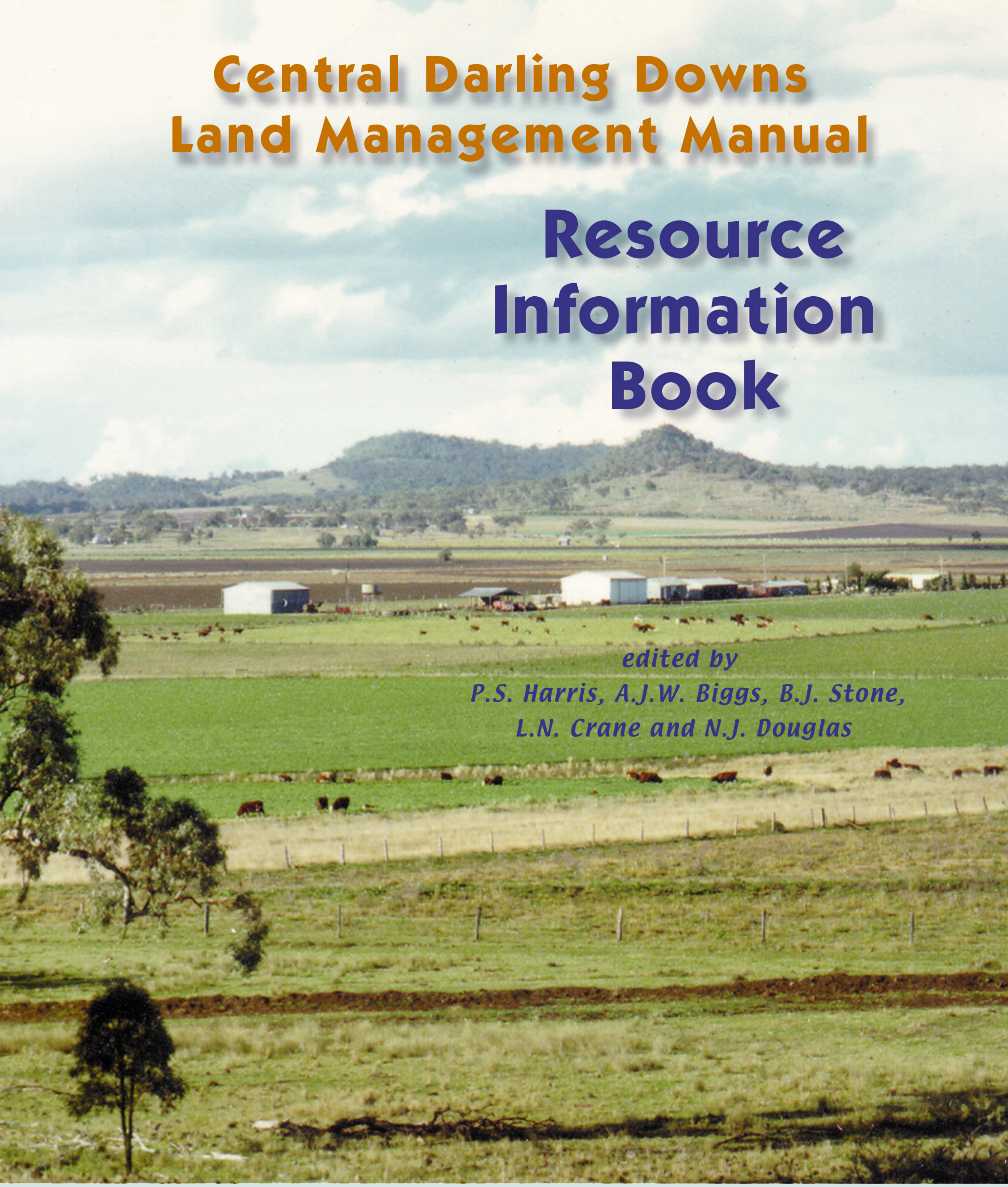
Central Darling Downs Land Management Manual

Resource Information Book



edited by
P.S. Harris, A.J.W. Biggs, B.J. Stone,
L.N. Crane and N.J. Douglas

Understanding and Managing Land

in

Wambo, Pittsworth, Rosalie, Millmerran,
Jondaryan Shires, Dalby Town and Toowoomba City

Department of Natural Resources
DNRQ990102

Central Darling Downs Land Management Manual

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Edited by P.S. Harris, A.J.W. Biggs, B.J. Stone,
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Department of Natural Resources
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Maher, J.M., Harris, P.S. and Biggs, A.J.W. (1998). *Central Darling Downs Land Resource Areas Map (1:250 000)*. Department of Natural Resources, Queensland. 97-MCD-I-P3107.

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6. Vegetation

7. Agricultural landuse

8. Land and environmental degradation

9. Land planning and management strategies for sustainability

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Acknowledgments

As Project Leader, I found the writing, editing and publication of this Land Management Manual was a large and challenging task that required patience, persistence, dedication, and unwavering optimism.

Many, many people were involved. Their patience, advice, willingness to contribute, knowledge, skills and experience are very much appreciated. The list of authors, contributors and those involved in production are shown on the previous page. In particular, I wish to mention:

- The massive efforts of the co-ordination team - Andrew Biggs, Barry Stone and Nev Douglas, for co-ordinating regional input, writing/contributing to most parts of the manual and editing.
- Lisa Crane, Alistair Coutts and Meggan McKie for collating information from many, many sources – several being less than co-operative! Lisa, Meggan and Alistair took our notes from files, boxes and piles on the desk, collated graphs, tables, photos, appendices, glossaries, figures, text and actually started to put the manual together. They also helped some authors complete contributions.
- Kathy Noble and John Maher for their substantial contributions during the early stages.
- Dave Burton for producing the maps in the Resource Information Book.
- Diane Bray for graphics, editing and production of the LRA Map and helping with printing.
- John Maher, Geoff Sharp, Ben Harms, and Andrew Biggs for technical and chemical data on soils.
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- John Maher, Andrew Biggs for LRA mapping, field checking and soil classification.
- Denise Parkinson for diagrams in the Field Manual and the Resource Information Book.
- Landholders throughout the area who freely allowed access to their properties, particularly those who participated in over 30 soil field days and provided valuable local knowledge on management techniques.
- Frank Van Schagen, Ed Power and Phil McCullough who accessed funding to keep the project alive.
- Greg Claydon, John Cutler, Ed Power, Nev Hunt and Lamond Graham for management support and patience.

Make no mistake; this was a herculean task. When Kathy Noble, then leader of the Land Management Manual Project and John Maher, Land Resources Officer, visited Dalby in early 1994 to start compiling the Central Darling Downs Land Management Manual, it seemed achievable. But, in less than two years, with the project just started, there was no project officer, no project funds and any further development was left up to regional staff….”*in their spare time*”…In hindsight the signals should have been clear – this same ambitious project had twice been previously attempted in the 1970’s and 1980’s with little or no outcomes. However, through the efforts of a dedicated team, and the recognition of a high demand for this information, the project was pushed to completion.

The information in this Land Management Manual is extremely valuable because of the expertise and breadth of knowledge of the large number of people who contributed to its production.

Paul Harris
Senior Extension Officer
Department of Natural Resources
Dalby
November, 1999

1. INTRODUCTION

Paul Harris

The Central Darling Downs Land Management Manual is part of a Department of Natural Resources 'self-help' initiative to help make decisions for planning and sustainable land management. The aim of the Manual is to increase awareness of land resources information within the community and provide a tool to support planning and management from the property level to catchment scale.

The Central Darling Downs Land Management Manual commenced as part of a state initiative in 1994 and continued as a regional initiative after the completion of State funding in 1995. Key scientists and extension officers in their respective fields have written chapters in the Resource Book and provided management information. More importantly, many farmers have participated in soil field days and shared invaluable local knowledge on the sustainable management of particular soil types and recommendations for future land use.

The compilation of the Central Darling Downs Land Management Manual has been supported by the Department of Natural Resources (DNR), Department of Primary Industries (DPI) and the Environmental Protection Agency (EPA). The printing and publication has been funded by the Natural Heritage Trust (NHT) and DNR.

1.1 What area does the Land Management Manual cover?

The area covered by the Land Management Manual (Map 1) largely includes the central Condamine catchment. This is bounded by the Great Dividing Range to the east and north, the Kumbarilla Ranges to the west, and includes the broad area of Condamine River floodplains in the centre of the catchment. The Manual describes the attributes and limitations of the soils of the 14 Land Resource Areas (LRAs) for the 1.49 million hectares in the shires of Wambo, Pittsworth, Millmerran, Jondaryan, Rosalie (excluding Division 4), the town of Dalby and the city of Toowoomba.

1.2 Adjacent Land Management Manuals

This Manual is supported by similar publications related to surrounding areas, including:

- *Understanding and managing soils in the Stanthorpe/Rosenthal region* — including Stanthorpe Shire and that part of Warwick Shire previously called Rosenthal Shire (Maher, 1996a);
- *Understanding and managing soils in the Murilla, Tara and Chinchilla Shires* (Maher, 1996b);
- *Land management field manual in the Crow's Nest district* (Bierenbroodspot and Mullins, 1983);
- *Understanding and managing soils in the Moreton Region* — including the shires of Kilcoy, Esk, Pine Rivers, Gatton, Laidley, Moreton, Redland, Albert, Boonah, and Beaudesert (Noble, 1996);
- *Land management manual, Waggamba Shire* (Thwaites and Macnish, 1991);
- *Land management manual, Shire of Inglewood* (Cassidy, 1988);

- *Understanding and managing soils in the Inland Burnett district* — including the shires of Monto, Perry, Eidsvold, Mundubbera, Gayndah, Wondai, Murgon, Kilkivan, Kingaroy and Nanango (Maher, 1996c);
- *Land management field manual, south-east Darling Downs districts* (Marshall *et al*., 1988).

1.3 Why have a Land Management Manual?

This Manual is designed to increase awareness of the capabilities of the land and soils within the area, and in so doing, minimise potential land degradation. Resource management should be determined by the ability of the resource to produce — not on historical practices which in some cases have led to resource degradation. The Manual is a handy tool to identify and evaluate soils and provide information when developing strategies for sustainable property management or for local planning.

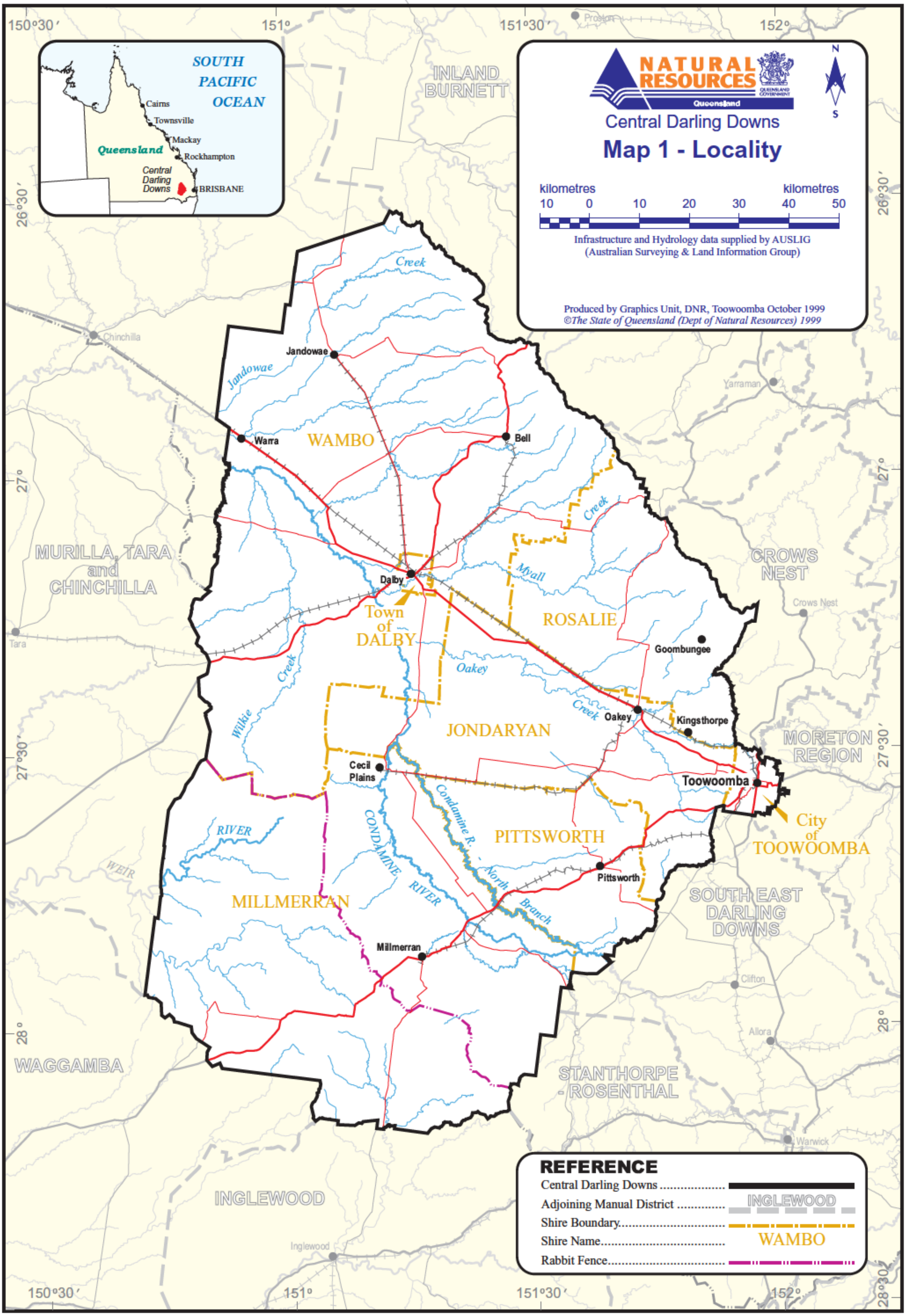
Decision making and planning for sustainable resource management relies heavily on the provision of information, the development and integration of information networks and the increased skills and knowledge of decision makers. This manual aids decision making by providing available resource data and practical management information in a format that is easy to understand and use.

The Central Darling Downs has experienced an extended history of land resource studies from the property scale to larger catchment or regional scales. Examples include:

- Thompson and Beckmann (1959) describing soils and land use in the Toowoomba area;
- Beckmann and Thompson (1960) describing soils and land use in the Kurrawa area;
- Dawson (1972) describing landscapes and land capability in the Jandowae area;
- Vandersee (1975) describing landscapes and land capability in the Eastern Darling Downs area;
- Vandersee and Mullins (1977) describing soils of the Marburg Formation and poplar box Walloons of the eastern Darling Downs;
- Mullins (1978) describing soils of the eastern Darling Downs;
- Mullins (unpub.) describing soils of the brigalow belah Walloons of the eastern Darling Downs;
- Forster (1986) describing land resources and limitations to land use in the Darling Downs;
- Biggs (1999a) describing soils and agricultural suitability of key areas of the eastern Darling Downs.

Early in the compilation of the Manual it became apparent that several key issues needed to be addressed as a result of previous studies and publications including:

- the need to use soil types as the smallest unit for land resource descriptions;
- the need to introduce uniform and consistent descriptions of soil types and link with surrounding studies;
- the need to establish benchmarks for soil, vegetation and landscape features across the Central Darling Downs;



NATURAL RESOURCES
Queensland
Central Darling Downs
Map 1 - Locality
kilometres
10 0 10 20 30 40 50
kilometres
Infrastructure and Hydrology data supplied by AUSLIG
(Australian Surveying & Land Information Group)
Produced by Graphics Unit, DNR, Toowoomba October 1999
©The State of Queensland (Dept of Natural Resources) 1999
SOUTH
PACIFIC
OCEAN
Cairns
Townsville
Mackay
Rockhampton
Queensland
Central
Darling
Downs
BRISBANE
INLAND
BURNETT
MURILLA, TARA
and
CHINCHILLA
CROWS
NEST
MORETON
REGION
SOUTH EAST
DARLING
DOWNS
STANTHORPE
- ROSENTHAL
WAGGAMBA
INGLEWOOD
WAMBO
ROSALIE
JONDARYAN
PITTSWORTH
MILLMERRAN
Town
of
DALBY
City
of
TOOWOOMBA
Jandowae
Warra
Bell
Dalby
Goombungee
Oakey
Kingsthorpe
Toowoomba
Cecil
Plains
Pittsworth
Millmerran
Chinchilla
Tara
Yarraman
Crows Nest
Clifton
Allora
Warwick
Inglewood
Creek
Myall
Oakey
Creek
Wilkie
Creek
Condamine R.
North
Branch
CONDAMINE
RIVER
RIVER
WEIR
150°30′
151°
151°30′
152°
26°30′
27°
27°30′
28°
28°30′
REFERENCE
Central Darling Downs
Adjoining Manual District
INGLEWOOD
Shire Boundary
Shire Name
WAMBO
Rabbit Fence

- the need to use similar mapping symbols, names and codes as previous and surrounding studies; and
- the need to collate the large amount of written and unwritten information on land management and natural resources into one publication with directions to find more detailed information should it be required.

A key aim of this manual is to collate the information from previous studies and establish new benchmarks for the description of soils and land resources in the area. Variations in natural resources e.g. soils and vegetation are difficult to represent at the scale of the map accompanying the Manual, therefore sheets describing individual soils are provided.

1.4 What does the Land Management Manual contain?

- The ***Land Resource Area Map*** (*LRA Map* in back pocket) is a full colour map showing the distribution of Land Resource Areas or landscape units within the Central Darling Downs. Each Land Resource Area is made up of a series of common and associated soils with key landscape and vegetation characteristics.

- The ***Field Manual,*** with summary sheets for 68 soils, is the core and most important component of the package. It provides a summary of the soil and land characteristics of the area, and provides recommendations for appropriate management and use. This section also provides information on how to identify soils, using visual aids including diagrams, tables, summary sheets and landscape/soil photographs.

- The ***Resource Information Book*** is a reference document that provides a regional overview on natural resources and places the soils information from the *Field Manual* within this context. Potential land use/land management problems are described, and recommendations made regarding prevention and solutions of these problems.

- The ***Soil Chemical Data Book*** is a reference document containing analytical data from representative soil profiles supporting the *Field Manual*.

1.5 Who should use the Land Management Manual?

The following list illustrates the range of potential users of the Manual. Although the list only gives one example per user, the range of possible uses is more extensive.

- Present landholders – to re-assess the potential of their property
- New landholders – to assess the realistic potential of their property
- Potential landholders – to assess the realistic potential of a property
- Property Management Planning (PMP) groups – for property planning
- Landcare and Catchment groups – for resource-based planning
- Planners/consultants – to assess land use limitations for development and to prescribe measures to minimise degradation
- Extension staff – for advice on land management
- Educators – for education on soils and their use
- Land valuers – for property potential and valuation
- Rural banks – for informed decision making on loans
- Local authorities – for shire development plans

- Managers of public infrastructure (e.g. Queensland Rail, Energex, Telstra, Dept. of Transport) – to assess land use limitations to reduce the impact of development and maintenance.

Photo 1 Stripcropping for runoff control on floodplains

Photo 2 Contour banks for runoff control on sloping lands

2. CLIMATE AND ITS INFLUENCE ON AGRICULTURE

Nev Douglas
Andrew Biggs
Paul Harris
Roger Stone

2.1 Introduction

The climate of the Central Darling Downs is sub-tropical. Average annual rainfall varies across the area e.g. 662 mm at Millmerran and 961 mm at Toowoomba. The only constant aspect of the climate is its variability. Droughts, floods, frosts, heat waves, and monthly variability in rainfall all have a major influence on agricultural production throughout the Central Darling Downs. The Southern Oscillation is also a significant influence on annual rainfall and temperature variability in eastern Australia. Knowledge of it and other features of the climate in the Central Darling Downs is important in making land management decisions.

Further information on climate may be found in *Australian Rainman* (Clewett *et al*., 1999) and from the Climate and Consultative Services Section, Bureau of Meteorology, Brisbane.

2.2 Rainfall

On average, almost two thirds of annual rain falls during summer (November to March). The highest totals occur in the eastern elevated areas of the Great Dividing Range, with totals declining rapidly to the west of the Range and continuing to decline further west (Map 2). For example, Toowoomba records a mean of 961 mm annually, while Westbrook, 10 kilometres to its west, records only 669 mm per year (Table 2.1).

Table 2.1 Mean monthly rainfall (mm) for selected towns in the Central Darling Downs

Location	J	F	M	A	M	J	J	A	S	O	N	D	Year
Toowoomba	134	124	100	66	55	57	54	40	46	72	86	172	961
Pittsworth	96	76	64	41	40	43	43	31	37	64	72	96	703
Oakey	90	77	60	38	35	40	37	28	33	60	72	92	663
Dalby	84	78	65	39	35	40	42	30	38	58	73	93	675
Westbrook	97	72	63	38	34	40	38	29	34	62	69	93	669
Millmerran	92	78	63	34	41	39	38	32	34	61	66	85	662
Goondiwindi	77	70	59	38	42	40	41	33	39	48	60	70	617

Source: Clewett *et al*. (1999)

Spring and early summer rain is normally generated by storm activity and can include violent winds, hail and intense rainfall. Mid-summer rains are more widespread and are often related to rain depressions, which develop from the remains of tropical cyclones or monsoon troughs in northern Australia. Significant rainfall in summer is often associated with upper level troughs and low-pressure systems. Rain produced by these influences can be important for refilling surface water storages for stock and irrigation purposes, and the recharge of soil moisture reserves for crops and pastures. Upper troughs may also influence winter rainfall patterns, especially in years following the autumn breakdown of an El Niño pattern in the Pacific Ocean.

Intense rain, with high erosion potential, is more likely in the early summer months. However, serious erosion in the area can occur with autumn and winter rains on land prepared for, or just planted to, winter crop. While rain at this time of the year may have a lower intensity, the soil prepared for winter crop may have a high level of stored moisture from summer rainfall. Stubble from the previous crop has usually been incorporated and broken down. Very little moisture soaks into soil in this condition and a high percentage of rainfall becomes runoff. This greatly increases the risk of erosion and flooding.

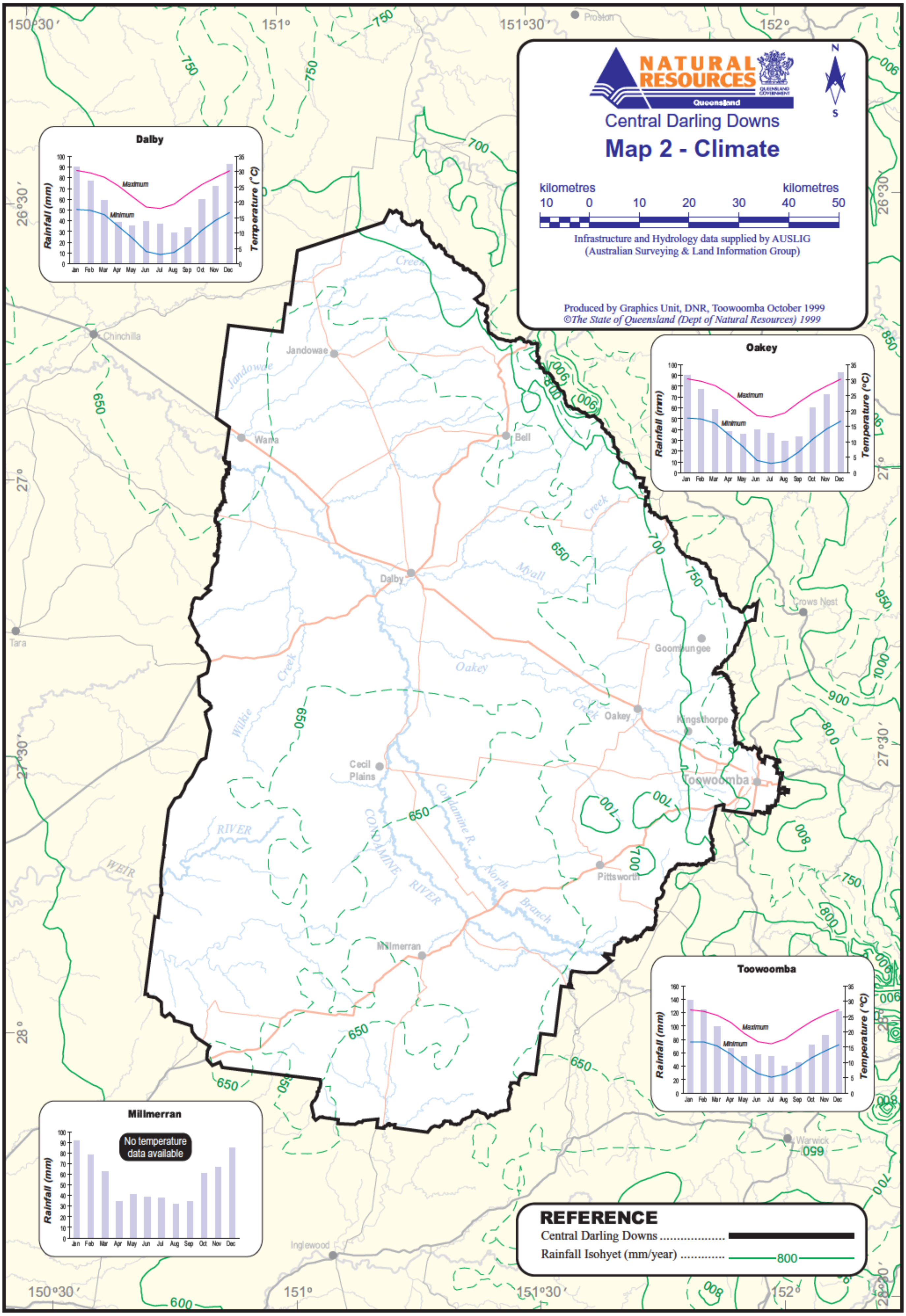
2.3 Floods

Floods occur periodically on the floodplains of the Condamine River and its tributaries, and have been one of the main factors affecting the formation of these plains. Records for the Condamine River at Cecil Plains show minor flooding occurs at 6 metres (m), moderate flooding at 7 m and major flooding at 8 m. Historical data for flood events is presented in Table 2.2

Table 2.2 Peak flood heights on the Condamine River at Cecil Plains (1924 – 99)

Minor		Moderate		Major	
Date	Gauge height (m)	Date	Gauge height (m)	Date	Gauge height (m)
20/06/1948	6.78	13/10/1950	7.32	28/03/1890	9.26
29/06/1956	6.14	02/04/1951	7.47	06/26/1950	8.23
25/12/1956	6.71	21/10/1954	7.36	01/22/1956	8.84
22/02/1959	6.53	13/02/1956	7.44	01/23/1956	8.81
16/03/1962	6.07	05/05/1956	7.87	06/02/1971	8.40
30/03/1963	6.64	28/12/1956	7.80	08/02/1971	8.05
31/03/1963	6.81	03/11/1964	7.32	10/30/1972	8.20
24/07/1965	6.50	16/01/1968	7.16	12/25/1975	8.48
18/12/1965	6.35	11/01/1972	7.42	12/02/1976	9.20
12/10/1970	6.76	29/01/1974	7.88	04/05/1983	8.51
28/01/1971	6.22	01/03/1974	7.97	06/23/1983	8.29
02/04/1971	6.60	30/05/1983	7.73	05/04/1988	8.79
28/02/1975	6.48	30/04/1984	7.63	07/05/1996	8.40
25/01/1976	6.80	30/07/1984	7.63		
02/08/1980	6.27	02/11/1991	7.47		
02/10/1981	6.21	22/11/1995	7.20		
13/03/1982	6.74	01/06/1996	7.05		
16/02/1988	6.78	03/05/1999	7.54		
07/09/1988	6.46				

Source: Bureau of Meteorology


NATURAL RESOURCES
Queensland
Central Darling Downs
Map 2 - Climate
kilometres
10 0 10 20 30 40 50
kilometres
Infrastructure and Hydrology data supplied by AUSLIG
(Australian Surveying & Land Information Group)
Produced by Graphics Unit, DNR, Toowoomba October 1999
©The State of Queensland (Dept of Natural Resources) 1999
Dalby
Oakey
Toowoomba
Millmerran
No temperature data available
Rainfall (mm)
Temperature (°C)
Maximum
Minimum
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
REFERENCE
Central Darling Downs
Rainfall Isohyet (mm/year)
Chinchilla
Jandowae
Wandoan
Bell
Dalby
Tara
Goombungee
Crows Nest
Oakey
Kingsthorpe
Toowoomba
Cecil Plains
Pittsworth
Millmerran
Warwick
Inglewood
Proston
CONDAMINE RIVER
Condamine R. North Branch
Myall Creek
Oakey Creek
Wilkie Creek
Jandowae Creek
RIVER
WEIR
150°30′
151°
151°30′
152°
26°30′
27°
27°30′
28°
28°30′

Drainage lines throughout the floodplains are poorly defined and lack sufficient capacity to carry flood runoff from upland catchments. As a result, the plains are regularly flooded and in some areas, crops and pastures are inundated for extended periods of time. These inundations cause crop damage and soil erosion and can significantly affect productivity. The flooding can be beneficial by increasing soil moisture and nutrient reserves, and can increase the yield of following crops.

Large amounts of flood flows are concentrated, diverted or blocked by farm, rail and road infrastructure. These factors contribute to considerable degradation and water co-ordination issues in the area. Sustainable management practices have been developed to address problems caused by flood flows (*refer to Chapter 9 for more information on floodplain management*).

Photo 3 Flooding on the Central Darling Downs can interrupt farm operations

2.4 Droughts

Droughts are a recurring feature of the climate in the district, with the duration of the dry period determining their severity. A severe drought has less rainfall than that received in the driest 5% of calendar years at that location, and a moderate drought receives rainfall between the driest 5% and the driest 10% of years. There have been 21 moderate or severe droughts at Dalby during the last 126 years. Table 2.3 illustrates the occurrence of droughts in Dalby from 1871.

Table 2.3 Occurrence of droughts at Dalby (1870 – 1999)

Period of drought	Duration (months)	Driest 12 months (mm)	% of time in severe drought
Jan 1871 to Dec 1871	12	452	0
Jul 1876 to Oct 1878	28	268	71
Jun 1880 to Jan 1882	20	422	0
Jan 1883 to Oct 1884	22	338	36
Mar 1885 to Apr 1886	14	415	0
Oct 1887 to Apr 1889	19	334	25
Jul 1901 to Feb 1903	20	233	89
Apr 1908 to Mar 1909	12	456	0
Feb 1911 to May 1912	16	420	0
Jun 1913 to Jan 1916	32	315	57
Jan 1918 to Jun 1920	30	337	53
Jan 1922 to Nov 1923	23	348	75
Sep 1945 to Feb 1947	18	373	29
Dec 1950 to May 1952	18	296	43
Nov 1952 to Nov 1953	13	416	0
Jan 1957 to Feb 1958	14	363	100
Aug 1962 to Sep 1963	14	474	0
Jul 1967 to Aug 1969	26	445	0
Jan 1982 to Feb 1983	14	409	0
Aug 1990 to Nov 1993	40	364	24
Jun 1996 to Sep 1997	16	432	0

Source: Clewett *et al*. (1999)

Small, isolated falls of rain (<20 mm) can occur during a drought period, however the moisture is usually trapped in the top 10 cm of the soil surface, where it is lost to evaporation. Such rainfall is less effective in adding to the soil moisture reserves during extended hot dry periods or droughts (Freebairn, 1993).

Photo 4 Drought feeding sheep

A careful analysis of the trend in rainfall for the Central Darling Downs from Clewett *et al*. (1999) shows little variation over the long term.

2.5 Temperature

Temperature variation has a significant influence on land management in the area, through impacts from evaporation, frosts and heatwaves. Long term average maximum and minimum monthly temperature for Dalby and Toowoomba is shown in Table 2.4.

Table 2.4 Mean monthly temperatures (°C) for Dalby and Toowoomba

	J	F	M	A	M	J	J	A	S	O	N	D
Dalby:												
Max	31.6	31.1	29.5	27.0	22.5	19.6	18.8	20.5	23.8	27.1	30.1	31.4
Min	18.8	18.4	16.7	12.9	8.4	5.7	4.1	5.5	8.5	12.8	15.7	17.7
Toowoomba:												
Max	27.2	26.7	25.4	23.1	19.5	16.8	16.1	17.6	20.7	23.5	25.7	27.3
Min	16.7	16.7	15.4	12.7	9.2	6.4	5.2	6.2	8.6	11.6	13.8	15.8

Source: Clewett *et al*. (1999)

2.5.1 Frosts

The average minimum daily temperature for Dalby in July is 4.1°C**,** with frost likely when air temperature is below 2 °C at 1 m above the ground. Frosts are frequent and can be severe. Frost data for Dalby is shown in Table 2.5.

Table 2.5 Occurrence of frost for Dalby

Air temperature 1 m above ground	Minus 2°C	Minus 1°C	Zero°C
Average first frost	27/7	30/6	11/6
Median first frost	4/7	21/7	7/6
First ever frost	8/5	8/5	5/5
Last ever frost	6/10	6/10	18/10

Source: French (1995)

Frost has a major influence on the time of planting for both wheat and barley. This is discussed briefly in section 2.8, using data from WHEATMAN *plus* BARLEYPLAN.

2.5.2 Heatwaves

The average maximum daily temperature for Dalby in January is 31.6°C. Heat waves are defined as three consecutive days of >38°C. They are most likely to occur in December and January. Table 2.6 shows the occurrence and duration of heatwaves for Dalby. Similar information for other localities in the Central Darling Downs can be obtained from the Bureau of Meteorology.

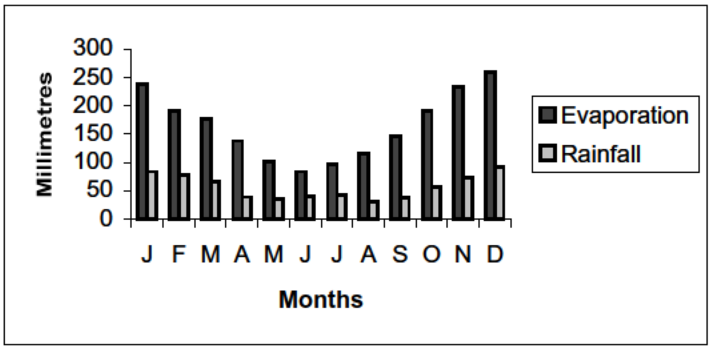
Table 2.6 Heatwave (> 38°C) occurrence and duration probabilities (%) for Dalby

Month	Duration probabilities (%)		
	At least 1 day	At least 2 days	At least 3 days
January	38.1	19.0	9.5
February	21.4	4.8	0
March	7.1	0	0
April	0	0	0
May	0	0	0
June	0	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	4.8	2.4	0
November	23.8	11.9	9.5
December	31	21.4	11.9

Source: Bureau of Meteorology

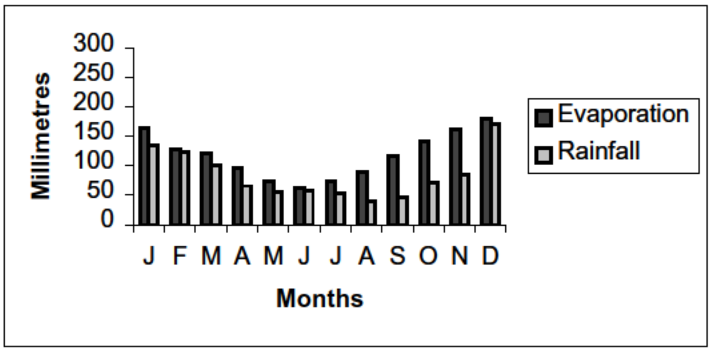
2.5.3 Evaporation

The average monthly pan evaporation and monthly rainfall for Dalby and Toowoomba are shown in Figure 2.1 and Figure 2.2. Evaporation rates can exceed 10 mm/day. The Figures illustrate the significant impact of evaporation on land management and emphasises the importance of frequency of effective rainfall for the survival of crops.



Source: Clewett *et al.* (1999)

Figure 2.1 Monthly evaporation and rainfall for Dalby



Source: Clewett *et al.* (1999)

Figure 2.2 Monthly evaporation and rainfall for Toowoomba

The average evaporation rates exceed the average rainfall for every month of the year in both Dalby and Toowoomba, even though Toowoomba's rainfall is approximately 300 mm higher than Dalby. The soil water deficit for the summer months combined with low moisture holding capacity of some of the soils in the area makes dryland summer cropping unreliable. As the evaporation rate for Dalby is over twice that of the rainfall rate, management practices which reduce runoff, increase infiltration and reduce evaporation, are important. Practices such as stubble retention and fallowing are practical ways to retain soil moisture for cropping.

2.6 Using the Southern Oscillation Index to make better management decisions

The Southern Oscillation is one of the most important influences on year-to-year rainfall and temperature variability in eastern Australia. The Southern Oscillation describes atmospheric pressure between the eastern equatorial pacific and the western equatorial Pacific/eastern Indian Ocean regions. The Southern Oscillation fluctuates in conjunction with major changes in sea-surface temperatures in the central, eastern and western Pacific. An index of the Southern Oscillation (Southern Oscillation Index or SOI) is a very useful means of gauging the relative strength or change in the Southern Oscillation. The SOI is the measurement of the standard deviation above or below the pressure means across the Pacific. To be precise, it is measured as the difference in surface pressure between Tahiti and Darwin divided by the standard deviation of the difference.

An El Niño event occurs when the sea surface temperatures are warmer than normal in the eastern and central Pacific. This often results in drier than normal conditions over much of eastern Australia (and wetter than normal in many parts of the Americas). Because the Southern Oscillation tends to 'phase lock' between the autumn of one year and the autumn of the following year, the SOI can be used after the end of autumn to predict rainfall patterns up to nine months in advance. Therefore it is a useful tool for on-farm decisions.

A key to incorporating the SOI into farming decisions is to recognise that a change in SOI can be as important, or even more important, than its mean value over a number of months. For the Central Darling Downs, the change or trend in SOI through late autumn is very important for identifying the rainfall likely when winter crops are growing. The SOI pattern established at the end of May is, in fact, very important for assessment of the following winter, spring and summer rainfall. It is also useful for assessing the date of last frost, as there is a higher probability of later than normal frosts following a consistently negative SOI. A consistently negative SOI is a value consistently below about –6 through April/May.

Information on the local effect of the SOI on rainfall is available for 105 locations across the Darling Downs and Warrego within the Australian Rainman program (Clewett *et al*., 1999).

2.7 Climate in relation to agriculture

The clay cropping soils on the Central Darling Downs have the capacity to store seasonal summer rainfall for use by crops grown during winter and spring. This ability to grow winter crops on summer rainfall has influenced the development of farming systems in the region.

2.7.1 Winter crops

Winter grain crops are grown on moisture accumulated in the soil profile during the summer fallow. Lower evaporation rates during the winter allows more efficient water use by crops. Providing the soil profile is fully moist at planting, very little growing season rain is required to produce a good crop of wheat, barley or chickpeas. However rain to stimulate secondary roots and at flowering greatly enhances yields.

Summer fallows designed to store as much moisture as possible incorporate such practices as minimum tillage and fallow weed spraying, to retain stubble on the soil surface for as long as practicable. These techniques improve moisture infiltration, reduce evaporation and minimise soil erosion, especially when combined with strip cropping or runoff control measures such as contour banks.

Frosts

Frosts have a major influence on the planting time of both wheat and barley. Generally, early-planted crops have a higher yield potential but heavy frosts (0°C at head height or colder) around flowering time seriously reduce yield. Opportunities for planting under favourable soil moisture conditions have to be taken when they occur and usually involve using an early or late maturing variety.

The data in Table 2.7 illustrates the percentage chance of a severe frost (–4 °C) at head height at flowering for different maturity rates for wheat. Local landscape features and topography will affect the influence of frost on the time of planting for both wheat and barley. For example, low lying valley floors in upland areas will tend to hold colder pockets of air than mid and upper slopes of rolling hills. Similarly, due to their open and unprotected nature, floodplain areas will experience light winds through nights that will help prevent frosts from forming. However, strong, cold southwesterly winds around 65 km/hour can cause crop damage and lodging.

Table 2.7 Percentage chance of a –4°C minimum temperature at head height at flowering and onwards for the Dalby District

Maturity rates	Your site compared to Dalby Met. station	Planting dates															
		April				May				June				July			
		1	8	15	22	1	8	15	22	1	8	15	22	1	8	15	22
Slow	2°C colder	90	90	90	76	57	52	42	35	27	20	12	5	1	1	0	0
(e.g. Sunbri)	Similar	70	65	60	46	27	21	16	12	7	5	3	2	1	0	0	0
	1°C warmer	62	60	44	18	5	4	2	2	1	1	1	1	1	0	0	0
Medium	2°C colder	91	91	90	90	90	82	67	56	47	35	28	21	8	5	3	1
(e.g. Cunningham)	Similar	90	86	77	68	60	52	37	25	18	12	8	5	3	2	1	1
	1°C warmer	78	68	64	61	44	31	11	7	6	5	4	3	2	1	1	0
Quick	2°C colder	91	91	91	90	90	90	81	70	55	42	32	28	21	12	5	2
(e.g. Hartog)	Similar	90	90	90	80	65	60	51	40	24	16	10	8	5	3	2	1
	1°C warmer	80	78	70	65	60	44	30	13	5	4	4	3	3	2	1	1

Source: French (1995)

For example, if planting wheat on the 1st of June, there would be a 27% chance of a severe frost at flowering that will affect later flowering varieties such as Sunbri in comparison to a 55% chance for quicker maturing varieties such as Hartog.

2.7.2 Summer crops

Grain sorghum is the preferred dryland summer grain crop as it is hardier and more tolerant of dry weather than maize. Poor pollination occurs in sorghum and maize when temperatures exceed 38°C.

Cotton can use soil moisture at depth and is grown on the deeper alluvial soils including *Waco, Anchorfield* and *Mywybilla*, and the heavier box soils such as *Condamine* and *Cecilvale* (*for further information refer to the Field Manual).* Cotton has become a major irrigated and dryland fibre crop in the region. Cotton yield can be reduced by dry weather, which stunts plant growth. Fibre quality can be affected by cool, wet weather during harvest.

Other summer crops such as sunflower, millet, panicum, maize, soybean, mungbean and navybean can be successfully grown and are important components of rotations with wheat and barley. These crops are suited to a large number of soils in the area.

2.7.3 Pastures

Although cropping is the main agricultural enterprise on the Central Darling Downs, there is a significant cattle industry on mixed farming properties, particularly in the uplands on the western slopes of the Great Dividing Range.

Pasture growth in summer follows the pattern and amount of rainfall, with good summer rain leading to prolific grass growth. However, feed quality quickly declines after the grasses flower. The bulk of mature grass is usually carried over into autumn and winter as dry feed.

In winter, grass growth virtually ceases, although some of the more cold tolerant, introduced species (such as purple pigeon grass and bambatsi) may produce some green pick during winter periods. Moderate rain in winter promotes ‘herbage’ such as trefoils and medics (both naturalised and introduced). This herbage is high in nitrogen and as part of the ruminant diet, increases digestion and allows better use of mature and frosted summer grasses, especially in late winter and early spring.

(For further information on cropping and pastures on the Central Darling Downs, refer to the relevant sections of Chapter 7).

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Photo 5 Risks from variable rainfall are reduced by conservation farming (e.g. zero till cropping)

3. GEOLOGY AND LANDFORM

Andrew Biggs

3.1 Introduction

The geology of the Central Darling Downs has a major influence on the landforms and land resources of the area. An understanding of geology assists in identifying:

- the Land Resource Areas (LRAs – *see Chapter 4*);
- the soil types within the LRAs (*see Chapter 4*);
- the land use limitations associated with these units (*see Field Manual)*;
- the water resources (*see Chapter 5*); and
- the vegetation resources (*see Chapter 6*).

The majority of this chapter is adapted from the geology section in Part B of the Natural Resource Management Strategy for the Queensland Murray-Darling Basin (Queensland Murray-Darling Basin Coordinating Committee, 1998).

