pm_2 e_3 a_4	5
Bendidee (12)	m_5 nd_5 w_4 ps_5 pm_2 e_3 a_2	5
Uranilla (26)	m_5 nd_5 w_4 ps_4 pm_3 e_3 a_2	5
Westmar soils (27)	m_5 nd_5 w_4 $r_{1\text{-}3}$ $ps_{4\text{-}5}$ $pm_{2\text{-}4}$ $e_{3\text{-}4}$ a_2	5
Karbullah (29)	m_5 nd_5 r_5 ps_5 pm_4 e_5 a_2	5
Flinton shallow (28)	m_5 nd_5 r_4 ps_5 pm_4 e_5 a_2	5
Yelarbon (13)	cf_2 m_5 nd_4 $sa_{1\text{-}2}$ w_5 ps_5 pm_5 a_5	5

Table III.2. Soil limitations for annual forage cropping

Soil (No.)	Limitations	Class
Kurumbul (16)	sa_2 w_2 tm_{1-2} ps_2 a_{1-2}	2
Tandawanna (20)	sa_{1-2} w_2 tm_{1-2} ps_2 a_{1-2}	2
Arden (21)	sa_2 w_{1-2} e_2	2
Wynhari (19)	nd_2 sa_{1-2} w_{1-2} r_{1-2} ps_2 e_2	2
Mt. Carmel (17)	nd_2 sa_{1-2} w_{1-2} ps_2 e_2	2
Tarewinnabar (22)	nd_2 w_2 r_{1-2} tm_{1-2} e_2	2
Kalanga (4)	nd_2 w_2 f_{2-3}	2-3
Undabri (3)	nd_2 w_2 f_{2-3} ps_2 pm_2	2-3
Wondalli (14)	sa_2 w_{2-3} tm_{2-3}	2-3
Calingunee (15)	sa_{1-2} w_{2-3} tm_{2-3} e_{2-3}	2-3
Moruya (18)	m_{1-2} nd_2 ps_3 pm_3 e_3 a_2	3
Murra Cul Cul (5)	m_2 sa_{1-2} w_2 f_{1-2} ps_3 pm_3 e_{1-2} a_2	3
Yambocully (6)	m_{1-4} nd_2 sa_2 f_{1-2} ps_3 pm_3 a_3	3
Oonavale (7)	m_2 nd_2 f_{1-2} ps_3 pm_3 a_3	3
Tarewinnabar shallow (23)	m_4 nd_2 r_2 ps_2 pm_2 e_3	4
Jindabyne (8)	m_4 sa_2 w_2 f_{1-2} ps_3 pm_3 e_{1-2} a_3	4
Weengallon (24)	m_4 nd_2 ps_3 pm_2 e_3 a_3	4
Flinton (25)	m_4 nd_3 ps_3 pm_2 e_4 a_2	4
Keetah (1)	m_4 nd_2 w_{1-2} f_{2-4} ps_4 pm_2 e_3 a_3	4
Bengalla (2)	m_6 nd_2 w_6 ps_4 pm_4 a_4	5
Marella (11)	m_6 nd_2 ps_4 pm_2 a_3	5
Wondoogle (9)	m_6 nd_3 ps_6 pm_2 e_2 a_4	5
Wai Wai (10)	m_6 nd_4 ps_6 pm_2 e_3 a_4	5
Bendidee (12)	m_6 nd_6 w_4 ps_6 pm_2 e_3 a_2	5
Uranilla (26)	m_6 nd_6 w_4 ps_4 pm_3 e_3 a_2	5
Westmar soils (27)	m_6 nd_6 w_4 r_{1-3} ps_{4-6} pm_{2-4} e_{3-4} a_2	5
Karbullah (29)	m_6 nd_6 r_6 ps_6 pm_4 e_6 a_2	5
Flinton shallow (28)	m_6 nd_6 r_4 ps_6 pm_4 e_6 a_2	5
Yelarbon (13)	m_6 nd_4 sa_2 w_6 ps_6 pm_6 a_6	5