3.2 Regional geology

The Central Darling Downs lies within the western part of the Moreton Basin, which is separated from the Surat Basin to the west by the Kumbarilla ridge (Map 3). The study area is surrounded to the east and north by the Great Dividing Range, which is comprised mostly of basalt. Under the basalt are layers of Walloon Coal Measures and Marburg Subgroup, which are exposed where the basalt has been removed by erosion and weathering. This relationship is illustrated in Figure 3.1. The sediments of the Kumbarilla Ridge on the western side of the Moreton Basin are similar to the coarse grained sediments of the Marburg Subgroup. The minor areas of Brigalow Clay Sheet in the Warra-Kupunn-Cecil Plains areas are the eastern portions of a larger surface that extends through the Tara, Murilla and Chinchilla shires to the west.

Some geological units give rise to a variety of landform, soil and vegetation types. For example, both poplar box and brigalow communities on cracking and non-cracking clay soils are formed on the Walloon Coal Measures.

3.3 Geological history and stratigraphy

A good understanding of the geological history of the area helps to predict the present geology, hydrology and occurrence of soils.

The oldest rocks in the basin are the metamorphically altered sediments and volcanics known locally as ‘traprock’, which occur in the south of the Central Darling Downs. These rocks were formed in Ordovician to Permian times i.e. 450–250 million years ago (mya). Granitic rocks are the next oldest, formed in the latter Permian and early Triassic Periods (280–225 mya). The insertion of these acid plutonic rocks in to the ‘traprock’ sediments caused considerable uplift in the area. Only a few minor elements of granite and traprock are present in the south-eastern extent of the Central Darling Downs.

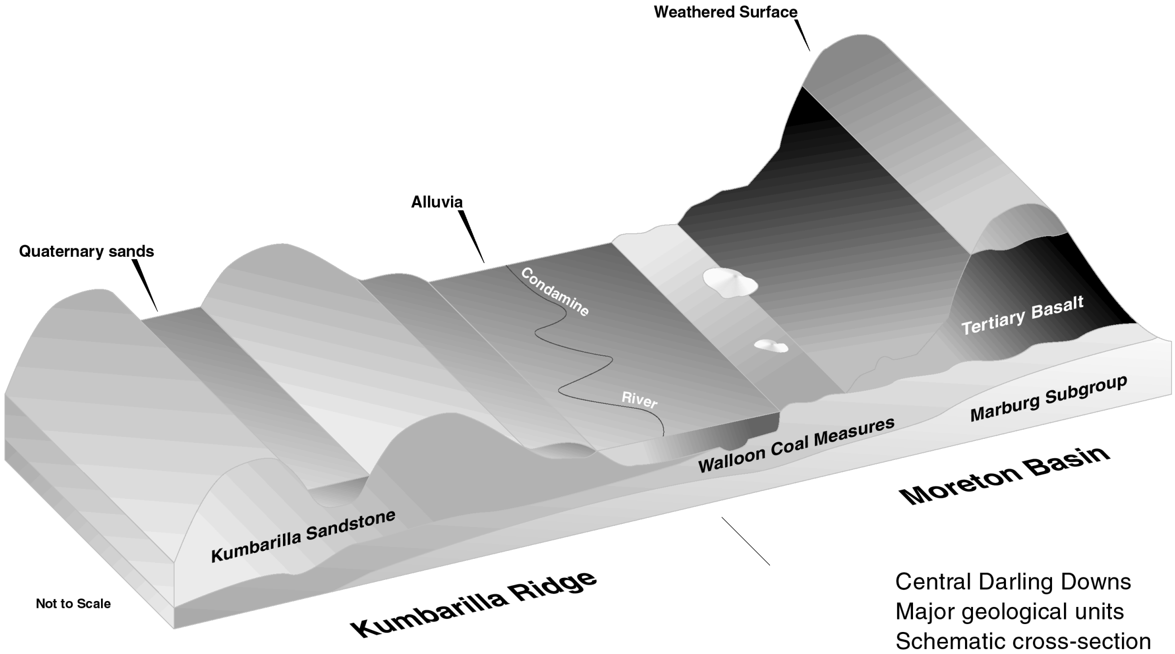


Figure 3.1 Simplified geology of the Central Darling Downs

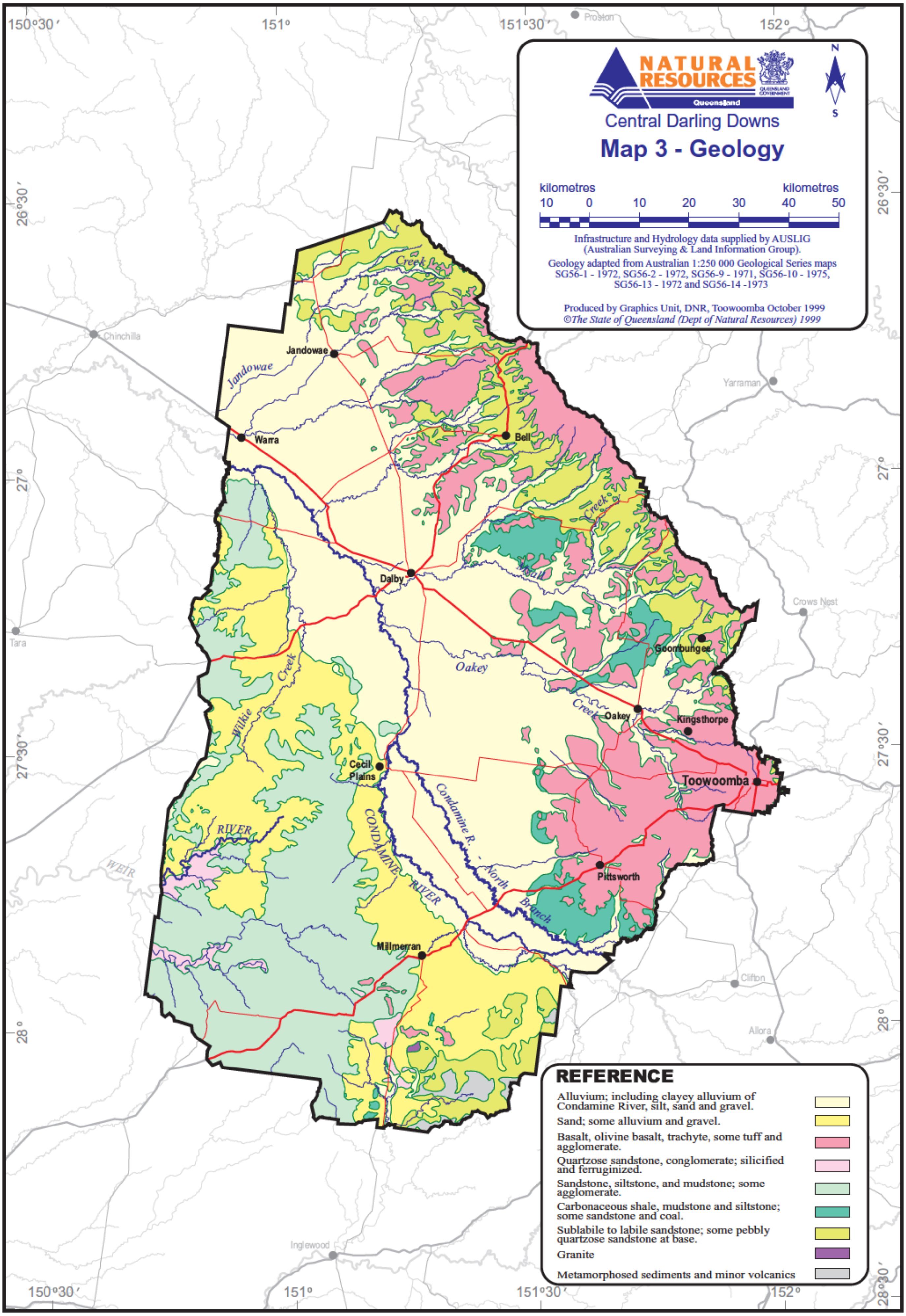
A series of deposition cycles in the Mesozoic (255–65 mya) resulted in the formation of extensive sedimentary layers within the Moreton Basin. In the late Triassic, coarser sandstones such as the Bundamba Group (Marburg Sandstone and Helidon Sandstone) were deposited, followed by finer sediments (Walloon Coal Measures) in the Middle Jurassic. These Coal Measures consist of upper and lower coal bearing units, separated by a barren zone (Nutter *et al*., 1981). Much of the bitumenous coal resources of the Darling Downs are derived from the lower coal bearing units.

During the Tertiary Period, specifically in the late Oligocene to early Miocene (37–23 mya), volcanic activity from a number of areas, including the Bunya Mountains, Toowoomba and near Cunninghams Gap, resulted in basaltic flows to form the Great Dividing Range (Whitehouse, 1955). A mix of volcanic flows and eruptive events, coupled with weathering, resulted in the deposition of inter-basaltic material such as ash and dust.

The weathering and erosion of the basaltic material has resulted in re-exposure of the underlying Marburg and Walloon sandstones. Unpredictable outcropping is found where prior folding and dissection of the sandstone has occurred. This is compounded by variation in the physical and chemical nature of the sediments.

Continued erosion of both basaltic and sedimentary surfaces has provided source material for the formation of extensive alluvial surfaces, particularly in the central Darling Downs. Local source materials such as sandstone, basalt or traprock influence the nature of the alluvia within the Condamine floodplain.

The origin of the Brigalow Clay Sheet is unclear, but possibly involved extensive stripping of the Tertiary surface, followed by extensive weathering and re-distribution of the sediments (Maher, 1996b).


NATURAL RESOURCES
Queensland
Central Darling Downs
Map 3 - Geology
kilometres
10 0 10 20 30 40 50
Infrastructure and Hydrology data supplied by AUSLIG (Australian Surveying & Land Information Group).
Geology adapted from Australian 1:250 000 Geological Series maps SG56-1 - 1972, SG56-2 - 1972, SG56-9 - 1971, SG56-10 - 1975, SG56-13 - 1972 and SG56-14 -1973
Produced by Graphics Unit, DNR, Toowoomba October 1999
©The State of Queensland (Dept of Natural Resources) 1999
150°30′
151°
151°30′
152°
26°30′
27°
27°30′
28°
28°30′
Proston
Chinchilla
Yarraman
Crows Nest
Tara
Clifton
Allora
Inglewood
Jandowae
Warra
Bell
Dalby
Goombungee
Oakey
Kingsthorpe
Toowoomba
Cecil Plains
Pittsworth
Millmerran
Creek
Jandowae
Myall
Oakey
Creek
Wilkie
Creek
RIVER
WEIR
CONDAMINE
RIVER
Condamine R.
North
Branch
REFERENCE
Alluvium; including clayey alluvium of Condamine River, silt, sand and gravel.
Sand; some alluvium and gravel.
Basalt, olivine basalt, trachyte, some tuff and agglomerate.
Quartzose sandstone, conglomerate; silicified and ferruginized.
Sandstone, siltstone, and mudstone; some agglomerate.
Carbonaceous shale, mudstone and siltstone; some sandstone and coal.
Sublabile to labile sandstone; some pebbly quartzose sandstone at base.
Granite
Metamorphosed sediments and minor volcanics

The Kumbarilla Beds to the west of the Condamine River are variable in nature, but typically similar to the coarse grained sediments in the Marburg Subgroup. Many exposures of the sandstones have been silicified, laterised or kaolinised during an extensive weathering period in the Tertiary. Erosion of the Kumbarilla Beds has given rise to deposits of Quaternary sands to the west of the Condamine floodplain.

3.4 Landforms

The landforms of the Central Darling Downs are closely related to the lithology and geological history of the region. Many of the geological units display characteristic landform features, which influence land use and management. The common landforms of each geological unit are summarised in Table 3.1.

Table 3.1 Common landforms associated with each geological unit

Geological unit	Dominant landform
Quaternary alluvia	Level plains with levees, stream channels, ox-bows and river terraces
Quaternary sands	Level to gently undulating plains
Walloon Coal Measures (fine grained sediments)	Gently undulating plains and rises to undulating to steep, low hills and rises
Marburg Subgroup (coarse grained sediments)	Undulating to rolling rises and plains with some steep low hills
Kumbarilla Beds	Gently undulating to undulating plains and rises with some plateaus and low hills
Toowoomba volcanics	Gently undulating plains, undulating rises and rolling low hills with steep hills and mountains in the east
Granite	Steep hills
Texas Beds (traprock)	Steep hills

Source: Maher *et al.* (1998).

3.4.1 Alluvia

By definition, the alluvial plains are level to very gently inclined surfaces. Within the Condamine floodplain however, there are some important variations. Older alluvial surfaces are typically elevated, flat and featureless, in comparison to more recent alluvia. They are usually not affected by current over-bank flood flows, but are continually eroded and added to by overland flows from adjacent catchments. The recent alluvial systems are dominated by features such as levees, terraces, ox-bows and prior streams. The complexity of these features may hinder use for agricultural cropping, and is discussed further in Chapter 4.

Photo 6 Coarse grained sandstone

Photo 7 Basalt road cutting

3.4.2 Quaternary sands

Within the Kumbarilla Ridge are gently undulating plains of sandy soils derived from erosion and re-distribution of the surrounding coarse grained sediments. These sand deposits are both colluvial and alluvial in nature, and may be quite extensive, or localised along streams.

3.4.3 Fine grained sediments

The Walloon Coal Measures, and similar fine grained sediments within the area, weather into undulating plains to rises, although in some areas, typically where the sediments are slightly coarser, the landform may be steeper (Matheson, 1993). The boundary between some low slope areas and associated alluvia is often indistinct.

3.4.4 Coarse grained sediments

The coarse-grained sandstone units of the Marburg Subgroup and Kumbarilla Ridge typically form undulating plains to rolling rises. Resistant sections are often flat topped, with steep scarp faces on the edges. In general, the terrain of the coarse grained sandstone units is steeper than that associated with the finer sediments.

3.4.5 Toowoomba volcanics

Landform patterns within the basalt units are complex. In the east and north are very steep hills and low hills associated in the Great Dividing Range. A large plateau exists on the Great Dividing Range in the vicinity of Toowoomba. The majority of the basaltic uplands are comprised of undulating plains and rises, with some minor alluvial plains. This dissected landscape has resulted from stream incision associated with uplift and eustatic (sea level) change. Small benches and scarps are commonly associated with the boundaries between basalt flows. Scattered throughout the uplands are some relict steep low hills and flat-topped ridges, mostly associated with vents and valley infills.

3.4.5 Granite and Texas Beds

Only a few small instances of these units occur in the southern part of the Central Darling Downs. The hard rocks of the granite and traprock units typically weather into very characteristic landforms, usually steep low hills to hills. Fracture planes in the mass may lead to distinctive patterns of stream incision.

(*Refer to Field Manual for more detailed information on relationships between landform, geology and soil types in the Central Darling Downs*).

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4. LAND RESOURCES

Andrew Biggs
Alistair Coutts

4.1 Introduction

The Central Darling Downs has been the scene of considerable Land Resource investigation in the last fifty years (*see Section 1.3*). Many of these works were unrelated, at different scales and for a range of purposes. This manual attempts to draw on all of the previous work and present a consistent baseline at a broad scale. This is done using the concept of Land Resource Areas (LRAs) as employed in the adjacent manual covering Murilla, Tara, Chinchilla Shires (Maher, 1996b).

Land Resource Areas are broad landscape units made up of groups of different soils developed from related geological units with recurring patterns of topography and vegetation. These are mapped to reduce landscape complexity and for easy identification of a particular soil, based on its location within a given landscape and the vegetation associated with it (*LRA Map in back pocket*). Each LRA is described in terms of its common and less common (associated) soils.

It is the individual soil or group of soils to which the user (such as a farmer) applies management principles based on the likely performance for the intended use. These individual soils in the area have not been mapped, but their characteristics and distribution can be found through recognisable patterns of vegetation, landform and geology within the mapped LRAs.

Photographs and descriptions of 68 soils are included in the *Field Manual* to aid identification. The *Soil Summary Sheets* are designed to illustrate the most representative example of each soil. Although soils are generally named after a specific location, they can occur throughout the region. For example, *Downfall* soils are found in the Downfall Creek area (Jandowae) and also in the Millmerran area.

4.2 Land Resource Areas

Fourteen LRAs are described in this manual, some of which, (e.g. Older Alluvia Plains) occupy large areas, while others (e.g. Granite Hills) are present in only very small areas. The LRAs and their component groups are described briefly in Table 4.1 (*on page 44*). Their distribution is illustrated on the map provided in the *LRA Map* (*in back pocket*).

As the map indicates, certain LRAs often exist in recurring patterns. The relationships between LRAs are illustrated in Figure 4.1, which is useful when identifying LRAs in the field.

It must be stressed that each LRA is defined by the **dominant** characteristics of landform, soil and vegetation. Considerable variation in these features can occur within any individual LRA.

The names for many of the LRAs in the Central Darling Downs are closely linked to the underlying geology. Table 4.2 relates the broad geological units to the Land Resource Areas.

Table 4.1 Geological units and associated LRAs

Geological unit	Land Resource Areas#
Quaternary alluvia – Condamine	Recent Alluvial Plains (1), Older Alluvial Plains (2)
Quaternary alluvia – Other	Recent Alluvial Plains (1), Older Alluvial Plains (2), Loamy Sodosols (3), Sandy Sodosols (4)
Quaternary sands	Ironbark/Bull Oak Sodosols (10), Cypress Pine Sands (11)
Brigalow clay sheet	Brigalow Plains (5)
Marburg Subgroup (coarse grained sediments)	Sandstone Forests (12), Ironbark/Bull Oak Sodosols (10), Poplar Box Sodosols (9)
Walloon Coal Measures (fine grained sediments)	Poplar Box Walloons (8), Brigalow Uplands (6)
Kumbarilla Beds (coarse grained sediments)	Sandstone Forests (12), Ironbark/Bull Oak Sodosols (10),
Toowoomba and Main Range Volcanics (basalt)	Basaltic Uplands (7)
Granite	Granite Hills (13)
Texas Beds (traprock)	Traprock Hills (14)

numbers = mapping unit for LRAs on LRA Map in back pocket

Many of the LRAs possess characteristic landform patterns relating to the nature of the underlying material, stream patterns and soil type. The LRAs also occur in certain associations e.g. the Basaltic Uplands are usually upslope from Poplar Box Walloons. The typical landforms associated with each LRA, and their relationships to other LRAs are described in Figure 4.1.

4.2.1 Alluvial Plains

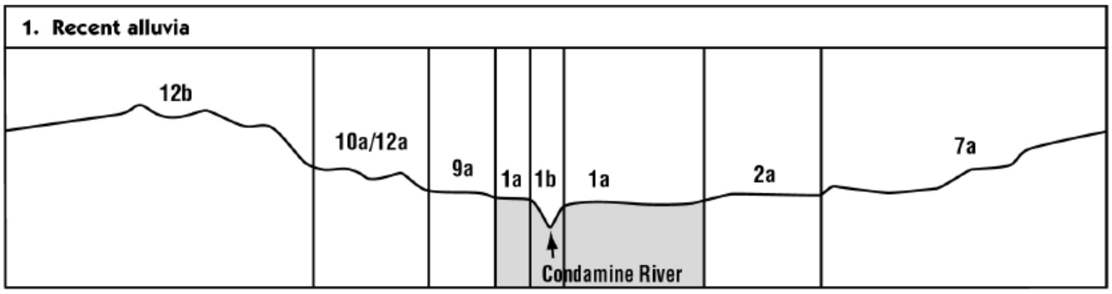
By definition, the alluvial plains are level to very gently inclined surfaces. Within the Condamine floodplain however, there are some important variations. The Older Alluvial Plains (LRA 2) are elevated surfaces, generally not affected by current over-bank flood flows, but continually eroded and aggraded by overland flows from adjacent catchments. The Recent Alluvial Plains (LRA 1) are dominated by features such as levees, terraces, ox-bows and prior streams. The complexity of these features may hinder use for agricultural cropping, particularly in the 1b and 2c units (*see Table 4.2, on page 44*).

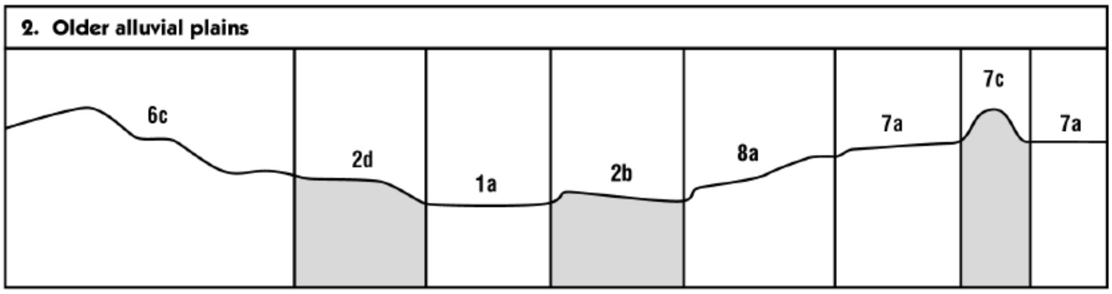
4.2.2 Brigalow Uplands, Poplar Box Walloons

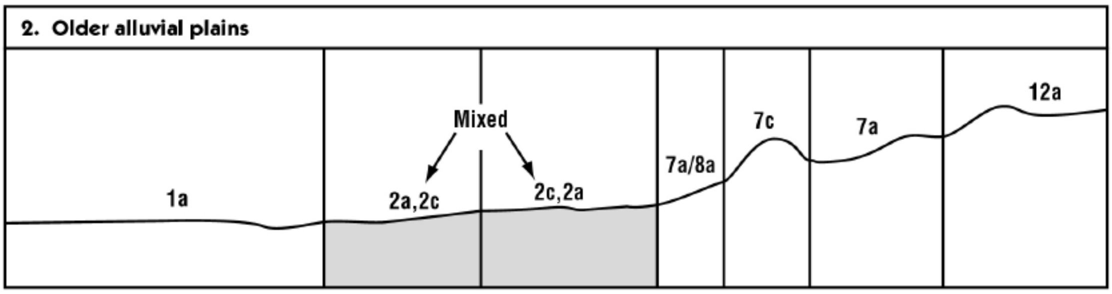
The Brigalow Upland and Poplar Box Walloon LRAs (6 and 8 respectively) are formed on fine grained sediments associated with the Walloon Coal Measures. Weathering of the relatively soft Walloon Coal Measures results in gently sloping relief such as long undulating plains with occasional undulating rises (Matheson, 1993). The boundary between the Walloon Coal Measures and nearby alluvial units is often very gradual, whereas the boundary between the coarser sandstones and alluvia is typically very distinct.

The Brigalow Uplands are divided by dominant landform and/or soils. The 6a, 6c and 6d units are mostly undulating plains to rises, whereas the 6b unit is comprised mostly of undulating to steep rises and low hills. The difference in landform is reflected by the nature of the soils within the units. For example, the steep landforms within 6b have produced a buried soil known as *Clayburn*, not found in the lower sloping brigalow units.

Figure 4.1 Generalised relationships between LRAs







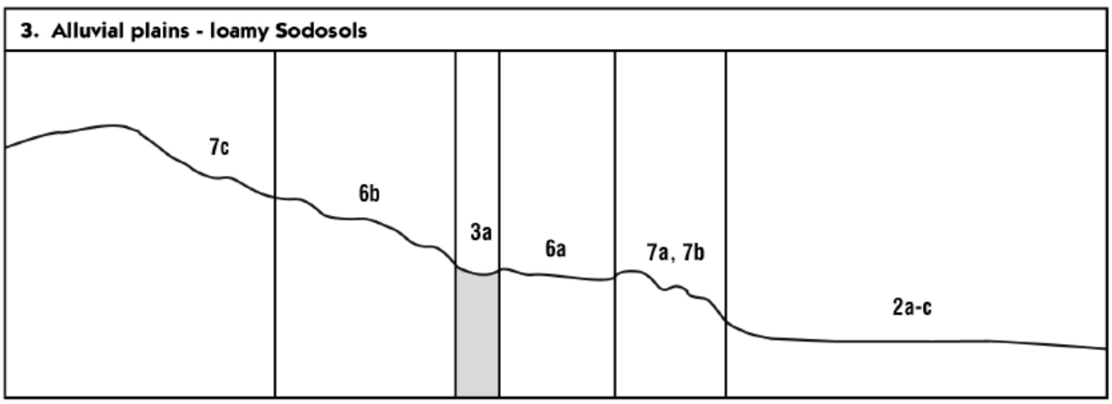
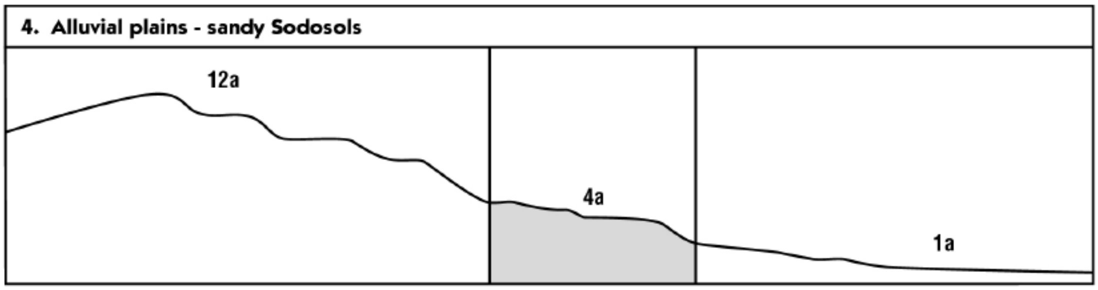
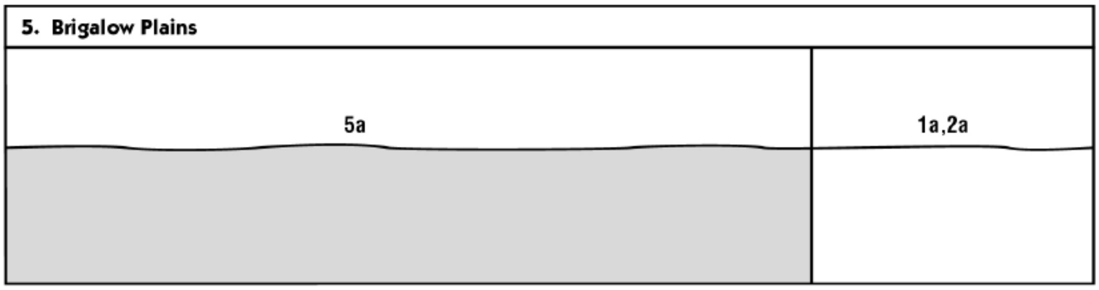
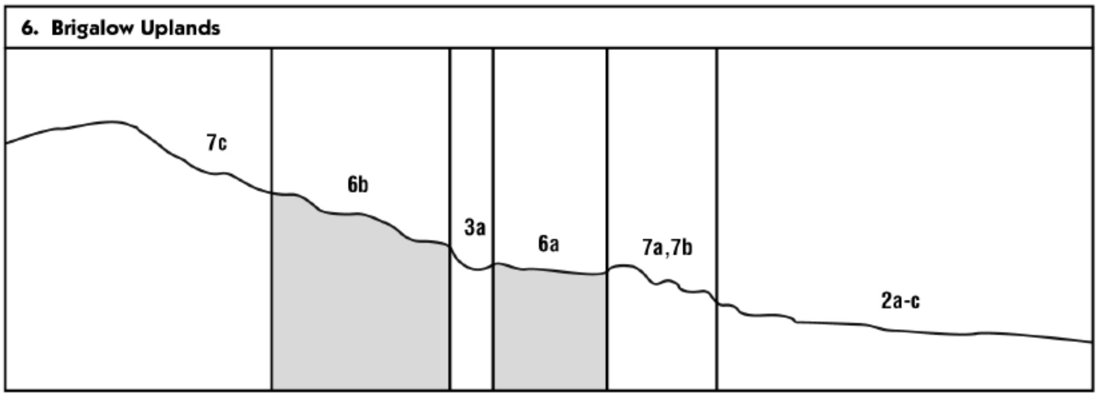


Figure 4.1 Generalised relationships between LRAs (cont'd)







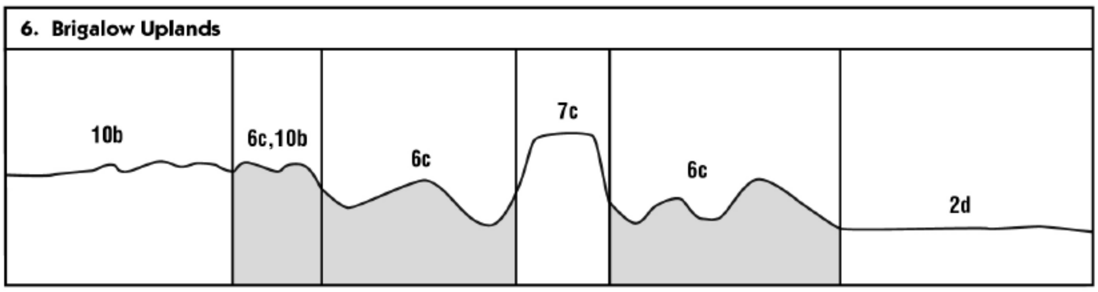


Figure 4.1 Generalised relationships between LRAs (cont'd)

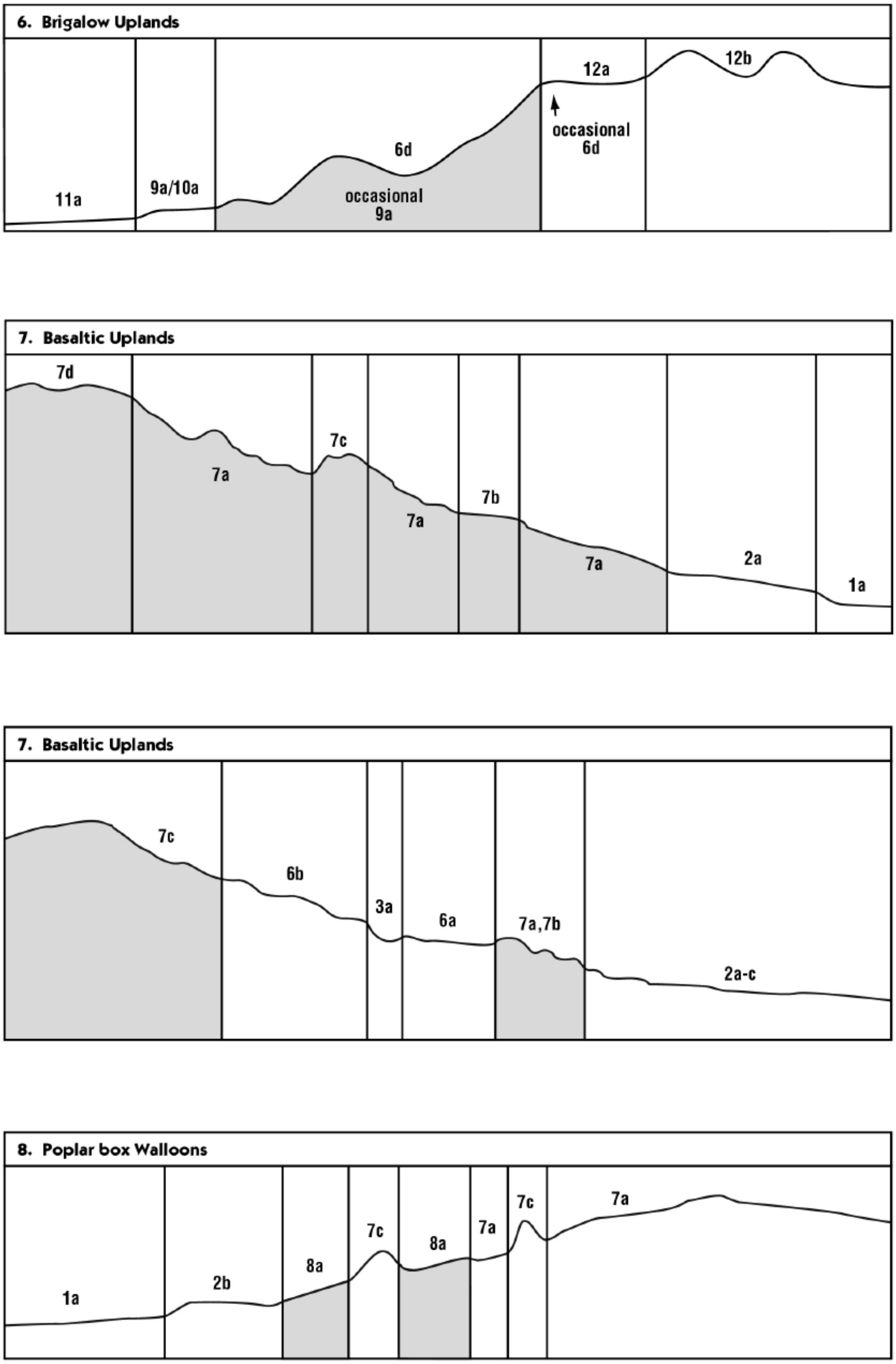
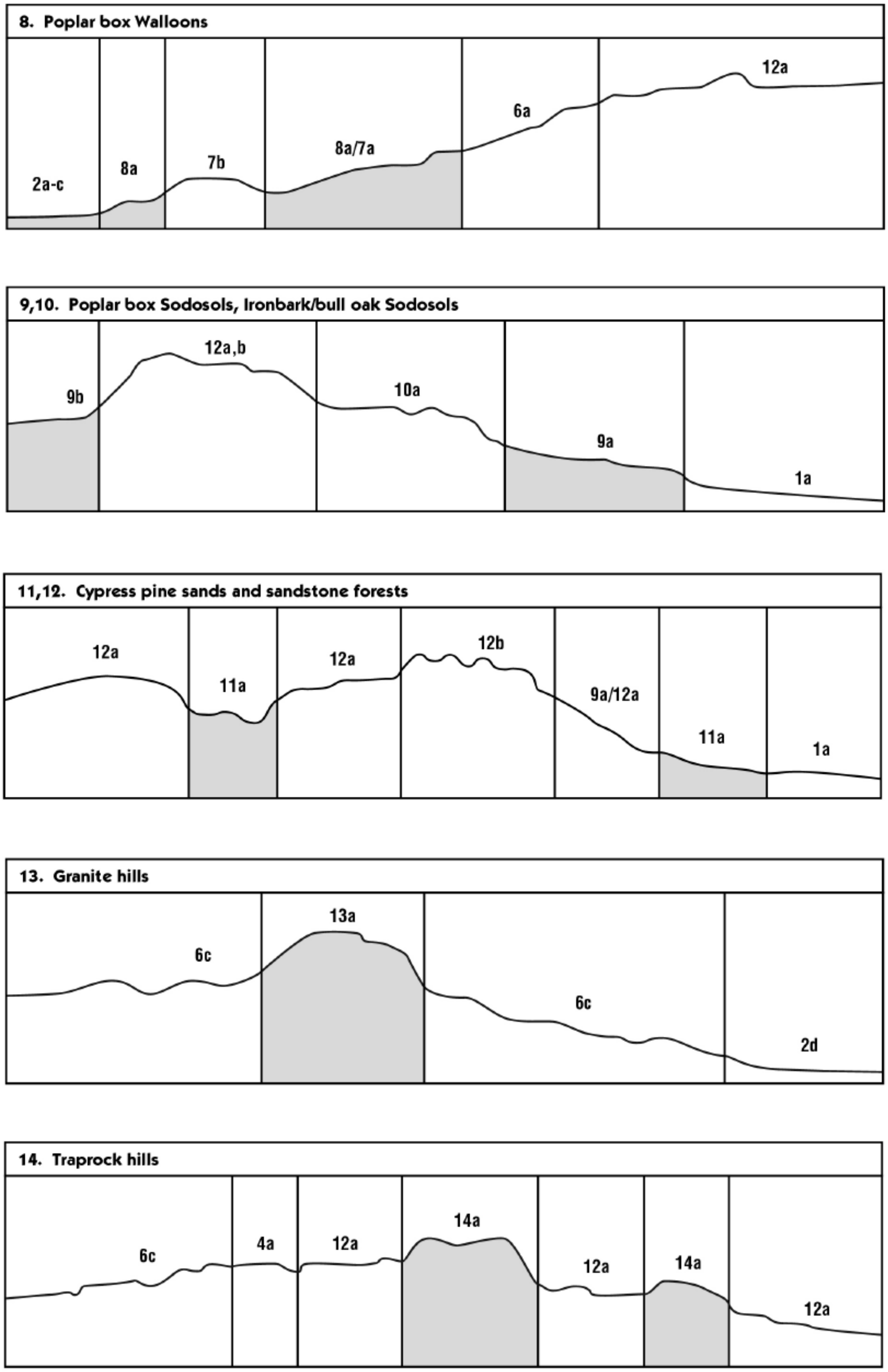


Figure 4.1 Generalised relationships between LRAs (cont'd)



4.2.3 Brigalow Plains

The Brigalow Clay Plains (LRA 5) are located on the western edges of the Central Darling Downs, but are contiguous with larger areas in the Tara-Chinchilla district. The origin of the surfaces is unclear, but they are typically level to very gently undulating plains.

4.2.4 Ironbark/Bull Oak Sodosols, Sandstone Forests

The coarse-grained sandstone units (LRAs 10 and 12) of the Marburg Subgroup and Kumbarilla Ridge are generally in the form of undulating plains to rises. LRA 12b is characterised by steeper terrain, with some scarps associated with the more resistant, laterised sediments.

4.2.5 Poplar Box Sodosols, Cypress Pine Sands

Dissection of the Kumbarilla sandstone has created valleys, some of which have been filled with material eroded from the surrounding rocks, to form the gently undulating sandy surfaces of LRA 11. The gently undulating to undulating plains of LRA 9 may be formed on finer, softer sediments underlying the coarser layers which form LRAs 10 and 12.

4.2.6 Basaltic Uplands

Landform patterns within the basalt units (LRA 7) are complex. In the east are very steep hills and low hills associated in the Great Dividing Range. Some relict steep low hills and ridges such as the 7c units are scattered throughout the uplands. A large plateau exists on the Great Dividing Range in the vicinity of Toowoomba. The majority of the Basaltic Uplands are comprised of undulating plains and rises, with some minor alluvial plains. This dissected landscape has resulted from stream incision associated with uplift and eustatic (sea level) change. Small benches and scarps are common and these are associated with the boundaries between basalt flows.

4.2.7 Granite and Traprock Hills

The hard rocks of the Granite and Traprock units (LRAs 13 and 14) weather into very characteristic landforms, usually steep low hills to hills. Fracture planes in the mass may lead to distinctive patterns of stream incision.

4.3 Soils

A large correlation exercise was undertaken when compiling the soils information for this Land Management Manual. In a number of instances, previous studies identified soils with very similar properties, some of which have been grouped together within this Manual. This does not mean the individual soils are no longer recognised, but simply that at the scale involved in this Manual, their character and management were deemed similar enough to group them. There are over 100 soils identified for the Central Darling Downs, of which 68 are included in this report. Appendix 1 of the *Field Manual* correlates the soil names from previous work with those used in this report.

The soils listed in Table 4.3 (*on page 46*) are grouped under the LRAs with which they are commonly associated. A brief description of each is included in Table 4.4 (*on page 47*). For each LRA, common and less common (associated) soils are listed. Because of mapping scale, it is possible that either a common or an associated soil may not be present in all map units of an LRA. Some associated soils are restricted in their distribution within the area.

Similarly, the major soils on the Older Alluvial Plains are all cracking clays, however there are some considerable differences in their agricultural suitability. It was not possible to map the individual distributions of these soils and their many intergrades. However these soils within each LRA are located diagrammatically in the *Field Manual*.

The distinguishing morphological characteristics of the soils are summarised in Table 4.5 (*on page 52*).

The *Field Manual* explains the technique for identifying soils (*see Section 2*). The methodology adopted ensures the user can achieve this with little or no technical background in soils. Steps include:

- the *LRA Map* and Table 4.1 which allow determination of the LRA;
- Figure 4.1 which shows generalised relationships between LRAs;
- Table 4.3 which describes the occurrence of the soils by LRA;
- Table 4.4 which briefly describes each soil; and
- the *Soil Summary Sheets* from the *Field Manual*.

Detailed soil descriptions in the *Soil Summary Sheets* describe representative soil profiles for that soil. The nature of soils and landscapes is such that soil properties vary in the field. It is more important to understand the properties of a soil and the way in which these properties affect land use than to identify the specific soil type.

Additional information, including analytical and morphological data for representative soils are given in the *Soil Chemical Data Book.*

4.4 Soil properties and characteristics important to land management

Many soil properties and characteristics adversely affect land use and management, as indicated by reduced productivity and/or land degradation. An understanding of these properties and characteristics is essential if management requirements and appropriate strategies, such as fertiliser inputs, are to be developed for the soils of the area.

4.4.1 Fertility

The chemical properties of soil play a vital role in plant growth and soil stability through their effects on nutrition, toxicity and soil physical condition. Soil tests or analyses should now be an integral part of all management strategies. They are useful in providing a guide for fertiliser requirements and to monitor trends. The fertility of soils is expressed through both surface and subsoil measurements of certain nutrients.

Analytical data for soil surface nutrient levels from representative profiles of each soil are given in the *Soil Chemical Data Book.* Interpreted ratings of the surface values for each soil are provided in Table 4.6 (*on page 64*). The rating descriptions are found in both the following text and in the *Soil Chemical Data Book.*

There will be a range of values for a particular soil but the limited data does not allow an estimate of the extent to which sampled sites are representative of other examples of a given soil. However, the data can be used to give a general indication of regional trends. For example, nearly all Vertosols[1] (cracking clay soils) of the area are well supplied in most nutrients, but those of basaltic origin generally have higher levels of phosphorus than those of sandstone or mixed basalt-sandstone origin.

The fertility of cropping and pasture soils in the region is declining with time. More frequent opportunity cropping and the use of higher yielding varieties require growers to monitor nutrient levels as part of their existing management programs. Use of pastures, cereal-legume rotations and fertilisers are important to the maintenance of soil fertility in the cropping lands of the Central Darling Downs.

The most important nutrient deficiencies for cropping on the Central Darling Downs are phosphorus (P), nitrogen (N) and zinc (Zn). Soil erosion, soil structural problems (e.g. hard pans) and root diseases can all increase the likelihood of nutrient deficiency.

Soil pH

The pH of soil is a measure of its acidity or alkalinity and is important in determining the degree and likelihood of acidification, in estimating possible nutrient deficiencies and assessing suitability for certain crops.

Although most plants will tolerate a range in pH conditions from 5.5 to 8.5, most respond best when soil pH is between 6.0 and 7.5. The pH of a soil can affect the availability of nutrients (Figure 4.2). Soils which are excessively acid (i.e. <5.5, strongly to extremely acid), may suffer from aluminium or manganese toxicity. On the other hand, soils that are excessively alkaline may suffer from phosphorus and trace element deficiencies.

Most soils within the Central Darling Downs have a surface soil pH between 5.5 and 8.5. The majority of clay soils, particularly the cracking clay soils, have a surface pH greater than 7.

Many of the clay 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). Examples include *Arden*, *Dulacca*, *Kupunn*, *Tandawanna* and *Tara* (*see Soil Chemical Data Book*). The Central Darling Downs is dominated by neutral to alkaline soils (particularly in the alluvial units). The predominance of zinc deficiency in the region is mostly related to the high pH of most cropping soils. Increased acidity has been documented in a number of cropping soils, particularly *Burton* and *Oakey*. Problems such as manganese toxicity have been associated with these low pH values (Aitken *et al*., 1989).

Problems with acid subsoil clays (particularly the brigalow or belah soils) usually only occur after they are exposed by levelling of gilgai (melonholes), or by the construction of earthworks. As many of these highly acid subsoils also have high salinity and sodicity, it is recommended that they be left undisturbed.

[1] Australian Soil Classification (Isbell, 1996)

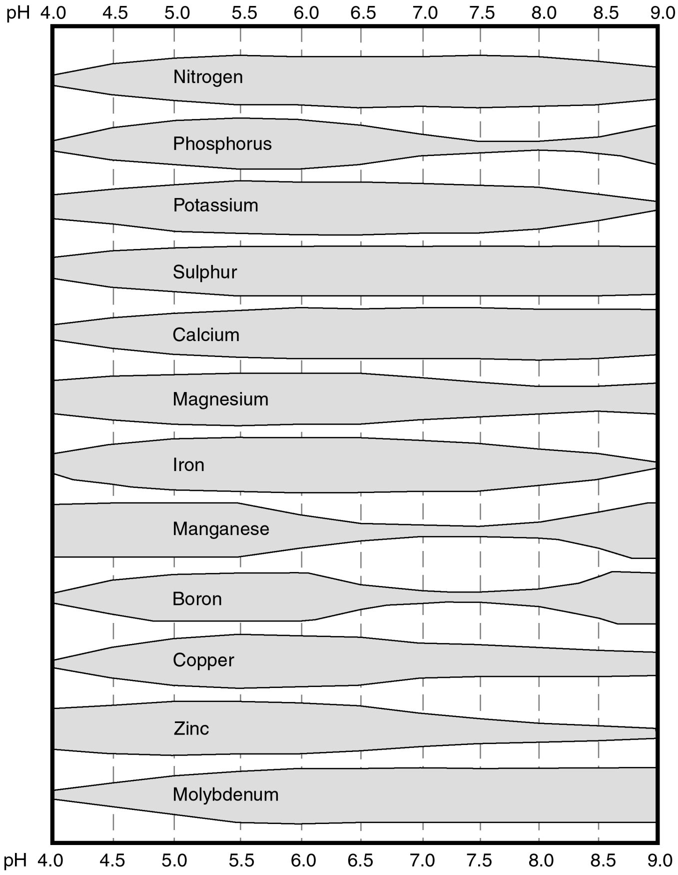


Figure 4.2 Availability of nutrients *vs* soil pH

Organic carbon and nitrogen

Organic carbon (OC) is the main component of organic matter and acts as a soil aggregate stabiliser (thereby improving porosity), and as a storehouse for nutrients. Soils with low or very low organic carbon values may have low nutrient holding capacity. Most of the soils with sandy surfaces have a naturally low or very low OC. Organic carbon decline is also a serious problem in clay soils that have been cropped for a long time without stubble retention.

Most of the total nitrogen (N) within the organic matter fraction of a soil is not immediately available to plants, although some may be mineralised to available forms. Low to very low values of total N indicate potential problems for plant growth (since only a fraction is available). Fertilisers or legumes may be needed to correct N deficiency. Ratings from Bruce and Rayment (1982) for organic carbon, total N and C/N ratio are given below.

Rating	Organic carbon (%)	Total N (%)	C/N ratio
very low	<0.5	<0.05	<8
low	0.5-1.5	0.05-0.15	8-10
medium	1.5-2.5	0.15-0.25	10-15
high	2.5-5	0.25-0.50	15-25
very high	>5	>0.50	>25

The ratio of carbon to nitrogen (C/N) is often a more useful indicator of the ability of the soil to supply N in an available form (Hazelton and Murphy, 1992). A C/N ratio of 10–15 is normal for an arable soil. High figures (15–20) indicate a slowing in the decomposition process (mineralisation) while a very high ratio (>25) shows that the organic matter is unlikely to breakdown quickly. Legume crop stubble such as chickpea or mungbean has a low C/N ratio, and breaks down more rapidly than cereal crop stubble such as wheat or barley.

The following indicators show the likelihood of yield responses to applied nitrogenous fertiliser:

- A history of cultivation greater than 30 years.
- A high yield potential (i.e. full moisture profile and early planting date).
- Poor mineralisation of nitrogen during the preceding fallow (i.e. high to very high C/N ratio).
- Large quantities of stubble especially when combined with zero tillage.
- Crops that have consistently low protein levels.

Phosphorus

Many of the soils sampled had low or very low levels of available (extractable) phosphorus (P), which will limit plant growth. This is more evident in soils of sandstone origin, particularly those with a sandy surface.

As P is not very mobile, phosphate fertilisers are more efficient when applied in direct contact with the seed at planting. Mycorrhizae help increase the ability of plant roots to access available P reserves in the soil. Soil populations of mycorrhiza will decline after long fallows or drought. Therefore crops will show an increased response to phosphate fertiliser.

Available phosphorus in soils can be measured a number of ways, depending mainly on soil pH. The analysis used for acid soils is generally Olsen *et al.* (1954)[1] and the method used for alkaline soils is Colwell (1963)[2]. Total soil P (includes both available and unavailable P) is measured using another method, and is often much greater than the available P.

When interpreting P values other factors need to be considered (Baker and Eldershaw, 1993). Some of these factors include:

- There are differences in P uptake by different crops, for example, legumes have a larger requirement than grasses; thus the amounts removed over time (cropping history) should be considered as well as the potential demands of current crops.
- Under permanent pasture, phosphate fertilisers tend to accumulate in the surface zone as organic (unavailable) P.
- P applications on P deficient soils can produce limited growth responses because of a second limiting deficiency – the most likely ones are nitrogen and potassium, or more commonly, available soil moisture.
- Reduced soil mycorrhiza populations following non-host plants (e.g. canola) in rotations.

Ahern *et al.* (1994) stated that pasture yield and quality, and hence animal production, continued to increase as soil P increased from 4 mg/kg and reached a maximum between 8 and 10 mg/kg. The categories of available P suggested by Ahern *et al.* (1994) for pasture growth are listed below, with associated categories for crop growth, as suggested by Baker and Eldershaw 1993.

---

[1] Commonly referred to as ‘acid P’.
[2] Commonly referred to as ‘bicarb P’.

Rating	Available soil P (mg/kg) For pasture growth	For crop growth
extremely low	<4	—
very low	4-6	<10
low	7-9	10-20
medium	10-15	20-30
high	16-25	30-40
very high	>25	>40

There is little evidence of production responses following additional phosphorus to cattle on pasture land with P values greater than 10 mg/kg (Ahern *et al*., 1994). The introduction of legumes into grass pastures can improve animal production, without the use of phosphorus fertilisers, on soils with low P levels (Shields and Anderson, 1989).

Potassium

Most of the soils sampled have adequate available potassium (extractable K) levels (>0.2 meq/100g). Low values were recorded in some sandy surface soils. Ratings from Bruce and Rayment (1982) are listed below.

Rating	Available soil K (meq/100g)
very low	<0.1
low	0.1-0.2
medium	0.2-0.5
high	0.5-1.0
very high	>1.0

Baker and Eldershaw (1993) list a number of instances where economic returns are most likely from the use of K fertilisers. They are:

- on soils low in both exchangeable K and total forms;
- where soil moisture from either rainfall or irrigation is sufficient to allow uninterrupted growth during the growing season;
- where heavy removal of K is likely, as in hay cutting or forage harvesting; and
- where large amounts of K are transferred off the site via animals, as in strip grazing and the use of night paddocks on dairy farms.

Zinc

Zinc (Zn) plays a vital role in a plant's ability to use nitrogen and transform it into yield and protein. Major cropping soils in the Central Darling Downs with very low Zn levels include *Kupunn, Condamine, Moola, Anchorfield* and *Langlands*. Zinc related problems are closely linked to pH — increasing pH reduces Zn availability. Zinc deficiencies in crops are not common in acid soils. Ratings from Baker and Eldershaw (1993) are listed below.

Rating	Available soil Zn (mg/kg)	
	pH<7	pH>7
very low	<0.2	<0.3
low	0.2-0.5	0.3-0.8
medium	0.5-5.0	0.8-5.0
high	5.0-15.0	5.0-15.0
very high	>15.0	>15.0

As for phosphorus, the availability of zinc to many crops is increased by the presence of mycorrhizae in the soil. Crops following long fallows or other events that deplete soil mycorrhizal population will be most at risk of suffering zinc deficiency.

Zinc-deficient winter cereal crops often have a patchy appearance. The plants are stunted with short, thin stems and usually pale green foliage. Initial symptoms in wheat appear as yellow chlorotic areas between the mid vein and leaf margin and extend outward towards the tip and the base of the leaf. These chlorotic areas eventually die and turn pale grey or brown.

There are a number of methods to correct Zn deficiency. The most common is soil applied zinc sulphate that will last for a number of years. Foliar sprays or zinc applied at planting with the seed have also been successful.

Sulphur

Plants and animals require sulphur to build proteins which are important in the quality and quantity of plant material produced, and in the health of animals (Hall, 1997). It can also give plants an increased tolerance to very cold conditions. Data for the Central Darling Downs soils is limited, however current information in Table 4.6 shows that levels in most soils are moderate to high. Deficiencies may be found in sandy soils, but correction through applying fertiliser may not be economical. Clay soils with a long cropping history may show responses to gypsum and other sulphur fertilisers.

Rating	Available soil S (mg/kg)
low	<4
medium	4-10
high	>10

4.4.2 Moisture availability

One of the main functions of soil is to store moisture and supply it to plants between rainfall or irrigations. If the water content becomes too low, plants become stressed. The plant available water capacity (PAWC) of a soil is a measure of the soil water that is available for plant growth. Decisions about crop type, sowing times and density of planting are made on the basis of the amount of water stored in the soil and the expectations of rain or the ability to irrigate.

PAWC is a measure of soil moisture reserves available between field capacity and permanent wilting point (Figure 4.3). The most important soil properties that affect PAWC include:

- The ability of the soil to retain moisture is determined by the number and size of pore spaces. Because the total and available moisture storage capacity is linked to porosity, clay type (e.g. cracking or non-cracking) the particle sizes (soil texture e.g. clay content) and their arrangement (soil structure) are the critical factors. Evaporation from the soil surface, transpiration by plants and deep drainage is also important.

- The effective rooting depth represents the depth to severe physical or chemical barriers that restrict root growth. Such barriers may be in the form of a dense gravel or stone layer, compacted layers, impermeable sodic or saline clay subsoil, or strongly acid clay subsoil. For many of the Central Darling Downs clay cropping soils, it is estimated as the depth to which salts have been leached. This is usually where the salt content in the soil increases abruptly.

- Soil surface characteristics that reduce infiltration and increase runoff. For example, structureless or poorly structured surface soils that have high levels of fine sand, silt or dispersible clay and low levels of organic matter. These are usually prone to surface sealing after rain. They may also be hardsetting or crusting when dry.

- Landscape position. Steep slopes have high runoff, therefore less water available for infiltration and subsequent soil storage. In flat, poorly drained or flooded areas, water supply may exceed PAWC, making soils waterlogged. Air in the soil pores is displaced by water, therefore little oxygen is available to plant roots or for soil microbial activity. Extended waterlogging can cause significant crop or pasture losses.

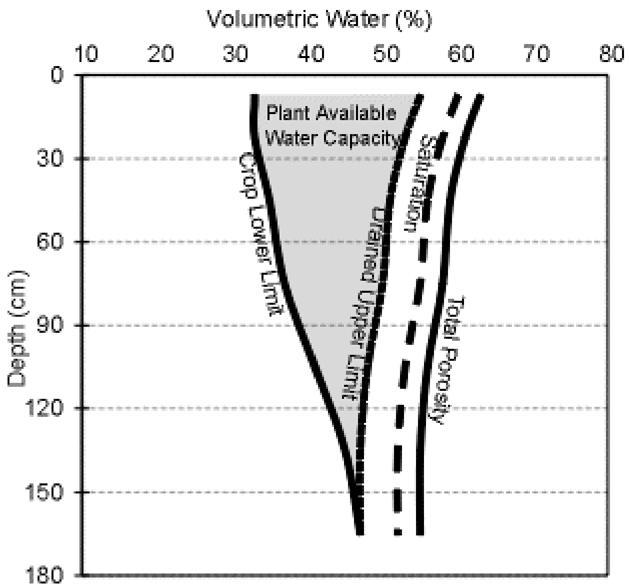


Figure 4.3 Plant available water capacity for a typical clay soil

Table 4.7 (*on page 66*) gives an estimate of the PAWC (measured in millimetres of water) in the root zone for the representative soil profiles. These estimates have been derived using the method of Littleboy and Glanville (1995) and apply the following ratings to interpret the results.

Rating	PAWC in root zone (mm)
very low	<50
low	50-100
moderate	100-150
moderately high	150-200
high	200-250
very high	>250

4.4.3 Salinity

Salinity refers to the concentration of soluble salts in a soil. These salts are dissolved in the soil water and move down the profile by leaching or into plant roots by uptake. Plant growth is affected by high levels of soluble salts which reduce the availability of water to plants as well as inducing specific element toxicities and nutrient disorders.

Table 4.7 shows that many of the Central Darling Downs soils have moderate to high levels of salinity in their subsoils. This includes many soils used for cropping. As previously mentioned, these high salinity levels have a marked influence on the effective rooting depth and hence the PAWC. Soils of the Central Darling Downs that have salinity as a limiting factor in their subsoil are shown in Table 4.10 (*on page 77*). The electrical conductivity ($EC_{1:5}$) of the soil solution (given for each representative soil profile in the *Soil Chemical Data Book*) is used to estimate soil salinity. The following ratings (from Shaw, 1988) are used to interpret EC values for soils with different clay contents.

Salinity rating	Root zone salinity ($EC_{1:5}$ dS/m)			
	10-20% clay	20-40% clay	40-60% clay	60-80% clay
very low	<0.05	<0.08	<0.12	<0.18
low	0.10	0.165	0.25	0.37
medium	0.25	0.40	0.58	0.85
high	0.45	0.67	1.00	1.5
very high	0.70	1.05	1.58	2.4
extreme	>0.70	>1.05	>1.58	>2.4

Changes in land use and intensity have affected the hydrological balance in many soils, and therefore altered the naturally occurring salinity equilibrium. A comparison between a *Kupunn* with an extensive cropping history, and a virgin site, confirms research (Dalal, 1986) and local observations that dryland cropping can promote the leaching of salts downwards over time in clay soils. This increases the effective rooting depth and PAWC. Leaching of salts is also occurring within irrigated soils (Gordon *pers. comm.*) Insufficient data is currently available to quantify the hydrological impact of such leaching.

4.4.4 Sodicity and dispersion

Sodicity is caused by the presence of sodium held on the surface of clay particles in a soil. Sodicity becomes a problem when it reaches a concentration where it starts to affect the soil structure (Rengasamy and Walters, 1994). The measure of sodicity is commonly referred to as the exchangeable sodium percentage (ESP). It is the ratio of sodium to the sum of the exchangeable basic cations (calcium, magnesium, sodium, potassium). A sodic soil is defined as one in which sodium makes up 6% or more of the exchangeable cations, as listed below (from Northcote and Skene, 1972).

Sodicity rating	ESP (%)
non-sodic	<6
sodic	6-15
strongly sodic	>15

Sodium weakens the bonds between soil particles when they are wetted, making clays swell then disperse. The dispersed clay acts as a filler and binder, clogging pores in the soil, reducing infiltration and drainage, and increasing the size and density of aggregates. Sodic soils often have impermeable, dense subsoils that restrict root growth and water uptake. Sodicity and dispersion is often visible as cloudy water in dams and depressions. Soils of the Central Darling Downs that have sodicity as a limiting factor in their subsoil are shown in Table 4.10. The basaltic soils are the only clay soil types within the area that are usually non-sodic.

Symptoms of sodicity problems include poor infiltration and drainage resulting in waterlogging, increased runoff and poor water storage; surface crusting causing poor emergence of crops and pastures; gully erosion and tunnel erosion in sloping country (Rengasamy and Walters, 1994).

Table 4.7 shows that many of the cropping soils in the Central Darling Downs that are sodic or strongly sodic also have medium to extreme salinity levels in the subsoils. Examples include *Arden, Cecilvale, Kupunn, Moola*, and *Elphinstone*. The salt in these soils prevents the clay particles from dispersing and any difficulties experienced managing these soils will be due to salinity not sodicity. If the salts are leached from these soils (e.g. under cropping), sodicity symptoms may start to appear in the form of increased dispersion and reduced water and air movement throughout the soil profile.

Management practices that may bring sodic material to the surface, e.g. deep tillage or land levelling, are not recommended. Sealing and crusting problems will occur if the sodic clays are incorporated with the surface layer. Gypsum can be used to improve the surface structure of sodic clays.

Dispersion and Ca/Mg ratios

The dispersion ratio and the Ca/Mg ratio are two other soil attributes that are used to assess soil physical behaviour and should be considered in conjunction with ESP values. Table 4.7 also shows results for both dispersion and Ca/Mg ratios for the soils of the Central Darling Downs.

The dispersion ratio (R1) is the ratio of readily dispersible silt and clay determined by particle size analysis. It gives an indication of the dispersibility of soil layers and is particularly important in soils with high clay content, especially in areas that experience high rainfall intensities. The table below (from Baker and Eldershaw, 1993), gives an interpretation of R1 values.

Rating (tendency to disperse)	Dispersion ratio R1
low	<0.6
medium	0.6-0.8
high	>0.8

The R1 values are taken from representative soil profiles in the *Soil Chemical Data Book*.

Soils with a Ca/Mg ratio of <0.1 exhibit a dominance of magnesium in their subsoils indicating cation imbalance and an increase in the dispersion tendency (even at low ESP). Examples of soils with impermeable and dense subsoils with low Ca/Mg ratios include *Braemar, Channing, Karangi* and *Weranga*.

4.5 Land suitability

The land resources of the Central Darling Downs are suitable for a wide range of agricultural uses. Their suitability for a specified use is a function of limiting factors such as slope, fertility, rockiness, (*see Section 9.3*). Table 4.8 (*on page 74*) lists the LRAs and their general suitability for a number of agricultural uses. This is on the assumption that the 'common soils' are dominant within an LRA, and as discussed in section 4.2, this may vary at a local level. Further discussion on agricultural suitability for the eastern Downs may be found in Biggs (1999b).

All LRAs are suitable for grazing of native pastures. The quality of the pasture, stocking rates and animal productivity are generally better in the alluvial, basalt and brigalow upland units than in the traprock, granite and sandstone forest units. Most LRAs are suitable for improved pastures, although slope, soil depth, rockiness, and levels of sodicity and salinity are common limitations in the granite, traprock and, sandstone forest units.

The LRAs most suitable for cropping are those with clay soils (both cracking and non-cracking). These include the alluvial, basalt and brigalow units, although as with pasture production, the productivity of these LRAs varies. Wetness/drainage can be a limitation to cropping in some of the alluvial units. Fertility has historically not been a major limitation, although fertility decline is becoming a major concern in the cropping lands of the Central Darling Downs (*see Section 8.6*). Nutrient availability can however be an issue on some of the marginal soils within the sandstone units. Irrigated cropping is a major economic enterprise on the Darling Downs. Table 4.9 (*on page 75*) lists the soil types suitable for irrigation and the suitability for different forms of irrigation — furrow, spray and trickle irrigation. Slope and excessive permeability are factors restricting the use of furrow irrigation on some otherwise highly suitable cropping soils.

Table 4.2 Brief description of LRAs

Land Resource Area	Landform	Major soils	Vegetation	Areas (ha)
Recent Alluvial Plains				
1a	Broad level plains of mixed basaltic and sandstone alluvium.	Black and grey cracking clays with bleached sands or loams over brown or black clays	Poplar box or Qld bluegum open woodland, or grassland.	188 800
1b	River terraces, channels and associated alluvial plains, subject to flooding.	As for 1a.	Qld bluegum, river red gum and Moreton Bay Ash woodland.	19 020
Older Alluvial Plains				
2a	Broad level plains of basaltic alluvium.	Black, self-mulching cracking clays.	Open grassland.	156 550
2b	Broad level plains of mixed basaltic and sandstone alluvium.	Grey cracking clays.	Poplar box open woodland.	61 540
2c	Broad level plains of mixed basaltic and sandstone alluvium.	Red or brown loams over red or brown clays with black, self-mulching cracking clays.	Poplar box open woodland or grassland.	23 220
2d	Broad level plains of mixed basaltic and sandstone alluvium.	Grey cracking clays.	Poplar box, Qld blue gum, and Moreton Bay Ash woodland with belah and wilga.	28 680
Alluvial Plains - loamy Sodosols				
3a	Level alluvial plains and stream terraces.	Bleached clay loams over black, grey or brown clays.	Poplar box and Moreton Bay Ash woodland with wilga.	41 620
Alluvial Plains - sandy Sodosols				
4a	Level alluvial plains and stream terraces.	Bleached sands over brown or black clays.	Poplar box and Moreton Bay Ash woodland with wilga.	10 920
Brigalow Plains				
5a	Flat to gently undulating clay plains with shallow gilgai.	Grey, self-mulching, cracking clays.	Brigalow, belah forest with wilga.	44 050
5b	Flat plains with moderately deep to deep gilgai.	Grey, cracking clays.	Brigalow, belah forest with wilga and some black tea tree.	4 930
Brigalow Uplands				
6a	Gently undulating rises and plains on Walloon sandstone.	Grey-brown, cracking clays.	Brigalow, belah, wilga forest.	27 050
6b	Undulating to steep, low hills and rises of Walloon sandstone.	Grey-brown cracking clays with brown sands over brown clays.	Brigalow, belah open forest with wilga or softwood scrub with narrow leafed ironbark.	63 080
6c	Gently undulating rises and plains on Walloon sandstone.	Grey-brown, cracking clays.	Brigalow, belah, wilga forest with black tea tree.	40 670
6d	Gently undulating to undulating rises and plains on fine grained sediments and clay sheets.	Grey and brown cracking clays with grey-brown loams over brown clays	Brigalow, belah, open forest with box or poplar box open woodland.	28 460

Table 4.2 (Cont'd)

Land Resource Area	Landform	Major soils	Vegetation	Areas (ha)
Basaltic Uplands				
7a	Undulating rises and rolling low hills.	Grey-brown and brown clays or clay loams.	Mountain coolibah open woodland.	203 040
7b	Level to gently undulating plains.	Reddish brown to greyish brown clays.	Poplar box open woodland.	14 680
7c	Steep hills and mountains.	Grey-brown and brown clays or clay loams.	Mountain coolibah open woodland.	44 960
7d	Gently undulating plains to undulating rises on the Toowoomba Plateau.	Red clays.	Mountain coolibah open woodland and Sydney blue gum, white stringybark, bloodwood open forest.	8 260
Poplar Box Walloons				
8a	Undulating rises and low hills on Walloon sandstone.	Self-mulching, black cracking clays.	Poplar box open woodland.	21 070
Poplar Box Sodosols				
9a	Gently undulating plains on sandstone.	Bleached sands and loams over brown and grey clays.	Poplar box and gum topped box open woodland.	60 800
9b	Undulating plains and rises on sandstone.	Bleached sands to loams over mottled, grey or yellow clays.	Poplar box and bull oak open woodland.	3 560
Ironbark/Bull Oak Sodosols				
10a	Gently undulating plains on sandstone.	Bleached sands to loams over mottled, grey or yellow clays.	Narrow leaved ironbark, bull oak, cypress pine, rusty gum and poplar box open forest.	63 030
10b	Undulating plains and rises on sandstone.	Bleached sands or loams over mottled, grey or yellow clays; or brown or red clays.	Narrow leaved ironbark, bull oak, cypress pine and poplar box open forest.	19 310
Cypress Pine Sands				
11a	Flat to gently undulating sandy alluvial plains.	Deep sands and deep bleached sands over mottled, yellow or grey clays.	Cypress pine, rough-barked apple, blue gum, rusty gum and poplar box open forest.	27 970
Sandstone Forests				
12a	Rises and undulating plains on sandstone; often lateritised.	Bleached sands to loams over mottled, grey or yellow clays.	Narrow leaved ironbark, bull oak, cypress pine, rusty gum and poplar box open forest.	177 320
12b	Plateaus and low sandstone hills to undulating plains; lateritic scarps are common.	Shallow, gravelly sands to loams; deep sands or bleached sands over mottled, grey or yellow clays.	Narrow leaved ironbark, spotted gum and rusty gum open forest; or cypress pine, bull oak, rusty gum and ironbark open forest.	99 320
Granite Hills				
13a	Steep granite hills with rock outcrops.	Gritty sands over a natural, impermeable hardpan; or coloured sands.	New England blackbutt, tumbledown gum, ironbark and stringybark woodland.	600
Traprock Hills				
14a	Steep traprock hills with rock outcrops.	Gravelly loams over reddish brown or yellowish brown clays or bleached loam to clay loam acid subsoils.	Ironbark and brown box woodland with grey, yellow and fuzzy box and wattles.	8 390

Source: Maher *et al.* 1998.

Table 4.3 Relationship of soils to LRAs

Land Resource Area	Soils	
	Common soils	**Associated soils**
1. Recent Alluvial Plains		
1a	*Condamine, Haslemere Mywybilla, Anchorfield*	*Downfall, Combidiban, Waco, Cecilvale*
1b	*Condamine, Haslemere*	*Cecilvale*
2. Older Alluvial Plains		
2a	*Waco*	*Anchorfield, Mywybilla, Cecilvale, Yargullen*
2b	*Cecilvale*	*Mywybilla, Haslemere, Downfall, Waco, Oakey*
2c	*Oakey, Haslemere, Waco*	*Formartin, Cecilvale, Mywybilla*
2d	*Millmerran*	*Downfall, Oakey*
3. Alluvial Plains - loamy Sodosols		
3a	*Downfall, Haslemere*	*Millmerran, Cecilvale, Oakey, Condamine, Leyburn*
4. Alluvial Plains - sandy Sodosols		
4a	*Leyburn, Haslemere*	*Millmerran, Chinchilla, Davy*
5. Brigalow Plains		
5a	*Kupunn*	*Belahville, Haslemere, Tara, Langlands*
5b	*Tara*	*Kupunn, Haslemere*
6. Brigalow Uplands		
6a	*Moola*	*Acland, Walker, Knoll, Edgefield, Kenmuir, Downfall*
6b	*Moola, Diamondy, Walker*	*Toolburra, East, Clayburn, Edgefield, Downfall, Knoll, Kenmuir*
6c	*Gate, Moola*	*Walker, Edgefield, Knoll, Downfall*
6d	*Calingunee, Kurumbul, Murra Cul Cul*	*Arden, Wynhari, Tandawanna, Moruya*
7. Basaltic Uplands		
7a	*Craigmore, Irving, Charlton, Purrawunda, Kenmuir*	*Beauaraba, Aubigny, Waco, Southbrook, Mallard, Burton, Aberdeen, Yargullen*
7b	*Nungil, Kenmuir*	*Beauaraba, Charlton, Purrawunda, Southbrook, Aubigny, Aberdeen*
7c	*Kenmuir, Beauaraba*	*Charlton, Purrawunda*
7d	*Drayton, Ruthven*	*Middle Ridge, Toowoomba*
8. Poplar Box Walloons		
8a	*Elphinstone*	*Talgai, Walker, Kenmuir, Charlton, Purrawunda, Toolburra*
9. Poplar Box Sodosols		
9a	*Leyburn, Downfall*	*Haslemere, Nudley, Combidiban, Davy*
9b	*Weranga*	*Braemar*

Land Resource Area	Soils	
	Common soils	Associated soils
10. Ironbark/Bull Oak Sodosols 10a	*Weranga, Braemar, Cutthroat*	*Channing, Knoll, Drome, Davy, Chinchilla, Combidiban*
10b	*Weranga, Channing*	*Cutthroat, Drome, Braemar, Davy*
11. Cypress Pine Sands 11a	*Davy, Combidiban*	*Leyburn, Downfall, Chinchilla, Nudley*
12. Sandstone Forests 12a	*Braemar, Weranga*	*Cutthroat, Knoll, Hanmer, Drome, Flinton, Davy, Allan, Leyburn, Binkey*
12b	*Knoll, Cutthroat, Drome*	*Braemar, Hanmer, Allan, Davy, Binkey*
13. Granite Hills 13a	*Banca*	*Cottonvale*
14. Traprock Hills 14a	*Gammie, Karangi*	*Leyburn*

Table 4.4 Brief description of soils

Soil	Brief description	Vegetation (dominant species)	Occurrence by LRA[1]
Aberdeen	Moderately deep to deep (75-150 cm), reddish brown, coarse structured cracking clays on basalt	Mountain coolibah, rough barked apple	*7a, 7b*
Acland	Moderately deep to very deep (100-160 cm), uniform, non-cracking red and brown light clays on Walloon sandstone	Belah and wilga	*6a*
Allan	Moderately deep to deep (65-110 cm), texture contrast soil with a dark brown loam to sandy clay loam surface (frequently bleached) over brown to yellowish brown clay subsoils on sandstone	Narrow-leaved ironbark, spotted gum, bull oak, cypress pine	*12a, 12b*
Anchorfield	Deep to very deep (80-180 cm), self-mulching, very dark brown cracking clays on mixed basaltic and sandstone alluvium	Queensland bluegrass	**1a** *2a*
Arden	Moderately deep to deep (90-150 cm), self-mulching, red brown to cracking clays on sandstone and clay	Brigalow, belah, poplar box, wilga, false sandalwood	*6d*
Aubigny	Shallow to moderately deep (30-70 cm), brown to reddish brown light clays over red clay subsoils on basalt	Mountain coolibah, Moreton Bay Ash, poplar box	*7a, 7b*
Banca	Shallow to moderately deep (30-90 cm), very dark grey to brown, gritty, structureless siliceous sands amongst granite rock outcrops, frequently underlain by a colour B horizon of similar texture and/or a natural, impermeable hardpan	New England blackbutt, tumbledown gum, Youman's stringybark, Caley's ironbark, broad leaved stringybark	**13a**
Beauaraba	Very shallow (10-30 cm), dark granular to blocky cracking clays overlying basalt	Mountain coolibah	**7c** *7a, 7b*

[1] **Bold** = Common; *Italics* = Associated

Soil	Brief description	Vegetation (dominant species)	Occurrence by LRA[1]
Belahville	Texture contrast soil with a moderately thick (15-30 cm), sandy loam to sandy clay loam surface may be bleached, over brown or reddish brown clay subsoils	Poplar box, belah, yarran, limebush, false sandalwood	*5a*
Binkey	Moderately deep to deep (90-140 cm) texture contrast soils, with a (20-40 cm) bleached sandy surface, over mottled, gravelly clay subsoil	Cypress pine; bull oak; rusty gum; narrow-leaved ironbark	*12a, 12b*
Braemar	Texture contrast soil with a moderately thick (20-40 cm), bleached sandy surface, over mottled, yellow or grey clay subsoils on sandstone	Bull oak, cypress pine, narrow-leaved ironbark, rusty gum	**10a, 12a** *9b, 10b, 12b*
Burton	Moderately deep to deep (75-150 cm), reddish brown light clays, over red clay subsoils on strongly weathered basalt or red material	Mountain coolibah, narrow-leaved ironbark, rough bark apple	*7a*
Calingunee	Moderately deep to deep (60-150 cm), dark brown or grey self-mulching cracking clays with moderate gilgai on fine grained sediments	Brigalow, belah, poplar box, wilga	**6d**
Cecilvale	Deep to very deep (120-170 cm), grey cracking clays on mixed basalt / sandstone alluvial plains with poor surface structure and coarse blocky subsoils	Poplar box	**2b** *1a, 1b, 2a, 2c, 3a*
Channing	Texture contrast soil with a thin (<15 cm), bleached sandy loam to clay loam surface, over brown or red clay subsoils on sandstone	Narrow-leaved ironbark, cypress pine, bull oak	**10b** *10a*
Charlton	Moderately deep (50-100 cm), fine to coarse self-mulching, dark brown to black cracking clays	Mountain coolibah, narrow-leaved ironbark	**7a** *7b, 7c, 8a*
Chinchilla	Moderately deep to very deep (80-160 cm), reddish brown sands	Moreton Bay ash, cypress pine and wattle	*4a, 10a, 11a*
Clayburn	Texture contrast soil with a dark brown or grey clay loam surface (30 cm) over dark brown clays with moderate gilgai microrelief on Walloon sandstone	Brigalow, wilga, black teatree, gum top box, poplar box	*6b*
Combidiban	Deep texture contrast soil with a thick to very thick (30-100 cm), bleached, loose sandy surface, over mottled, yellow, grey or brown sandy clay subsoil on alluvial plains	Cypress pine, rusty gum and tumbledown gum	**11a** *1a, 9a, 10a*
Condamine	Deep to very deep (80-180 cm), coarse structured, black cracking clays on mixed basalt / sandstone alluvia adjacent to the Condamine River	Queensland blue gum, river red gum	**1a, 1b** *3a*
Cottonvale	Moderately deep (65-100 cm) gritty texture contrast soil with very dark grey, bleached, sandy surface to 30-45 cm over mottled, brown, grey and yellowish grey clay subsoils on granite	New England blackbutt, New England peppermint, manna gum, tumbledown gum, Youman's stringybark, Caley's ironbark, broad leaved stringybark	*13a*
Craigmore	Deep to very deep (100-180 cm), fine to coarse self-mulching, dark greyish brown to black cracking clays with reddish brown or brown subsoil on basalt or basaltic colluvium	Mountain coolibah, Queensland bluegrass	**7a**
Cutthroat	Texture contrast soil with a thick (>30 cm), bleached, loose sandy surface, over mottled, yellowish brown sandy clay subsoils on sandstone	Cypress pine, bull oak, some narrow-leaved ironbark, rusty gum and tumbledown gum	**10a, 12b** *10b, 12a*

[1] **Bold** = Common; *Italics* = Associated

Soil	Brief description	Vegetation (dominant species)	Occurrence by LRA[1]
Davy	Deep (100-150 cm), yellow or brown sands	Queensland blue gum, rough-barked apple, cypress pine, Moreton Bay ash	**11a** *4a, 9a, 10a, 10b, 12a, 12b*
Diamondy	Texture contrast soil with a thick brown to dark brown sandy surface (30 cm), over yellowish brown to brown sandy clay subsoils on sandstone	Bottle tree softwood scrub, narrow-leaved ironbark, brigalow, poplar box, gum top box	**6b**
Downfall	Texture contrast soil with a medium (15-20 cm), hardsetting, loam to clay loam surface, over yellowish brown or greyish brown clay subsoils on mixed sandstone / basalt alluvial plains	Poplar box, wilga	**3a, 9a** *1a, 2b, 2d, 6a, 6b, 6c, 11a*
Drayton	Moderately deep (50-100 cm) non-cracking red-brown to red clays over basalt on the Toowoomba Plateau	Narrow-leaved ironbark, mountain coolibah, white box	**7d**
Drome	Deep (100-120 cm) sand with a dark brown to light brownish grey, loamy sand surface, over a bleached sand, commonly becoming more yellow with depth on sandstone	Spotted gum, narrow-leaved ironbark, Queensland blue gum	**12b** *10a, 10b, 12a*
East	Moderately deep to deep soil (> 75 cm), brown clay loam to clay surface, over reddish brown clay subsoils on Walloon sandstone	Poplar box, belah, wilga, brigalow, softwood scrub	*6b*
Edgefield	Deep to very deep (100-180 cm) cracking grey clays, with dark grey surfaces grading to dark brown or dark grey subsoils on Walloon sandstone	Brigalow, belah, wilga	*6a, 6b, 6c*
Elphinstone	Deep (100-150 cm), fine self-mulching, dark cracking clays on Walloon sandstone	Poplar box, narrow-leaved ironbark and Queensland blue gum	**8a**
Flinton	Moderately deep to deep (50-105 cm) soils with red or brown loams over red or brown clay loam to clay subsoils on lateritised sandstone	Narrow leaved ironbark, spotted gum, quinine, wattles and red ash	*12a*
Formartin	Deep texture contrast soil with a thick (>30 cm), bleached sandy surface, over red clay subsoils on mixed basalt / sandstone alluvial plains	Poplar box, Moreton Bay ash	*2c*
Gammie	Very shallow to shallow (20-40 cm), gravelly, hardsetting brown loams to clay loams over a brown or bleached acid subsoil on Traprock	Brown box with fuzzy box and yellow box or mugga and broad leaved red ironbark	**14a**
Gate	Moderately deep to deep (70-120 cm), self-mulching grey clays with moderate gilgai on Walloon sandstone	Brigalow, belah, wilga, and black teatree, with gum top box	**6c**
Hanmer	Texture contrast soil with a shallow to moderately deep hardsetting, gravelly, dark brown, very acid loam surface (40 cm), frequently underlain by a bleached layer, over reddish brown to grey clay acid subsoils on sandstone	Narrow-leaved ironbark, Queensland blue gum, broad leaved stringybark, softwood scrub	*12a, 12b*
Haslemere	Deep texture contrast soil with a thin (<15 cm) sandy loam to clay loam surface, over black or dark brown clay subsoils on alluvial plains	Poplar box, Queensland blue gum, Moreton Bay ash and wilga	**1a, 1b, 3a, 4a** *2b, 5a, 5b, 9a*
Irving	Deep to very deep (100-180 cm), fine self-mulching, brownish black cracking clays with brown or reddish brown subsoils on basaltic colluvium	Mountain coolibah	**7a**

[1] **Bold** = Common; *Italics* = Associated

Soil	Brief description	Vegetation (dominant species)	Occurrence by LRA[1]
Karangi	Shallow to moderately deep (40-100 cm) texture contrast soil with a gravelly, medium, bleached, brown, sandy loam to clay loam surface (30 cm), over reddish brown or yellowish brown clays on traprock	Narrow-leaved ironbark, dusky-leaved ironbark, tumbledown gum, grey box, yellow box, spotted gum and wattles	**14a**
Kenmuir	Very shallow (5-25 cm), gravelly or stony, brown to red brown loams or clay loams on basalt	Narrow-leaved ironbark, silver-leaved ironbark, mountain coolibah, softwood scrub	**7a, 7b, 7c** *6a, 6b, 8a*
Knoll	Very shallow (30 cm), gravelly, grey or dark reddish brown sandy loams to loams over sandstone	Broad-leaved red and blue-leaved ironbarks, rusty gum, spotted gum, softwood scrub, cypress pine, wattles	**12b** *6a, 6b, 6c, 10a, 12a*
Kupunn	Deep to very deep (100-170 cm), self-mulching, grey cracking clays with shallow to moderately deep gilgai on brigalow alluvial plains	Brigalow, belah, wilga	**5a** *5b*
Kurumbul	Deep (100-150 cm) texture contrast soil with a thin (<15 cm) brown clay loam over dark brown heavy clay on clay sheets	Belah, wilga, false sandalwood	**6d**
Langlands	Deep to very deep (100-160 cm), self-mulching, brown to greyish brown cracking clay with moderately deep to deep gilgai on the brigalow clay sheet	Brigalow	*5a*
Leyburn	Deep (100-150 cm) texture contrast soil with a shallow, hardsetting, bleached loamy sand to clay loam surface, frequently gravelly (20 cm), over yellowish brown and brown clay subsoils on mixed sandstone / traprock alluvium	Poplar box, gum top box	**4a, 9a** *3a, 11a, 12a, 14a*
Mallard	Very shallow to shallow soils (20-40 cm), brown to grey-brown clay loams, over gravelly, mottled, brown and red-brown clays on basalt	Mountain coolibah	*7a*
Middle Ridge	Deep (100-150 cm) non-cracking red clays on Toowoomba Plateau	Queensland blue gum, wattles	*7d*
Millmerran	Moderately deep to deep (90-150 cm), grey clays with brown to grey, hardsetting, light clay surfaces over grey clay subsoils on mixed alluvial plains	Poplar box	**2d** *3a, 4a*
Moola	Moderately deep to deep (75-150 cm), self-mulching, grey-brown cracking clays with very shallow gilgai on Walloon sandstone	Brigalow, belah, wilga	**6a, 6b, 6c**
Moruya	Texture contrast soil with a red brown or brown loam to clay loam with strong bleaching (10 cm) over red brown clays on labile sedimentary rocks	Belah, wilga, false sandalwood, occasional brigalow	*6d*
Murra Cul Cul	Texture contrast soil with a thin (<15 cm) bleached, brown or grey sandy clay loam over dark brown heavy clay on sandstone alluvium	Polar box, wilga, false sandalwood	**6d**
Mywybilla	Deep to very deep (100-180 cm), coarse structured, very dark grey cracking clays on mixed basalt / sandstone alluvial plains	Queensland bluegrass, Queensland blue gum	**1a** *2a, 2b, 2c*
Nudley	Moderately deep to deep (70-150 cm) clay loam or texture contrast soil with a brown loam to clay loam surface of 40-50 cm over grey clay loam to clay subsoils	Poplar box, cypress pine, Moreton Bay ash	*9a, 11a*

[1] **Bold** = Common; *Italics* = Associated

Soil	Brief description	Vegetation (dominant species)	Occurrence by LRA[1]
Nungil	Moderately deep to deep (60-140 cm)soils with a brown light clay surface, over dark reddish brown to dark brown clay subsoils on weathered basalt; shallow phase may contain weathered basalt from 20 cm, stony surface phase also exists	Poplar box	**7b**
Oakey	Texture contrast soil with a thin (10-20 cm), reddish brown to brown, loamy surface, over brown clay subsoils on mixed basalt / sandstone alluvial plains	Poplar box	**2c** *2b, 2d, 3a*
Purrawunda	Moderately deep (50-100 cm), fine self-mulching, brownish black cracking clay on basalt	Mountain coolibah	**7a** *7b, 7c, 8a*
Ruthven	Deep to very deep (100-200 cm) non-cracking red clays on Toowoomba Plateau	Queensland blue gum, narrow-leaved ironbark, wattles	**7d**
Southbrook	Moderately deep (50-100 cm) stony, brown clay loam surface, over red clay subsoils on basalt	Narrow-leaved ironbark, rough-barked apple, poplar box	*7a, 7b*
Talgai	Moderately deep to deep (75-130 cm), fine, self-mulching, black cracking clay surface, over brown clay subsoils on Walloon sandstone	Poplar box, wilga, narrow-leaved ironbark, gum top box	*8a*
Tandawanna	Deep (110-150 cm), weakly self-mulching, red or brown non-cracking clays on clay sheets	Belah, wilga, false sandalwood	*6d*
Tara	Very deep (180 cm) brown to grey cracking clays with moderately to very deep gilgai on brigalow plains	Brigalow, belah, wilga	**5b** *5a*
Toolburra	Moderately deep to deep (75-150 cm) red brown light clays over red clay subsoils on Walloon sandstone	Poplar box, silver-leaved ironbark, wattles	*6b, 8a*
Toowoomba	Deep (100-150 cm) non-cracking red clays on Toowoomba Plateau	Queensland blue gum, narrow-leaved ironbark, wattle	*7d*
Waco	Deep to very deep (100-180 cm), fine self-mulching, dark brown cracking clays on basaltic alluvium	Queensland bluegrass	**2a, 2c** *1a, 2b, 7a*
Walker	Moderately deep to deep (75-150 cm), texture contrast soil with a thin (10-20 cm) dark brown to greyish brown, sandy loam to clay loam surface, over brown, dark reddish brown or dark greyish brown clays on Walloon sandstone	Brigalow, wilga, softwood scrub (bottle trees and vine scrub), belah and poplar box	**6b** *6a, 6c, 8a*
Weranga	Texture contrast soil with a thin (<15 cm), bleached sandy loam to sandy clay loam surface, over mottled, grey or yellow sandy clay subsoil on sandstone	Poplar box, bull oak, narrow-leaved ironbark	**9b, 10a, 10b, 12a**
Wynhari	Deep (100 cm), dark brown non cracking clays on labile sedimentary rocks	Belah, wilga, false sandalwood	*6d*
Yargullen	Moderately deep (50-100 cm), soft, granular dark clay on soft calcareous material	Queensland bluegrass	*2a, 7a*