Table III.3. Soil limitations for perennial forage cropping

Soil (No.)	Limitations	Class
Kurumbul (16)	sa_2 ps_2	2
Tandawanna (20)	sa_2 ps_2	2
Arden (21)	sa_2	2
Wynhari (19)	nd_2 sa_{1-2} ps_2	2
Mt. Carmel (17)	nd_2 sa_{1-2} ps_2	2
Tarewinnabar (22)	nd_2	2
Kalanga (4)	nd_2 f_2	2
Undabri (3)	nd_2 f_2 ps_2 pm_2	2
Wondalli (14)	sa_2 w_{1-2} tm_{1-2}	2
Calingunee (15)	sa_{1-2} w_{1-2} tm_{1-2} e_{1-2}	2
Moruya (18)	m_{1-2} nd_2 ps_3 pm_2 e_2	3
Murra Cul Cul (5)	m_2 sa_2 ps_3 pm_2	3
Yambocully (6)	m_{1-2} nd_2 sa_2 ps_3 pm_2 a_2	3
Oonavale (7)	m_2 nd_2 ps_3 pm_2 a_2	3
Tarewinnabar shallow (23)	m_4 nd_2 ps_2 pm_2 e_2	4
Jindabyne (8)	m_4 sa_2 ps_3 pm_2 a_2	4
Weengallon (24)	m_4 nd_2 ps_3 e_2 a_2	4
Flinton (25)	m_4 nd_3 ps_3 e_3 a_2	4
Keetah (1)	m_4 nd_2 f_{2-3} ps_4 e_2 a_2	4
Bengalla (2)	m_6 nd_2 w_4 ps_4 pm_3 a_4	5
Marella (11)	m_6 nd_2 ps_4 a_3	5
Wondoogle (9)	m_6 nd_3 ps_6 e_2 a_4	5
Wai Wai (10)	n_6 nd_4 ps_6 e_2 a_4	5
Bendidee (12)	m_6 nd_6 w_3 ps_6 e_2 a_2	5
Uranilla (26)	m_6 nd_6 w_3 ps_4 pm_2 e_2 a_2	5
Westmar soils (27)	m_6 nd_6 r_{1-2} ps_{4-6} pm_{1-3} e_{2-3} a_2	5
Karbullah (29)	m_6 nd_6 r_6 ps_6 pm_3 e_6 a_2	5
Flinton shallow (28)	m_6 nd_6 r_4 ps_6 pm_3 e_6 a_2	5
Yelarbon (13)	m_6 nd_4 sa_2 w_6 ps_6 pm_6 a_6	5

Table III.4. Soil limitations for sown pastures

Soil (No.)	Limitations	Class
Kurumbul (16)	v_{1-2} ps_2	2
Tandawanna (20)	v_{1-2} ps_2	2
Arden (21)	sa_{1-2} v_2	2
Wynhari (19)	nd_2 v_2 ps_2	2
Mt. Carmel (17)	nd_2 v_2 ps_2	2
Tarewinnabar (22)	nd_2	2
Kalanga (4)	nd_2 f_2 v_2	2
Undabri (3)	nd_2 f_2 v_{1-2} ps_3 pm_2	2
Wondalli (14)	w_{1-2} v_{2-3} tm_{1-2}	2-3
Calingunee (15)	w_{1-2} v_{2-3} tm_{1-2} e_{1-2}	2-3
Moruya (18)	m_{1-2} nd_2 v_{1-2} ps_3 pm_2	3
Murra Cul Cul (5)	m_2 v_2 ps_3 pm_2	3
Yambocully (6)	m_{1-2} nd_2 v_2 ps_3 pm_2 a_2	3
Oonavale (7)	m_2 nd_2 v_2 ps_3 pm_2 a_2	3
Tarewinnabar shallow (23)	m_3 nd_2 ps_3 pm_2 e_2	3
Jindabyne (8)	m_3 v_3 ps_3 pm_2 a_2	3
Weengallon (24)	m_3 nd_2 v_3 ps_3 a_2	3
Flinton (25)	m_3 nd_3 v_3 ps_3 e_2 a_2	3
Keetah (1)	m_3 nd_2 f_{2-3} v_3 ps_3 a_2	3
Bengalla (2)	m_4 nd_2 w_4 v_3 ps_4 pm_3 a_4	4
Marella (11)	m_4 nd_2 v_3 ps_3 a_3	4
Wondoogle (9)	m_6 nd_3 v_4 ps_6 e_2 a_4	5
Wai Wai (10)	m_6 nd_4 v_4 ps_6 e_2 a_4	5
Bendidee (12)	m_6 nd_6 w_3 v_4 ps_6 e_2 a_2	5
Uranilla (26)	m_6 nd_6 w_3 v_4 ps_4 pm_2 e_2 a_2	5
Westmar soils (27)	m_6 nd_6 w_3 v_4 r_{1-2} ps_{4-6} pm_{1-3} e_{2-3} a_2	5
Karbullah (29)	m_6 nd_6 v_4 r_6 ps_6 pm_3 e_6 a_2	5
Flinton shallow (28)	m_6 nd_6 v_4 r_4 ps_6 pm_3 e_6 a_2	5
Yelarbon (13)	m_6 nd_4 w_6 v_4 ps_6 pm_6 a_6	5