[1] **Bold** = Common; *Italics* = Associated

Table 4.5 Distinguishing morphological characteristics of the major soils

Soil	Colour	Texture	Structure[1]	Other profile characteristics
Aberdeen				
surface soil	dark	light medium clay	strong granular	self-mulching, cracking
upper subsoil	brown	medium clay	strong angular blocky parting to lenticular	—
lower subsoil	red brown	light clay	lenticular	few calcareous concretions
Acland				
surface soil	grey brown or brownish black	light clay	weak fine crumb or sub-angular blocky, non-cracking	ironstone gravel may be present
upper subsoil	grey brown, brown, to reddish brown	medium to heavy clay	sub angular blocky to angular blocky	ironstone gravel and nodules may be present
lower subsoil	pale yellow	light medium clay	polyhedral	—
Allan				
surface soil	dark brown to dark yellowish brown	loamy sand to sandy clay loam	moderate blocky	hardsetting, may be underlain by a bleached A2 horizon to 10-40 cm
upper subsoil	brown to yellowish brown	clay	strongly blocky	sharp change between surface and subsoil, contains manganese and/or carbonate concretions, generally strongly sodic and highly saline
lower subsoil	yellow	clay loam, coarse sandy	massive	few manganese/iron veins, soft carbonate segregations common
Anchorfield				
surface soil	dark grey and very dark brown becomes browner with depth	cracking clays	moderate granular	weakly self-mulching
upper subsoil	mottled greyish brown and yellowish brown	heavy clay	fine to medium blocky structure becoming coarse blocky to lenticular with depth	cracks extensively when dry
lower subsoil	brownish black	heavy clay	moderate lenticular	few calcareous concretions
Arden				
surface soil	brown to reddish brown	medium clays	finely structured	moderately to strongly self-mulching
upper subsoil	reddish brown to brown clays	medium heavy clay, well-structured	well to moderately structured	faint mottles, a few carbonate segregations, a little gravel
lower subsoil	reddish brown	medium heavy clay	weakly structured	strongly sodic with extreme salinity levels but low dispersibility, strongly acid

Table 4.5 (Cont'd)

Soil	Colour	Texture	Structure[1]	Other profile characteristics
Aubigny				
surface soil	reddish brown	sandy loam		hardsetting
upper subsoil	red	Light medium to medium clay	moderate angular blocky parting to moderate columnar	very few medium calcareous crystals
lower subsoil	brown	fine sandy medium clay	moderate angular blocky	very few medium pebbles, angular basalt
Banca				
surface soil	very dark grey to brown	loamy coarse sands with a loose surface	gritty, structureless	—
upper subsoil	brown	clayey coarse sand	massive	with quartz gravel
lower subsoil	yellow	coarse sand	massive	natural hardpan
Beauaraba				
surface soil	black, very dark brown or very dark grey	heavy clay	moderate medium to strong coarse granular structure	occasional gravels
upper subsoil	black, very dark brown or very dark grey	heavy clay	moderate medium to coarse blocky structure	gravels increase with depth to hard weathered basalt with clay pockets, non-sodic, non-saline
lower subsoil	black, very dark brown or very dark grey	heavy clay	moderate medium to coarse blocky structure	—
Belahville				
surface soil	brown, yellowish red or very dark grey	sandy loam to sandy clay loam occasionally clay loam	massive	hardsetting, thick surface soils usually have a conspicuously bleached layer indicating periods of waterlogging
upper subsoil	brown, greyish brown or occasionally brownish grey clays, which may be mottled	medium heavy clay	poorly structured	strongly alkaline, sodic to strongly sodic, highly saline at depth
lower subsoil	light yellowish brown	medium clay	massive	some carbonate modules
Binkey				
surface soil	grey or brown to reddish brown	loamy sand to loam, usually sandy loam	massive	abundant stone on surface and in profile, thin bleached layer at base of surface soil, strongly acid
upper subsoil	yellowish brown or grey, occasionally brown to reddish brown	sandy clay to medium clay	strong, coarse columnar	abundant stone and gravel, strongly acid, mottled
lower subsoil	yellow or grey	medium clay	weak blocky	very strongly acid clays overly weathered parent material

Table 4.5 (Cont'd)

Soil	Colour	Texture	Structure[1]	Other profile characteristics
Braemar				
surface soil	greyish brown, dark brown or brown	loamy sand to sandy loam	massive	—
upper subsoil	greyish brown, yellowish brown or brown	clay	massive	conspicuously bleached
lower subsoil	greyish brown, mottled	sandy clay	massive, impermeable	generally strongly sodic and highly saline
Burton				
surface soil	dark reddish brown	clay loam to light clay	weak to moderate, fine blocky	—
upper subsoil	red to reddish brown	clay	moderate to strong, fine blocky structure	depth varies, a few black manganese concretions
lower subsoil	reddish brown	heavy clay	fine blocky structure	—
Calingunee				
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
Cecilvale				
surface soil	grey, light brownish grey or dark grey	sandy clay to light clay	weakly structured	surface crust, mildly alkaline
upper subsoil	grey to dark brownish grey	clay	very coarse blocky, may become massive with depth	very strongly alkaline, very few ironstone nodules
lower subsoil	dark greyish brown	medium heavy clay	moderately structured	moderately alkaline, some carbonate nodules
Channing				
surface soil	dark reddish brown, greyish brown or dark brown	sandy loam to sandy clay loam or clay loam	massive	hardsetting, strongly acid, thin bleach usually occurs in lower part of surface layer
upper subsoil	reddish brown, brown or yellowish	medium clay	weakly structured to massive	may be mottled
lower subsoil	brown	medium clay	massive	mottled
Charlton				
surface soil	black or very dark grey	heavy clay	strong coarse granular	—
upper subsoil	black or very dark grey to dark brown	heavy clay	strong coarse blocky	occasional gravel and few carbonate nodules
lower subsoil	black, very dark grey or brown, occasionally mottled reddish brown	heavy clay	lenticular	some carbonate nodules, large amounts of basalt gravel

Table 4.5 (Cont'd)

Soil	Colour	Texture	Structure[1]	Other profile characteristics
Chinchilla				
surface soil	dark reddish brown	sandy loam	loose	—
upper subsoil	yellowish red	clayey sand	massive	becomes more acid with depth non-sodic, non-saline
lower subsoil	red	loamy sand	massive	—
Clayburn				
surface soil	dark brown, reddish brown or grey	clay loam	weak polyhedral	hardsetting, bleached subsurface layer occasionally ironstone gravel occurs in patches
upper subsoil	dark brown, occasionally dark yellowish brown	medium clay	weak to moderate polyhedral	may be mottled; ironstone
lower subsoil		weathered parent material	moderate polyhedral	commonly mottled; ironstone
Combidiban				
surface soil	brownish grey, greyish brown or greyish yellow-brown	sand to sandy loam	loose	slightly acid to neutral, bleached subsurface layer
upper subsoil	brownish grey, light brown or light yellowish brown or light grey with bright yellow mottles	mottled clay	strong, very coarse columnar	neutral pH, mottled
lower subsoil	dark greyish brown, mottled red	light medium clay, coarse sandy	strongly columnar, blocky	neutral pH, mottled
Condamine				
surface soil	dark greyish brown, black or light grey	medium heavy clay	weak blocky to fine granular surface mulch	self-mulching, sometimes crusts, strongly alkaline, some water-worn gravel and sand grains
upper subsoil	black or dark grey	medium heavy clay	strong blocky	strongly alkaline to moderately alkaline
lower subsoil	dark greyish brown	heavy clay	well structured	strongly alkaline to moderately alkaline
Cottonvale				
surface soil	very dark grey to black at the surface, grading to yellow	coarse sandy clay loam	moderate granular	hardsetting surface
upper subsoil	grey with orange mottles	coarse sandy light clay becoming more gritty with depth	moderate blocky	—
lower subsoil	grey with orange mottles	coarse sandy light clay	massive	—
Craigmore				
surface soil	black	heavy clay	strong coarse granular	self-mulching
upper subsoil	black	heavy clay	coarse blocky	some carbonate nodules
lower subsoil	brown and yellowish brown	heavy clay	coarse blocky	soft and nodular carbonate

Table 4.5 (Cont'd)

Soil	Colour	Texture	Structure[1]	Other profile characteristics
Cutthroat				
surface soil	brown, greyish brown or greyish yellow-brown	sand, loamy sand or occasionally sandy loam	loose	thick bleached subsurface layer, strongly to slightly acid
upper subsoil	brown, yellowish brown or light grey	sandy clay to medium to heavy clay	massive or weakly columnar to blocky	neutral to strongly alkaline, mottled
lower subsoil	yellowish brown	coarse sandy clay loam	massive	strongly alkaline
Davy				
surface soil	brown or greyish brown	sand to loamy sand	loose	slightly acid, thick bleached subsurface layer
upper subsoil	light yellowish brown	sand to sandy loam	loose, may be coherent	neutral pH
lower subsoil	brownish yellow	sand to sandy loam	loose, may be coherent	slightly acid
Diamondy				
surface soil	dark reddish brown, dark brown or dark grey	sandy loam to sandy clay loam	weak polyhedral	hardsetting surface
upper subsoil	mottled, reddish brown, brown or yellowish brown	sandy clay	coarse blocky structure	moderately impermeable; generally sodic and saline
lower subsoil	yellowish brown	medium clay	moderate to weak coarse blocky structure	very few medium calcareous nodules
Downfall				
surface soil	brown to grey-brown	sandy loam to clay loam	massive	hardsetting, usually includes a bleached subsurface layer
upper subsoil	yellowish brown, brown or greyish brown	medium heavy to medium clay	coarse blocky or columnar structure	sodic to strongly sodic; some ironstone gravel; few coarse calcareous soft segregations
lower subsoil	greyish brown	medium clay	coarse blocky or prismatic	—
Drayton				
surface soil	dark reddish brown	clay loam to light clay	strong granular to angular blocky structure	—
upper subsoil	dark reddish brown	light medium clay	strong angular blocky structure	—
lower subsoil	brown	light medium clay	moderate angular blocky structure	common large and few medium angular basalt pebbles, few medium manganiferous laminae
Drome				
surface soil	brown	sandy loam	weak granular structure	—
upper subsoil	brownish-yellow	loamy sand	single grain	few medium red mottles
lower subsoil	brownish-yellow	sandy loam	single grain	common red mottles

Table 4.5 (Cont'd)

Soil	Colour	Texture	Structure[1]	Other profile characteristics
East				
surface soil	dark brown or dark reddish brown	friable clay loam to light clay (occasionally loam)	weak fine blocky structure	hardsetting
upper subsoil	red, reddish brown, brown or greyish brown	light to heavy permeable clay	moderate angular blocky	some ironstone gravel
lower subsoil	parent material	medium to heavy clay	strong angular blocky	soft segregations and nodules of calcium carbonate; some ironstone gravel
Edgefield				
surface soil	very dark grey, very dark greyish brown, or occasionally dark reddish brown	medium, occasionally light, clay	moderate granular	weakly to moderately self-mulching, moderate surface cracking
upper subsoil	dark grey, dark brown or dark greyish brown (occasionally dark reddish brown)	medium to heavy clay	moderate platy parting to moderate sub-angular blocky or weak lenticular	common medium calcareous concretions many fine manganiferous veins
lower subsoil	light brownish grey	heavy clay	weak sub-angular blocky	few distinct orange mottles
Elphinstone				
surface soil	dark grey to black	medium to heavy clay	fine	self-mulching, moderate surface cracking
upper subsoil	dark grey to black with brownish grey mottles, going yellowish brown or yellowish grey with depth	heavy clay	strong medium blocky structure	calcium carbonate
lower subsoil	yellowish brown and yellowish grey	heavy clay	strong coarse to medium blocky structure	calcium carbonate
Flinton				
surface soil	reddish brown to dark brown	vary from sandy loam to sandy clay loam	weakly structured	—
upper subsoil	red	clay loam, light clay, occasionally medium clay	usually massive	ironstone gravel
lower subsoil	yellowish red	light clay	massive	—
Formartin				
surface soil	reddish brown	sandy loam to sandy clay loam	loose	hardsetting, sharp change between surface and subsoils
upper subsoil	dark reddish brown to dark brown	medium clay with fine sand at depth	weakly structured	—
lower subsoil	light brownish grey	fine sand	massive	—
Gammie				
surface soil	brown to dark brown	loam	massive	gravelly, hardsetting
upper subsoil	brown to yellowish brown or bleached	clay loam	massive	—
lower subsoil		rock	—	—

Table 4.5 (Cont'd)

Soil	Colour	Texture	Structure[1]	Other profile characteristics
Gate				
surface soil	dark greyish brown to very dark grey	clay	moderate angular blocky	weakly self-mulching
upper subsoil	grey to dark yellowish brown	medium to heavy clay	moderate columnar	strongly sodic and highly saline at depth
lower subsoil	red	medium clay	—	—
Hanmer				
surface soil	brown to dark brown	loam to clay loam	may be weakly structured	hard-setting, gravelly sharp change between the surface and subsoil
upper subsoil	red to reddish brown to grey	clay	blocky	—
lower subsoil	grey, mottled red	light clay	weak polyhedral structure	sandstone fragments
Haslemere				
surface soil	dark brown to very grey	sandy loam to clay loam	massive	hardsetting, sporadic bleach at subsoil interface
upper subsoil	dark brown, black, to brownish grey, may be mottled	clay	strong blocky structure	strongly sodic, moderately to highly saline
lower subsoil	brown	heavy clay	strong blocky structure	very few coarse calcareous soft segregations
Irving				
surface soil	brownish black to very dark brown	heavy clay	strong fine granular	—
upper subsoil	dark brownish black to reddish brown	heavy clay	medium coarse blocky	soft and nodular carbonate
lower subsoil	brown	medium heavy clay	lenticular	few calcareous soft segregations
Karangi				
surface soil	brown to dark brown	clay loam	massive	hardsetting, very abundant large pebbles
upper subsoil	reddish brown, brown, to yellowish brown	moderate blocky structure	moderate blocky structure	very few small pebbles
lower subsoil	yellow, mottled red	medium clay	massive	rock fragments
Kenmuir				
surface soil	brown	clay loam	strong, fine to medium crumb structure	abundant gravel
upper subsoil	dark reddish brown to very dark grey	light clay	moderate, fine to medium blocky structure	moderate gravel
lower subsoil		light clay		—
Knoll				
surface soil	dark brown	loamy sand	loose	—
upper subsoil	yellowish brown	sand to loamy sand	loose	some decomposing rock
lower subsoil		decomposing rock	—	—

Table 4.5 (Cont'd)

Soil	Colour	Texture	Structure[1]	Other profile characteristics
Kupunn				
surface soil	dark greyish brown or grey	light clay or medium	weak blocky	shallow to moderately deep gilgai, strongly alkaline
upper subsoil	dark grey, become browner with depth	light medium clay to heavy clay	strong blocky	very strongly alkaline, some carbonate
lower subsoil	brown to strong brown	medium heavy clay	weak blocky	strongly acid at depth
Kurumbul				
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
Langlands				
surface soils	brown to greyish brown	light clay	moderate granular	few fine faint orange mottles very few medium calcareous concretions
upper subsoil	brownish grey	heavy clay;	strong lenticular	very few medium manganiferous nodules
lower subsoil	brownish grey, greyish yellow-brown	medium heavy clay	strong lenticular	—
Leyburn				
surface soil	brown	fine sandy clay loam	weak granular structure	—
upper subsoil	yellowish brown	impermeable clay	coarse blocky or columnar structure	strongly sodic from 50 cm, highly saline from 50-90 cm
lower subsoil	yellowish brown	medium clay	massive	strong consistence
Mallard				
surface soil	brown to dark brown	clay loam to light clay	moderate granular to fine blocky structure	—
upper subsoil	dark reddish brown and brown	medium clay	moderate fine blocky structure	some weathered basalt gravel
lower subsoil	dark brown, dark reddish brown or reddish brown	light clay to medium clay	moderate to strong fine blocky structure	—

Table 4.5 (Cont'd)

Soil	Colour	Texture	Structure[1]	Other profile characteristics
Middle Ridge				
surface soil	dark reddish brown	light clay	moderate granular to fine sub-angular blocky	—
upper subsoil	red-brown	heavy clay	moderate fine blocky	few 2-20 mm lateritic nodules
lower subsoil	red, yellow-grey and yellow-brown	light clay	moderate fine blocky	few to very many lateritic fragments and nodules
Millmerran				
surface soil	brown to grey-brown	light clay	weak prismatic	hardsetting, occasionally a bleached subsurface layer may occur
upper subsoil	grey faint brown mottles	medium heavy clay	strong prismatic parting to strong lenticular	sodic to strongly sodic few coarse calcareous concretions; few medium manganiferous nodules
lower subsoil	light brownish grey faint yellow mottles	medium heavy clay	moderate lenticular	few coarse calcareous concretions
Moola				
surface soil	greyish brown or dark brown	light clay	moderate blocky	usually self-mulching, very shallow linear gilgai, some ironstone gravel, strongly to medium acid pH
upper subsoil	very dark grey, light grey or dark greyish brown	medium heavy clay	well structured	some ironstone gravel, sodic to highly sodic
lower subsoil	mottled, pale yellow	medium heavy clay, occasional light clay	strong blocky	some ironstone gravel, hard and soft carbonate, very strongly to strongly alkaline
Moruya				
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
Murra Cul Cul				
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	mottling; soft manganese; crystalline gypsum; coarse gravel; acid clays below1m

Table 4.5 (Cont'd)

Soil	Colour	Texture	Structure[1]	Other profile characteristics
Mywybilla				
surface soil	black	heavy clay	coarse blocky structure	self-mulching; cracking clays
upper subsoil	black or dark grey	heavy clay	coarse blocky structure	cracking clays
lower subsoil	very dark greyish brown	heavy clay	massive	cracking clays; some carbonate
Nudley				
surface soil	reddish brown, yellowish brown or greyish brown	loam to clay loam	moderately to weakly structured	hardsetting
upper subsoil	reddish brown to grey	sandy loam to clay loam or clay	massive	—
lower subsoil	dark grey	medium clay	weakly structured	—
Nungil				
surface soil	reddish brown to brown	clay loam to light clay	weak fine crumb or sub angular blocky structure	few large pebbles, sub-angular basalt
upper subsoil	dark reddish brown to dark brown	medium clay	weak sub-angular blocky parting to weak polyhedral	few large pebbles, sub-angular basalt
lower subsoil	dark grey	—	—	many large pebbles, angular basalt
Oakey				
surface soil	dark reddish brown to dark brown	loam to clay loam	—	hardsetting
upper subsoil	dark reddish brown, dark brown or occasionally yellowish brown	light to medium clay	strong angular blocky	moderately permeable sodic to strongly sodic
lower subsoil	brown	medium clay	moderate angular blocky	—
Purrawunda				
surface soil	black, dark brown or very dark grey	light medium clay	strong granular	—
upper subsoil	very dark brown or very dark grey	medium heavy to medium clay	strong sub-blocky parting to strong lenticular	very few calcareous soft segregations
lower subsoil	brown	sandy light clay	weak angular blocky	very few calcareous soft and few concretionary segregations
Ruthven				
surface soil	dark greyish brown	clay loam	moderate blocky	—
upper subsoil	dark greyish brown	light clay	moderate blocky	—
lower subsoil	red	heavy clay	moderate to weak blocky	fragments of very weathered basalt

Table 4.5 (Cont'd)

Soil	Colour	Texture	Structure[1]	Other profile characteristics
Southbrook				
surface soil	dark reddish brown	light clay	strong granular	—
upper subsoil	dark reddish brown	light medium clay to medium clay	strong angular blocky	few small pebbles, sub-rounded basalt
lower subsoil	dark reddish brown	medium clay	strong angular blocky	common sub-rounded basalt
Talgai				
surface soil	dark brown to black	medium to heavy clay	strong fine blocky	cultivation destroys the surface structure
upper subsoil	black heavy clay	heavy clay	medium to coarse blocky structure	abrupt change to brown clay with depth bleached layer occasionally occurs above
lower subsoil	mottled, light brown	heavy clay	—	some gravel and carbonate concretions
Tandawanna				
surface soil	dark brown	clay loam, occasionally light clay	massive	slight subsurface bleach may occur, neutral pH
upper subsoil	dark brown to dark reddish brown	medium heavy clay to heavy clay	strong blocky	trace amounts of carbonate nodules, moderately alkaline
lower subsoil	yellowish red to brown	medium clay to heavy clay	weak polyhedral	very strong to extremely acid at depth
Tara				
surface soil	grey or grey-brown	heavy clay	moderate blocky	moderately deep to very deep gilgai, may be self-mulching, slightly acid
upper subsoil	grey to greyish brown, occasionally dark reddish brown	heavy clay to medium clay	coarse blocky	moderately alkaline, soft carbonate
lower subsoil	greyish brown	heavy clay to medium clay	massive to lenticular structure	very strongly acid at depth
Toolburra				
surface soil	red to dark reddish brown	clay loam to light clay	moderate blocky structure	weakly self-mulching, some ironstone gravel
upper subsoil	red to dark reddish brown	light to medium heavy clay	strong coarse lenticular structure	ironstone gravel and carbonate nodules increase with depth
lower subsoil	dark reddish brown	medium heavy clay	moderate lenticular	very few fine manganiferous nodules
Toowoomba				
surface soil	dark reddish brown	loam	strong granular to blocky	few ironstone nodules
upper subsoil	yellow-red	loam	strong granular to blocky	few ironstone nodules
lower subsoil	red-brown	clay loam to medium clay	massive to weak blocky	abundant pisolitic lateritic gravel and small blocks of fragmentary laterite

Table 4.5 (Cont'd)

Soil	Colour	Texture	Structure[1]	Other profile characteristics
Waco				
surface soil	black, dark grey and very dark brown	clay	fine granular structure	becomes browner with depth, strongly self-mulching, cracks extensively when dry
upper subsoil	mottled greyish brown and yellowish brown	heavy clay	fine to medium blocky	soft and nodular carbonate
lower subsoil	mottled, greyish brown, brown and yellowish brown	heavy clay	lenticular	moderate amounts of soft and nodular carbonate
Walker				
surface soil	dark brown to grey-brown	sandy loam to clay loam	massive, structureless to weakly structured	mildly acid
upper subsoil	brown, dark reddish-brown or dark grey-brown	heavy clay	coarse blocky	neutral to moderately alkaline
lower subsoil	brownish yellow, faint brown mottles	medium clay	coarse blocky	neutral
Weranga				
surface soil	very dark greyish brown to dark brown	fine sandy clay loam to sandy clay loam	massive	slightly acid, thin subsurface bleach
upper subsoil	greyish brown, brownish grey or light yellowish brown	sandy medium to heavy clay	strong columnar	slightly acid, colour and degree of mottling varies
lower subsoil	brown	medium clay to heavy clay	medium to coarse blocky	carbonate concretions, strongly sodic with highly saline deep subsoils, neutral to alkaline
Wynhari				
surface subsoil	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 or 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
Yargullen				
surface soil	black, dark grey or very dark grey	clay	very soft, weak, fine , granular	surface subject to wind erosion
upper subsoil	black or dark grey mottled	clay	weak lenticular parting to moderate polyhedral	moderate amounts of carbonate, increasing with depth
lower subsoil	white to grey	calcareous clay	moderate polyhedral	predominantly soft, carbonate-rich material

Table 4.5 (Cont'd)

[1] Note:

- structure descriptions have been taken from McDonald *et al*. (1984) and may be interpreted as follows:

	Grade of structure	*description*
surface soil	loose/massive	structureless
	weak	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)	
	platy (relatively flat horizontal faces)	

Table 4.6 Summary of surface soil fertility for cropping (at sampled site only)

Soil	pH	Organic Carbon	Total nitrogen	C/N ratio	Available phosphorus	Available potassium	Available copper	Available zinc	Available sulphur
Aberdeen	7.6	medium	medium	low	very high	very high	medium	medium	medium
Acland	7.8	very high	high	high	high	very high	medium	high	medium
Allan	7.0	low	low	high	low	medium	low	medium	medium
Anchorfield	8.3	high	medium	high	very high	very high	medium	very low	high
Arden	8.5	medium	medium	low	low	very high	medium	medium	n.a.
Aubigny	7.5	medium	low	medium	high	n.a.	medium	medium	medium
Banca	6.2	low	low	medium	very low	n.a.	n.a.	n.a.	n.a.
Beauaraba	7.2	medium	low	medium	very high	high	n.a.	n.a.	n.a.
Belahville	7.3	low	low	medium	high	n.a.	medium	low	medium
Binkey	4.9	very low	very low	very low	very low	medium	n.a.	n.a.	n.a.
Braemar	5.6	low	low	high	very low	very high	low	medium	n.a.
Burton	6.6	medium	medium	medium	high	very high	medium	medium	high
Calingunee	7.4	medium	low	medium	low	very high	medium	low	n.a.
Cecilvale	7.1	low	low	high	high	high	medium	low	n.a.
Channing	5.5	very low	very low	medium	very low	low	low	very low	n.a.
Charlton	6.9	high	medium	medium	high	very high	medium	medium	medium
Chinchilla	6.7	low	low	high	medium	medium	low	medium	n.a.
Clayburn	6.2	medium	medium	medium	medium	very high	medium	high	medium
Combidiban	5.7	very low	very low	high	medium	high	low	low	n.a.
Condamine	8.7	low	low	high	high	very high	medium	very low	medium
Cottonvale	6.3	low	low	high	low	high	medium	high	n.a.
Craigmore (depression)	6.9	high	high	medium	high	very high	medium	medium	high
Craigmore (mound)	8.2	medium	medium	medium	medium	very high	medium	low	medium
Cutthroat	5.4	low	low	high	very low	low	very low	very low	n.a.
Davy	6.4	low	low	medium	low	n.a.	n.a.	n.a.	n.a.
Diamondy	6.4	medium	low	medium	high	high	medium	very low	medium
Downfall	6.8	low	low	medium	very low	very high	medium	medium	medium
Drayton	5.9	very high	very high	medium	very high	very high	high	very high	high
Drome	5.6	low	very low	very high	low	low	very low	medium	n.a.
East	6.1	low	low	medium	high	very high	medium	medium	medium
Edgefield	8.2	high	medium	medium	very high	medium	medium	medium	high
Elphinstone	7.2	medium	very low	very high	very low	very high	medium	low	medium
Flinton	5.1	medium	low	high	very low	high	very low	medium	n.a.
Formartin	6.5	low	low	high	high	high	medium	low	low
Gammie	6.8	low	low	medium	medium	high	low	medium	n.a.
Gate	7.8	low	low	medium	medium	very high	medium	low	medium
Hanmer	5.6	high	medium	high	low	medium	low	very high	n.a.
Haslemere	7.0	medium	medium	medium	very high	very high	medium	medium	medium
Irving	7.2	medium	medium	medium	medium	high	medium	low	medium
Karangi	6.0	medium	low	high	very low	medium	n.a.	n.a.	n.a.
Kenmuir	6.5	very high	high	medium	very high	n.a.	n.a.	n.a.	n.a.

Table 4.6 (Cont'd)

Soil	pH	Organic Carbon	Total nitrogen	C/N ratio	Available phosphorus	Available potassium	Available copper	Available zinc	Available sulphur
Knoll	4.6	medium	low	high	n.a.	n.a.	n.a.	n.a.	n.a.
Kupunn	8.5	low	low	medium	low	n.a.	medium	very low	medium
Kurumbul	7.4	medium	low	medium	low	very high	medium	low	n.a.
Langlands (depression)	8.7	medium	medium	low	low	medium	medium	very low	medium
Langlands (mound)	7.3	high	high	low	high	high	medium	low	high
Leyburn	6.0	low	low	high	very low	high	medium	medium	n.a.
Mallard	7.3	medium	low	medium	high	n.a.	n.a.	low	n.a.
Middle Ridge	6.3	high	medium	high	high	n.a.	n.a.	n.a.	n.a.
Millmerran	6.1	medium	high	low	medium	very high	medium	medium	medium
Moola	8.7	low	low	high	very low	high	medium	very low	n.a.
Moruya	8.1	low	low	medium	very low	high	medium	low	n.a.
Murra Cul Cul	6.9	medium	low	medium	medium	high	medium	medium	n.a.
Mywybilla	7.3	medium	low	very high	n.a.	n.a.	n.a.	n.a.	n.a.
Nudley	6.9	medium	low	medium	medium	high	low	low	n.a.
Nungil	6.7	medium	medium	medium	very high	very high	medium	medium	medium
Oakey	6.4	very high	high	medium	high	very high	high	high	medium
Purrawunda	6.9	high	high	medium	high	very high	medium	medium	high
Ruthven	6.2	very high	very high	high	low	n.a.	n.a.	n.a.	n.a.
Southbrook	6.5	very high	high	medium	very high	very high	medium	medium	high
Talgai	8.3	medium	low	medium	very low	very high	medium	low	low
Tandawanna	6.9	low	low	medium	medium	very high	medium	medium	n.a.
Tara (depression)	6.3	low	low	medium	medium	high	medium	low	n.a.
Tara (mound)	6.3	medium	medium	medium	medium	very high	medium	medium	n.a.
Toolburra	6.9	high	medium	medium	high	high	medium	medium	medium
Toowoomba	6.1	very high	very high	high	medium	n.a.	n.a.	n.a.	n.a.
Waco	8.3	low	low	high	high	very high	medium	low	medium
Walker	6.7	high	high	low	medium	very high	medium	medium	medium
Weranga	6.3	medium	medium	high	very low	medium	low	low	n.a.
Wynhari	8.2	low	low	medium	very low	high	medium	low	n.a.
Yargullen	7.7	high	high	medium	high	very high	medium	low	medium

Table 4.7 Important agronomic characteristics of the soils (at sampling site only)

Soil[1]	pH	Salinity[2]	Sodicity[3]	Dispersion ratio[4] (R1)	Ca/Mg ratio	Clay content (%)	Effective rooting depth (cm)	PAWC in root zone (mm)
Aberdeen								
surface soil	7.6	very low	non-sodic	low	1.05	60-65	150	>250
upper subsoil	8.0	very low	non-sodic	low	0.89	65-70		
lower subsoil	8.8	low	non-sodic	medium	0.91	65-70		
Acland								
surface soil	8.1	medium	non-sodic	low	3.20	35-40	80	100-150
upper subsoil	8.7	low	non-sodic	low	2.50	40-55		
lower subsoil	8.7	very high	strongly sodic	high	0.50	50-55		
Allan								
surface soil	6.7	very low	sodic	medium	1.30	15-20	65	50-100
upper subsoil	6.7	very low	sodic	medium	0.70	35-40		
lower subsoil	9.2	medium	strongly sodic	low	0.70	40-45		
Anchorfield								
surface soil	8.3	very low	non-sodic	medium	1.30	60	150-180	>250
upper subsoil	8.7	very low	non-sodic	medium	1.20	60-70		
lower subsoil	9.3	medium	strongly sodic	high	0.38	65-70		
Arden								
surface soil	7.5	very low	non-sodic	low	2.30	30-35	50	100-150
upper subsoil	8.6	medium	sodic	low	2.10	50-55		
lower subsoil	4.8	extreme	strongly sodic	medium	1.10	55-60		
Aubigny								
surface soil	7.0	very low	non-sodic	low	2.80	45-50	30-50	50
upper subsoil	6.9	very low	non-sodic	low	2.60	35-75		
lower subsoil	8.4	low	non-sodic	medium	2.50	50-55		
Banca								
surface soil	6.2	very low	non-sodic	n.a.	7.70	15-20	depth to hardpan or rock, usually 25-50	<50 (depends on surface depth)
upper subsoil	6.2	very low	non-sodic	n.a.	8.00	15-20		
lower subsoil	6.5	very low	non-sodic	n.a.	3.10	20-25		
Beauaraba								
surface soil	7.2	very low	n.a.	n.a.	n.a.	50-55	30	<50
upper subsoil	7.3	very low	n.a.	n.a.	1.30	50-55		
lower subsoil	8.0	very low	n.a.	n.a.	n.a.	15-20		
Belahville								
surface soil	6.2	very low	non-sodic	medium	2.20	20-25	90	50-100
upper subsoil	6.5	very low	non-sodic	low	1.90	40-45		
lower subsoil	9.2	n.a.	n.a.	n.a.	n.a.	n.a.		

Table 4.7 (Cont'd)

Soil[1]	pH	Salinity[2]	Sodicity[3]	Dispersion ratio[4] (R1)	Ca/Mg ratio	Clay content (%)	Effective rooting depth (cm)	PAWC in root zone (mm)
Binkey								
surface soil	4.9	very low	non-sodic	n.a.	n.a.	5-10	45	<50
upper subsoil	5.3	very low	sodic	n.a.	n.a.	50-55		
lower subsoil	4.9	low	strongly sodic	n.a.	n.a.	50-55		
Braemar								
surface soil	5.6	low	sodic	low	0.60	20-25	30	<50
upper subsoil	6.6	high	strongly sodic	high	<0.10	30-35		
lower subsoil	5.0	very high to extreme	strongly sodic	high	<0.10	30-35		
Burton								
surface soil	6.4	very low	non-sodic	low	1.44	60-65	75-100	100-150
upper subsoil	6.8	very low	non-sodic	low	1.71	75-85		
lower subsoil	7.4	very low	non-sodic	medium	1.36	75-80		
Calingunee								
surface soil	6.9	very low	non-sodic	low	3.86	30-35	80-100	100-150
upper subsoil	9.1	medium	non-sodic	high	2.18	50-55		
lower subsoil	4.9	high	strongly sodic	high	0.56	50-55		
Cecilvale								
surface soil	7.1	low	non-sodic	n.a.	2.00	35-40	150-170	200-250
upper subsoil	8.3	low	sodic	medium	1.20	40-55		
lower subsoil	8.6	very high	strongly sodic	high	0.54	55-60		
Channing								
surface soil	5.5	very low	sodic	low	0.40	15-20	20	<50
upper subsoil	5.1	very high	strongly sodic	high	0.10	30-35		
lower subsoil	4.5	very high to extreme	strongly sodic	medium	<0.10	35-40		
Charlton								
surface soil	6.8	very low	non-sodic	low	0.90	60-65	50-100	100-150
upper subsoil	7.9	very low	non-sodic	low	0.90	65-70		
lower subsoil	8.0	low	non-sodic	low	0.90	60-65		
Chinchilla								
surface soil	6.7	very low	non-sodic	low	3.30	5-10	150	50-100
upper subsoil	6.2	very low	non-sodic	low	2.20	5-10		
lower subsoil	5.5	very low	non-sodic	low	2.10	0-5		
Clayburn								
surface soil	6.1	low	non-sodic	low	2.00	20-40	100	100-150
upper subsoil	7.7	very low	non-sodic	low	2.50	50-55		
lower subsoil	9.1	medium	sodic	low	2.50	40-45		
Combidiban								
surface soil	5.7	very low	non-sodic	n.a.	2.50	10-15	80	<50
upper subsoil	7.1	very low	non-sodic	high	1.30	45-50		
lower subsoil	6.8	very low	sodic	n.a.	1.20	45-50		

Table 4.7 (Cont'd)

Soil[1]	pH	Salinity[2]	Sodicity[3]	Dispersion ratio[4] (R1)	Ca/Mg ratio	Clay content (%)	Effective rooting depth (cm)	PAWC in root zone (mm)
Condamine								
surface soil	8.7	very low	non-sodic	low	3.30	55-60	100	150
upper subsoil	9.1	medium	sodic	medium	1.80	60-65		
lower subsoil	8.1	high to very high	strongly sodic	medium	1.10	60-65		
Cottonvale								
surface soil	5.8	very low	non-sodic	low	0.90	15-20	30-45 (surface soil depth)	<50 (depends on surface depth)
upper subsoil	4.3	medium	strongly sodic	low	<0.10	45-50		
lower subsoil	4.5	medium	strongly sodic	low	<0.10	30-35		
Craigmore (Depression)								
surface soil	7.4	very low	non-sodic	low	2.50	75-80	150	>250
upper subsoil	8.7	low	non-sodic	low	1.70	70-80		
lower subsoil	9.0	medium	sodic	medium	0.50	75-80		
Craigmore (Mound)								
surface soil	8.4	low	non-sodic	low	3.60	65-70	150	>250
upper subsoil	8.8	low	non-sodic	low	1.40	70-75		
lower subsoil	9.1	medium	sodic	low	0.40	70-75		
Cutthroat								
surface soil	5.4	very low	n.a.	high	3.50	10-15	60	<50
upper subsoil	7.8	low	sodic	high	0.30	20-25		
lower subsoil	8.8	medium to high	sodic	high	0.10	15-20		
Davy								
surface soil	6.4	medium	non-sodic	n.a.	n.a.	10-15	150	50-100
upper subsoil	6.5	low	non-sodic	n.a.	n.a.	10-15		
lower subsoil	n.a	low	non-sodic	n.a.	n.a.	10-15		
Diamondy								
surface soil	6.7	very low	sodic	low	2.80	10-15	70	50-100
upper subsoil	7.0	very low	non-sodic	low	3.90	50-65		
lower subsoil	8.9	high	strongly sodic	high	n.a.	n.a.		
Downfall								
surface soil	6.5	low	non-sodic	medium	2.30	15-20	100	100-150
upper subsoil	7.4	very low	sodic	medium	0.90	40-45		
lower subsoil	9.0	high	strongly sodic	high	0.45	45-50		
Drayton								
surface soil	6.0	low	non-sodic	low	1.90	45-50	75-100	100-150
upper subsoil	6.8	very low	non-sodic	low	1.90	60-65		
lower subsoil	7.2	very low	sodic	low	0.60	50-55		
Drome								
surface soil	5.8	very low	non-sodic	low	1.50	0-5	100	50-100
upper subsoil	6.3	very low	non-sodic	low	0.30	0-5		
lower subsoil	6.6	very low	non-sodic	low	<0.10	0-5		

Table 4.7 (Cont'd)

Soil[1]	pH	Salinity[2]	Sodicity[3]	Dispersion ratio[4] (R1)	Ca/Mg ratio	Clay content (%)	Effective rooting depth (cm)	PAWC in root zone (mm)
East								
surface soil	5.7	very low	non-sodic	low	2.50	15-20	90	100-150
upper subsoil	5.5	very low	non-sodic	low	3.20	20-30		
lower subsoil	7.2	low	non-sodic	low	1.90	50-55		
Edgefield								
surface soil	8.2	medium	non-sodic	low	4.20	20-25	100	150-200
upper subsoil	8.4	medium	non-sodic	low	5.70	50-55		
lower subsoil	5.4	n.a.	n.a.	n.a.	n.a.	n.a.		
Elphinstone								
surface soil	6.7	very low	non-sodic	low	1.60	30-35	80	100-150
upper subsoil	7.3	medium	sodic	high	1.30	55-65		
lower subsoil	8.9	high	strongly sodic	n.a.	1.00	50-55		
Flinton								
surface soil	5.1	low to medium	non-sodic	medium	1.30	10-15	80	100-150
upper subsoil	4.4	very low	non-sodic	low	0.60	20-25		
lower subsoil	4.8	very low	sodic	low	<0.10	30-35		
Formartin								
surface soil	6.5	very low	non-sodic	low	1.20	10-15	150	50-100
upper subsoil	7.4	very low	non-sodic	medium	1.40	45-50		
lower subsoil	8.0	very low	non-sodic	n.a.	1.30	30-35		
Gammie								
surface soil	6.8	very low	non-sodic	medium	3.70	30-35	20 (depth to weathered rock)	<50 (depends on profile depth)
upper subsoil	7.7	very low	sodic	medium	2.50	30-35		
Gate								
surface soil	7.4	very low	non-sodic	low	2.50	40-45	80	100-150
upper subsoil	8.9	medium	sodic	low	1.80	30-55		
lower subsoil	5.3	medium	strongly sodic	n.a.	0.83	35-40		
Hanmer								
surface soil	5.7	very low	sodic	low	2.40	15-20	50	<50-100 (depends on gravel and stone content)
upper subsoil	5.1	very low	non-sodic	low	<0.10	50-55		
lower subsoil	5.2	very low	non-sodic	low	<0.10	55-60		
Haslemere								
surface soil	6.9	very low	non-sodic	high	1.30	20-25	80	50-100
upper subsoil	7.8	low	sodic	high	1.10	25-45		
lower subsoil	9.4	medium	strongly sodic	n.a.	0.77	n.a.		
Irving								
surface soil	7.1	very low	non-sodic	low	1.30	70-75	150	>250
upper subsoil	7.3	very low	non-sodic	low	1.00	70-75		
lower subsoil	8.3	medium	non-sodic	n.a.	0.60	65-70		

Table 4.7 (Cont'd)

Soil[1]	pH	Salinity[2]	Sodicity[3]	Dispersion ratio[4] (R1)	Ca/Mg ratio	Clay content (%)	Effective rooting depth (cm)	PAWC in root zone (mm)
Karangi								
surface soil	6.0	very low	non-sodic	medium	1.60	10-15	<50	<50-100
upper subsoil	6.0	very low	sodic	high	0.10	40-45		(depends on
lower subsoil	6.3	medium	strongly sodic	high	<0.10	40-45		rock content)
Kenmuir								
surface soil	6.5	very low	n.a.	n.a.	2.60	30-35	20	<50
upper subsoil	7.4	n.a.	n.a.	n.a.	n.a.	n.a.		
Knoll								
surface soil	4.6	very low	non-sodic	low to medium	4.20	10-15	30	<50
Kupunn								
surface soil	8.5	low	non-sodic	low	6.60	40-45	100	150-200
upper subsoil	9.0	low	sodic	low to medium	3.80	40-45		
lower subsoil	4.3	high	strongly sodic	high	1.00	40-45		
Kurumbul								
surface soil	7.1	low	non-sodic	low	4.24	25-30	60-100	50-150
upper subsoil	9.3	medium	sodic	moderate	1.27	40-45		
lower subsoil	4.9	high to extreme	strongly sodic	high	0.70	45-50		
Langlands (Depression)								
surface soil	8.9	low	sodic	low	2.90	50-55	100	100-150
upper subsoil	9.2	medium	strongly sodic	medium	1.60	55-60		
lower subsoil	5.9	very high	strongly sodic	high	0.76	60-65		
Langlands (Mound)								
surface soil	8.5	low	non-sodic	low	4.80	50-55	60	50-100
upper subsoil	9.1	low	sodic	medium	3.90	50-60		
lower subsoil	9.1	high	strongly sodic	high	1.20	50-55		
Leyburn								
surface soil	7.0	very low	non-sodic	medium	2.20	15-20	50	50
upper subsoil	6.1	very low	sodic	medium	0.80	25-30		
lower subsoil	7.7	high-medium	strongly sodic	high	0.70	25-30		
Mallard								
surface soil	6.4	very low	n.a.	n.a.	1.90	35-40	30-50	50
upper subsoil	7.1	very low	n.a.	n.a.	1.50	55-60		
lower subsoil	6.8	n.a.	n.a.	n.a.	n.a.	n.a.		
Middle Ridge								
surface soil	6.3	very low	n.a.	n.a.	n.a.	55-60	100-150	100-150
upper subsoil	6.6	very low	n.a.	n.a.	n.a.	65-75		
lower subsoil	5.9	very low	n.a.	n.a.	n.a.	45-50		

Table 4.7 (Cont'd)

Soil[1]	pH	Salinity[2]	Sodicity[3]	Dispersion ratio[4] (R1)	Ca/Mg ratio	Clay content (%)	Effective rooting depth (cm)	PAWC in root zone (mm)
Millmerran								
surface soil	6.1	very low	non-sodic	low	1.70	30-35	100	100-150
upper subsoil	7.0	low	sodic	high	1.60	45-55		
lower subsoil	8.9	medium	sodic	high	1.50	45-50		
Moola								
surface soil	8.7	low	non-sodic	low	5.00	40-45	80-100	100-150
upper subsoil	8.8	low	sodic	low to high	3.00	45-55		
lower subsoil	5.0	very high	strongly sodic	high	0.84	50-55		
Moruya								
surface soil	7.5	low	non-sodic	low	10.00	15-20	60-100	50-150
upper subsoil	9.0	low to medium	non-sodic to strongly sodic	low to high	3.06	40-45		
lower subsoil	5.6	high to very high	strongly sodic to very strongly sodic	very high	1.21	40-45		
Murra Cul Cul								
surface soil	7.2	very low to low	non-sodic	n.a.	2.06	15-20	40-80	50-150
upper subsoil	8.5	high to extreme	strongly sodic	medium	0.84	50-60		
lower subsoil	5.3	low to medium	strongly sodic	very high	1.01	45-55		
Mywybilla								
surface soil	7.3	medium	non-sodic	low	1.50	35-40	150	>250
upper subsoil	8.1	medium	sodic	low	0.80	40-45		
lower subsoil	8.7	medium	n.a.	low	n.a.	65-70		
Nudley								
surface soil	6.9	very low	non-sodic	low	2.20	20-25	150	100-150
upper subsoil	7.0	very low	non-sodic	high	2.90	15-20		
lower subsoil	8.1	low to medium	sodic	medium	2.00	20-25		
Nungil								
surface soil	6.7	very low	n.a.	low	3.00	40-45	70	50-150
upper subsoil	7.1	very low	n.a.	low	3.10	55-70		
lower subsoil	7.4	very low	n.a.	low	n.a.	45-50		
Oakey								
surface soil	6.4	very low	non-sodic	medium	1.90	15-20	110	100-150
upper subsoil	7.9	very low	non-sodic to strongly sodic	low	1.40	50-60		
lower subsoil	9.4	medium	strongly sodic	medium	0.37	60-65		
Purrawunda								
surface soil	7.0	very low	non-sodic	low	1.10	50-55	50-100	100-150
upper subsoil	7.6	very low	non-sodic	low	1.20	60-60		
lower subsoil	8.1	very low	non-sodic	low	1.30	70-75		
Ruthven								
surface soil	6.2	very low	n.a.	n.a.	1.30	45-50	100-200	150-200
upper subsoil	6.4	very low	n.a.	n.a.	0.40	65-80		
lower subsoil	6.1	very low	n.a.	n.a.	0.12	n.a.		

Table 4.7 (Cont'd)

Soil[1]	pH	Salinity[2]	Sodicity[3]	Dispersion ratio[4] (R1)	Ca/Mg ratio	Clay content (%)	Effective rooting depth (cm)	PAWC in root zone (mm)
Southbrook								
surface soil	6.7	medium	non-sodic	n.a.	3.10	50-55	75-100	50-150
upper subsoil	7.3	very low	non-sodic	n.a.	3.70	70-75		
lower subsoil	8.1	low	non-sodic	n.a.	3.10	65-70		
Talgai								
surface soil	8.4	low	non-sodic	low	5.60	35-40	100	100-150
upper subsoil	8.7	very low	non-sodic	low	2.70	45-55		
lower subsoil	9.2	high	strongly sodic	high	0.60	50-55		
Tandawanna								
surface soil	6.9	low	non-sodic	low	4.10	30-35	80	100-150
upper subsoil	8.1	very low	non-sodic	low	1.40	45-50		
lower subsoil	4.4	very high	strongly sodic	low	0.40	45-50		
Tara (Depression)								
surface soil	6.3	low	non-sodic	low	2.30	40-45	100	100-150
upper subsoil	8.6	very low	sodic	low	3.70	55-60		
lower subsoil	4.7	high	strongly sodic	high	1.10	50-55		
Tara (Mound)								
surface soil	6.3	low	non-sodic	low	2.60	65-70	50	50-100
upper subsoil	8.4	medium	sodic	medium	2.10	55-60		
lower subsoil	4.6	very high	strongly sodic	high	0.80	50-55		
Toolburra								
surface soil	6.8	very low	non-sodic	low	2.40	50-55	120	150-200
upper subsoil	7.1	very low	non-sodic	low	2.30	55-70		
lower subsoil	8.9	n.a.	non-sodic	low	n.a.	n.a.		
Toowoomba								
surface soil	6.1	very low	n.a.	n.a.	1.60	15-20	150	150-200
upper subsoil	6.2	very low	n.a.	n.a.	n.a.	30-35		
lower subsoil	6.4	very low	n.a.	n.a.	n.a.	40-45		
Waco								
surface soil	8.3	very low	non-sodic	low	1.20	70-75	150	>250
upper subsoil	8.6	low	sodic	medium	0.80	75-85		
lower subsoil	8.6	high	strongly sodic	medium	0.59	75-80		
Walker								
surface soil	6.1	medium	sodic	low	2.20	25-30	110	100-150
upper subsoil	5.6	low	sodic	low	0.40	35-40		
lower subsoil	8.1	very high	strongly sodic	n.a.	0.23	30-35		
Weranga								
surface soil	6.3	very low	non-sodic	low	0.50	15-20	10	<50
upper subsoil	6.4	medium	strongly sodic	low	0.10	20-25		
lower subsoil	7.1	high	strongly sodic	high	<0.10	20-25		

Table 4.7 (Cont'd)

Soil[1]	pH	Salinity[2]	Sodicity[3]	Dispersion ratio[4] (R1)	Ca/Mg ratio	Clay content (%)	Effective rooting depth (cm)	PAWC in root zone (mm)
Wynhari								
surface soil	8.4	low	non-sodic	low	6.80	35-40	80-100	100-150
upper subsoil	9.2	medium	strongly sodic	medium	2.95	45-50		
lower subsoil	8.7	high to very high	strongly sodic	medium to high	2.50	45-50		
Yargullen								
surface soil	7.7	very low	non-sodic	low	2.20	55-60	50	50-100
upper subsoil	8.5	very low	non-sodic	medium	1.50	70-75		
lower subsoil	8.3	very high	non-sodic	low	0.64	60-65		

Notes:

1. The soil depths used for analyses depend on the soil horizon depths which are described in *Soil Chemical Data Book*. The surface soil is usually the 0–10 cm sample. The upper subsoil depth represents the top of the B horizon and depends on the depth of the A horizon. The lower subsoil depth represents the bottom of the B horizon; usually the 110–120 cm or 140–150 cm sample, unless the soil is shallower than this depth. If this is the case, it represents the deepest sample possible for the particular representative soil profile.

2. Salinity is estimated from the measurement of electrical conductivity (EC) in a 1:5 soil: water suspension. Ratings as per Shaw (1988).

3. Sodicity is calculated as the percentage of exchangeable sodium (ESP) (Baker and Eldershaw, 1993).

4. Clay dispersibility, measured as a dispersion ratio (R1), is described in Baker and Eldershaw (1993).

Table 4.8 Land use suitability for land types in the Central Darling Downs Region

Land Resource Area	Dominant soil	Land Use Suitability			
		Field crops	Hortic. crops	Improved pasture	Native pasture
Broad level plains of mixed basaltic and sandstone alluvium.	Condamine	S	NS	S	S
	Haslemere	NS	NS	S	S
	Mywybilla	S	NS	S	S
	Anchorfield	S	NS	S	S
River terraces, channels and associated alluvial plains, subject to flooding.	Condamine	S	NS	S	S
	Haslemere	NS	NS	S	S
Broad level plains of basaltic alluvium.	Waco	S	NS	S	S
Broad level plains of mixed basaltic and sandstone alluvium.	Cecilvale	S	NS	S	S
Broad level plains of mixed basaltic and sandstone alluvium.	Oakey	S	NS	S	S
	Waco	S	NS	S	S
Broad level plains of mixed basaltic and sandstone alluvium.	Millmerran	S	NS	S	S
Level alluvial plains and stream terraces.	Downfall	S	NS	S	S
	Haslemere	NS	NS	S	S
Level alluvial plains and stream terraces.	Leyburn	NS	NS	S	S
	Haslemere	NS	NS	S	S
Flat to gently undulating clay plains with shallow gilgai.	Kupunn	S	NS	S	S
Flat plains with moderately deep to deep gilgai.	Tara	S	NS	S	S
Gently undulating rises and plains on Walloon sandstone.	Moola	S	NS	S	S
Undulating to steep, low hills and rises of Walloon sandstone.	Moola	S	NS	S	S
	Diamondy	S	NS	S	S
	Walker	S	NS	S	S
Undulating to steep, low hills and rises of Walloon sandstone.	Gate	S	NS	S	S
	Moola	S	NS	S	S
Gently undulating to undulating rises and plains on fine grained sediments and clay sheets.	Calingunee	S	NS	S	S
	Kurumbul	S	NS	S	S
	Murra Cul Cul	S	NS	S	S
Undulating rises and rolling low hills.	Craigmore	S	NS	S	S
	Irving	S	NS	S	S
	Charlton	S	NS	S	S
	Purrawunda	S	NS	S	S
	Kenmuir	NS	NS	S	S
Level to gently undulating plains.	Nungil	S	LS	S	S
	Kenmuir	NS	NS	S	S
Steep hills and mountains.	Kenmuir	NS	NS	S	S
	Beauaraba	LS	NS	S	S
Gently undulating plains to undulating rises on the Toowoomba Plateau.	Ruthven	S	S	S	S
	Drayton	S	S	S	S
Undulating rises and low hills on Walloon sandstone.	Elphinstone	S	NS	S	S
Gently undulating plains on sandstone.	Leyburn	NS	NS	S	S
	Downfall	S	NS	S	S
Undulating plains and rises on sandstone.	Weranga	NS	NS	NS	S
Gently undulating plains on sandstone.	Weranga	NS	NS	NS	S
	Braemar	NS	NS	NS	S
	Cutthroat	LS	LS	S	S
Undulating plains and rises on sandstone.	Weranga	NS	NS	NS	S
	Channing	NS	NS	NS	S
Flat to gently undulating sandy alluvial plains.	Combidiban	LS	S	S	S
	Davy	NS	S	S	S
Rises and undulating plains on sandstone; often lateritised.	Braemar	NS	NS	NS	S
	Weranga	NS	NS	NS	S

Land Resource Area	Dominant soil	Land Use Suitability			
		Field crops	Hortic. crops	Improved pasture	Native pasture
Plateaus and low sandstone hills to undulating plains; lateritic scarps are common.	Knoll	NS	NS	NS	S
	Cutthroat	LS	LS	S	S
	Drome	NS	S	S	S
Steep granite hills with rock outcrops.	Banca	NS	S	S	S
Steep traprock hills with rock outcrops.	Gammie	NS	NS	NS	S
	Karangi	NS	NS	S	S

S – Suitable *NS – Not Suitable* *LS – Limited Suitability*

Table 4.9 Soils suitable for irrigation. Suitability class and recommended land use for irrigated agriculture

Soil name	Irrigation System			Recommended Land Use
	Furrow	Spray	Trickle	
Aberdeen	✔	✔	✔	suitable for most dryland and irrigated field and forage crops
Acland		✔	✔	suitable for most field and forage crops
Anchorfield	✔	✔	✔	suitable for most dryland and irrigated field and forage crops
Aubigny		✔	✔	suitable for most field and forage crops and most horticultural crops where irrigation is available
Belahville		✔	✔	suitable for winter field and short term forage crops
Burton		✔	✔	suitable for most field and forage crops and horticultural crops where irrigation is available
Cecilvale	✔		✔	suitable for most dryland and irrigated field and forage crops
Charlton		✔	✔	suitable for most dryland and irrigated field and forage crops
Chinchilla		✔	✔	suitable for some field crops and short season and tap rooted forage crops and horticultural crops where irrigation is available
Combidiban			✔	suitable for forage crops with limited suitability for winter crops in deeper topsoils and for horticultural crops where the surface soils are deep and there is adequate water
Condamine	✔	✔	✔	suitable for most dryland and irrigated field and forage crops
Craigmore	✔	✔	✔	suitable for most dryland and irrigated field and forage crops
Cutthroat			✔	suitable for forage crops with limited suitability for winter crops in deeper topsoils and for horticultural crops where the surface soils are deep and there is adequate water
Davy		✔	✔	suitable for some short season and tap rooted forage crops
Diamondy		✔	✔	suitable for some winter field and forage crops
Downfall		✔	✔	suitable for winter field and short term forage crops
Drayton		✔	✔	suitable for most field and forage crops and horticultural crops where irrigation is available
Drome		✔	✔	suitable for some short season and tap rooted

Soil name	Irrigation System			Recommended Land Use
	Furrow	Spray	Trickle	
				forage crops
East		✔	✔	suitable for some field and forage crops
Edgefield	✔	✔	✔	suitable for most field and forage crops
Elphinstone	✔	✔	✔	suitable for most field and forage crops
Formartin		✔	✔	suitable for most field and forage crops
Gate		✔	✔	suitable for winter field and short season forage crops
Haslemere	✔	✔	✔	marginal cropping soil best suited to pastures
Irving	✔	✔	✔	suitable for most field and forage crops
Kupunn	✔	✔	✔	suitable for most field and forage crops
Kurumbul	✔	✔	✔	suitable for most field and forage crops
Langlands	✔	✔	✔	suitable for most field and forage crops
Middle Ridge		✔	✔	suitable for most field and forage crops and horticultural crops where irrigation is available
Millmerran	✔	✔	✔	suitable for most field and forage crops
Moola	✔	✔	✔	suitable for most field and forage crops
Mywybilla	✔	✔	✔	suitable for most dryland and irrigated field and forage crops
Nudley		✔	✔	suitable for winter field and short term forage crops
Nungil		✔	✔	suitable for a wide range of field and forage crops
Oakey		✔	✔	suitable for some field and short term forage crops
Purrawunda		✔	✔	suitable for most field and forage crops
Ruthven		✔	✔	suitable for most field and forage crops and horticultural crops where irrigation is available
Southbrook		✔	✔	suitable for a wide range of field crops
Talgai		✔	✔	suitable for most field and forage crops
Tandawanna	✔	✔	✔	suitable for most field and forage crops
Toolburra	✔	✔	✔	suitable for most field and forage crops
Toowoomba		✔	✔	suitable for most field and forage crops and horticultural crops where irrigation is available
Waco	✔	✔	✔	suitable for most field and forage crops
Walker		✔	✔	suitable for some field and forage crops

Table 4.10 Central Darling Downs soils limited by subsoil salinity and sodicity

SOIL	SALINITY	SODICITY
Cropping soils (field and forage)		
Acland	Very high	Strongly sodic
Anchorfield	Medium	Strongly sodic
Arden	Extreme	Strongly sodic
Calingunee	high	Strongly sodic
Cecilvale	Very high	Strongly sodic
Clayburn	medium	Sodic
Condamine	High to very high	Strongly sodic
Craigmore	Medium	Sodic
Diamondy	High	Strongly sodic
Downfall	High	Strongly sodic
Elphinstone	High	Strongly sodic
Gate	medium	Strongly sodic
Irving	Medium	Non-sodic
Kupunn	High	Strongly sodic
Kurumbul	High to extreme	Strongly sodic
Langlands	High to very high	Strongly sodic
Millmerran	Medium	Sodic
Moola	Very high	Strongly sodic
Moruya	High to very high	Strongly to very strongly sodic
Murra Cul Cul	Low to medium	Strongly sodic
Mywybilla	Medium	n.a.
Oakey	Medium	Strongly sodic
Tandawanna	Very high	Strongly sodic
Talgai	High	Strongly sodic
Tara	High to very high	Strongly sodic
Waco	High	Strongly sodic
Walker	Very high	Strongly sodic
Wynhari	High to very high	Strongly sodic
Yargullen	Very high	Non-sodic
Native and sown pastures soils		
Allan	Medium	Strongly sodic
Binkey	Low	Strongly sodic
Braemar	Very high to extreme	Strongly sodic
Channing	Very high to extreme	Strongly sodic
Combidiban	Very low	Sodic
Cottonvale	Medium	Strongly sodic
Cutthroat	Medium to high	Sodic
Flinton	Very low	Sodic
Gammie	Very low	Sodic
Haslemere	n.a.	Strongly sodic
Karangi	Medium	Strongly sodic
Leyburn	Medium to high	Strongly sodic
Nudley	Low to medium	Sodic
Weranga	High	Strongly sodic

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Photo 8 Soil pit field day

5. WATER RESOURCES

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5.1 Introduction

The Central Darling Downs is characterised by extensive surface water and groundwater resources. These resources have enabled close settlement of the area and have been extensively developed. Their location, availability, supply and quality have significantly influenced historical and current agricultural enterprises in the area.

The water resources of the area are variable and reflect the natural variability of rainfall. This variability has led to the construction of water storages to provide security of water supply and the need to regulate water resources from watercourses in the area.

Water quality is important in determining how water resources can be used. The timing, duration and intensity of rainfall, and the landform features through which the water passes before entering waterways, influence water quality. Similarly, the supply and quality of groundwater varies between aquifers, and is related to the local geology.

5.2 Surface water resources

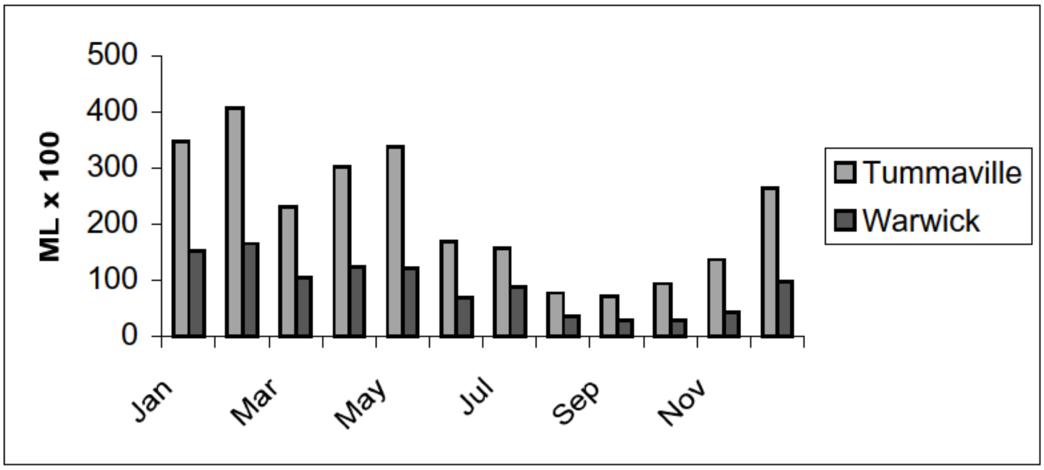
The surface water resources of the Central Darling Downs occur predominantly in the Condamine catchment, with the exception of the western section of Millmerran Shire, which occurs within the Weir River catchment. Both form part of the Queensland section of the Murray-Darling Basin.

The headwaters of the Condamine River are located in the Great Dividing Range near Killarney, south-east of Warwick. Approximately 50 km downstream of Warwick the river divides into the Condamine River (proper) and the Condamine River North Branch. These two major channels rejoin to the north of Cecil Plains. The river flows approximately 200 km across the Central Darling Downs in a north to north-easterly direction, with a catchment area of approximately 11 500 km^2.

The surface water resources of the Central Darling Downs are shown in Map 4.

5.2.1 Streamflow

Streamflow in the Central Darling Downs is variable and seasonal, with highest flows recorded during the 'wet' season between December and May. Lower flows are recorded during the 'dry' season, between June and November. Figure 5.1 shows mean monthly flow, in megalitres (ML), for the Condamine River at Warwick and Tummaville (near Pittsworth).



Source: HYDSYS Data, DNR.

Figure 5.1 Mean monthly flow in the Condamine River at Warwick and Tummaville

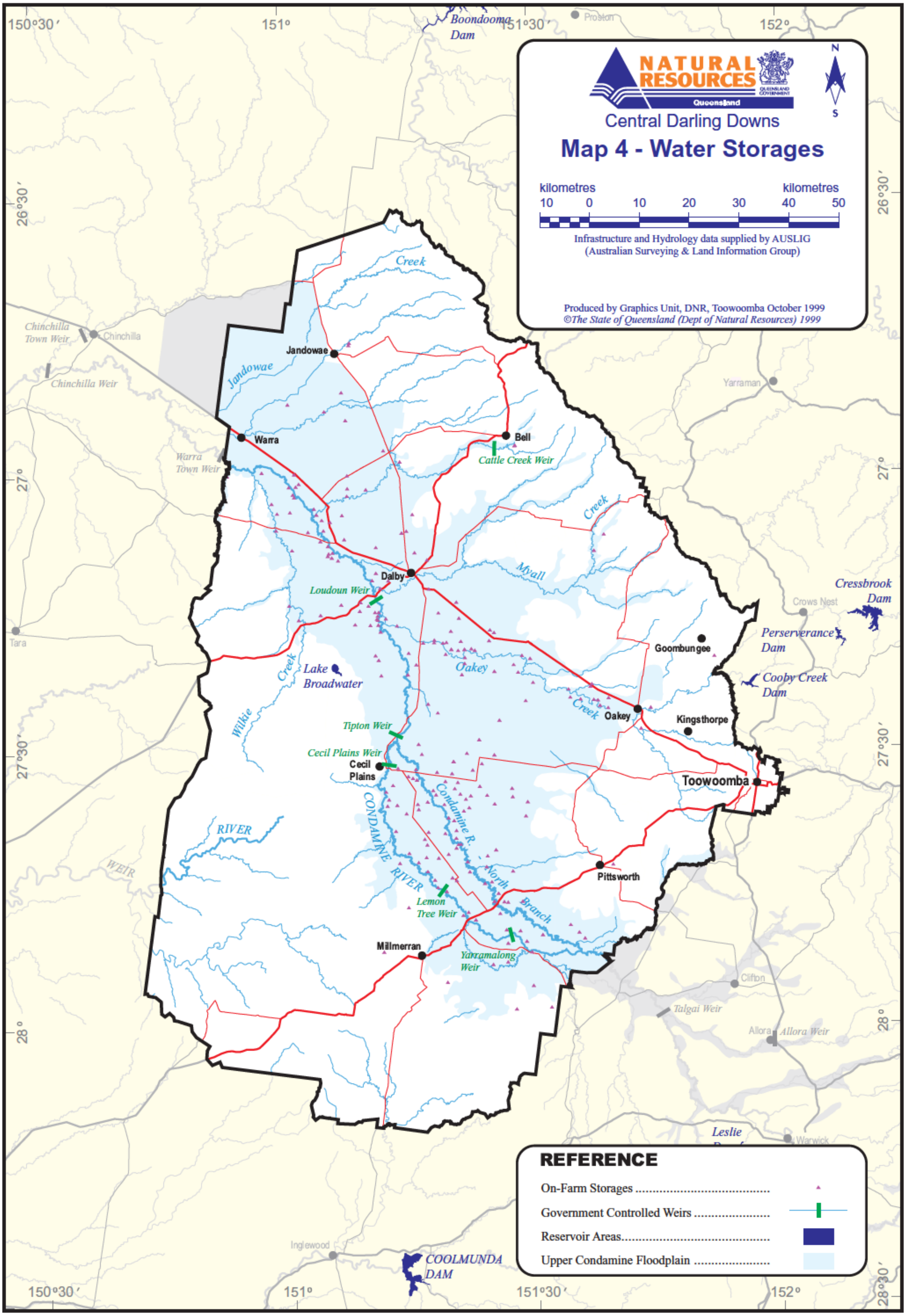
The Department of Natural Resources (DNR) records streamflow at 10 gauging stations within the Central Darling Downs. Continuous measurements have been collected since 1994. Table 5.1 lists the location of current streamflow gauging stations in the Central Darling Downs. Streamflow records can be obtained by contacting the Hydrographic Unit of the Department of Natural Resources.

Table 5.1 Current stream-flow gauging stations in the Central Darling Downs

Stream	Location	AMTD [1] (km)	Catchment Area [2] (km^2)	Mean Annual Flow [3] (ML)	Mean Annual Runoff [4] (mm/ha)
Hodgson Creek	Balgownie	11.4	560	35,290	63
Condamine River	Loudoun Bridge	834.0	12,380	400,000	32
Condamine River	Cecil Plains Weir	891.1	7,795	370,327	48
Condamine River	Lemon Tree Weir	943.4	7,080	-	-
Condamine River	Yarramalong	967.0	6,357	157,500	25
Condamine River	Tummaville	974.1	6,475	254,700	39
North Branch Condamine River	Pampas	47.6	-	15,450	-
Gowrie Creek	Oakey	4.0	142	16,150	1,154
Gowrie Creek	Cranley	32.2	47	8,694	185
Oakey Creek	Fairview	10.7	1,970	59,480	30

[1] AMTD=Average Middle Thread Distance from stream mouth
[2] Catchment area estimates based on AMTD location
[3] Mean annual discharge in megalitres
[4] Mean annual runoff = Mean annual discharge/Catchment area

Source: HYDSYS, DNR.


NATURAL RESOURCES
Queensland
Central Darling Downs
Map 4 - Water Storages
kilometres 10 0 10 20 30 40 50 kilometres
Infrastructure and Hydrology data supplied by AUSLIG
(Australian Surveying & Land Information Group)
Produced by Graphics Unit, DNR, Toowoomba October 1999
©The State of Queensland (Dept of Natural Resources) 1999
REFERENCE
On-Farm Storages
Government Controlled Weirs
Reservoir Areas
Upper Condamine Floodplain
Boondooma Dam
Chinchilla Town Weir
Chinchilla Weir
Jandowae
Warra
Warra Town Weir
Bell
Cattle Creek Weir
Dalby
Loudoun Weir
Lake Broadwater
Tipton Weir
Cecil Plains Weir
Cecil Plains
Oakey
Kingsthorpe
Goombungee
Toowoomba
Pittsworth
Lemon Tree Weir
Yarramalong Weir
Millmerran
Cressbrook Dam
Perserverance Dam
Cooby Creek Dam
Talgai Weir
Allora Weir
Leslie Dam
COOLMUNDA DAM
CONDAMINE RIVER
Condamine R. North Branch
Myall Creek
Oakey Creek
Wilkie Creek
Jandowae Creek
Yarraman
Crows Nest
Clifton
Allora
Warwick
Inglewood
Proston
Tara
Chinchilla
150°30′
151°
151°30′
152°
26°30′
27°
27°30′
28°

5.2.2 Management of surface water resources

All water resources in watercourses, lakes, springs and proclaimed groundwater areas are controlled by the State. Water entitlements are established through a system of licences issued by DNR.

Licences are issued to users on regulated or unregulated watercourses and in proclaimed groundwater areas to regulate water use and specify the licensees' entitlement. For further information on licensing and conditions, contact Resource Management, DNR Toowoomba.

In 1994, the COAG (Council of Australian Government) National Water Reform Framework Agreement formalised the government's commitment to address widespread degradation of the nation's natural resources and to support an efficient and sustainable water industry. In 1996, an interim cap was placed on the issue of new water entitlements in the Condamine-Balonne and Border Rivers catchment, in line with the existing cap arrangements placed on all catchments in the Murray-Darling Basin.

More recently, basin-wide planning approaches to water allocation have been initiated. These are known as Water Allocation and Management Plans (WAMPs) and Water Management Plans (WMPs). At this stage these planning processes have focused on surface water systems.

WAMP

WAMP refers to the Water Allocation and Management Planning process. It is a consultative process, which addresses Queensland's responsibilities for implementing reform of water allocations and entitlements. By taking into account scientific, environmental, social and economic issues, it seeks to find the appropriate balance between water used for urban, industrial and irrigation purposes, and water that should be left to maintain the health of the river.

The Condamine-Balonne WAMP process commenced in 1996. A WAMP process is also underway in the Border Rivers catchment. Existing licence arrangements will continue to apply until a WAMP is fully developed, with some restrictions on the issue of further licences. When completed, the WAMP will become a statutory plan under the proposed Natural Resource Management Legislation.

For further information on the WAMP process contact the WAMP Co-ordinator, DNR.

Regulation

The naturally variable flow regime of the Condamine River presents an unreliable water resource for land use. There has been significant flow modification of watercourses in the Central Darling Downs to prevent flooding and to provide water through dry seasons. Clearing and catchment development has changed the natural runoff rates and volumes. Roads, railways and other infrastructure have also changed the direction of natural flow pathways.

Several public (i.e. government-operated) water storages have been constructed within the Central Darling Downs. Table 5.2 summarises the major water storages in the area. There have also been a large number of water storages constructed on private property to impound overland flow and to store water pumped from the river in order to provide reliable supplies. Map 4 shows the location of government-operated water storages and private water storages that are licensed by DNR.

Table 5.2 Major water storages in the Central Darling Downs

Storage	Total Capacity (ML)	Year of completion
Connolly Dam [1]	2810	1927
Leslie Dam [1]	106250	1965
Allora Weir[1]	5	1928
Talgai Weir[1]	640	1981
Lemon Tree Weir	265	1981
Cecil Plains Weir	1040	1947
Tipton Weir	120	1945
Cooby Creek Dam[1]	23 100	1942
Loudoun Weir	588	1997
Cattle Creek Weir	68	1966
Warra Weir	120	1939

[1] = outside of the study area

5.2.3 Irrigation water supply

The Condamine River and its major tributaries have been extensively developed for irrigation for both regulated and unregulated sections of watercourses within the Central Darling Downs.

Water resources in the area are generally regarded as fully committed. DNR (in prep) provides an assessment of the potential for additional regulated and unregulated surface water resources development. Appropriate management practices are necessary to ensure equitable distribution of the surface water resources for irrigation on the Central Darling Downs.

Supply of irrigation water obtained from the following sources, is discussed below. For more information with regard to on-farm irrigation practices refer to DNR (1999).

Regulated

Upper Condamine Irrigation Project
The Upper Condamine Irrigation Project refers to the regulated supply of water from Leslie Dam, Yarramalong Weir, Lemon Tree Weir and Cecil Plains Weir. A nominal 22 400 ML is allocated annually to irrigators from the project. A further 7 200 ML is diverted by pipeline from Yarramalong Weir to the North Branch of the Condamine River. The project currently supplies 40 properties, irrigating approximately 6500 ha annually. This resource is fully allocated with no opportunity available for new users to access additional supplies.

Unregulated

Water is supplied from a number of unregulated streams in the Central Darling Downs, mainly the Gowrie-Oakey Creek system and Hodgson Creek.

Gowrie-Oakey creek system
Base flow in the eastern sections of the Gowrie-Oakey Creek system (adjacent to the Great Dividing Range) is fed by groundwater springs. Streams in this area receive frequent high streamflow events due to higher local rainfall and urbanisation of the catchment. Toowoomba City's sewage treatment plant (STP), Wetalla and other secondary industries contribute to the main baseflow. Effluent is discharged from the STP into Gowrie Creek approximately 7 km downstream of the Toowoomba central business district.

Effluent contributes up to 7000 ML per year of water to the system. This provides the main source of irrigation water from the system, supplying up to 100 irrigation and intensive stockwater licences and irrigating approximately 1000 ha annually. Irrigation demand along this system generally prevents sewage effluent from flowing beyond Oakey Creek into the Condamine River.

Unregulated water supplies in the Central Darling Downs are generally considered fully committed to existing licence holders and riparian users. No new (unconditional) irrigation licences have been issued in this area since the late 1970s. Priority is given to historic licences while more recent licences have restrictions.

Water harvesting

Water harvesting refers to the opportunistic extraction of water for irrigation from unregulated waterways.

DNR authorises the irrigation of approximately 2100 ha direct from waterways within the Central Darling Downs. This is comprised of:

- 250 ha of irrigation from the Condamine River downstream of Cecil Plains Weir;
- 900 ha of irrigation from lagoons in anabranches filled by overland flow and from Condamine River flood events;
- 380 ha of irrigation from waterways on the western slopes of the Great Dividing Range which is principally supplied by spring flows; and
- 600 ha of irrigation from tributaries on the floodplain, usually from waterholes within the waterways which are filled directly from rainfall or streamflow.

As with the Gowrie-Oakey Creek system, irrigation supplies from these unregulated sources are limited. The area authorised for irrigation under the licence is generally small i.e. less than 20 ha. In these situations irrigation water is generally used for pasture production or more intense cropping.

The development of water harvesting appears to have reached its limits. New licences for water harvesting along the Condamine River are not being considered, and applications are being held over until the WAMP process is completed.

Off-stream storages

Off-stream storages, including ring tanks, provide a major source of irrigation on the Central Darling Downs. They are used to harvest overland flow and to store water harvested from watercourses. Off-stream storages are often used in conjunction with the regulated supplies, or groundwater supply (*see Section 5.3*).

There are around 320 off-stream storages in the Central Darling Downs, with an average capacity of approximately 500 ML. Approximately half the storages draw supplies from major streams while the balance are filled from overland flow. The storages have a combined capacity of around 170 000 ML.

The low infiltration rates (when moist) of the cracking clays on the floodplains, promotes high run-off during high intensity rainfall events, contributing to overland flows available for harvesting.

5.2.4 Surface water quality

Water quality can have significant social, economic and environmental implications and influences the use of the resource. Water quality can determine agricultural land use, for example, use of water for irrigation of crops, stock watering or aquaculture.

A limited amount of regular water quality monitoring in the Central Darling Downs is undertaken by DNR through the Ambient Water Quality Network. Seven sites within the study area are regularly monitored for a range of parameters. Further information is available by contacting the Hydrographic Unit of DNR.

Water quality for the study area was collected during the joint DNR – Condamine Balonne Water Committee Inc. (CBWC) project. The project was carried out between 1993 and 1998 and involved regular monitoring of 15 sites in the study area (CBWC, 1999). During this project, the period between 1993–1995 experienced drought conditions. This may have caused poorer than normal water quality at the time of sampling. Review of the results highlighted:

Turbidity is a measure of the clarity or 'muddiness' of the water and was shown to be high to very high. It was usually too high for human consumption (without prior treatment) and swimming.

Total phosphorus is a measure of nutrient pollution and an indicator of potential for eutrophication and algal blooms. The report showed phosphorus was generally high to very high, with a risk of eutrophication.

Electrical conductivity is a measure of dissolved salts or salinity and was generally found to be low in the study area. However, higher conductivity occurs in watercourses in the south-east of the study area, resulting from influences of local geology.

Faecal coliforms are a measure of heat tolerant coliform bacteria and indicators of human and animal faecal contamination. Faecal coliform concentrations in water courses were high to very high. In some locations, for example Lemon Tree Weir, bacterial content was marginal for irrigation or stock watering.

Pesticides such as Atrazine™ and Metolachlor™ were regularly detected in Lemon Tree Weir while Atrazine™, Endosulfan™, Metolachlor™ and Prometryn™ were regularly detected in Loudoun Weir. In general a broader range of pesticides and higher concentrations were detected during the summer (cropping) months i.e. November to March when average or higher rainfall produces runoff from cropping lands. In some cases the concentration of the pesticide detected exceeded the drinking water guideline

(NHMRC & ARMCANZ 1996). However these guidelines refer to treated drinking water rather than raw supply water in which pesticides may be attached to sediment. Such sediment is normally removed during water treatment processes.

Water quality in the Central Darling Downs area is influenced by a number of variables including flow, local geology and land use. For example, the high concentrations of phosphorus, turbidity and faecal coliforms recorded in some locations resulted from the relatively high density of human and stock populations (and associated activities) in the catchment.

5.3 Groundwater resources

The occurrence, supply and quality of groundwater is closely related to geology with the major aquifer systems in the Central Darling Downs being linked to four basic divisions of geology. These divisions are further subdivided into a geological units described by geological name (*see Chapter 3*), as follows:

- **Unconsolidated sediments** - sands and gravels deposited by creeks and rivers. The geological unit is described as Alluvium and named after the associated creek or river. e.g. Condamine River Alluvium

- **Extrusive volcanics** - a fractured volcanic rock comprised mainly of basalt. The geological unit is described as Main Range Volcanics.

- **Consolidated sediments (sandstone).** There are a number of sandstone units within the Manual area.
  1. Surface sandstone units
     a. Kumbarilla Beds - west of the Condamine River
     b. Walloon Coal Measures - underlying the eastern basalts
     c. Marburg Subgroup - underlying the Walloon Coal Measures
  2. Deeper sandstone units associated with the Great Artesian Basin (GAB)
     a. Hutton Sandstone
     b. Precipice Sandstone.

- **Metamorphics (Traprock) -** a fractured rock consisting of mudstones, shales and older volcanics. The geological unit is described as the Texas Beds.

The geological unit will determine how the groundwater is stored and transmitted. Therefore, the characteristics of the groundwater in a particular area can be assessed using the geology. These characteristics include supply potential, water quality, depth to water table or Standing Water Level (SWL) and depth to aquifers or waterbeds. An aquifer or waterbed is defined as a porous layer within the rock that is capable of yielding useful quantities of water

Spring discharges associated with shallow groundwater flows are common throughout the Main Range Volcanics. These spring discharges can give rise to base flows of several creeks that occur on the western slopes of the Great Dividing Range.

Artesian or groundwater supplies flowing under pressure at the surface do not occur within the area. However, sub artesian supplies do occur in all aquifer systems. The deeper sandstone formations that are associated with the GAB do not flow within the Central Darling Downs.

5.3.1 Groundwater quality

Water quality is measured by average electrical conductivities (EC). Water supplies with EC readings greater than 3000 microsiemens/cm (µS/cm) are generally not suitable for irrigation on the heavy clay cropping soils of the Central Darling Downs (DNR, 1999). Groundwater supplies with such EC levels will affect plant growth and cause a build up of salts in the soil leading to degradation of soil structure. While the use of gypsum can help ameliorate surface structural problems, a better long-term strategy is to mix and supplement poor quality groundwater with better quality supplies, such as from overland flow.

5.3.2 Aquifers associated with alluvium

These aquifers are associated with the major creek and river systems within the area occurring as waterbeds in porous sand and gravel sections within the alluvium. Supplies are variable depending on the depth and extent of the alluvium and the composition of materials. For example, if the waterbed material has a high percentage of clays, then the yield will be lower than one with a high percentage of sand and gravel.

The major alluvial systems are:

a) Condamine River Alluvium (Tummaville to Warra)
b) Oakey Creek Alluvium

Condamine River Alluvium

The Condamine River Alluvium is the largest alluvial groundwater storage within the Central Darling Downs. Good supplies of irrigation quality water supports a large number of irrigation based enterprises and provides town water supplies to Pittsworth, Millmerran and Dalby. A range of industrial users are also supported by this source.

Supplies of 15 to 45 litres/second (l/s) are common and the majority of irrigation bores in the alluvium are capable of yields in this range. Larger supplies, up to 70 l/s, are encountered in the deeper sections of alluvium where the waterbed material is relatively free of clays. Depths to the Condamine River Alluvium vary from 30 metres at Tummaville to over 100 metres in the Norwin-Bongeen area.

Water quality in the Condamine River Alluvium varies from 1000 – 3000 µS/cm, with generally poorer quality north-west of Dalby in the range 2500 – 4000 µS/cm. Water quality can restrict crop choice in certain areas.

Oakey Creek Alluvium

Groundwater from the Oakey Creek Alluvium provides supplies for domestic, stock, irrigated enterprises and town water to Oakey and Jondaryan, Oakey Army Base and industrial uses such as the Oakey abattoir.

Supplies are generally consistent within an area and vary between 5 to 30 l/s. Depths of alluvium are generally greater than 10 metres and range up to 40 metres downstream of Oakey. Water quality is generally suitable for most purposes and average EC values range from 1500 to 3500 µS/cm. Depths to water table are generally consistent across the alluvium and range from 7 to 16 metres.

5.3.3 Aquifers associated with basalt (Main Range Volcanics)

The Main Range Volcanics constitute most of the Great Dividing Range within the eastern and northern parts of the Central Darling Downs. This geological unit is commonly referred to as the Basaltic Uplands. Two types of aquifers occur within basalt strata:

i) honeycomb or vesicular basalt formed by air pockets rising to the surface after volcanic flows

ii) fractured and jointed zones created during cooling of the volcanic material.

Supplies vary depending on the porosity and fracturing of the rock and the number of aquifers penetrated. Yields can vary from 0.1 to 20 l/s. The depth of basalt is variable and is often greater than 150 metres in upland areas. Depths to water table or Standing Water Level can vary from 5 to 40 metres depending on the topography of the site. Average EC of groundwater is in the range of 500 to 2500 µS/cm. Water quality is generally suitable for all purposes.

5.3.4 Aquifers associated with sandstone

Aquifers in sandstone occur in porous sections and limited jointed/fractured zones. Sandstone units within the region overlie basement rock such as granite and/or another sandstone unit of a different composition and age in a 'sandwich type' arrangement. For example the sandstone unit described as Kumbarilla Beds overlies Walloon Coal Measures which in turn overlies Hutton Sandstone. The exposed section of the sandstone unit is referred to as the outcrop area. Generally, all sandstone units within the Central Darling Downs are dipping in a south-westerly or westerly direction from the Great Dividing Range. Therefore, the depth to a particular sandstone unit that is not exposed will increase from east to west across the area.

Surface sandstone units

a) Kumbarilla Beds consist of sandstone, siltstone and mudstone with some conglomerate and outcrop in the south-western part of the Central Darling Downs, west of the Condamine River. Supplies are variable and are generally in the range 0.4 to 6 l/s. A suitable supply is usually encountered from depths of up to 90 metres, however, it is not uncommon for bores to be completed up to 200 metres in depth. Water quality is generally suitable for stock and most domestic applications. Average ECs are in the range 1500–3500 µS/cm.

b) Walloon Coal Measures consist of carbonaceous mudstone, siltstone, sandstone and coal seams and outcrop in the north-eastern section of the region. Walloon Coal Measures underly most of the areas of Alluvium, Main Range Volcanics and Kumbarilla Beds. Groundwater is often encountered within coal seams, however, the reliability of supply can depend on the extent of the coal seam. Supplies are generally in the range 0.1 to 4 l/s from depths below 40 metres to 150 metres. Water quality is generally only suitable for stock, intensive animal industries and most domestic applications. Average ECs are in the range 1500–4000 µS/cm.

c) Marburg Subgroup consists of feldspathic sandstone, shale and siltstone and is found in the north-eastern and southern sections of the area. Supplies are generally in the range 0.4 to 10 l/s from depths below 50 metres. Water quality is generally suitable for stock, intensive animal industries and most domestic applications. Average ECs are in the range 1200–3500 µS/cm.

Deeper Sandstone Units

a) Hutton Sandstone underlies the Walloon Coal Measures. It is found in the western parts of the Central Darling Downs, and is equivalent to the Marburg Subgroup found in the north-eastern part of the area. Hutton Sandstone consists of quartzose sandstone, some conglomerate, siltstone and mudstone. The depth to the top of the Hutton Sandstone varies from approximately 150 metres at Millmerran, 350 metres at Dalby and 600–700 metres to the west of the manual area. The average thickness of the Hutton Sandstone is approximately 200–250 metres.

Supplies are generally in the range 5 to 20 l/s depending upon the thickness of aquifer encountered. Average ECs are in the range 1500–3000 µS/cm and is generally suitable for stock, intensive animal industries, industrial and most domestic applications.

b) Precipice Sandstone is referred to as the basal (bottom) sandstone aquifer unit within the area and consists of quartzose sandstone and some siltstone. The extent of the Precipice Sandstone is discontinuous across the Central Darling Downs, thinning out from a line east of Millmerran to Toowoomba to Jimbour associated with the Great Dividing Range. The thickness of the unit varies from 40 to 100 metres in the remainder of the area. The depth to the top of the Precipice Sandstone varies from approximately 750 metres at Aubigny to 1200 metres at Kogan, west of Dalby.

Based on limited data, supplies are anticipated in the range 10 to 40+ l/s depending upon the thickness of the aquifer encountered. Average ECs range from 1200–1800 µS/cm and is generally suitable for stock, intensive animal industries, industrial and domestic applications.