Table III.5. Soil limitations for native pastures

Soil (No.)	Limitations	Class
Kurumbul (16)	v_{1-2}	1-2
Tandawanna (20)	v_{1-2}	1-2
Arden (21)	v_2	2
Wynhari (19)	nd_2 v_2	2
Mt. Carmel (17)	nd_2 v_2	2
Tarewinnabar (22)	nd_2	2
Kalanga (4)	nd_2 v_2	2
Undabri (3)	nd_2 v_{1-2}	2
Wondalli (14)	v_{2-3}	2-3
Calingunee (15)	v_{2-3}	2-3
Moruya (18)	nd_2 v_{1-2}	2
Murra Cul Cul (5)	v_2	2
Yambocully (6)	nd_2 v_2 a_2	2
Oonavale (7)	nd_2 v_2 a_2	2
Tarewinnabar shallow (23)	m_2 nd_2	2
Jindabyne (8)	m_{2-3} v_3 a_2	3
Weengallon (24)	m_3 nd_2 v_3 a_2	3
Flinton (25)	m_3 nd_3 v_3 a_2	3
Keetah (1)	m_2 nd_2 v_3 a_2	3
Bengalla (2)	m_3 nd_2 v_3 a_3	3
Marella (11)	m_3 nd_2 v_3 a_2	3
Wondoogle (9)	m_4 nd_2 v_4 a_3	4
Wai Wai (10)	m_4 nd_3 v_4 a_3	4
Bendidee (12)	m_4 nd_4 v_4	4
Uranilla (260	m_4 nd_4 v_4	4
Westmar soils (27)	m_4 nd_4 v_4	4
Karbullah (29)	m_4 nd_4 v_4 e_4	4
Flinton shallow (28)	m_4 nd_4 v_4 e_4	4
Yelarbon (13)	m_4 nd_3 v_4 a_4	4

Table III.6. Soil limitations for flood irrigated cropping

Soil (No.)	Limitations	Class
Kalanga (4)	w_2 f_2 $tm_{1\text{-}2}$	2
Undabri (3)	w_2 f_2 ps_2 pm_2	2
Kurumbul (16)	$sa_{1\text{-}2}$ $w_{1\text{-}2}$ tm_2 ps_2 i_2	2
Tandawanna (20)	$sa_{1\text{-}2}$ $w_{1\text{-}2}$ tm_2 ps_2 i_2	2
Yambocully (6)	$m_{1\text{-}2}$ $sa_{1\text{-}2}$ $w_{1\text{-}2}$ $f_{1\text{-}2}$ xs_2 ps_3 pm_2 i_3	3
Oonavale (7)	m_2 $w_{1\text{-}2}$ $f_{1\text{-}2}$ xs_2 ps_3 pm_2 i_3	3
Jindabyne (8)	m_2 $sa_{1\text{-}2}$ $w_{1\text{-}2}$ xs_2 ps_3 pm_2 i_3	3
Wondalli (14)	sa_2 w_3 tm_4	4
Keetah (1)	m_4 $f_{2\text{-}4}$ xs_2 ps_4 pm_2 i_4	4
Marella (11)	m_4 xs_2 ps_4 pm_2 i_4	4
Wondoogle (9)	m_5 xs_2 ps_4 pm_2 i_4	5
Wai Wai (10)	m_5 xs_2 ps_5 pm_2 i_5	5
Bengalla (2)	m_5 w_4 ps_5 pm_4 i_5	5