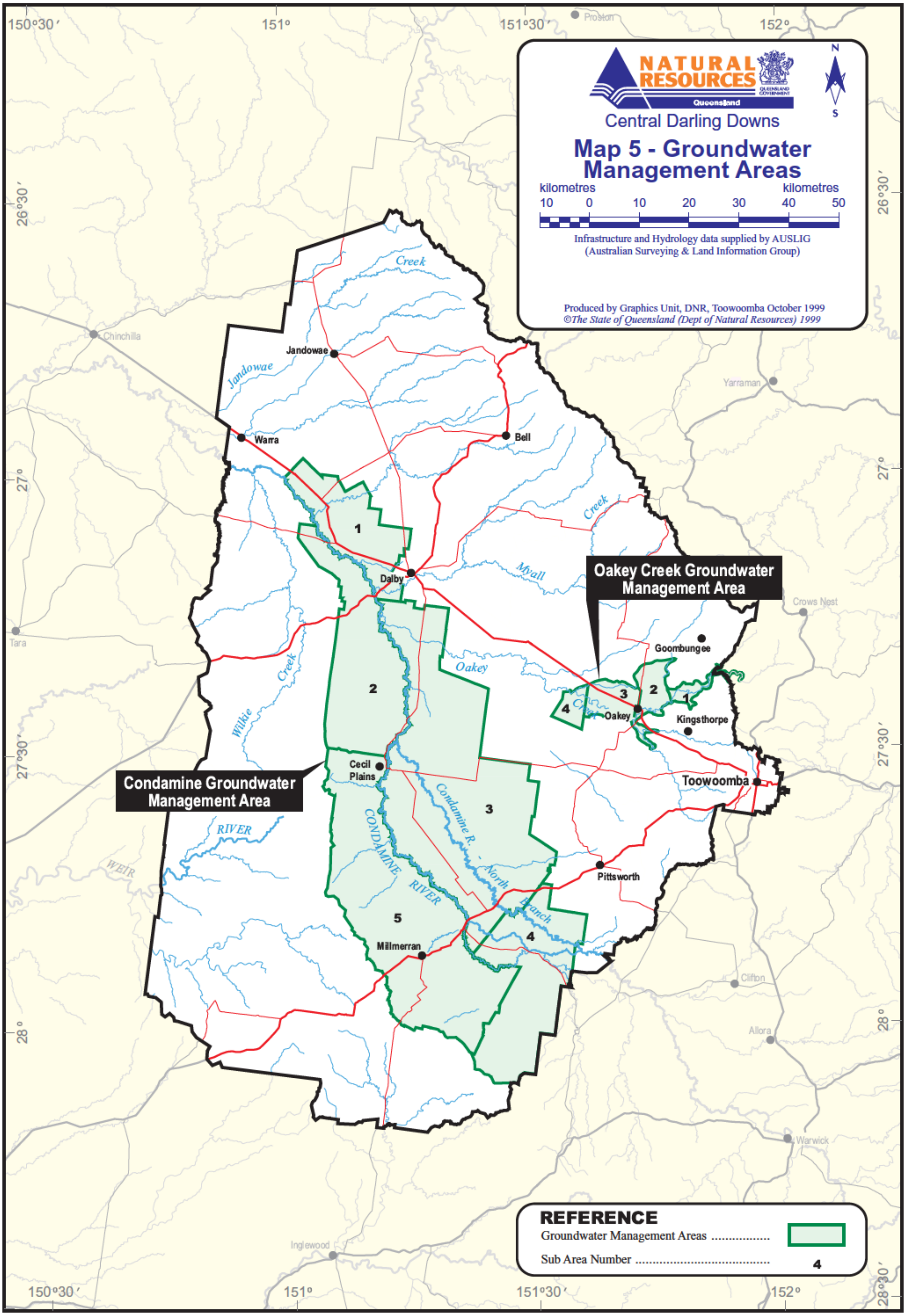
5.3.5 Aquifers associated with Traprock (metamorphics)

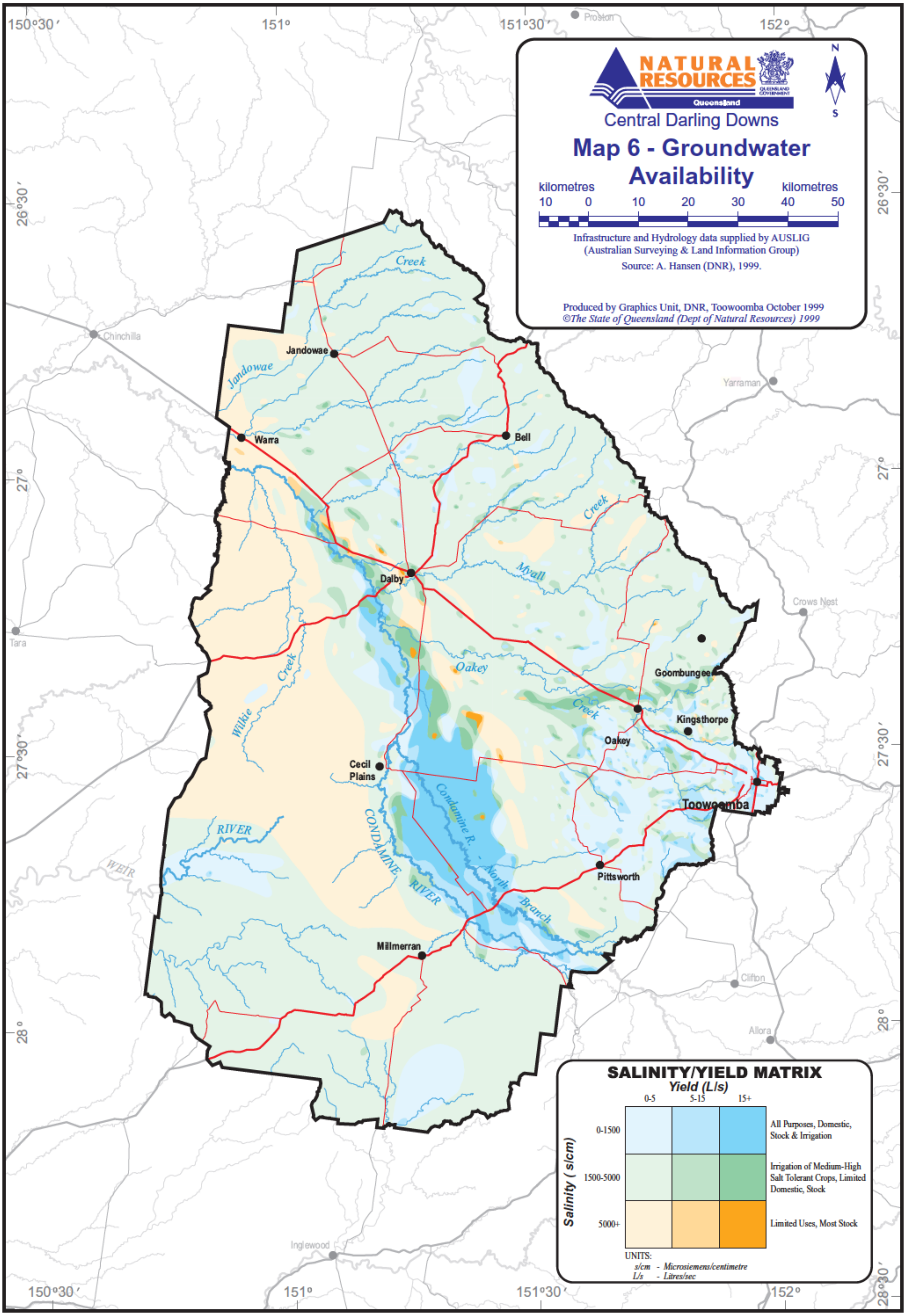
Aquifers in traprock occur in small areas within the southern part of the region, although aquifer systems within metamorphics are generally localised and discontinuous. They are located in fractured and jointed zones within the traprock. Supplies are highly variable depending upon the degree of fracturing. Bore yields in the range 0.1–6 l/s are generally encountered at depths below 40 metres and up to a maximum of 120 metres. Water quality is generally suitable for most stock, but marginal for domestic applications. These groundwaters often contain high concentrations of individual ions. A water analysis is recommended to determine suitability for specific uses. Average ECs are in the range 2500–10000 µS/cm.

5.3.6 Groundwater management

A Waterworks Licence issued under the provisions of the Water Resources Act, 1989, is required to construct or alter a bore, to access and use groundwater. Bores used solely for domestic purposes are exempt from requiring a waterworks licence. Further information regarding bore licensing requirements can be obtained from the Department of Natural Resources, Toowoomba.

Within the Central Darling Downs, there are four groundwater Management Areas relating to the aquifer systems (Map 5):


Central Darling Downs
Map 5 - Groundwater Management Areas
NATURAL RESOURCES
Queensland
kilometres
10 0 10 20 30 40 50
Infrastructure and Hydrology data supplied by AUSLIG
(Australian Surveying & Land Information Group)
Produced by Graphics Unit, DNR, Toowoomba October 1999
©The State of Queensland (Dept of Natural Resources) 1999
Oakey Creek Groundwater Management Area
Condamine Groundwater Management Area
Jandowae
Warra
Bell
Dalby
Oakey
Goombungee
Kingsthorpe
Toowoomba
Cecil Plains
Pittsworth
Millmerran
Chinchilla
Yarraman
Crows Nest
Tara
Clifton
Allora
Warwick
Inglewood
Proston
Condamine R. - North Branch
CONDAMINE RIVER
REFERENCE
Groundwater Management Areas
Sub Area Number


NATURAL RESOURCES
Queensland
Central Darling Downs
Map 6 - Groundwater Availability
kilometres
10 0 10 20 30 40 50
Infrastructure and Hydrology data supplied by AUSLIG
(Australian Surveying & Land Information Group)
Source: A. Hansen (DNR), 1999.
Produced by Graphics Unit, DNR, Toowoomba October 1999
©The State of Queensland (Dept of Natural Resources) 1999
150°30′
151°
151°30′
152°
26°30′
27°
27°30′
28°
Proston
Chinchilla
Yarraman
Crows Nest
Tara
Clifton
Allora
Inglewood
Jandowae
Warra
Bell
Dalby
Goombungee
Kingsthorpe
Oakey
Toowoomba
Cecil Plains
Pittsworth
Millmerran
Jandowae Creek
Myall Creek
Oakey Creek
Wilkie Creek
Condamine R.
North Branch
CONDAMINE RIVER
WEIR RIVER
SALINITY/YIELD MATRIX
Yield (L/s)
0-5
5-15
15+
Salinity (s/cm)
0-1500
1500-5000
5000+
All Purposes, Domestic, Stock & Irrigation
Irrigation of Medium-High Salt Tolerant Crops, Limited Domestic, Stock
Limited Uses, Most Stock
UNITS:
s/cm - Microsiemens/centimetre
L/s - Litres/sec

- Condamine Groundwater Management Area, CGMA, covers most of the Condamine River Alluvium and has been divided into five sub-areas for management purposes. The CGMA has been a restricted licence area since 1970 when rapid development coincided with falling water levels. In 1978, meters on pumps were introduced to monitor the system, record water use and assist with yearly allocations.

- Oakey Creek Groundwater Management Area, OCGMA, covers most of this Oakey Creek Alluvium. The OCGMA was formed in 1992 when the alluvial system reached full development. Management guidelines have been developed and include restrictions on new allocations. Water meters have been introduced and allocation guidelines announced.

- Toowoomba City basalts (basalt aquifers within the Toowoomba City Area).

- Great Artesian Basin Sediments (Deeper sandstone units).

These groundwater management areas have been established to allow closer monitoring of groundwater use and to better manage the more intensively developed aquifers in the Central Darling Downs. The availability of groundwater in the Central Darling Downs in relation to water quality is shown in Map 6.

Photo 9 Flood irrigation of sorghum

Further Reading

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6. VEGETATION

Rod Fensham
Bruce Lawrie
Bronwen Jones

6.1 Introduction

"The plains as we passed, were covered with the most luxuriant grass and herbage. Plants of the leguminosae and compositae, were by far the most prevalent; the colour of the former, generally a showy red, that of the latter, a bright yellow. Belts of open forest land, principally composed of the Box-tree of the Colonists (a species of Eucalyptus), separate the different plains; and patches of scrub, consisting of several species of Acacias, and of a variety of small trees, appear to be the outposts of the extensive scrubs of the interior." (Leichhardt, 1847).

Leichhardt's description provides a succinct picture of some broad vegetation patterns in the Central Darling Downs. The passage is useful for its clarity and provides an historical record of vegetation patterns that have become greatly modified during the agricultural development of one of Australia's most fertile districts. A critical insight into the early vegetation communities prior to development for agriculture is found in the records of the land surveyors of the latter part of the nineteenth century.

The vegetation of the district is strongly influenced by the soils and topography of the area. Knowledge of relationships between soil types and vegetation was used extensively in the development of the *Land Resource Areas Map* included in the back pocket of the Land Management Manual.

Summaries of the dominant vegetation for each LRA and soil are located in Tables 4.2 and 4.3 in Chapter 4. The dominant vegetation types, vegetation communities and comments on the remnant status for each vegetation type for each LRA are shown in Table 6.3 (*on page 103*). Further details are included in the soil summary sheets contained in the *Field Manual*.

6.2 Historical description

The open plains that Leichhardt described are the black cracking clays of the alluvial plains (LRAs 1 and 2) to the east of the Condamine River. The older, broad, level plains of basaltic alluvium (LRA 2a) were dominated by an open grassland of Queensland bluegrass. Records show that the fertile and arable soils of this unit did not support trees. It would appear that the cracking clay soils discourage the establishment of tree seedlings. In contrast, dense brigalow scrubs occupy similar landforms on the plains between Jandowae and Brigalow.

This shift from treeless alluvial plain to dense brigalow scrub is related to the change in the geology and the relevant soil characteristics. The source material for the grassland alluvium is largely the basalts of the Great Dividing Range, while the source material for the brigalow alluvium is mostly sedimentary rock. Thus while both the brigalow scrubs and grasslands occur on cracking clays, the physical and chemical differences between these soils is sufficient to produce different vegetation.

It is possible that fires, initiated by lightning strikes or Aborigines, have affected the brigalow-grassland interface. However, despite the lack of burning in recent times, the extent and position of the grassland and brigalow remnants tallies very closely with Leichhardt's description of this country. This interface reflects the more detailed descriptions of the early land surveyors.

The early nineteenth century land surveyors recorded extensive areas of shrubby eucalypt woodlands. Today, large areas of mountain coolibah woodland have dense shrubby understorey similar to softwood scrub. Also, poplar box woodland can have shrubby species that are commonly associated with brigalow. Shrubby understoreys in eucalypt woodland do not appear to be a post-European development.

6.3 Regional ecosystems

Sattler and Williams (1999) described a systematic approach for nature conservation and suggested it essential for the maintenance of biodiversity. This approach provided the framework for the Environmental Protection Agency (EPA) to describe and plan for nature conservation based on regional ecosystems (REs). These are part of a hierarchical framework commencing with the classification of Queensland into Bioregions.

Bioregions, representing the primary level of classification, are large areas over which there is a broadly similar pattern of climate, geology and biota. They are delineated at a scale of 1:2 500 000 or larger, and used for assessment and planning at a national and state-wide level. There are 20 bioregions in Queensland, for example, the South East Queensland Bioregion covers the coastal plains and adjacent hinterland between Gladstone and the Gold Coast. The Central Darling Downs lies in the Brigalow Belt Bioregion which is a very large and complex area covering much of the 500–750 mm per annum rainfall zone from Townsville to the New South Wales Border.

Bioregions can be subdivided into land zones that are areas of similar geology, landforms and soils. They are used to indicate fundamental differences in geomorphological origins and current physical processes. Provinces, a sub-unit of bioregions, are defined by similar patterns of local climate, geomorphology and the associated patterns of soil and vegetation. Provinces are delineated at a scale of 1:250 000 to 1:2 500 000 and used for bioregional assessment and planning. The Brigalow Belt Bioregion has 36 provinces (Sattler and Williams, 1999).

The mapping of REs for each province describes and classifies the vegetation community that identifies the unit. REs broadly correlate to LRAs, which describe plant communities, landform and soil types relating to their underlying geology (*see Chapter 4*). Table 6.4 (*on page 106*) correlates REs with soil types for the Central Darling Downs. Table 6.2 shows the conservation status of REs as either Endangered, Of Concern or Not of Concern. The conservation status of regional ecosystems is based on the percentage extent remaining compared to pre-European coverage (eg <10% = Endangered, 10-30% = Of Concern, >30% = Not of Concern). The conservation status for an RE can change as land is cleared and developed. Geographic information systems (GIS) are used to record data on vegetation and land cover and to update the conservation status of each RE. Regulations are periodically published under relevant legislation to advise the current conservation status of each RE.

6.4 Conservation values

The original vegetation communities of the Central Darling Downs have been greatly modified by the introduction and development of rural enterprises. The most severely affected are the natural grasslands, (LRAs 1a, 2a), that have been reduced to about 1% of their former extent. Some of the largest remnants of this vegetation type are along stock routes, including the Warrego Highway between Oakey and Bowenville.

The area of brigalow, poplar box woodlands and the woodlands on the basalt hills have also been greatly diminished. The white box woodlands represent the best remaining examples of this vegetation type, which once spanned the area from the Central Darling Downs, across the entire breadth of New South Wales, to Victoria.

The Bunya Mountains National Park, Lake Broadwater Conservation Park and Irongate Conservation Reserve are critical reserves, protecting limited areas of the vegetation within the area. State forests are another strategic area that can allow for improved nature conservation, (*see State Forests Section 6.5*). Furthermore, the careful management of roadsides, rail reserves and other public lands, will help the long-term preservation of some rare plants, now restricted to roadsides that are infrequently grazed.

Strategies for nature conservation on private and leasehold land are described in *Nature Conservation,* Section 9.4. Large areas of the natural vegetation of the Central Darling Downs will only be protected where there is an understanding of the importance and value of nature conservation practices. Grazing by domestic stock can be compatible with the preservation of many plant species in native pastures, provided over-grazing does not occur. Many species can be eradicated by mismanagement. *(For further information on land degradation, refer to Chapter 8).*

6.5 State forests

State forests are an important economic, social and environmental resource in the Central Darling Downs. Table 6.1 lists the locality of State forests in the Central Darling Downs and associated LRAs. These reserves are managed by the Queensland Department of Natural Resources (DNR) for multiple uses that include timber production, nature conservation, recreation, water quality, forest grazing, cultural heritage, quarrying, scenic quality and honey production. Map 7 shows the distribution of state forests and other land tenure within the Central Darling Downs.

Table 6.1 State forests within the Central Darling Downs

Local Authority	State Forest	Area (ha)	Land Resource Area (LRA)
Wambo	SF 4 Braemar	14370	10a, 12a, 9a
Wambo	SF 93 Nudley (part)	10700	10a, 12b
Wambo	SF 98 Mahen	580	12b
Wambo	SF 155 Marmadua	84700	10a, 12a, 9a, 11a
Wambo	SF166 Mahen	688	12b
Wambo	SF 183 Miles	1684	12a, 4a
Wambo	SF 187 Daandine	1033	12a, 10a
Wambo	SF 197 Diamondy	5600	12b, 7c, 9a
Wambo	SF 201 Weranga	579	12a, 10a, 6d
Millmerran	SF 131 Millmerran	582	13a

Millmerran	SF 150 Dunmore	19700	12a, 12b, 10a, 6d
Millmerran	SF 154 Western Creek	79457	12a, 12b, 10b, 6c, 9a, 11a, 10a/11a, 6d
Millmerran	SF 189 Western Creek	7636	12a, 12b
Millmerran	SF 229 Domville	239	7c
Millmerran	SF 232 Western Creek	393	12b

There are a variety of forest types across the Central Darling Downs. The northern forests are predominantly spotted gum (*Corymbia citriodora*) while the areas of forest near Millmerran are predominantly white cypress pine (*Callitris glaucophylla*). Narrow-leaved ironbark (*Eucalyptus crebra*) is present across both these forest types. These are the main commercial timber species for the area.

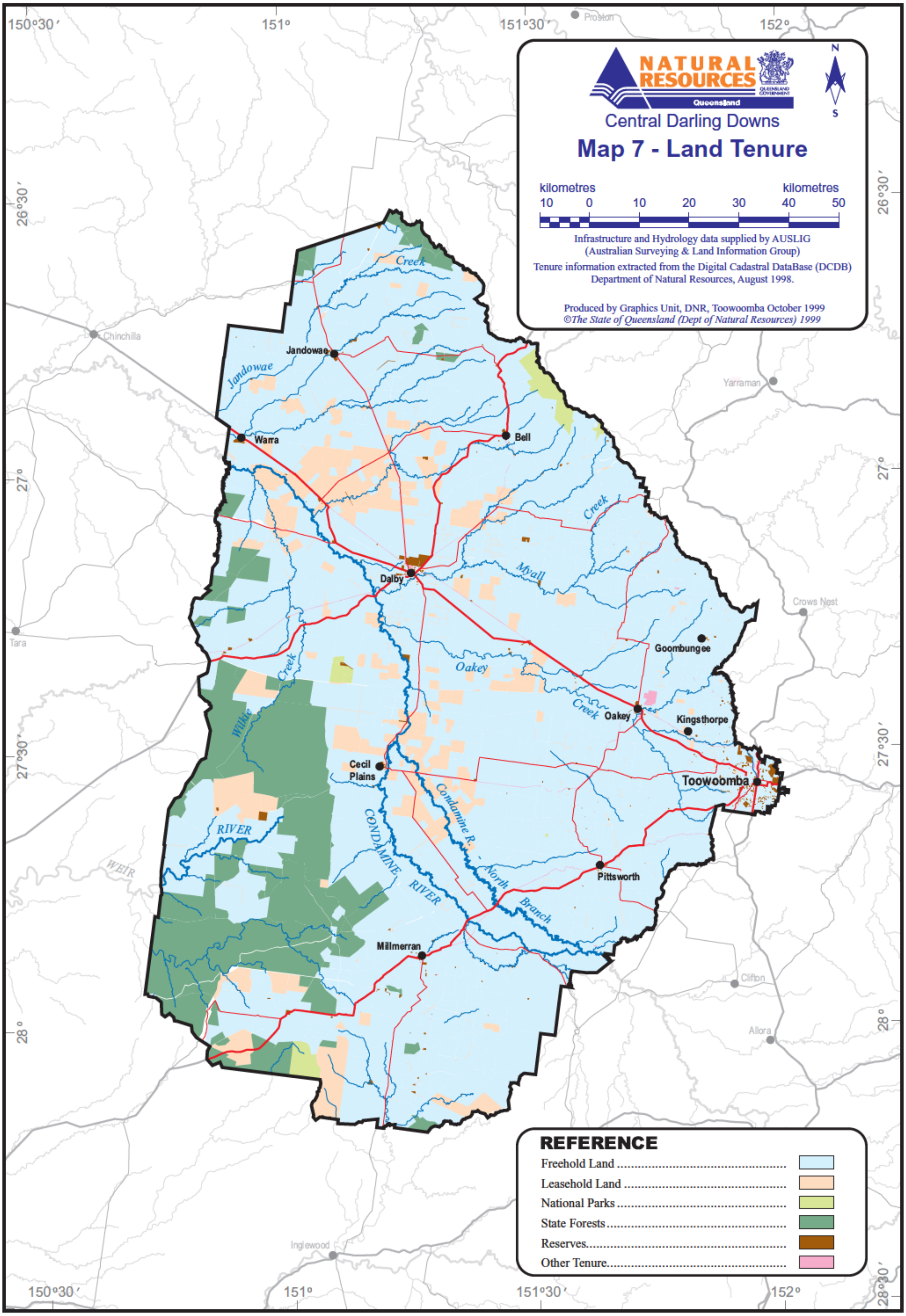
Timber production is a primary use of these forests. Approximately 16 500 m^3 of cypress pine sawlog and a minor volume of hardwood sawlog is harvested annually from State forests in the area. Sale of sawlogs is made on the basis of an annual allocation to ensure sustainable production from the forest resource. The sale of forest products and quarry materials, including sawlogs, is controlled by Department of Primary Industries Forestry (DPIF). Other timber products include fencing and landscaping materials, sleepers and firewood.

Nature conservation on State forests in the Central Darling Downs is managed through an Environmental Management System (EMS) that includes a Species Management Information System (SMIS), Codes of Practice, Multiple Use Management Plans (MUMPS) and monitoring systems. Table 6.4 lists the Endangered, Vulnerable and Rare (EVR) flora and fauna species by State forest that occur in the Central Darling Downs as listed in the SMIS.

Table 6.2 Conservation status of species on Central Darling Downs State forests

Species name	Common name	State Forest	Status[1]
Calyptorhynchus lathami	Glossy-Black Cockatoo	4	Vulnerable
Diplodactylus taenicauda	Golden-tailed Gecko	4	Rare
Paradelma orientalis	Brigalow Scaly-foot	4, 150, 154, 155, 189	Vulnerable
Acacia chinchillensis		155	Vulnerable
Petauras australis australis	Yellow-bellied Glider	131, 197	Of management concern
Eucalyptus rhombica		150, 154	Endangered, Vulnerable or Rare
Eucalyptus curtisii	Plunkett Mallee	154	Rare
Prostanthera spp.		189	Vulnerable

[1] **Endangered.** A species is endangered if its numbers have been reduced to a critical level or its habitat has been so drastically reduced that it may be in danger of extinction; or, a species that has not been sighted in the wild for a period critical to its life cycle although no thorough search has been made for it.
Vulnerable. A species is vulnerable if: its population is decreasing because of threatening processes; or its population has been seriously depleted and its protection is not secured; or its population, while abundant, is at risk because of threatening processes; or its population is low or localised, or is dependent on limited habitat that is at risk because of threatening processes.
Rare. A species is rare if its population is represented by a relatively large population in a restricted range; or smaller populations thinly spread over a wide range.
Of management concern. species that are common under the Nature Conservation Act; and found on State forest or timber reserves; and in the opinion of the PMC either:
- the species is highly likely or known to be significantly adversely impacted by forest management activities, this can include local extinctions or significant disruptions to local populations; or
- the species is likely to become locally extinct on State forest as a result of actions occurring in the regional area, (i.e. may not necessarily be adversely impacted by forest management but may be a remnant population that is susceptible to stochastic events such as wildfire due to clearing of surrounds)


NATURAL RESOURCES
Queensland
Central Darling Downs
Map 7 - Land Tenure
kilometres
kilometres
10 0 10 20 30 40 50
Infrastructure and Hydrology data supplied by AUSLIG
(Australian Surveying & Land Information Group)
Tenure information extracted from the Digital Cadastral DataBase (DCDB)
Department of Natural Resources, August 1998.
Produced by Graphics Unit, DNR, Toowoomba October 1999
©The State of Queensland (Dept of Natural Resources) 1999
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Yarraman
Crows Nest
Tara
Clifton
Allora
Inglewood
Jandowae
Warra
Bell
Dalby
Goombungee
Oakey
Kingsthorpe
Toowoomba
Cecil Plains
Pittsworth
Millmerran
Jandowae
Creek
Creek
Myall
Oakey
Creek
Creek
Wilkie
RIVER
WEIR
CONDAMINE
RIVER
Condamine R.
North
Branch
REFERENCE
Freehold Land
Leasehold Land
National Parks
State Forests
Reserves
Other Tenure

Table 6.3 Dominant vegetation types, vegetation communities and remnant status of various species found in each Land Resource Area

Major vegetation types	Associated species	Comments	Remnant status	LRAs
River red gum (*Eucalyptus camaldulensis*) woodland	Belalie (*Acacia stenophylla*); various grasses and herbs.	Prone to dieback and invasion by 'Condamine couch' (*Phyla canescens*, also known as Lippia;*);* widely cleared except for stream banks; important habitat (food sources and hollows) for arboreal mammals and birds.	5-20% remains	1b
Blue gum (*E. tereticornis*) woodland	Popular box (*E. populnea*) on flats and rough-barked apple (*Angophora floribunda*) on secondary watercourses; Fuzzy box (*E. conica*) can also dominate where the sources of alluvium on secondary watercourses are sedimentary.	Widely cleared except for banks; important habitat for arboreal mammals and birds.	5-20% remains	1a-b 2d
Blue grass grassland	Queensland blue grass (*Dichanthium sericeum*) is typically the dominant grass although oat grass (*Themeda avenacea*) may be locally common.	Includes the eastern-most occurrences of Mitchell grass (*Astrebla lappacea* and *A.elymoides*) and Flinders grass (*Iseilema membracaceum*). These grasslands are near the northern limit for temperate species such as the wallaby grasses (*Danthonia* spp.) and southern spear grasses (*Stipa* spp), while other grasses, such as the northern spear grasses (*Aristida* spp) are not well represented further south. Daisies, sedges, peas, plantains, euphorbs and chenopods and other species form the inter-tussock flora; largely eliminated through cultivation.	<5% remains	2a
Poplar box woodland	Rich understorey of grasses and herbs; dominant grasses include purple wiregrass (*Aristida ramosa*), pitted blue grass (*Bothriochloa pertusa*), and Queensland blue grass (*D. sericeum*); where understories are shrubby brigalow (*Acacia harpophylla*), yarran (*A. omalophylla*), myall (*A. pendula*), belah (*Casuarina cristata*), wilga (*Geijera parviflora*) can be common.	The rare grass *Homophilis belsonii* can be locally common in lightly grazed situations; widely cleared; important habitat for arboreal mammals and birds, including the koala (*Phascolarctos cinereus).*	5-20% remains	2b-d, 3a, 4a, 7b, 8a, 9a 6d, 9b?
Brigalow, belah (*Casuarina cristata*) and yarran scrubs can occur.	Wilga (*G. parviflora*) and sandalwood (*Santalum lanceolatum*)) are commonly associated with these scrubs; a suite of characteristic grasses and herbs can be found in the understories.	Heavily cleared; fauna characterised by a range of species with specialist habitat needs. Yarran scrubs are not common elsewhere in the state and remnants of these scrubs are still evident around Jondaryan.	<5% remains	5a-b, 6a-d

Table 6.3 (cont'd)

Major vegetation types	Associated species	Comments	Remnant status	LRAs
Mountain coolibah (*E. orgadophila*) open woodland.	Kangaroo grass (*Themeda triandra*), Queensland blue grass (*D. sericeum*) and a rich associated herbaceous flora.	Original dominant grass of these open woodlands was almost certainly kangaroo grass, but the understorey in most grazed paddocks now is typically dominated by Queensland blue grass. A number of rare and threatened species including the austral toadflax (*Thesium austrate*), the Australian anchor plant (*Discaria pubescens*), the native thistle (*Stemmacantha australe), Indigofera baileyi* and one of the native hawk weeds (*Picris evae*) are associated with this vegetation type; important habitat for arboreal mammals and birds.	20-50% remains	7a, 7c-d
Other eucalypt woodlands of basalt hills.	Narrow-leaved ironbark (*E. crebra*), silver-leaved ironbark (*E .melanophloia*), white box (*E. albens*), blue gum (*E. tereticornis*) and yellow box (*E. melliodora*); understories are similar to mountain coolibah woodland.	These vegetation types tend to become dominant in slightly more elevated situations closer to the Great Dividing Range, although in many localities the environmental reason for any particular dominant species is obscure; provides extensive habitat for insectivorous and nectivorous birds and mammals.	20-50% remains	7c
Softwood scrub	There are a wide range of dominant species including broad-leaved bottle tree (*Brachychiton australis*) scrub boonaree (*Alectryon diversifolia*), round-leaved myrtle (*Canthium buxifolium*), meemeei (*Pittosporum phyllriaeoides*) and native olive (*Notelaea microcarpa*)	Widely cleared away from steep or rocky terrain; this vegetation is related to rainforest and occurs in fire protected situations; large areas where mountain coolibah has softwood scrub in the understorey; fauna characterised by a range of species with specialist habitat needs.	5-20% remains	6b, 7c
Narrow-leaved ironbark communities with shrubby understoreys	Bull oak (*Allocasuarina leuhmannii*), acacia spp. (*A. crassa, A. burrowii, A. tiptera*) false sandwalwood (*Eremophila mitchellii*) and cypress pine (*Callitris glaucophylla*).	Extensive habitat for insectivorous and nectivorous birds and mammals; *Allocasuarina* seeds are an important food source for the Glossy black cockatoo (*Calyptorhynchus lathami*).	>50% remains	10a, 10b, 12a, 12b
Cypress pine forest	Rough-barked apple (*Angophora floribunda*), blue gum (*E. tereticornis*), bull oak (*Allocasuarina leuhmannii*), narrow-leaved ironbark (*E. crebra*)	This vegetation is prone to changes in structure depending on fire regime; provides extensive habitat for a range of insectivorous birds.	>50% remains	11a
Gum-topped box (*E. pilligaensis*) forest	Poplar box (*E. populnea*), smooth-barked apple (*Angophora leiocarpa*) and Barradine gum (*Eucalyptus chloroclada*) may be locally dominant; Bull oak commonly forms the understorey that becomes most dense where the sub soil is clayey.	Extensive habitat for insectivorous and nectivorous birds and mammals.	>50% remains	6d 9a?

Table 6.3 (Cont'd)

Major vegetation types	Associated species	Comments	Remnant status	LRAs
Blue-leaved ironbark (*E. fibrosa* sub. *nubila*)	Gum topped ironbark (*E. decorticans*), spotted gum (*Corymbia citriodora*), budgeroo (*Lysicarpus angustifolius*), Bakers mallee (*E. bakeri*) and Queensland peppermint (*E. exserta*) may be locally dominant.	Extensive habitat for insectivorous and nectivorous birds and mammals.	>50% remains	9b?
Eucalypt forest associated with traprock	Dominant species on the traprock areas include narrow-leaved ironbark, brown box (*E. mollucana*) tumbledown gum (*E. dealbata*) with white gum and yellow box on adjacent alluvial flats	Limited extent in the south of the study area. Habitat for the rare Regent honeyeater (*Xanthomyza phrygia)*. Important habitat for insectivorous and nectivorous birds and mammals	>50% remain	13a
Eucalypt forest associated with granite	The granite areas are likely to support narrow leaved ironbark, yellow box and blue gum (*E. tereticornis*).	Limited extent in the south of the study area. Important habitat for insectivorous and nectivorous birds and mammals.	>50% remains	14a

Table 6.4 Correlation of soils and Regional Ecosystems for the Central Darling Downs. (from Sattler and Williams, 1999)

Soil	Vegetation, landform and geology	Regional Ecosystem	Conservation Status [1]
Aberdeen	Mountain coolibah and rough-barked apple; gently undulating plains and rises; basalt	11.8.5	No concern at present
Acland	Open forest of belah and wilga, poplar box, brigalow and scrub species may occur; mid to upper slopes of undulating rises and low hills; sandstone	11.9.5	Endangered
Allan	Open forest of narrow-leaved ironbark, spotted gum, bull oak, cypress pine, rusty gum and poplar box, occasional brown box with yellow box and fuzzy box south of Millmerran; gently undulating sandstone plains and rises; sandstone (arenaceous)	11.5.1, 11.10.1, 11.7.4, 11.3.23	No concern at present Endangered
Anchorfield	Open grassland of Queensland blue grass, occasional poplar box and Queensland blue gum; gently sloping to flat alluvial plains	11.3.21 11.3.4	Endangered Of concern
Arden	Brigalow with belah and occasional poplar box, understorey of wilga and false sandalwood; lower slopes of gently undulating plains to rises; clayey alluvium	11.9.5	Endangered
Aubigny	Poplar box and Moreton bay ash woodland, occasional mountain coolibah; gently undulating low basalt hills and rises	11.8.5	No concern at present
Banca	New England blackbutt shrubby open forest to woodland with tumble down gum, Youman's stringybark, Caley's ironbark and broad-leaved stringybark; undulating to rolling granite hill; Herries adamellite	13.12.2	No concern at present
Beauaraba	Mountain coolibah and narrow-leaved ironbark woodland, may have a softwood scrub understorey; upper slopes on low hills and crests of ridges; basalt	11.8.3, 11.8.8 11.8.5	Of concern No concern at present
Belahville	Brigalow, poplar box, belah, sandalwood forest with lime bush and yarran; levees and terraces of marginal and dissecting creeks within the brigalow plains; alluvium	11.4.10	Endangered
Binkey	Grassy woodland to open forest of narrow-leaved ironbark and bull oak, some cypress pine and rusty gum; gently undulating plains and dissected low hills; sandstone	11.5.1	No concern at present
Braemar	Open forest of bull oak or bull oak and cypress pine with associated narrow-leaved ironbark, rusty gum and occasionally paperbark tea tree; gently undulating sandstone plains	11.5.1	No concern at present
Burton	Open woodland of mountain coolibah, narrow-leaved ironbark, or rough-barked apple box; gentle slopes (<5%) and on broad flat basalt ridges	11.8.5, 11.8.4	No concern at present
Calingunee	Tall, open forest of brigalow with belah and occasional poplar box., understorey of wilga and false sandalwood; gently undulating plains or rises; labile sedimentary rocks	11.9.5	Endangered
Cecilvale	Poplar box grassy woodland with some scattered wilga; elevated plains of mixed alluvium	11.3.2, 11.3.17	Of concern Endangered
Channing	Narrow-leaved ironbark open forest with cypress pine, bull oak, rusty gum and wattles, or open forest of grey box, rough-barked apple, tumbledown gum and narrow-leaved ironbark with some poplar box, in the south; low sandstone hills and undulating sandstone plains	11.5.1	No concern at present
Charlton	Mountain coolibah and narrow-leaved ironbark open woodland; mid to upper slopes on rises to low hills; basalt	11.8.5, 11.8.4	No concern at present
Chinchilla	Forest of rough-barked apple, Moreton Bay ash and sally wattle, associated species include poplar box, cypress pine, wilga and false sandalwood; terraces, sand ridges and flats of alluvial plains; sandstone alluvium	11.3.14	No concern at present

Table 6.4 (Cont'd)

Soil	Vegetation, landform and geology	Regional Ecosystem	Conservation Status [1]
Clayburn	Open forest of brigalow, wilga and black tea tree associated with melonholes, some gum topped or poplar box in clumps; mid to lower slopes of undulating rises and low hills; sandstone	11.9.5	Endangered
Combidiban	Open forest of cypress pine, rusty gum and tumbledown gum; associated species include rough-barked apple, Queensland blue gum and Moreton Bay ash, occasionally bull oak; flat to gently undulating alluvial plains; sandstone	11.3.14	No concern at present
Condamine	Woodland to open forest of river red gum, Queensland blue gum, and some acacia species; alluvial plain	11.3.4	Of concern
Cottonvale	New England blackbutt shrubby open forest to woodland with New England peppermint, tumbledown gum, Youman's stringybark, Caley's ironbark and broad-leaved stringybark; undulating to rolling hills and ridges; granite	13.12.2	No concern at present
Craigmore	Mountain coolibah open woodland to grassland; mid to lower slopes of basalt rises and hills	11.8.5	No concern at present
Cutthroat	Open forest of cypress pine and bull oak with associated species including narrow-leaved ironbark, rusty gum and tumbledown gum; low sandstone hills and gently undulating sandstone plains	11.5.1, 11.5.4, 11.10.9	No concern at present
Davy	Open forest of Queensland blue gum, rough-barked apple, cypress pine, rusty gum and tumbledown gum; flat to gently undulating alluvial plains draining the sandstone hills	11.3.14	No concern at present
Diamondy	Bottle tree softwood scrub or shrubby forest of narrow leaved ironbark and poplar box with softwood scrub species, occasional brigalow; upper slopes (2-4%) of undulating sandstone rises and undulating broad sandstone ridges	11.9.4	Of concern
Downfall	Poplar box grassy woodland with wilga, occasional bull oak and grey box, rough-barked apple and Queensland blue gum; flat plains and very gently sloping (<1%) valley floors of mixed sandstone and basalt alluvium	11.3.2 11.3.18	Of concern No concern at present
Drayton	Mountain coolibah, white box, narrow-leaved ironbark woodland; gently undulating plains; basalt	11.8.8 11.8.2	Of concern No concern at present
Drome	Open forest of Queensland blue gum, rough-barked apple, cypress pine, rusty gum, narrow-leaved ironbark; gently undulating sandstone rises and plains	11.5.4	No concern at present
East	Open forest of poplar box and wilga intermixed with softwood scrub species, occasional brigalow, belah, bottle trees, crows ash and narrow leaved ironbark; gently undulating to undulating broad sandstone ridges	11.9.7, 11.9.4, 11.9.9	Of concern
Edgefield	Open forest of brigalow, belah and wilga; lower slopes (1-3%) and valley floors of gently undulating plains to rises and low hills; alluvium	11.9.5	Endangered
Elphinstone	Open woodland of poplar box, associated species include narrow-leaved ironbark and Queensland blue gum; slopes (2-6%) of gently undulating to undulating plains and rises; sandstone (argillaceous)	11.9.7	Of concern
Flinton	Open forest of narrow-leaved ironbark and spotted gum with red ash, quinine bush, black wattle and other acacia species; sandstone rises and undulating plains	11.5.9, 11.10.1	No Concern at present
Formartin	Grassy open woodland of poplar box and occasionally Moreton Bay ash; flat alluvial plains	11.3.2	Of concern

Table 6.4 (Cont'd)

Soil	Vegetation, landform and geology	Regional Ecosystem	Conservation Status[1]
Gammie	Brown box grassy woodland with fuzzy box and yellow box or mugga ironbark and broad-leaved red ironbark shrubby open forest; undulating low traprock hills and isolated traprock knolls	13.11.3, 13.11.5 13.3.4	No concern at present Endangered
Gate	Open forest of brigalow, belah and wilga with black tea tree, occasional gum top box; mid to upper slopes and broad ridges; sandstone	11.9.5	Endangered
Hanmer	Narrow leaved ironbark and blue gum shrubby/grassy woodland with tumble down gum and broad leaved stringybark, vine thicket or "softwood scrub"; flat topped sandstone ridges and steep scarps	11.7.4	No concern at present
Haslemere	Grassy open woodland of poplar box and wilga with scattered Queensland blue gum and Moreton Bay ash; alluvial plains	11.3.2	Of concern
Irving	Woodland to open forest of mountain coolibah; occurs on mid and lower slopes of low hills and rises; basalt	11.8.5	No concern at present
Karangi	Layered open forest of narrow-leaved ironbark, dusky-leaved ironbark and tumbledown gum with some grey box, yellow box, spotted gum and wattles; undulating to rolling low traprock hills and ridges	13.11.3, 13.11.5	No concern at present
Kenmuir	Grassy forest to tall woodland of narrow-leaved ironbark or mountain coolibah, may have a softwood scrub understorey; steep hillslopes and scarps (10-20% or steeper) and crests of flat-topped and rounded low hills to hills; basalt	11.8.3, 11.8.8 11.8.4, 11.8.5	Of concern No concern at present
Knoll	Open forest of narrow-leaved ironbark, broad-leaved red ironbark, blue-leaved ironbark, spotted gum and rusty gum with some cypress pine, wattles and poplar box; rocky hilltops, drop-offs or steep hillslopes; sandstone	11.7.4	No concern at present
Kupunn	Brigalow, belah, wilga scrub, black tea tree; flat to very gently undulating brigalow clay plains	11.4.3	Endangered
Kurumbul	Open forest of belah with occasional brigalow, poplar box or gum-topped box, understorey of wilga and false sandalwood; elevated, level plains and undulating rises; alluvium	11.3.17	Endangered
Langlands	Brigalow, belah, wilga scrub, black tea tree; flat to very gently undulating brigalow plains	11.4.3	Endangered
Leyburn	Poplar box grassy woodland with wilga; or poplar box, gum topped box open forest; flat plains and very gently sloping (<1%) valley floors of mixed sandstone and traprock alluvium	11.3.2 11.3.26	Of concern No concern at present
Mallard	Woodland of mountain coolibah; upper slopes and broad flat ridges on basalt	11.8.5	No concern at present
Middle Ridge	Blue gum woodland; gently undulating plains on basalt	11.8.2	No concern at present
Millmerran	Poplar box grassy woodland with some wilga, belah and Queensland blue gum, occasional clumps of brigalow; elevated plains and very gently sloping (<1%) valley floors of mixed sandstone and basalt alluvium	11.3.2 11.3.17	Of concern Endangered
Moola	Open forest of brigalow, belah and wilga, occasional sandalwood and softwood scrub species; lower and mid slopes and broad ridges of undulating to rolling rises and low sandstone hills	11.9.5	Endangered
Moruya	Tall open forest of belah with occasional brigalow, understorey of wilga and false sandalwood; gently undulating plains or rises; labile sedimentary rocks	11.9.5	Endangered
Murra Cul Cul	Tall, open woodland of poplar box with occasional belah or myall. Understorey of false sandalwood and wilga; level or gently undulating, narrow, alluvial plains	11.3.2 11.3.17	Of concern Endangered

Table 6.4 (Cont'd)

Soil	Vegetation, landform and geology	Regional Ecosystem	Conservation Status [1]
Mywybilla	Grassland of Queensland blue grass or grassy tall open woodland with Queensland blue gum; gently sloping to flat alluvial plains	11.3.4 11.3.21	Of concern Endangered
Nudley	Poplar box woodland on alluvial plains with associated cypress pine, understorey of false sandalwood, wilga, sally wattle, myall and beefwood, Moreton Bay ash, Queensland blue gum and rough-barked apple occur on creek terraces; flat alluvial plains and terraces	11.3.2, 11.3.4	Of concern
Nungil	Poplar box grassy woodland with Moreton Bay ash; gently sloping rises (0-3%), benches or mid to lower slopes in the basalt uplands	No equivalent RE	
Oakey	Poplar box grassy open woodland; flat mixed sandstone and basalt alluvial plains	11.3.2	Of concern
Purrawunda	Mountain coolibah woodland; mid to lower slopes (4-8%) of basalt rises to low hills	11.8.5	No concern at present
Ruthven	Blue gum woodland; gently undulating plains on basalt	11.8.8	Of concern
Southbrook	Woodland of narrow-leaved ironbark, rough-barked apple, mountain coolibah; upper slopes, benches and flat-topped ridges of undulating basalt rises to hills	11.8.4	No concern at present
Talgai	Woodland of poplar box with some narrow-leaved ironbark; often with a thick understorey of wilga; slopes (3-6%) and hilltops of dissected low sandstone hills; sandstone (argillaceous)	11.9.7	Of concern
Tandawanna	Belah forest, occasionally with brigalow and some poplar box, understorey: false sandalwood and wilga; elevated, level plains and undulating rises; sandstone	11.9.5	Endangered
Tara	Brigalow, belah scrub, black tea-tree; flat to very gently undulating brigalow plains	11.4.3	Endangered
Toolburra	Woodland of poplar box or silver leaved ironbark often with a thick understorey of wilga, wattles and occasional softwood scrub species; gently undulating to undulating broad sandstone ridges and slopes (3-6%)	11.9.2, 11.9.7	Of concern
Toowoomba	Blue gum woodland; gently undulating plains on basalt	11.8.8	Of concern
Waco	Open grassland of Queensland blue grass; gently sloping to flat alluvial plains	11.3.21	Endangered
Walker	Brigalow, belah, wilga open forest with poplar box and softwood scrub species; upper slopes of undulating sandstone rises	11.9.5	Endangered
Weranga	Shrubby woodland of poplar box with bull oak and narrow-leaved ironbark; gently undulating sandstone plains	11.5.1	No concern at present
Wynhari	Tall open forests of belah with occasional brigalow, understorey of wilga and false sandalwood; gently undulating plains or rises; labile sedimentary rocks	11.9.5	Endangered
Yargullen	Open grassland of Queensland blue grass, occasional Queensland bluegum; lower slopes, valley floors and alluvial fans originating from basaltic uplands	11.3.21	Endangered

[1] **Endangered**: <10% of pre-European extent remains in an intact condition across the bioregion, or its distribution has contracted to <10% of its former range.
Of concern: 10–30% pre-European extent remains in an intact condition in the bioregion.
No concern at present: >30% of pre-European extent remains in an intact condition in the bioregion.