Appendix IV

PASTURE CONDITION AND KEY PASTURE SPECIES FOR THE LAND RESOURCE AREAS IN WAGGAMBA SHIRE

Richard Silcock and David Blacket

1. MACINTYRE LRA - Undabri and Kalanga soils

	Pasture condition		
	Good	Fair	Poor
Erosion status	none	slight	obvious
Basal area (%)	> 2.5	1.5 - 2.5	< 1.0
% Key perennial grasses	> 70	20 - 60	< 15
% Perennial wiregrasses	< 5	10 - 25	> 30
% Canopy cover of woody weeds	< 10	20 - 60	> 70

Key perennial species: rat's tail couch, rigid panic, early spring grass, northern wallaby grass, neverfail grass, pale goodenia, nardoo, *Leptochloa digitata*, *Paspalidium distans*

Undesirable herb plants: pale spikerush

Main woody weeds: coolibah, belalie, lignum, black box, gooramurra, grey germander

2. DUMARESQ, SERPENTINE and BOOGARA LRAs - Keetah, Bengalla, Murra Cul Cul, Yambocully, Oonavale and Jindabyne soils

	Pasture condition		
	Good	Fair	Poor
Erosion status	none obvious	scalding	pedastalling
Basal Area (%)	> 3.0	1.5 - 2.5	< 1.0
% Key perennial grasses	> 75	30 - 70	< 25
% Perennial wiregrasses	< 20	30 - 60	> 70
% Canopy cover woody weeds	< 10	20 - 60	> 70

Key perennial species: pitted bluegrass, rough speargrass, corkscrew grass, slender bluegrass, katoora, windmill grass, tall chloris, common fringerush, small saltbush, *Einadia nutans*, *Eragrostis microphyllum*, *Eragrostis molybdea*

Undesirable herb plants: purple wiregrass, dark wiregrass

Main woody weeds: poplar box, false sandalwood, eastern cotton bush, wilga

3. BROOMFIELD and GOODAR LRAs - Wondoogle, Wai Wai, Marella and Bendidee soils

	Pasture condition		
	Good	Fair	Poor
Erosion status	slight	obvious	obvious
Basal area (%)	> 2.0	1.0 - 2.0	< 1.0
% Key perennial grasses	> 30	10 - 30	< 10
% Perennial wiregrasses	< 30	40 - 70	> 80
% Canopy cover of woody weeds	< 25	30 - 50	> 60

Key perennial species: buffel grass, golden beard grass, silky umbrella grass, Jericho wiregrass, hairy panic, purple lovegrass, curly windmill grass

Undesirable herb Plants: spiny burr grass, galvanised burr, *Aristida lignosa*

Main woody weeds: Murray wattle, common sida, white cypress pine

4. COMMORON, BILLA BILLA and BUNGUNYA NORTH LRAs - Wondalli, Calingunee, Kurumbul, Mt. Carmel, Moruya, Wynhari, Tandawanna and Arden soils

	Pasture condition		
	Good	Fair	Poor
Erosion status	none	rills	gullies
Basal area (%)	> 3.0	2.0 - 2.5	< 1.5
% Key perennial grasses	> 80	40 - 70	< 30
% Perennial wiregrasses	< 5	10 - 40	> 50
% Canopy cover of woody weeds	< 15	20 - 50	> 60

Key perennial species: Queensland bluegrass, early spring grass, curly windmill grass, warrego grass, fairy grass, weeping panic, slender canegrass

Undesirable herb plants: white speargrass

Main woody weeds: brigalow, limebush

5. LUNDAVRA LRA -
Tarewinnabar and Tarewinnabar shallow soils

	Pasture condition		
	Good	Fair	Poor
Erosion status	none	rills	gullies
Basal area (%)	> 3.0	2.0 - 2.5	< 1.5
% Key perennial grasses	> 85	30 - 80	< 25
% Perennial wiregrasses	< 5	10 - 30	> 40
% Canopy cover of woody weeds	< 5	10 - 30	> 40

Key perennial species: curly mitchell grass, hoop mitchell grass, native millet, fairy grass, Queensland bluegrass, early spring grass, western rat's tail grass

Undesirable herb plants: White speargrass, yabila grass, spiked malvastrum

Main woody weeds: gundabluie, mimosa bush

6. GERALDA LRA -
Flinton, Weengallon soils

	Pasture condition		
	Good	Fair	Poor
Erosion status	slight	scalding	bad scalds
Basal area (%)	> 2.5	1.5 - 2.0	< 1.0
% Major perennial grasses	> 70	30 - 60	< 20
% Perennial wiregrasses	< 20	30 - 80	> 85
% canopy cover of woody weeds	< 15	20 - 60	> 70

Major perennial species: mulga mitchell grass, rough speargrass, curly windmill grass, cotton panic grass, kangaroo grass, pitted bluegrass, mulga oats, hairy panic, tall chloris, windmill grass, leafy nineawn, northern wallaby grass, barbwiregrass, glycine pea, corrugated sida, slender tick trefoil, *Justicia procumbens*, *Ruellia australis*, *Sclerolaena convexula*, *Thyridolepis xerophila*

Undesirable herb plants: purple wiregrass, branched wiregrass

Main woody weeds: poplar box, false sandalwood, Deane's wattle, desert cassia, broadleaf hopbush, nipan

7. BOONDANDILLA LRA - Uranilla soils

	Pasture condition		
	Good	Fair	Poor
Erosion status	sheets	rills	gullies
Basal area (%)	> 2.0	1.0 - 2.0	< 1.0
% Key Perennial Grasses	> 70	20 - 60	< 15
% Perennial wiregrasses	< 20	30 - 70	> 85
% Canopy cover of woody weeds	< 20	30 - 70	> 80

Key perennial species: pitted bluegrass, bull oak lovegrass, curly windmill grass, early spring grass, golden beard grass, gilgai grass, poverty grass, weeping grass, silky browntop, slender canegrass

Undesirable herb plants: purple wiregrass, Leichhardt wiregrass, yellow buttons

Main woody weeds: bull oak, Mudgee wattle, velvet hibiscus, Pilliga grey box, *Acacia ixiolaena*

8. WESTMAR and JUMPUP LRAs - Flinton shallow and Karbullah soils

	Pasture condition		
	Good	Fair	Poor
Erosion status	sheet	rills and sheets	gullies
Basal area (%)	> 1.0	0.5 - 1.0	< 0.5
% Key perennial grasses	> 65	30 - 60	< 20
% Perennial wiregrasses	< 20	30 - 70	> 80
% Canopy cover of woody weeds	< 40	50 - 80	> 90

Key perennial species: hooky grass, slender panic, gilgai grass, purple lovegrass, curly windmill grass, poverty grass, *Cleistochloa subjuncea*, *Thyridolepis xerophila*