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7. AGRICULTURAL LANDUSE

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7.1 Introduction

Landuse in the five shires of the Central Darling Downs embraces a diverse range of industry. Table 7.1 lists the areas of broad land cover in the Central Darling Downs, which are illustrated in Maps 8a and 8b. The number of establishments and the value of production for each industry are outlined in Table 7.2 (*on page 117*). The major agricultural land uses within the Central Darling Downs are grain and cotton growing, beef cattle, dairy cattle and pig farming.

Table 7.1 Broad land cover in the Central Darling Downs

Description	Area (km^2)	% of Total Area
Urban Areas	59	0.4
Crops/ Grassland	10765.4	72.1
Woodland	784.9	5.3
Open forest	3229.8	21.6
Closed forest	75.2	0.5
Water	7.1	0.1
Total Area	14921.4	100.0

Source: MDBC Project M305 (1995)

The fertile soils and climate of the region are capable of growing a wide variety of crops. The area planted to crop is driven by market demand, and the likely on-farm price of the produce. Soil type has a major influence on enterprise selection. The main limitations to long-term cropping enterprises are decreasing soil fertility, the risks of soil structural degradation, soil erosion, and the security of good quality irrigation water supplies. Land and environmental degradation issues, including decline in soil fertility, structural breakdown and soil erosion are discussed in detail in Chapter 8. Chapter 9 discusses the strategic planning and management of significant issues.

Grain and forage production in the region has generated the establishment of intensive livestock enterprises. A number of year-round cattle feedlots, large piggeries and poultry farms exist in the region (Map 9*)*.

The Central Darling Downs supports extensive grazing industries for beef, sheep and dairy production. Extensive grazing is based on native pastures and also occurs on mixed farming enterprises combining grain and fodder production.

Timber production from on-farm forest resources is another important enterprise within the Central Darling Downs.

A number of other minor industries have developed in the area due to the diversity of soils, proximity to markets and a favourable climate. For example, horticulture, floriculture, horse and goat studs, ostriches and emus.

7.2 Cropping lands

Cropping for grain and cotton production is one of the largest agricultural land uses and industries within the Central Darling Downs (*Table 7.2 on page 117*). Cultivation for cropping and/or sown pasture is carried out to some extent in all LRAs except in the more fragile and unproductive sodosols and sands in the west of the region (LRAs 10, 11, 12, 13, 14). While both summer and winter crops are grown, summer crops are preferred due to higher economic returns and the summer dominant rainfall patterns on the Central Darling Downs.

The deep black and grey clays of the Recent and Older Alluvial Plains (LRAs 1a, 1b, 2a–c), and brigalow plains (LRA 5a) are the most intensely used for grain, oil, fibre and some fodder crops, using irrigation or a fallow management system.

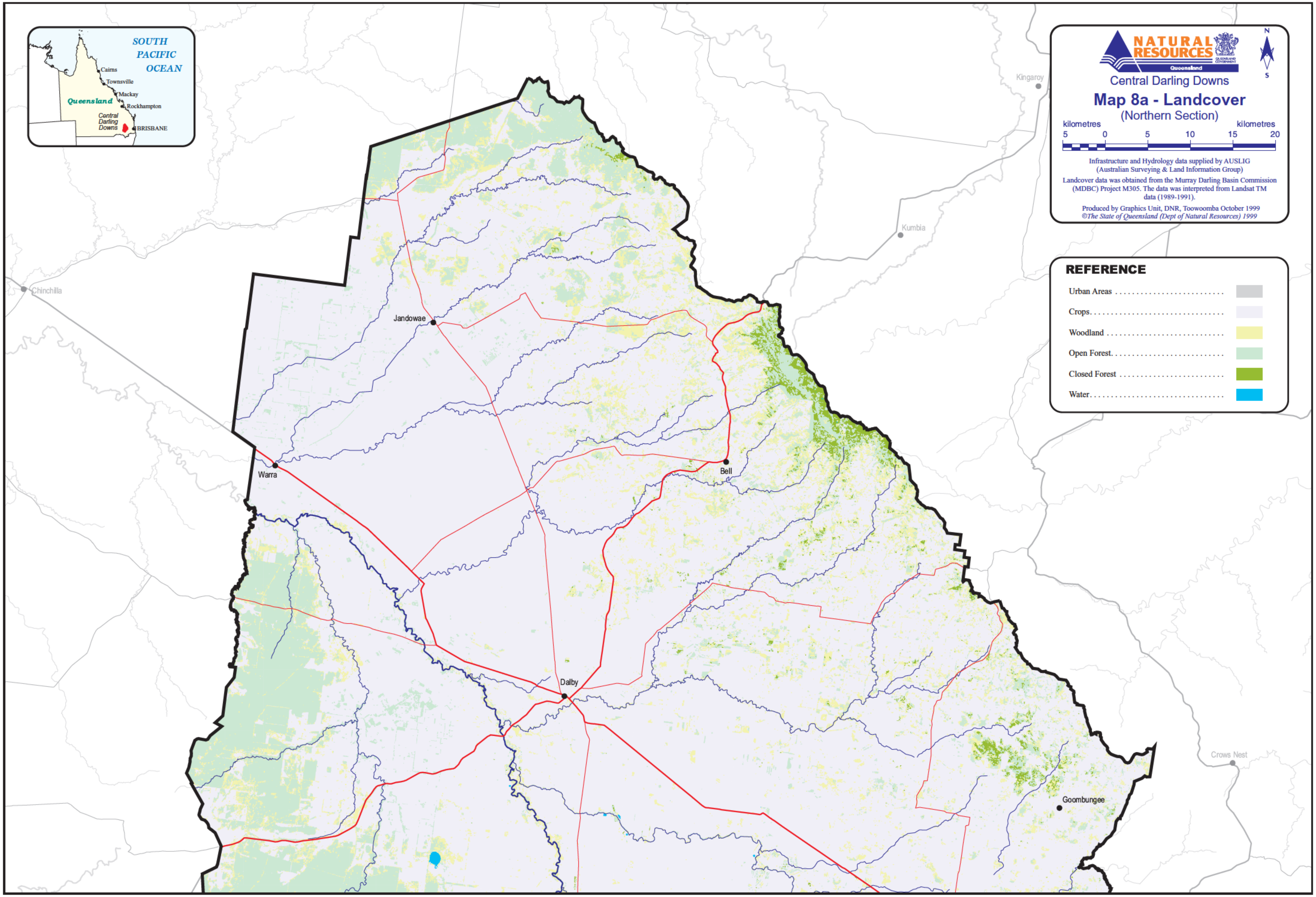
Marginal cropping soils of the Loamy, Sandy and Poplar Box Sodosols (LRAs 3, 4, 9) are used for winter grain and forage cropping.

The shallower brigalow/belah grey, brown cracking clays (LRAs 5b, 6a–d), are used for opportunity summer cropping, winter grain and forage crops. Crops in the eastern uplands (LRAs 7a and 8a) depend largely on seasonal soil moisture or, in limited areas, irrigation, where it is available. Grain and forage crops, both summer and winter, are grown as well as sown pastures. Table 7.3 (*on page 118*) shows the area and production of grain and fibre crops for the Central Darling Downs.

Photo 10 Herbicides are used for fallow weed control

7.2.1 Field crops

Main summer crops in the Central Darling Downs are cotton and grain sorghum followed by mung beans, millets, sunflowers, maize and soybeans. Wheat and barley are the main winter crops, with chickpeas increasing in importance. Summer and winter forage crops are also grown for grazing and/or harvesting as hay or silage (*see Table 7.4 on page 121*).



SOUTH PACIFIC OCEAN
Cairns
Townsville
Mackay
Queensland
Rockhampton
Central Darling Downs
BRISBANE
NATURAL RESOURCES
Queensland
Central Darling Downs
Map 8a - Landcover
(Northern Section)
kilometres
5
0
5
10
15
20
kilometres
Infrastructure and Hydrology data supplied by AUSLIG
(Australian Surveying & Land Information Group)
Landcover data was obtained from the Murray Darling Basin Commission (MDBC) Project M305. The data was interpreted from Landsat TM data (1989-1991).
Produced by Graphics Unit, DNR, Toowoomba October 1999
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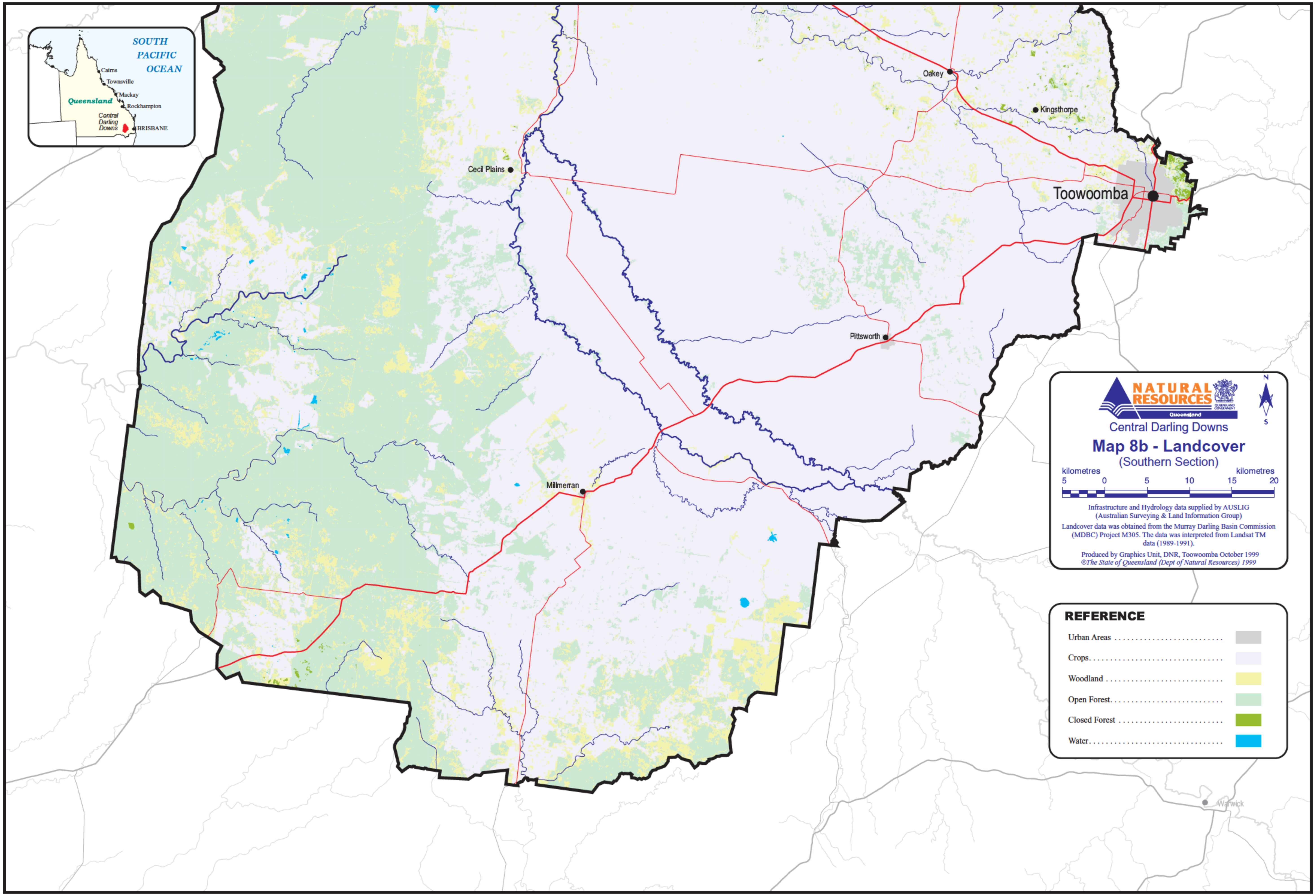
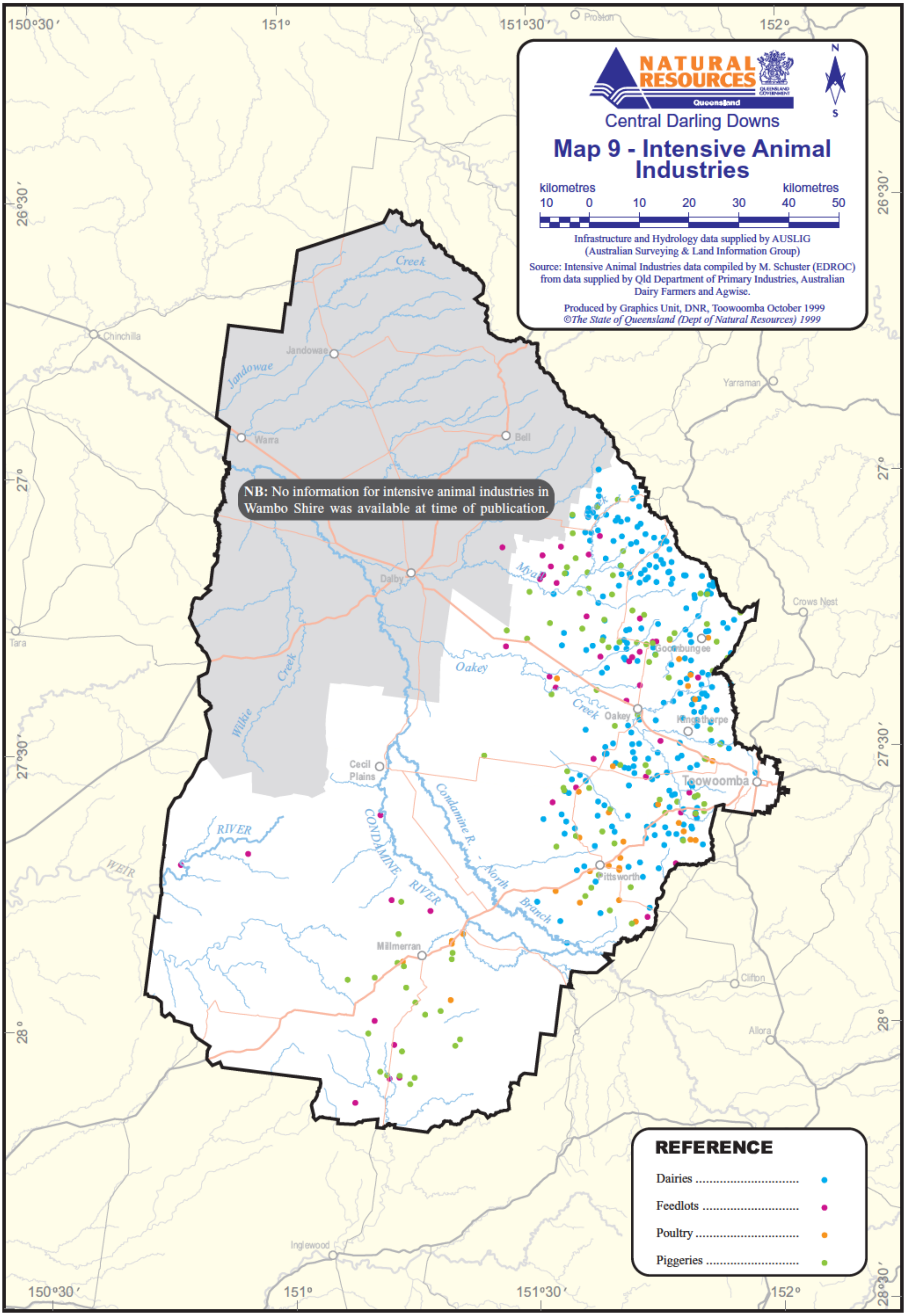
REFERENCE
Urban Areas
Crops
Woodland
Open Forest
Closed Forest
Water
Kingaroy
Kumbia
Chinchilla
Jandowae
Warra
Bell
Dalby
Goombungee
Crows Nest



SOUTH PACIFIC OCEAN
Cairns
Townsville
Mackay
Queensland
Rockhampton
Central Darling Downs
BRISBANE
Oakey
Kingsthorpe
Cecil Plains
Toowoomba
Pittsworth
Millmerran
Warwick
NATURAL RESOURCES
Queensland
Central Darling Downs
Map 8b - Landcover
(Southern Section)
kilometres
kilometres
5 0 5 10 15 20
Infrastructure and Hydrology data supplied by AUSLIG (Australian Surveying & Land Information Group)
Landcover data was obtained from the Murray Darling Basin Commission (MDBC) Project M305. The data was interpreted from Landsat TM data (1989-1991).
Produced by Graphics Unit, DNR, Toowoomba October 1999
©The State of Queensland (Dept of Natural Resources) 1999
REFERENCE
Urban Areas
Crops
Woodland
Open Forest
Closed Forest
Water



NATURAL RESOURCES
Queensland
Central Darling Downs
Map 9 - Intensive Animal Industries
kilometres 10 0 10 20 30 40 50 kilometres
Infrastructure and Hydrology data supplied by AUSLIG (Australian Surveying & Land Information Group)
Source: Intensive Animal Industries data compiled by M. Schuster (EDROC) from data supplied by Qld Department of Primary Industries, Australian Dairy Farmers and Agwise.
Produced by Graphics Unit, DNR, Toowoomba October 1999
©The State of Queensland (Dept of Natural Resources) 1999
NB: No information for intensive animal industries in Wambo Shire was available at time of publication.
REFERENCE
Dairies
Feedlots
Poultry
Piggeries
Chinchilla
Jandowae
Warra
Bell
Dalby
Yarraman
Crows Nest
Goombungee
Oakey
Kingsthorpe
Toowoomba
Cecil Plains
Pittsworth
Millmerran
Clifton
Allora
Inglewood
Tara
Proston
Jandowae
Creek
Myall
Oakey Creek
Wilkie Creek
CONDAMINE RIVER
Condamine R. - North Branch
RIVER
WEIR
150°30′
151°
151°30′
152°
26°30′
27°
27°30′
28°
28°30′

Table 7.2 Number of Establishments and Value of Production by Industry Class for Local Government Areas, QLD, 1996-97

Local Government	Jondaryan		Millmerran		Pittsworth		Rosalie		Toowoomba		Wambo		Total	
Industry Class	All Agricultural Establishments		All Agricultural Establishments		All Agricultural Establishments		All Agricultural Establishments		All Agricultural Establishments		All Agricultural Establishments		All Agricultural Establishments	
	No. of Estabs	Prod^{n} Value $	No. of Estabs	Prod^{n} Value $	No. of Estabs	Prod^{n} Value $	No. of Estabs	Prod^{n} Value $	No. of Estabs	Prod^{n} Value $	No. of Estabs	Prod^{n} Value $	No. of Estabs	Prod^{n} Value $
Grain growing	157	36 772 180	141	38 863 531	115	21 768 356	114	13 303 330	1	284 438	431	74 352 920	958	185 344 755
Cotton growing	76	30 463 148	49	40 336 435	59	34 237 148	6	1 325 085			118	55 610 927	308	161 972 743
Beef cattle farming	214	23 096 690	187	10 158 846	183	3 238 997	440	13 124 380	2	48 110	468	32 251 130	1492	81 918 150
Dairy cattle farming	77	9 619 458	5	257 558	39	4 217 515	169	22 055 110	1	271 114	51	5 878 087	341	42 298 842
Pig farming	21	3 335 252	24	9 707 236	13	1 335 517	76	3 815 715			51	14 397 927	185	32 591 647
Poultry farming (eggs)	4	227 865	3	5 415 845	8	6 490 669	3	336 988			2	66 990	20	12 538 357
Vegetable growing	9	1 155 354	5	1 898 156	1	2 139 239	4	64 318	1	134 018	5	175 442	24	5 566 527
Cut flower and flower seed	3	1 779 480	1	19 772	1	7 909	2	474 528			6	1 779 480	11	4 061 169
Sheep farming	16	163 616	21	1 456 507	15	64 138		45 240			34	710 413	86	2 439 914
Grain-sheep/beef cattle farming	55		83		57		56		1		143		395	
Sheep-beef cattle farming	2		11		1						5		19	
Poultry farming (meat)	4	38 030	3	574 332	11	918 273	6	27 940			2	5 048	26	1 563 623
Plant nurseries	3	95 882	1	43 583					4	139 464	0		4	278 929
Fruit growing [1]	5	31 926	1	14 066			4	885	4	116 291	4	26 990	18	190 158
Stone fruit growing	2	14 226											2	14 226
Other Industries														
Grape growing											3	239 759	3	239 759
Horse farming	78		50		68		135		1		159		491	
Ostriches	2		1				2				6		11	
Emus	1												1	
Other livestock farming [2]	7		5		2		9		1		9		33	

[1] – other small specialised fruit growing enterprises
[2] – includes donkeys, goats, bees, camels, deer, alpacas and ducks
Source: Australian Bureau of Statistics, 1997.

Table 7.3 Area (hectares) and production (tonnes and bales) of grain and fibre crops for the Central Darling Downs 1993-1994 (Source: ABS, 1997.)

Crop	Units	Jondaryan	Millmerran	Pittsworth	Rosalie	Wambo	% of Qld Total	Qld Total
Total area of holding	ha	173196	370190	100809	191840	547161	0.90%	152569197
Crops and pastures - total area	ha	91992	80881	56416	47687	196117	19.20%	24681334
Wheat for grain area	ha	10209	15170	8072	4703	30997	12.50%	555539
Wheat for grain - production	*t*	12977	27062	14915	4366	36574	17.30%	555378
Barley for grain area	ha	19809	23538	13357	9502	37558	44.70%	232217
Barley for grain - production	*t*	26038	31475	19518	9264	37362	47.50%	260539
Grain sorghum for grain area	ha	25920	14163	12382	6762	60004	29.90%	398746
Grain sorghum for grain - production	*t*	76287	29977	24332	10965	189901	38.90%	851594
Maize for grain area	ha	2159	661	670	281	1385	18.70%	27618
Maize for grain production	*t*	6526	1881	3421	601	5661	20.80%	87118
Cereal crops for grain - total area	ha	61965	59175	36855	25478	143832	25.70%	1273180
Cereal crops for grain - total production	*t*	126653	94300	64021	29459	282455	33.20%	1800526
Mung and other dry edible beans - total area	ha	1942	2507	1752	171	7320	41.30%	33182
Mung and other dry edible beans - total production	*t*	1609	1667	1066	90	6562	55.50%	19814
Soybeans area	ha	1055	461	554	190	1031	19.90%	16532
Soybeans production	*t*	1379	736	924	275	1932	17.90%	29235
Cotton - irrigated area	ha	3496	4156	3384	40	3820	31.30%	47539
Cotton - irrigated production (seed)	*t*	13645	13358	13593	140	14538	29.30%	188383
Cotton - irrigated production (raw)	*Bales*	21468	21016	21385	220	22873	29.30%	296385
Cotton - non irrigated area	ha	3175	2767	3993	906	9846	57.20%	36068
Cotton - non irrigated - production (seed)	*t*	3802	3772	4351	814	16346	74.40%	39115
Cotton - non irrigated production (raw)	*Bales*	5981	5934	6845	1281	25717	74.40%	61539
Cotton - total area	ha	6672	6923	7316	946	13665	42.50%	83606
Cotton - total production (seed)	*t*	17447	17130	17944	954	30884	37.10%	227497
Cotton - total production -(raw)	*Bales*	627449	2950	288230	1501	48590	37.10%	357792
Total oil seeds area	ha	4237	1440	1330	654	3658	12.90%	87912
Total oilseeds - production	*t*	5145	1846	1790	630	4559	17.10%	81748
Legumes for grain - total area	ha	3476	3272	2527	614	10439	44.00%	46175
Legumes for grain - total production	*t*	2335	2294	1582	302	8119	50.60%	28944
Cow and field peas for grain - total area	ha	40	162	0	65	270	34.30%	1564
Cow and field peas for grain - total production	*t*	8	45	0	4	85	30.10%	472

Sunflowers are temperate in nature and are usually sown in September/October or December/January. Millets and panicum species are suited to lighter surface soils (loam/light clay) and are a preferred crop in the Jandowae, Moola, Acland, Oakey and Millmerran areas. Planted in October/December they are harvested in 3 to 4 months. Maize requires a significant amount of plant available water and is usually grown under irrigation and harvested after 5 to 6 months. Soybeans are usually planted in December. Mungbeans are a quick growing grain legume planted in December/January. Navy beans have a similar growth cycle but are usually grown under irrigation on lighter soils. For more information on field crops refer to Crop Management Notes (DPI, 1996; DPI, 1998).

Crop rotation

Farming systems throughout the region incorporate the rotation of different crops. Grain legumes such as chickpeas and mungbeans are used in low nitrogen situations (e.g. old cultivation or where double cropping is practised). These leguminous crops will fix enough nitrogen from the atmosphere for their own use and therefore do not require nitrogenous fertiliser. Normally, some residual nitrogen will be available for the next crop. The main agronomic benefit of crop rotation, apart from providing stubble cover, is the breaking of disease and weed cycles. For example, crown rot in wheat or barley can be managed successfully by rotating with chickpeas or a summer crop. Winter weeds in wheat (e.g. wild oats and wild canary) can be virtually eliminated through a rotation with grain sorghum and by using a residual herbicide, such as, Atrazine™.

Fallow management

A fallow, defined as the rest period between crops, is used to increase soil moisture reserves and is an integral part of farming systems on the Central Darling Downs. While the key aim is to conserve soil moisture, fallows are also useful for breaking disease and pest cycles.

The key objective of fallow management is to keep the land free of weeds that can deplete soil moisture reserves. A feature of modern fallow management is the adoption of conservation cropping practices such as retaining stubble from previous crops on the surface and using herbicides for weed control. These practices maximise infiltration of rainfall, help reduce runoff and minimise land degradation. For more information on conservation cropping practices see Section 9.8.

The length of a fallow is usually less than 6 months, but is influenced by seasonal conditions and crop rotation choices. If soil moisture reserves are rapidly replenished during a wet season, an opportunity crop such as mungbeans, chickpeas or barley is planted. Long fallows of 12 months or more are used for high value crops such as cotton and when rotating out of ley pastures. A minimum of 200 mm of plant available moisture is required at planting of dryland cotton to reduce the risk of crop failure.

Pasture leys

Grain farms on the Central Darling Downs with a long history of crop production show soil fertility and structure decline. Rotation with a mixed grass/legume pasture ley has helped to restore organic matter levels and provided improvement in the grain quality of subsequent crops.

Where nitrogen fertility has significantly declined, a long-term (three to five years) rotation with lucerne can rebuild soil nitrogen reserves to a level adequate for cropping for another three to five years. A rotation with a grass/legume pasture (e.g. Rhodes and/or purple pigeon grass with lucerne and barrel medic) will improve surface structure (through increased organic matter) as well as nitrogen fertility, for a longer period. Many properties on the Recent Alluvial Plains (LRA 1) do not have the complementary livestock facilities (fences, watering points etc) and cannot currently exercise this option. This means they need to rely on the use of artificial fertilisers in conjunction with conservation cropping practices to address fertility and soil structure decline in cropping lands (*see Section 9.8*).

7.2.2 Horticulture

Vegetable and fruit growing enterprises are of minor agriculture importance on the Central Darling Downs (*see Table 7.2*). It is recommended that wide spread consultation be carried out before investing in the horticultural industry. The fresh vegetable market is oversupplied and niches such as the production of organic vegetables, hydroponics, seedling production or fine quality olive oil need to be recognised. Any future expansion of the industry is dependent on the export market.

Successful horticultural enterprises in the Central Darling Downs are dependent on a number of factors. Farmers must accurately match soil type, irrigation method and crop choice while taking into account the microclimate of the area. This involves considering the extremes of temperatures that can occur, the summer rainfall pattern and the low rainfall reliability. Large areas of the Central Darling Downs have soils that are suitable for horticultural production however, limited supplies of water restrict the areas that can be used for production.

The Toowoomba Plateau has milder summers and winters than other horticultural areas (e.g Lockyer Valley), allowing some production of crops such as lettuce, celery and broccoli. The soils are generally deep and well drained red clays. They require lime and fertiliser for vegetable production, being usually acid to neutral, and less fertile than the black clays. The addition of organic matter to maintain suitable soil structure is also important. Also the type of cultivation that is necessary to provide the fine seedbed to establish vegetables can have a significant effect on soil structure and organic matter levels. As a result, management problems associated with these soils include severe structural decline and inadequate drainage.

Low temperatures during the winter prevent frost sensitive vegetable crops being produced in other parts of the Central Darling Downs. Obviously, the production season for most cold or frost sensitive crops ends with the onset of cold weather or frosts. However, there are some areas that produce horticultural crops. For example, broccoli is grown near Brookstead on the Recent and Older Alluvial Plains (LRA 1a, 2c) where the soils are generally black, self-mulching clays with good soil moisture reserves. Grapes are produced near Maclagan on light textured well-drained soils (LRA 6b).

Further information on horticulture can be obtained from *DPI Notes: Producing Vegetables for a Market* and Buying the Farm for Horticulture (DPI, 1986).

Floriculture

Floriculture enterprises for cut flower, foliage production and ornamental products are a small and very specialised industry on the Central Darling Downs *(see Table 7.2)*

Most of the existing floriculture enterprises have been established as a means to diversify farm income from traditional grazing and cropping enterprises. However, floriculture requires a much higher level of technical, managerial and marketing expertise compared with most other primary industries. The potential for a commercial return depends on good market research and product development, as well as careful matching of land types to plant/ crop types.

Crops must be produced within strict quality and size limits. Poor quality product results in profit reduction. There are limited formal marketing systems and hence poor development of product image.

Additionally, there is a high level of capital investment and the industry is very labour intensive. Marketing and production costs are high and there is strong competition within existing markets. Extreme climatic conditions such as hail, frost, wind or fire can destroy floricultural crops easily and there is a very low tolerance of disease or insect presence in the final product. It is recommended that wide spread consultation be carried out before investing in the floriculture industry. Established enterprises in the area include the production of Australian native flowers, foliage, buds and gumnuts as well as more traditional cut flowers such as roses, carnations and gypsophila.

Native foliage and flower production is as yet a small industry but one with significant potential to supply products to local, national and international markets. Many growers of native foliage and flowers have joined a primary producer's co-operative, called AUSBUD, which assists in product development and in co-ordination of marketing. This co-operative consists of 70 grower shareholders spread across Queensland and New South Wales.

Plants such as Geraldton wax and riceflower are also grown in the area and there are grower networks associated with these crops (such as the Queensland Wax and Native Flower Association).

Production of traditional cut flowers is confined to the eastern-most areas of the Central Darling Downs. The elevated range area around Toowoomba provides a climate with moderate summer day temperatures and cool nights which is ideal for production of high quality summer flowers. Winters are cool to cold, which limits volume production for the generally higher priced winter market. The preferred land types for floriculture are those that are well drained, readily accessible and which have adequate supplies of good quality water (e.g. LRA 7b, 7d). Aspect is also an important factor with a north-easterly slope preferred for greater winter radiation.

Although there is good potential for a wide range of floriculture enterprises on a range of soil types in the area, future growth will depend on the development of lucrative national and international niche markets. Seasonal advantage during the Northern Hemisphere's winter allows for supply into these markets at peak times. Another benefit is that only a small area of land is required to produce a commercial crop.

7.2.2 Forage crops

The production of annual forage crops is a key part of mixed farming and livestock enterprises on the Central Darling Downs with approximately 180 000 ha of forage crops planted annually. Forage crops provide strategic high quality grazing in both summer and winter, particularly for dairy production, prime lamb production and finishing beef cattle.

Summer forages

The three most commonly used summer forage crops are forage sorghum, forage millets and forage legumes.

There is a range of forage sorghum varieties grown predominantly on the clay soils of the Poplar Box Walloons, Brigalow and Basaltic Uplands (6a–d, 7a–b, 8a). Varieties include hybrid forage sorghums, Sudan grass, and sweet sorghums. They are grown for their characteristic ability to produce large amounts of feed. However, nutritive value deteriorates rapidly as growth progresses. They also carry (according to variety) a risk of prussic acid poisoning which can be minimised with strict grazing management. Horses are particularly susceptible to prussic acid poisoning.

Millets do not produce the same quantity of feed as forage sorghums and are suited to light textured, low fertility soils. If planted too deep or on heavy clay soils emergence problems can occur. Forage millet has the following distinct advantages when compared to forage sorghum:

- It can be used to fill feed gaps during late spring and autumn
- It has a higher feed quality than forage sorghum, without risk of prussic acid poisoning
- Supplementation with sulphur and salt blocks is not required
- Forage millet is suitable for horses.

Millets include *Echinochloa* spp. and *Pennisetum* spp. (pearl millets). The former can be planted earlier than the latter and under ideal conditions can be ready for grazing within 3 to 4 weeks of planting. Pearl millets, however, supply more feed and have better regrowth potential than *Echinochloa* types.

Forage legumes are fast growing annuals that recover quickly after grazing. They are grown on soils ranging from light sands to heavy clays. The two major groups of summer forage legumes are lab lab and cowpeas. They are grown for high-protein forage and are frequently planted for grazing in conjunction with sorghum. This is particularly important in autumn when the feed quality of mature pasture and other forages can be low. Lab lab, a later maturing summer forage compared to cowpeas, provides better regrowth and is used for high quality, autumn feed. For further information, refer to Crop Management Notes (DPI 1998).

Winter forages

The most commonly sown winter forage crops include oats, barley, triticale and winter legumes.

Oats are the most widely grown winter forage in the Central Darling Downs and are used when summer pastures decline in feed value. Most of the oats planted as a winter forage crop is grazed, but can also be harvested to provide hay, green chop or silage. A range of varieties is used, differing from each other in their rate of maturity. The recommended strategy is to plant late maturing varieties early in the season. Quicker maturing varieties are best kept for later planting.

Barley can be used as a dual-purpose crop, yielding some grazing as well as maturing for grain. There are no barley lines selected for forage. It can be grazed earlier than oat varieties planted at the same time in early winter. However, barley cannot be planted as early as the late maturing oat varieties, because it will run to head. Forage lines of triticale yield better overall than early oat varieties. However the awns of triticale, once it runs to head, make it less palatable to grazing stock than oats at the same growth stage. Triticale is best suited to acid soils with pH <6.0.

Annual winter legumes such as snail medic, barrel medic and woolly pod vetch are frequently included in planting of winter forage crops to improve the quality of the grazing.

Irrigated forage crops

The use of irrigation reduces the limitation to forage production imposed by available soil moisture but requires the use of higher producing species and an increased use of fertiliser. The most intensive irrigated forage crop is annual rye grass combined with regular heavy dressings of nitrogen fertiliser. This system, used mainly for winter/spring dairy production, depends on adequate supply of irrigation water and a very high seeding rate. Other irrigated forage crops use winter forages or perennial pasture mixtures based on temperate species such as phalaris, cocksfoot, ryegrasses, white clover, red clover, subterranean clover and lucerne. These are used for high quality grazing in winter/spring.

Hay and silage crops

Lucerne is the principal crop grown for hay for use on the farm and for supply to feedlots and horse studs. Silage is made mostly from crop residues or surplus summer forage. It is stored in round bale form for use as a conserved fodder on the farm to help fill anticipated feed gaps and can also be sold into the local market. Table 7.4 shows production of hay, lucerne and silage in the shires for 1997.

Table 7.4 Production of hay, lucerne and silage in the Central Darling Downs (1997)

	Wambo	Rosalie	Jondaryan	Pittsworth	Toowoomba	Millmerran	Total
Crops and pastures for hay – total area (ha)	2082	2081	2074	786.8	12	996.5	8032
Crops and pastures for hay – total production (t)	5477	7652	10520	3177	60	1990	28876
Pure lucerne cut for hay – area (ha)	248	407	775	105	12	13	1560
Pure lucerne cut for hay – production (t)	1367	2241	5344	537	60	29	9578
Lucerne cut for hay –value ($'000)	242	396	945	95	11	5	1694
Pastures (excl lucerne) cut for hay – area (ha)	261	445	112	81	—	188	1087
Pastures (excl lucerne) cut for hay – production (t)	902	1279	381	244	—	545	3351
Pasture (excl lucerne) cut for hay – value ($'000)	138	195	58	37	—	83	511
Pastures –total cut for hay – area (ha)	510	852	888	186	12	201	2649
Pastures –total cut for hay – production (t)	2269	3520	5725	781	60	574	13930
Pasture hay – total value ($'000)	379	591	1003	132	11	88	2204
Silage made during year ended 31 March (t)	3265	11725	28612	1567	—	4340	49509
Hay sold during year ended 31 March (t)	1766	2071	3078	273	60	109	7357

Source: ABS, 1997.

7.3 Pasture lands

Pasture lands are those uncultivated areas in the Central Darling Downs which carry native or sown grasses supporting grazing livestock. These lands are the basis of the beef and sheep enterprises and, to a lesser extent, the dairy enterprises of the whole area. The greatest proportion of these lands is under native pasture. Although sown pastures are more productive, they represent a very small part of this total resource.

7.3.1 Native pastures

The major areas of native grasslands that provide useful grazing in the Central Darling Downs are found on the Alluvial Sodosols, Brigalow Plains, Steep Basalt Hills, Poplar Box Sodosols and the Sandstone Forests west of the Condamine River (LRAs 3a, 4a, 5a–b, 7c, 9a–b, 10a–b, 11a, 12a–b). The heavy clay soils of the area are capable of very high production from native pastures, but due to the high returns from cropping very little is used for this purpose.

Existing native pastures maintain breeding animals (beef, dairying and sheep enterprises) during the summer growing season, and provide basic roughage during the winter. Standing winter roughage can sometimes be supplemented by naturalised winter growing annual medics (woolly burr medic and common burr medic), depending on the occurrence of winter/spring rainfall.

Desirable native grass species include Queensland, pitted and forest blue grass, brigalow grass, windmill grass, curly windmill grass and early spring grass. However, these grasses, particularly Queensland blue grass, are remnant species and their persistence requires careful grazing management. Preferential grazing under high stocking pressure can alter pasture composition and density resulting in the more desirable species being replaced with less palatable, inferior species.

Timber regrowth control is a particular problem in native grasslands in the Brigalow Plains and Sandstone Forests west of the Condamine River (LRAs 5, 9, 10, 11, 12). Active regrowth control programs are required to maintain good production levels.

7.3.2 Perennial sown pastures

The main introduced grass species used in the Central Darling Downs include green panic, bambatsi, purple pigeon grass, creeping blue grass and Rhodes grass, combined with the standard legumes, lucerne and annual medics. The following species are still being tested for suitability.

- Strickland finger grass (*Digitaria milarjina*) seems adapted to the poplar box and gum topped box country (LRA 9).
- Swan forest blue grass seems adapted to the lighter, brigalow soils (LRA 6a–d).
- Legumes which seem adapted to the lighter sandier soils are Namoi woolly pod vetch, Aztec siratro, Seca stylo and fine stemmed stylo (LRA 10, 11, 12).

Recommended species in relation to soils

The choice of species is influenced by soil fertility, surface structure, drainage, topography, palatability and management options. Bambatsi is best suited to the black and grey cracking clays of the Central Darling Downs. It does particularly well on the heavier clays in the recent alluvial plains (LRAs 1a–b), and benefits from occasional flooding or wet conditions. In moderately to deeply gilgaied country (LRAs 5a–b), bambatsi and purple pigeon grass is a good mixture as bambatsi does well in the depressions and purple pigeon survives well on the mounds.

Green panic, Gatton panic, Katambora Rhodes grass and creeping blue grass are important productive pasture species in the Brigalow and Basaltic Uplands (LRA 6, 7). The Rhodes grasses are very adaptable and are the best introduced pasture species on the lighter Sandy and Loamy Sodosols (LRAs 9, 10). Digit grass species also have a potential on lighter textured surface soils (LRAs 9, 11).

Lucerne is the most adaptable legume for sown pastures throughout the Central Darling Downs. Being a perennial tap rooted species, lucerne is able to access subsoil moisture and nutrients and is suited to soils with moderate to high PAWC. A new legume, Desmanthus is also showing promise on the self-mulching clay soils. Naturalised or sown medics can contribute greatly to feed requirements, — particularly during reasonably wet winters, which generally occur in 3 years out of 10.

Thompson (1988) described soil/vegetation land types relevant to the Central Darling Downs as a basis for pasture species recommendations. Table 7.5 relates these soil/vegetation land types with the Central Darling Downs LRAs and recommended species. For more information on the land resource areas and soils in these areas refer to chapter 4 and the *Field Manual*.