Undesirable herb plants: iron grass, many headed wiregrass, dark wiregrass

Main woody weeds: currant bush, Burrow's wattle, nipan, heather bush

GLOSSARY

Acid clay	Clay subsoils of low pH that occur particularly under brigalow-belah vegetation.
Alluvial plain	A plain formed by the accumulation of alluvium over a considerable period of time; this accumulation may be still occurring at present (recent alluvium) or may have ceased (relict alluvium).
Alluvium (pl. alluvia)	Deposits of gravel, sand, silt, clay or other debris, moved by streams from higher to lower ground.
Bleach	Subsurface soil that is white, near white or much paler than adjacent soil layers. It occurs in varying proportions.
C material	Layers below the B horizon which may be weathered parent material little affected by soil forming processes.
Clays	Soils with a uniform clay texture throughout the surface soil and subsoil.
- cracking	Clay soils that develop vertical cracks when dry.
- non-cracking	Clay soils that do not develop vertical cracks when dry.
Colluvium (pl. colluvia)	Slope deposits of soil and rock material.
Colour	see *Soil colour*.
Cracking clays	see *Clays, cracking*.
Deep weathering	The process by which earthy or rocky materials are slowly broken down into finer particles and soil by chemical and physical processes to a substantial extent.
Dispersion (dispersivity)	The capacity of a soil to break down or separate soil aggregates into their constituent particles. This is often associated with soils which are highly sodic or saline. This process greatly aids erosion. Dispersivity is measured as a clay dispersion ratio (x:1). Dispersibility ratings come from D. Baker (Agricultural Chemistry Branch, QDPI, Brisbane, personal communication).

The classes are:

low	-	less than 0.6
moderate	-	between 0.6 and 0.8
high	-	between 0.8 and 0.95
very high	-	greater than 0.95

Dissection	The process of streams or erosion cutting the land into hill, ridges and flat areas.

Duplex soil	A soil in which there is a sharp change in soil texture between the A and B horizons over a distance of 10cm or less.
Duricrust	A cemented layer at or near the surface resulting from concentration of breakdown products of rock weathering.
Earths	Soils with a sandy to loamy (including clay loam) surface soil gradually increasing to a loamy to light clay subsoil.
- massive	Earths in which the subsoil is not arranged into natural soil aggregates and appears as a coherent, or solid mass.
- structured	Earths in which the subsoil is arranged into natural soil aggregates which can be clearly seen.
Effective rooting depth (ERD)	Depth to which most plant feeder roots will penetrate. This is taken here to be the depth to which salts have been leached and have therefore accumulated. This represents the long-term depth of wetting. The quoted ERD is adjusted to horizon boundaries.
Ferruginisation	Breakdown of iron-rich minerals under intense weathering to produce iron oxides (the equivalent of rust). See also *Laterite.*
Horizon	see *Soil horizon*, also *Soil horizon boundary.*
Kaolinisation	Breakdown of minerals (particularly feldspars) under intense weathering to form kaolinite clay (china clay). See also *Laterite.*
Labile	see *Sedimentary rocks.*
Laterite	A profile formed by intense weathering. Many deeply weathered profiles termed 'lateritic' exhibit a distinct series of layers including a surface duricrust, a ferruginised zone and mottled and pallid (kaolinised) zones. See also *Duricrust, Ferruginisation, Kaolinisation.*
Lithology	The use of characteristics such as colour, mineral composition and grain size to describe rocks.
Local relief	The altitude difference between the base and crest of slopes in undulating or hilly areas.
Loams	Soils with a uniform loam (including clay loam) texture throughout the surface soil and subsoil. See also *Texture.*
Loose surface	The surface soil is easily disturbed by pressure of the forefinger as it consists of an incoherent mass of individual particles or aggregates.
Massive earths	see *Earths, massive.*
Massive structure	see *Soil structure, apedal.*
Nodules (in soil)	Small, hard, rounded masses of mineral compounds accumulated and concentrated in the soil by chemical action with water. They vary in size, shape and colour. (compare with *Segregations*).

Permeable

The capacity for transmission under pressure (mainly gravity) of a fluid through a porous rock, sediments or soil.

Plant available water capacity (PAWC)

The quantity of water held in a soil that can be extracted by plant roots; the capacity is usually expressed as depth of water in millimetres.

pH

A measure of the acidity or alkalinity of the soil on a scale of 1 to 14. The pH of a soil is a measure of its hydrogen activity. Acid soils have a high level of active hydrogen, while alkaline soils do not. Soil pH may be acid (3.0 to 6.5), neutral (6.5 to 7.5) or alkaline (7.5 to 10.0+). Each unit change in pH represents a 10-fold change in either the acidity or alkalinity of the soil. For example, a pH of 5.0 is 10 times more acid than a pH of 6.0.

Salinity

The presence of soluble salts (mainly sodium chloride but also sodium carbonate, sodium nitrate, potassium carbonate, sodium nitrate and potassium nitrate) in the soil profile as solution or as accumulated crystalline salts. High salinity adversely affects root growth if it occurs within the rooting zone. It is expressed as a level of electrical conductivity (EC). EC units are deciSiemens per metre (dSm^{-1}).

The classes are defined as follows:

very low	-	less than 0.5
low	-	0.15 to 0.30
medium	-	0.30 to 0.70
high	-	0.70 to 1.20
very high	-	1.20 to 1.90
extreme	-	more than 1.90

Sands

Soils with a uniform sand (including sandy loam) texture throughout the surface soil and subsoil.

Sedimentary rocks

Rocks formed from the accumulation of material which has been weathered and eroded from pre-existing rocks, then transported and deposited as sediment by wind or water.

Sedimentary rocks have been classified according to grain size and constituent minerals:

Sedimentary rocks	Clay-sized grains	**Mudstone**
	Silt-sized grains	**Siltstone**
	Sand-sized grains	**Sandstone**
	Gravel-sized grains	**Conglomerate**

Sandstone is further subdivided on the basis of the dominated minerals making up the clasts (solid inclusions) or the matrix which cements the clasts together:

Sandstone:
- 90% or more of grains are quartz: **Quartzose sandstone**
- less than 75% of grains are quartz: **Labile sandstone**

Labile sandstone may be dominated by rock fragments and is therefore called **lithic sandstone.**

Segregations (in soil)

Soft, finely divided mineral compounds accumulated in the soil through chemical action with water. They are not easily separated as discrete bodies (compare with *Nodules*).

Self-mulching

A condition of the surface soil, notably of clays, in which the aggregates fall apart naturally as the soil dries to form a loose surface mulch.

Silicification

Impregnation of rocks with silica during weathering.

Sodicity

A characteristic of soils (usually subsoils) containing exchangeable sodium to the extent of adversely affecting soil stability. It is measured as an exchangeable sodium percentage (ESP) of the cation exchange capacity (CEC) of the soil.

The classes are defined as follows:

non-sodic	-	less than 6%
slightly sodic	-	between 6 and 10%
sodic	-	between 10 and 15%
strongly sodic	-	between 15 and 35%
very strongly sodic	-	more than 35%

Soil colour

The colour of soil material is determined by comparison with a standard Munsell soil colour chart. The colour classes used for soil description in this manual is as follows:

Value/Chroma rating*	1	2a	2b	4	5
Hue					
10R	dark	red-grey	red-brown	red	red
2 5YR	dark	grey-brown	red-brown	red	red
5 YR	dark	grey-brown	brown	red-brown	red-brown
7.5YR	dark	grey-brown	brown	yellow brown	brown
10YR	dark	grey	yellow-brown	yellow	brown
2 5Y	dark	grey	yellow-grey	yellow	olive-brown
5Y	dark	grey	yellow-grey	yellow	olive

* Value/chroma rating is that defined by Northcote (1979)

Soil depth

The terms used in this manual for soil depths are governed by sampling methods.

Surface depth represents the A horizons (A1, A2), usually a 0 to 10 cm sample. It may include 20 to 30 cm and occasionally 50 to

60 cm samples where A horizons are deep; for example, Keetah, Bengalla, Marella, Bendidee, Oonavale.

Upper subsoil depth represents the top of the B horizon; usually a 20 to 30 cm and, or a 50 to 60 cm sample. It may include a 80 to 90 cm sample where A horizons are deep; for example, Keetah.

Lower subsoil depth represents the bottom of the B horizon; usually a 80 to 90 cm and, or 110 to 120 cm sample. It may include a 50 to 60 cm sample where soils are shallow; for example, Tarewinnabar shallow.

Soil horizon

A layer of soil material within the *soil profile* with distinct characteristics and properties produced by soil processes, and which are different from those of the layers above and/or below. The three main horizons are: A (topsoil); B (subsoil) C (see *C material*).

Soil horizon boundary

Boundaries between horizons take many forms. The terms used in the Soil Descriptions of Part B are:

Sharp - less than 5 mm wide; **Abrupt** - 5 to 20 mm wide; **Clear** 20 to 50 mm wide; **Gradual** - 50 to 100 mm wide; **Diffuse** - more than 100 mm wide.

Soil profile

A vertical cross-sectional exposure of a soil, from the surface to the parent material or *substrate*.

Soil structure

The arrangement of natural soil aggregates that occur in soil; structure includes the distinctness, size and shape of these aggregates.

- apedal

There are no observable natural soil aggregates; the soil may be either a coherent mass (massive) or a loose, incoherent mass of individual particles such as sand grains (single grain).

- blocky

The natural soil aggregates have the approximate shape of cubes with flat and slightly rounded sides.

- prismatic

The natural soil aggregates have the approximate shape of elongated blocks.

- columnar

The natural soil aggregates are like those of *prismatic* but have domed tops.

- polyhedral

The natural soil aggregates are irregular, many sided and multi-angled.

- lenticular

The natural soil aggregates are like large vertical lens shapes with curved cracks between the aggregates.

- coarse

The natural soil aggregates are relatively large; an average size of 20 mm or more is coarse for the purposes of this manual.

- medium

The average size of the natural soil aggregates is between fine and coarse.

- fine	The natural soil aggregates are relatively small; an average size of 5 mm or less is fine for the purposes of this manual.
- strong	The natural soil aggregates are quite distinct in undisplaced soil; when displaced more than two-thirds of the soil material consists of aggregates.
- moderate	Natural soil aggregates are well formed and evident but not distinct in undisplaced soil; when displaced more than one-third of the soil material consists of aggregates.
- weak	The natural soil aggregates are indistinct and barely observable in undisplaced soil; when displaced up to one-third of the soil material consists of soil aggregates.
Soil texture	The coarseness or fineness of soil material as it affects the behaviour of a moist ball of soil when pressed between the thumb and forefinger. Texture classes used in this manual are defined primarily by the total clay content:

	Group	Clay content (%)
	Sand	less than 5
Coarse	Loamy sand	5 to 10
	Sandy loam	10 to 20
	Loam	$\approx$ 25
Medium	Sandy clay loam	20 to 30 + sand
	Clay loam	30 to 35
	Sandy clay	35 to 40 + sand
	Light clay	35 to 40
Fine	Medium clay	40 to 50
	Heavy clay	more than 50

Structured earths	see *Earths, structured*.
Subsoil	Soil layers below the surface with one of the following attributes: - a larger content of clay, iron, aluminium, organic material (or several of these) than the surface and subsurface soil; - stronger colours than those of the surface and subsurface soil above, or the *substrate* below.
Substrate	The material below the soil profile which may be the parent material or may be unlike the material from which the soil has formed; substrate which is not parent material for the soil above may be layers of older alluvium, rock strata unrelated to the soil or the buried surface of a former landscape.
Subsurface soil	Soil layers immediately under the surface soil which usually have less organic matter, paler colours and may have less clay than the surface soil.

Surface soil	The soil layer extending from the soil surface down which has some organic matter accumulation and is darker in colour than the underlying soil layers.
Terrace	Any long, relatively level or gently sloping surface, generally narrower than a plain and bounded by a steeper ascending slope on one edge and a steeper descending slope on the other. Often associated along the margin and above the level of a body of water eg. stream or lagoon.
Texture	see *Soil texture.*
Uniform clays	see *Clays.*
Uniform loams	see *Loams.*
Uniform sands and sandy loams	see *Sands.*
Waterlogged	An area in which water stands near, at or above the land surface, so that the roots of all plants except those with extreme water tolerance are drowned and the plants die.

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