Table 7.5 Soil/vegetation types, LRAs and recommended grasses and legumes

Land Resource Area	Soil/vegetation type	Suitable species of grasses/legumes
1. Recent Alluvial Plains 2. Older Alluvial Plains 3. Alluvial Plains Loamy Sodosols 4. Alluvial Plains Sandy Sodosols	Condamine plains	g, h, i, k, l, n, o
5. Brigalow Plains	Brigalow/belah forest plains	a, c, d, e, f, g, h, i, l, n, o
6. Brigalow Uplands 7. Basaltic Uplands 8. Poplar Box Walloons	Eastern Uplands	a, b, d, g, h, i, j, k, l, n, o, q, r, s, t
9. Poplar Box Sodosols	Poplar and gum top box	a, e, f, h, i, m, n, o, p,
10. Ironbark/Bull oak Sodosols	Cypress pine/ bull oak sodosols	c, m, o
11. Cypress Pine Sands	Deep sands	e, f, i, m, p
12. Sandstone Forests	Cypress pine/ bull oak sodosols	c, m, o
13. Granite Hills	Granite	u
14 Traprock Hills	Traprock	u

Grasses	Grasses	Legumes
a: Katambora Rhodes grass	h: Purple pigeon grass	n: Lucerne
b: Callide Rhodes grass	i: Creeping blue grass	o: medics
c: Pioneer Rhodes grass	j: Kikuyu	p: Serradella
d: Green/Gatton panic	k: Paspalum	q: White clover
e: Biloela buffel grass	l: Angleton grass	r: Wynn Cassia
f: Gayndah or American buffel grass	m: Premier Digit grass	s: Lotononis
g: Makarikari Grass (Bambatsi)		t: Wooly Pod vetch

u: No potential for sown pasture in this environment

Adapted form Thompson (1988) and Clarke & Mills (1998)

7.4 On-farm forest resources

The Central Darling Downs produces significant amounts of timber from cypress pine, spotted gum and ironbark forests. Although a reasonable amount of this timber is harvested from Crown-owned State forests, there is still a significant harvest from freehold and leasehold land. There are few on-farm plantation forestry enterprises in the area. There is an increase in tree planting for nature conservation corridors, chemical drift buffers, or land degradation control, which can also provide some economic benefit (*see section 9.6*).

The timber from private land is cut for sawlogs, landscape timbers, fencing materials, firewood, and as poles. There are expanding markets for small volumes of specialty craftwood timbers using a range of species such as brigalow (*A. harpophylla*), budgeroo (*Lysicarpus angustifolius)*, hairy oak *(Allocasuarina inophloia)*, and red ash *(Alphitonia excelsa).* Commercial timber species in the Central Downs are shown in Table 7.6. Forest species in relation to land resource areas are described in chapters 4 and 6.

Table 7.6 Commercial timber species in the Central Darling Downs.

Commercial use	Common name	Scientific name
General building material timber	Spotted gum	*Corymbia citriodora*
	Narrow-leaved ironbark	*Eucalyptus crebra*
	Gum top ironbark	*Eucalyptus decorticans*
	White cypress pine	*Callitris glaucophylla*
Species suitable for railway timbers	River red gum	*Eucalyptus cameldulensis*
	Spotted gum	*Corymbia citriodora*
	Narrow-leaved ironbark	*Eucalyptus crebra*
	Broad-leaved ironbark	*Eucalyptus siderophloia*
	Forest red gum	*Eucalyptus tereticornis*
Suitable species for fencing timber	Silver-leaved ironbark	*Eucalyptus melanophloia*
	Broad-leaved ironbark	*Eucalyptus siderophloia*
	Narrow-leaved ironbark	*Eucalyptus crebra*
	Budgeroo/Tom Russell mahogany	*Lysicarpus angustifolius*

7.5 Beef

Beef production is one of the largest agricultural landuses and industries within the Central Darling Downs (*see Table 7.2*) ranging from broad acre feeding and fattening enterprises, crop fattening, vealer growing and year round intensive feedlots. Table 7.7 shows beef cattle numbers and sales in the shires of the Central Darling Downs.

Table 7.7 Beef cattle numbers and sales in the Central Darling Downs

Shire	Jondaryan*	Millmerran	Pittsworth	Rosalie	Wambo	Total
Beef cattle numbers	49 053	56 293	18 687	79 764	100 020	303 817
Cattle and calf sales	54 843	24 072	7 675	31 099	76 421	194 110

* Number includes Toowoomba City
Source: ABS 1997

7.5.1 Grazing enterprises

Most breeding herds in the area are small (30 to 40 head) and are managed as a complementary enterprise to grain growing and/or dairying. Breeding animals are maintained on native pasture. Summer forage crops, lucerne and winter oats are used in various combinations to turn off yearlings, forward stores or fat animals.

On many grain farms crop stubble is an important source of maintenance feed for beef cattle, both for grazing and baled as conserved fodder. Fed in conjunction with a urea/molasses supplement, it is a valuable source of cattle feed however, this is counter to the need to retain crop residues for soil conservation purposes. For more information refer to section 9.7.2.

Regular cattle sales at Dalby, Millmerran, Oakey and Toowoomba provide a source of store cattle for finishing in the area. Meatworks at Oakey and Toowoomba contribute to the state, national and international beef market.

The Hereford breed dominates in beef herds throughout the area but studs for other breeds have been established including Brahman, Santa Gertrudis, Charolais and Murray Grey.

Photo 11 Dalby cattle sale

7.5.2 Feedlots

The Central Darling Downs is the most intensively developed cattle feedlot region within Queensland and Australia. The area is highly suitable for cattle feedlot development due to its moderate climate and proximity to reliable grain and fodder growing areas, major cattle breeding areas, cattle markets and abattoirs. Recent droughts, low grain prices and variable market conditions have accelerated interest in lot feeding in the area.

The first large-scale feedlots were established in this area in the early 1960s. Map 9 shows the location of large-scale commercial feedlots, smaller on-farm and opportunity feedlots in the Central Darling Downs. Feedlot development in the area closely followed the expansion of the Japanese market during the 1980s and early 1990s.

Large-scale commercial feedlots are either owned by large corporations with interests in grazing, abattoir and/or export marketing enterprises or individual graziers who have developed close links with cattle suppliers and export marketing groups. Some of these are involved in the custom feeding of cattle owned by other grazing enterprises throughout the State. Commercial feedlots have created stability in the beef and grain industries, as their continual year round operation allows them to be less affected by variations in seasonal conditions.

On-farm and opportunity feedlots are primarily used to finish cattle bred on the property when seasonal conditions do not favour pasture finishing and premiums are available for grain fed cattle. Cattle can be purchased for finishing when grain prices and marketing conditions are favourable. Cattle supplied to the feedlots usually come from western properties owned by the large feedlot companies or from producers within the Darling Downs region.

Feedlots and environmental management

Managing the environmental impacts of intensive livestock operations such as feedlots has become a significant issue with changing community values in environmental management on the Central Darling Downs.

In 1989, the Queensland Government amended the *Stock Act 1915* to incorporate a feedlot-licensing scheme administered by the DPI in consultation with local authorities. Significant advances have been made in the areas of feedlot site selection, design, operation and management since this time, resulting in a substantial reduction in complaints and a better overall perception of the industry by the community. Since July 1996 the environmental performances of feedlots are subject to licensing under the *Environmental Protection Act 1994.* The industry has also introduced a voluntary quality assurance scheme to ensure that its product is of a consistent high quality.

Feedlots are generally established on gently to moderately sloping land adjacent to good quality agricultural lands. Runoff from feedlots passes through a sedimentation system to settle out solids before the liquid effluent is collected and stored in a retention pond. The liquid effluent is then irrigated onto crop or pasture. Manure removed from feedlot pens and sedimentation basins is generally stockpiled on site prior to spreading onto crop or pastureland. It is used both as a nutrient source for crops and as a source of organic matter to improve soil structure.

Feedlots require a reliable supply of good quality water. Many feedlots in the area have deep bores tapping the water resources of the Great Artesian Basin. The annual supply required is approximately 24ML per 1000 head. Shade is an important consideration during hot summer months.

Salts are one of the key elements to consider in the feedlot waste program, water sources with low salt concentrations are preferred. Feedlots should have adequate supplies of good quality water for the dilution of effluent by irrigation to prevent contamination of land and water resources.

Production from feedlots

The feedlot industry has had a significant impact on the economy of the Central Darling Downs. At full production, feedlots in this area use approximately 350 000 tonnes of grain and 150 000 tonnes of roughage annually, much of which is produced locally. Up to 180 full-time staff are employed directly by cattle feedlots in the area, however this figure fluctuates with market conditions and is directly related to the level of feedlot production. A report by Clarke and Sparke, (1994) for the Meat Research Corporation indicates that a 25 000 head feedlot contributes $8.2 million to the regional economy.

The area includes 14% of the State's feedlots which is 29% of the State's licensed capacity. Tables 7.8 and 7.9 show the distribution of licensed feedlots and cattle numbers for various feedlot capacities within the study area. This shows that while Rosalie Shire has more feedlots, they are generally of smaller capacity.

Table 7.8 Number of cattle feedlot licences within the Central Darling Downs.

Shire	Feedlot cattle capacity range (SCU's[1])					Total
	50 – 499	500 – 999	1000 – 4999	5000 – 9999	10000 +	
Jondaryan	2	2	1	1	2	8
Millmerran	4	3	2	1	2	12
Pittsworth	0	1	1	0	0	2
Rosalie	9	1	5	1	0	16
Wambo	6	1	2	0	2	11
Total	**21**	**8**	**11**	**3**	**6**	**49**
% State	**10%**	**12%**	**19%**	**43%**	**30%**	**14%**

SCUs[1] = Standard Cattle Units i.e. a 600 kg beast.
Source: DPI, 1997.

Table 7.9 Licensed feedlot capacities within the Central Darling Downs.

Shire	Feedlot cattle capacity range (SCU's[1])					Total
	50 – 499	500 – 999	1000 – 4999	5000 – 9999	10000 +	
Jondaryan	600	1200	1000	7200	37600	47600
Millmerran	850	1700	8920	7000	70000	88470
Pittsworth	0	630	3600	0	0	4230
Rosalie	2195	500	11250	8000	0	21945
Wambo	1400	700	2500	0	30290	34890
Total	**5045**	**4730**	**27270**	**22200**	**137890**	**197135**
% State	**11%**	**12%**	**25%**	**49%**	**31%**	**29%**

SCUs[1] = Standard Cattle Units i.e. a 600 kg beast.
Source: DPI, 1997.

Table 7.10 Licence status, number of licences and licensed capacities of feedlots in the Central Darling Downs.

Shire	Construct authorities		Operational licences			All licences	
	No of current licences	**Proposed capacity** (SCU's[1])	**No of current licences**	**Conditional capacity** (SCU's)	**Licensed capacity** (SCU's)	**No of current licences**	**Licensed capacity** (SCU's)
Jondaryan	0	0	8	41400	47600	8	47600
Millmerran	3	45420	9	10550	43050	12	88470

Pittsworth	1	630	1	3600	3600	2	4230
Rosalie	2	1250	14	19445	20695	16	21945
Wambo	2	550	9	34240	34340	11	34890
Total:	**8**	**47850**	**41**	**109235**	**149285**	**49**	**197135**
% State	**13%**	**23%**	**14%**	**32%**	**31%**	**14%**	**29%**

SCUs[1] = Standard Cattle Units i.e. a 600 kg beast.
Source: DPI, 1997.

Table 7.10 indicates the number, capacity and status of feedlots within the Central Darling Downs. The conditional capacity varies from the licensed capacity due to the staged development of some feedlots. In some cases, developers have initially applied for a particular capacity but have elected to develop the facility in stages, depending on the economic climate and returns from the enterprise. In other cases, a construction authority has been issued for several years and no development has taken place. There are examples of significant undeveloped licence capacity within the Millmerran Shire.

Future major feedlot developments within the area will depend on the availability of suitable sites that are located at sufficient distances from neighbouring houses and towns.

7.6 Sheep

The sheep industry was the basis for settlement and agricultural development of the Central Darling Downs in the early 1840s. Wool production and sheep breeding was prominent on large properties such as Jondaryan, Daandine, Cecil Plains and St Ruths stations. A prominent fine wool stud was located at Jimbour station around the turn of the century. Drought, sharp decreases in the price for wool and greater returns from cropping have made it a non-viable use of the land resources over much of the eastern area. Sheep numbers within the Central Darling Downs are shown in Table 7.11.

The summer rainfall pattern in the area brings associated problems for sheep production. Parasites (particularly the barber's pole worm, *Haemonchus contortus* and the sheep blowfly, *Lucilia cuprina*) are responsible for deaths and production losses and increased expenditure on chemical controls. Good planning and management programs including strategic location of watering points are required to minimise these problems (*see section 9.3*).

Table 7.11 Sheep numbers within the Central Darling Downs

Shire	Jondaryan	Millmerran	Pittsworth	Rosalie	Wambo	Total sheep
Breeding ewes	1762	7555	601	507	12799	23224
Lambs & hoggets	1351	2574	597	662	7278	12462
All other sheep excl. breeding ewes	1756	43053	229	70	7449	52557
Total	4869	53182	1427	1239	27526	88243

Source: ABS 1997

7.6.1 Wool production

Merino wool production is mainly confined to land unsuitable for cropping in the western parts of Millmerran Shire on the Sandstone Forest, Cypress Pine Sands and Poplar Box Sodosols (LRAs 9, 11 and 12). Flocks are made up of medium wool merinos in the fibre diameter categories of 20–23 microns.

Properties vary widely in productivity depending on the level of improvement and management of the pasture resource. Low quality native pastures combined with the incidence of predators, such as wild dogs, foxes and pigs, result in poor survival of lambs from breeding flocks. Consequently many Millmerran properties run wethers, and choose to purchase replacement stock as required.

A small number of farms throughout the Central Darling Downs run merinos in conjunction with cropping. In some cases mobs of wethers are bought from western areas in early summer and used to control weeds in fallow paddocks over the wetter summer months. These sheep are usually shorn during this time and may be sold, once fattened into the higher priced, early winter sheep market.

The poor quality native pastures in the Central Darling Downs produce finer wool and lower fleece weights than the better quality native pastures of the Western Downs. In recent years two newly tested pastures species, digit grass and the legume, serradella, have shown potential for improving pastures in this environment and soil type.

7.6.2 Prime lamb production

The Central Darling Downs is well suited to prime lamb production. The more fertile land combined with summer-rainfall produces the good quality pastures necessary to fatten spring lambs for the higher priced winter market. A variety of sheep breeds serve this purpose, including pure merino, merino-cross, poll Dorset, Suffolk, Coolalee, and Texel.

In this area, most prime lamb production systems are relatively small and are usually part of bigger grain growing enterprises. The sheep are mostly sold through the saleyard rather than directly to an abattoir; direct sale to abattoirs is more common west of the Central Darling Downs. Dalby and Warwick provide the only weekly sheep and lamb sales in Queensland and are the focus for auction selling of prime lambs and other sheep. However, some producer groups are supplying larger volumes of lambs to specific markets. These lambs are usually grown to meet specified carcass weights and grades.

Sheep feedlotting

There are a number of small sheep feedlots operating on the Central Darling Downs from which production and stock numbers fluctuate according to current lamb prices. The area is highly suited to sheep feedlotting due to its moderate climate, proximity to reliable grain and fodder supplies and close proximity to markets and abattoirs. Sheep feedlots are capable of pursuing market opportunities as they have relatively low capital input compared to beef feedlots and do not need to be registered. Sheep feedlots simply comply with the local authority regulations that govern any business enterprise. One of the larger operations, “Bowenville Park”, custom feeds sheep and lambs.

7.6.3 Sheep and cropping integration

The practice of integrating sheep into farming operations has decreased markedly due to the severe slump in wool prices since 1991, which was triggered by the collapse of the Reserve Price Scheme. There is, however some interest in the use of sheep for low cost weed control during summer. This is a result of greatly improved sheep meat prices, a rising wool market and the advantage of reducing herbicide applications or mechanical tillage operations.

This kind of enterprise is limited to properties where the infrastructure (fencing, water points, shearing sheds etc.) has not been removed. In addition, husbandry needs – especially related to worms and flies in high rainfall areas – and the difficulties associated with running sheep on black clay soils when heavy rains occur, are enough to prevent many farmers going back into sheep.

The sheep enterprise offering the most to grain growers is prime lamb production. High returns are achievable on mixed legume/grass pastures with a stocking capacity of over 3 sheep per hectare. Sown pastures in rotation also provide a break to disease cycles and can arrest the soil fertility decline on most cropping lands (*refer to Section 9.6*).

Another crop/livestock enterprise is growing of hybrid forage sorghum for weaner merino lambs. High returns can be obtained from fine merino wool, shorn prior to the sale of merino lambs in the prime lamb market each winter. This enterprise demands skill in husbandry as well as buying and selling the stock. However, it has the additional advantage of being a low or nil chemical option for environmentally conscious farmers.

7.7 Dairying

Dairying is an important agricultural industry in the Central Darling Downs (*see Table 7.2*). Approximately 340 farmers carry out dairying in the shires of Pittsworth, Jondaryan, Rosalie, Wambo and Millmerran. The average farm area is 278 ha, with an average milking herd of 88 cows run on 114 ha. The majority of farms are dryland farms with only 40% having access to some form of irrigation. The number of dairy cattle within the Central Darling Downs is shown in Table 7.12.

Table 7.12 Dairy cattle in the Central Darling Downs

Shire	Jondaryan	Millmerran	Pittsworth	Rosalie	Toowoomba	Wambo	Total
Dairy cows	8778	215	3782	19550	244	5196	37765

Source: ABS 1997

The average dairy farm in the area produces 347 538 litres per year or an average of 3 949 litres per cow annually. Milk is generally supplied to the 'Dairy Farmers' Co-Operative in Toowoomba, although Pauls in Brisbane or Dairyfields Pauls in Warwick, do collect milk from farms in these shires. Milk is produced all year round to supply both the whole milk and manufacturing product markets.

The type of dairy farming operation varies from dryland farming to fully irrigated systems, and in recent years the industry has seen the introduction of lot-fed operations. Over the last 7 years, the level of silage feeding has increased from 2 % to 39 % of the total dairying population in both partial and fully lot-fed systems.

Although most major dairy breeds exist within the Central Darling Downs, Holstein Friesian is the predominant breed of milking cow with around 80% of the total dairy cow population being either of this breed or originating from this breed. Jerseys and Illawarra breeds are the next most popular.

7.7.1 Location

Dairying is best suited to the gentle undulating, mixed farming areas in the basalt and brigalow uplands (LRAs 6, 7) where there is potential to grow crops and permanent pasture. The heavy clay soils of the alluvial plains are not suitable to dairying because of problems with cattle bogging in wet weather. On almost all dairy farms there is a mix of soils suitable for cropping (forage or grain), as well as poorer soils on steeper lands more suited to permanent pasture for heifers and dry cows. Map 9 shows the location of dairies in the Central Darling Downs.

7.7.2 Forage cropping for dairy production

Almost all dairy farms rely on both summer and winter forage crops to provide the bulk of paddock feed for their milking herd. This is essential in order to supply a fairly constant supply of feed all year round to meet the market requirements for an even supply of good quality milk throughout the year.

The main summer crops are forage sorghum, millet and legume crops such as lab lab and cowpea. These crops are planted from mid September to late February, and usually provide grazing from late October to late April. The majority of these crops rely on seasonal rainfall.

Oats and barley are the two main winter forage crops along with small areas sown to wheat and triticale. Generally, winter legume crops are not grown for forage. Winter crops are planted from late February to early July and generally provide feed from mid May to late October.

7.7.3 Fodder conservation

Fodder conservation is practised where there is an excess of fodder for the requirements of the milking herd. The forage is either conserved as hay or round bale silage, and is usually kept on the farm to fill in feed gaps caused by seasonal variations.

In recent years there has been a shift towards chopped silage on a number of farms. These farms either grow dual-purpose grain/forage sorghum varieties, or they contract other landholders to produce grain crops, such as maize and barley to meet their requirements. Legume crops such as soybeans or navy beans are normally obtained as an opportunity crop from outside the property.

7.7.4 Pastures for dairying

Both native and sown pastures are used to provide feed for dairying. High production systems are dependent on use of irrigation for both temperate annual and mixed perennial pastures. Temperate pastures are planted in early April and provide feed from late May to the end of October. Irrigated lucerne can be grown over summer to provide quality forage into autumn. Excess forage can be made into hay and stored on the property for later use.

Native pastures on the poorer soils on steeper lands are used for heifers and dry cows. Key native species include the blue grasses, spear grass, naturalised couch and medics.

The main permanent sown pasture species are Rhodes grass or green panic. These pastures are generally planted on the lighter textured soils (e.g. Walker and Diamondy - LRA 6b) and on the steeper sloping hills unsuitable for cultivation. It is quite common for lucerne and both snail and barrel medics to be included in a pasture mix for these areas. Smaller areas of bambatsi, purple pigeon, and creeping blue grass are also grown.

While it is recommended that these pastures should be topdressed with 50 kg of nitrogen per hectare at least once or twice over the summer growing season, this practice is seldom used because of the uncertainty of regular rainfall over this period. Base levels of fertiliser elements are generally adequate for most soils within the Central Darling Downs, apart from sulphur, which should be applied at planting and, depending on soil test results, as an annual topdressing for optimal pasture production.

Irrigated pastures

Irrigated pastures are used for a high feed production system to maximise milk production. The type of irrigated pasture will depend on the quantity and suitability of water and the area of land available for irrigation. Most irrigation water for dairy production in the Central Darling Downs comes from groundwater supplies. Commonly these bores have a flow rate of 45 000 litres per hour which is sufficient to irrigate pasture for 100 milking cows all year round, with some excess available for fodder conservation as hay or silage. A flow of 18 000 litres per hour will support enough irrigated pasture for a herd of 50 milking cows.

Where there is limited land or water the recommended irrigated pasture species is annual ryegrass. A well-managed ryegrass pasture can support 7–8 milking cows per hectare over the growing season from April to late October. This type of pasture system requires 4.5 megalitres per hectare of water and a high input of nitrogen fertiliser, approximately 300–350 kg of nitrogen per hectare, over the growing season.

Where land and water for irrigation are less limiting, mixed perennial temperate pastures can be grown. The stocking rate needs to be no more than 5 milking cows per hectare to allow the legume component to persist. The pasture usually includes perennial ryegrass, fescue, red and white clovers, and lucerne. Irrigated perennial pastures will require up to 6–7 ML/ha of water due to a longer growing season. However, because of the lower stocking rate and the use of a legume, the nitrogen requirement can be as low as 200 kg per hectare.

Dock, turnip weed, thistles and horehound are the most common weeds in irrigated pastures. These can usually be controlled through mowing or baling the pasture, or spraying with herbicide when the weeds are at the small seedling stage. The key to suppressing weeds in an irrigated pasture is to have a thick healthy plant stand, which is well fertilised and has good grazing management.

7.7.5 Milk production

While the area of dairy farms and milking area has declined gradually over time, herd sizes and the volume of milk per farm has increased over the last 8 years. This is shown in Table 7.13.

Table 7.13 Dairy production in the Central Darling Downs

	1986/87	1994/95
Farm area (ha)	2 324	278
Milking area (ha)	164	114
Herd size	74	88
Milk production per farm (litres)	219 694	347 538
Milk production per cow (litres)	2 969	3 949

Source: ABS 1997

7.7.6 Extension services

Both the DPI and Milk Processor (Factory) groups provide extension services to the Dairy Industry on the Central Darling Downs. There is a Contract Agreement between each milk processor and the DPI where the DPI Dairy Extension Officers provide an exclusive extension service to a particular milk processor. The largest of these groups is the *Target 10* Team, which has officers, situated at Toowoomba and Oakey, and they are contracted to the Dairy Farmers Group. The *Think Milk* Team is contracted to Dairyfields Pauls Co-Operative at Warwick, while the *Aim High* Team, which is contracted to Pauls QUF Industries, has an officer in Toowoomba. Additionally, a cost of production financial analysis recording scheme is operated by DPI for the Dairy Industry. This scheme, known as the Queensland Dairy Accounting Scheme (QDAS), examines the variable cost of milk production on farms and allows various benchmarks to be set for financial management on these farms.

7.8 Pigs

Income from pig production makes an important contribution to rural economies in the Central Darling Downs (*see Table 7.2*). Piggeries are a specialised intensive industry with over 99% of producers using a cereal-based diet mixed with protein concentrates. They are also an important customer for other rural industries, especially those providing infrastructure equipment, feed grains, and supplements.

The industry is closely linked with grain growing areas and the Central Darling Downs contains close to 50% of Queenslands pig population. Map 9 shows their location. The distribution of pigs in the Central Darling Downs is shown in Table 7.14.

Table 7.14 Pig numbers in the Central Darling Downs

Shire	Total pigs	Sows and gilts
Jondaryan	10629	1419
Wambo	48486	5790
Rosalie	14217	1703
Pittsworth	5371	374
Millmerran	53542	6048
Total	132245	15334

Source: ABS 1997

The number of pigs in the area have risen significantly over the last 15 years while at the same time the number of piggeries has dropped markedly. As well as the move into fewer, larger holdings, there is also the move towards vertical integration in the industry. Many farmers are moving towards separate breeding and growing facilities to maximise output.

A 1000 sow piggery contains about 10 000 pigs of all sizes, uses approximately 143 ML of water and consumes about 5 665 tonnes of grain based feed a year. This piggery would also produce about 1 120 tones of solid waste and 1000 tonnes of volatile solids (Queensland Murray-Darling Basin Coordinating Committee, 1998).

Piggery waste is currently disposed of in anaerobic ponds that can be very smelly. Several piggeries within the Central Darling Downs are testing alternative treatments for solid piggery wastes, including vermiculture and composting, in an effort to improve working conditions, quality of life and ensure better environmental management.

Most pigs are consigned direct to Bacon Factories in Toowoomba and Brisbane where payment is based on dressed weight and a measured backfat thickness. Some pigs are marketed via local saleyards under the auction system.

Costs vary considerably, depending on the type and size of piggery, labour required, land values and other factors. Records, either computerised or manual are vital tools for the producer to monitor the economics of the production unit and make informed decisions. Competition from imports can be a factor in piggery returns, and therefore viability.

7.8.1 Environmental legislation

The *Environmental Protection Act 1994 (EPA)* classifies piggeries as Environmentally Relevant Activities (ERAs). The Queensland Pork Producers' Organisation (QPPO) represents pig producers at a local, state and national level. The pig industry has supported the production of an Industry Code of Practice to enable producers to meet requirements under the EPA. It is expected that producers following the code of practice will achieve the following outcomes:

- **Waste utilisation** Piggeries are to be managed so that nutrient, organic matter and the water component of liquid and solid wastes are used in accordance with the principles of Ecologically Sustainable Development.
- **Land degradation** Piggeries are to be managed so that the production capacity of waste utilisation areas are maintained or improved so that land is not degraded.
- **Water resources** Piggeries and effluent disposal areas are to be sited, designed, constructed and operated such that the quality of the State's groundwater and surface water resources are not affected by piggery enterprises.
- **Community amenity** New piggeries are to be sited, designed, constructed and operated so as not to cause unreasonable interference with the comfortable enjoyment of life and property off site or with off-site commercial activity

7.9 Poultry

Poultry production is a small industry on the Central Darling Downs with most farms specialising in egg production. Although there is a small poultry-meat industry in the area, it is insignificant compared with egg production (*see Table 7.2*). Jondaryan and Pittsworth Shires have the most poultry farms in the area with a smaller number of large poultry enterprises in Millmerran Shire. The ready availability of grain supplies, close proximity to feed processors and the availability of markets makes the Central Darling Downs well suited to poultry production.

There are 22 intensive poultry farms on the Central Darling Downs with approximately 1.2 million birds producing about 18 million dozen eggs a year. This represents approximately 60% of the gross value of egg production in Queensland. Free range and organic eggs represent only about 2% of the market, but they provide a good income for a number of small producers. Table 7.15 shows the number of poultry farms and birds in the Central Darling Downs.

Table 7.15 Poultry farms and birds in the Central Darling Downs

Shire	Poultry farms	Number of birds
Jondaryan	11	112 840
Millmerran	5	323 939
Pittsworth	12	669 116
Rosalie	9	44 295
Wambo*	-	-

*There are no statistics available for Wambo
Source: ABS 1997

7.10 Other industries

Other minor industries within the Central Darling Downs include goats, emus, ostriches, horse breeding and apiculture. These industries are generally a means of diversifying farm income from the major enterprises of cropping, beef and dairy production. As the farming and breeding of emus, ostriches and goats are specialised and fledgling industries their long-term viability has not been assessed. Table 7.16 shows the number of goats, emus, ostriches and horses within the Central Darling Downs.

Table 7.16 Minor animal industries numbers in the Central Darling Downs

Shire	Jondaryan	Millmerran	Pittsworth	Rosalie	Wambo	Total No.
Goats	0	134	123	443	672	1372
Emu	1040	0	0	0	0	1040
Ostriches	62	95	8	200	357	722
Horses	2342	248	424	740	803	4557

Source: ABS 1997

7.10.1 Goats

A small number of farms have diversified into Boer goat breeding or the mohair/cashmere industries. Interest in the local goat fibre industry has increased as fashion houses worldwide became more aware of the excellent qualities of mohair and cashmere garments. This interest has been moderated by falling prices for fibre products, a shortage of buyers and low outputs. The major markets for goat meat are in Asia, especially Taiwan.

7.10.2 Emus

Emus are farmed for their meat, oil and leather. A few farms have been established in the Central Darling Downs following the legalising of emu farming in Queensland in 1993.

7.10.3 Ostriches

A small number of ostrich farms exist on the Central Darling Downs. The local industry is a relatively small proportion of the national flock which is estimated to grow to 100 000 birds by 2000 (Dale, 1997). Ostriches are farmed for their meat, oil, leather and feather products.

7.10.4 Horses

Horse numbers within the Central Darling Downs reflect a wide range in commercial and recreational uses. The most prominent horse enterprises in the area are breeding thoroughbred and stock horses. A number of smaller breeders provide horses for special purpose recreational uses such as for pony club members, polo and polo-cross sports.

Large thoroughbred racehorse studs are located in Pittsworth and Jondaryan Shires, close to the major racing venues at Toowoomba, Brisbane, the Gold Coast and Sunshine Coast. Other advantages include the milder climate of the area and ready availability of quality food supplies. Thoroughbred racehorse studs can have up to three stallions serving 60-70 mares per year, at a fee up to $55 000 per service.

Table 7.16 shows the number of horses in racehorse breeding studs, horses for recreational uses and stockhorses used on properties in the Central Darling Downs.

The proliferation of small rural subdivisions in each of the shires has added to the wider dispersal of horse owners and breeders. The large number of horse owners who have only small numbers of horses (1-3), for family recreational uses can total to a significant number within each shire.

The Show Societies within the Central Darling Downs conduct a number of equestrian events annually. The Toowoomba Royal Agricultural Show generally attracts over 1000 horses each year. Other notable events include the large annual Australian Stockhorse Sale at Dalby and the draughthorse competitions at Jondaryan Woolshed.

7.10.5 Apiculture

Although honey and beeswax production is worth more than $5m a year to Queensland, the contribution from the Central Darling Downs is relatively insignificant. However, due to the contribution from pollination and value to subsequent crop yields, the overall value of the industry is considerable. Sunflower growers in particular depend on bee pollination to maximise yields.

Apiculture in the area is largely practised in the sandstone forests and heavily wooded hills which are relatively free from the insecticides used in crop production (LRAs 4, 9, 10, 11, 12, 13, 14). Preferred tree species for apiculture include yellow box (*Eucalyptus melliodora*), mountain coolibah (*Eucalyptus orgodaphila*), river red gum (*Eucalyptus camaldulensis*), gum topped box (*Eucalyptus moluccana*), narrow leaved ironbark (*Eucalyptus crebra*), mugga ironbark (*Eucalyptus sideroxylon*), spotted gum (*Corymbia citriodora*), rough barked apple (*Angophora floribunda*), smooth barked apple (*Angophora costata*) and yapunyah (*Eucalyptus ochrophloia*).

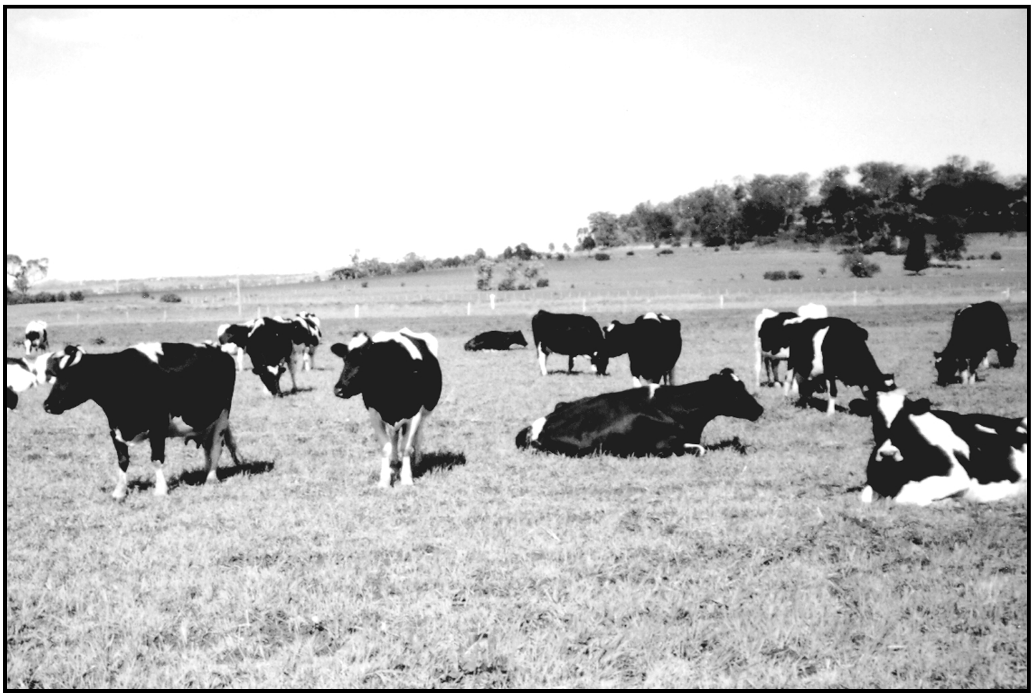


Photo 12 Friesians are the predominant breed of milking cow in the Central Darling Downs

Photo 13 Harvesting chickpeas at Dalby

Further Reading

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8. LAND AND ENVIRONMENTAL DEGRADATION

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8.1 Introduction

The type, occurrence, causes and impact of land degradation depend on the land resource, the landuse and land management practices adopted. The properties of the soil, location in the landscape, relationship with other soils and local climatic conditions are also factors that affect the type and severity of land degradation. Management practices should be aimed at using the land conservatively and in accordance with its capability, in order to minimise land degradation and maximise production.

This chapter discusses the type of land degradation occurring in the Central Darling Downs and describes some of the historic causes of this land degradation. Types of land degradation discussed include loss of natural habitat, pasture deterioration, soil erosion, decline of soil fertility and structure, acidification of cropping lands, salinity and sodicity, incidence of weeds and pests, and impacts on water resources.

8.2 History of land degradation

Significant land and environmental degradation of the Central Darling Downs began with the development of agriculture in the 1850s. It accelerated with time, as settlement, land clearing and more intensive landuse increased. Grazing of native pastures by sheep and cattle was the first form of landuse, followed by dairying and cropping for grain. Land was first cropped during the 1890s and, by the early 1900s, the practice of cultivation for grazing crops and wheat was well established but confined to the lower slopes and valley floors of the Basaltic and Brigalow Uplands (LRAs 6, 7). Cropping extended to the plains in the late 1920s. The destruction of ground cover by cultivation heralded the beginning of rapid soil erosion.

Prickly pear invasion, predominantly in the brigalow lands (LRAs 5 and 6), interrupted the development of the grazing industry during the early 1900s (*see Section 8.10*). After this pest was virtually eliminated by the cactoblastis moth in the late 1920s, progress resumed with the development of mixed grain growing and dairying. Improvements in land clearing machinery and techniques, and mechanisation of grain growing enabled rapid expansion of these industries. Rapid agricultural expansion occurred after the First World War, between 1920 and 1940, which led to severe and widespread erosion. With the expansion of cultivation over the plains, construction of roads and on-farm structures increased the concentration and diversion of floodplain flows resulting in development of severe gullies and high soil losses.

Increased erosion and increased intensity of cultivation for crop production during this period also caused a decline in soil fertility as the produce was removed from the land. Mechanisation of crop production increased soil structure and compaction problems. Accelerated clearing during the development period has led to salinity problems in some areas as well as loss of wildlife habitats.

In more recent years, there has been an increase in the number of small rural holdings, particularly in close proximity to the established towns within the Central Darling Downs. This has resulted from the purchase and residential development of land contained in historic small subdivisions, and through subdivision of land previously used for agricultural production. The introduction of State Planning Policy 1/92, 'Development and the Conservation of Agricultural Land' (*see Section 9.2.1*) provided controls that could be implemented through Local Government Planning Schemes. Such developments now occur mainly on non-agricultural land.

8.3 Loss of natural habitat

A high proportion of land on the Central Darling Downs has been cultivated and cleared for cropping and pasture (*see Map 8a-b*). This has contributed to changes in the distribution and conservation status of native fauna and flora. Appendices 3 and 4 list Rare and Threatened species for the Central Darling Downs.

A range of changes within habitats impact on fauna and flora, most notably loss or reduction of the understorey, (the layers of shrubby vegetation beneath the taller trees). Animals including predatory insects, spiders, birds and reptiles rely on the understorey for food, shelter and breeding. Ecologists are just starting to understand the importance of understorey and these associated species in the overall health and survival of remnant woodland.

Of particular interest to agriculture is that the predatory species can play an active role in reducing insect pest pressure and removing disease carrying organisms. Wolf spiders, scorpions, hover and robber flies and certain ground beetles feed on insects affecting pasture such as scarab beetle larvae, moths and grasshoppers. These predators shelter under the peeling bark of trees and in leaf litter and are dependent on healthy native vegetation to survive.

Photo 14 Loss of native vegetation by land development

8.3.1 Threatened species

The Rare and Threatened species for the Central Darling Downs are listed in Appendices 3 and 4.

Overall, a total of 4 endangered, 17 vulnerable and 12 rare plant species are recorded for the Central Darling Downs. This is indicative of the degree of adverse change arising from a range of variables including conversion of land to cultivation, overgrazing, changes in fire regime and accompanying competition from native and introduced pasture species.

The bull oak jewel butterfly *Hypochrysops piceata* is the only species of fauna which can be regarded as endemic to the Central Darling Downs. However it is regarded as one of Australia's most threatened butterflies, now only occurring in two small patches of bull oak (*Allocasuarina leuhmannii)* near Leyburn. Bull oak communities generally have been greatly reduced in area on the Central Darling Downs since European settlement.

Although the paradise parrot (*Psephotus pulcherrimus*) and the bridled nail tail wallaby (*Onychogalea fraenata*) occurred in the Central Darling Downs at the time of settlement, both species are presumed extinct across their overall Australian distribution. The exception is an isolated population of bridled nail tail wallaby near Dingo in central Queensland. Clearing, stock grazing, predation by feral animals and increased stress in time of drought have all played a part in their demise.

8.3.2 Remnant vegetation

While forested areas along the Great Dividing Range provide for more or less continuous habitat, much of the Central Darling Downs is comprised of fragmented remnants. Vegetation corridors can contribute to the maintenance of ecological balance. Certain fauna species such as the koala (*Phascolarctos cinereus*) require large home ranges, which cannot be realistically accommodated in intensively developed agricultural areas. Connections between remnants allow for movement and breeding between populations. A limited gene pool in any species makes it less able to cope with environmental stress.

If clumps and shadelines are limited to a size where stock can readily graze out the understorey, their effectiveness as habitat for pest predators is substantially reduced. Similarly, where timbered areas are cleared to an open woodland or park like pattern, the value to wildlife and the overall health of natural systems is minimal.

Large and continuous remnants are required to sustain a diversity of plant and animal species. Research on the New England Tableland in northern New South Wales has indicated that 20 hectare woodland clumps can have a rich bird community if interconnected with other native vegetation. Smaller patches can still be of value, provided the aggressive and territorial noisy miner (*Manorina melanocephala*) is in low numbers. It appears that once a remnant area of woodland gets below 5 hectares, the native system is in danger of collapse (Barrett *et al.,* 1993).

8.3.3 Riparian vegetation

Riparian vegetation is found along the banks of rivers and creeks and around the perimeter of lakes, swamps and lagoons. It can provide vital habitat, food and breeding sites for a range of resident, migratory and seasonally occurring invertebrate and vertebrate species. It also helps stabilise the banks of watercourses.

The riparian vegetation on the upper banks, river terraces and floodplains provides a complex range of habitats. Large trees with numerous hollows are important for shelter and breeding for species including possums, gliders, owls, parrots and cockatoos.

Widespread clearing and development of floodplain areas has seriously impacted on watercourses. In places the drastic alteration of habitat has lead to invasion of weeds including Condamine couch or Lippia (*Phyla canescens*) and weeping willow (*Salix babylonica*). The riparian vegetation once acted as a filter, slowing and filtering runoff before it entered the stream system. Other problems include silt build up, erosion and water quality decline resulting from agricultural activities within and adjacent to the riparian zone.

Increased nutrient concentrations within stream systems can lead to blue green algal blooms. The extraction of water for irrigation, the construction of dams and weirs within the catchment and the disposal of sewerage effluent and industrial wastes all have a major impact on water quality and associated habitat values (*see Section 8.11*).

8.3.4 Die-back

Die-back in native trees occurs widely across the Central Darling Downs and is symptomatic of some form of land degradation. There are generally a number of factors which combine to place a tree under stress and even eventually kill it. These include insect attack through a reduction or lack of natural predators, old age, changes in soil nutrient levels, use of herbicides, fire damage, cultivation, damage by livestock, waterlogging and salinity, increase in mistletoe, pasture improvement, changes in microclimate and fungi attack.

8.3.5 Fire

Native forests and pastures can be adversely affected by too-frequent burning. Some plant and animal species are more fire-sensitive or fire tolerant than others and these species may occur together in the same community.

In the short term a high intensity fire is likely to result in the death of many plants and animals and removal of decomposing litter. The tree canopy may be lost or trees killed depending on the severity of the fire. Less mobile animals, such as reptiles and species sheltering and breeding in hollows are particularly hard hit.

Overall, an inflexible fire regime which does not account for variation in frequency, fire intensity, seasonal timing and extent can lead to low bio-diversity, low species numbers and loss of fire sensitive species. Conversely a ‘no burn’ strategy could eventually lead to the loss of some of the early opportunists which colonise after fire and the number of species could again decline. Such impacts are heightened in isolated remnants occurring in large areas of pastures or crops.

8.4 Soil erosion and siltation

Soil erosion in the form of water erosion is a serious form of land degradation which occurs on most of the soils in the area. The extent will depend on vegetative cover, soil type, degree and length of slope. Overland flows can be a significant problem on the alluvial plains. Over many years erosion has contributed to decline in soil fertility and soil structure. Erosion and silt deposition can cause damage to pastures, crops, farm infrastructure, community utilities, irrigation and drainage works.

When erosion by water occurs, soil particles are transported in the flowing water, resulting in downstream siltation when flow velocities decrease and soil particles settle out. As flow slows down, the coarse sand particles are the first to settle out, followed further along by the finer particles. When streams overflow onto the adjacent alluvial plains, sand particles settle out close to the stream while fine particles (silt and clay) settle out much further away, on level, flat areas. This gives rise to natural levees adjacent to watercourses on the floodplains.

Soil washed away from cultivated areas is filtered out by grass or crops that may occur lower down the slope. On slopes where contour banks have been installed, silt settles out in the bank channels, grass strips, grassed waterways and watercourses. Siltation reduces the hydraulic capacity of natural and artificial waterways, creeks, streams and dams.

On-farm production costs resulting from siltation include crop losses through inundation, repairs to fences, runoff control works, access tracks, water storages, and maybe buildings. Loss to the community occurs when infrastructure such as roads are damaged and the community incurs the cost of repairs.

It is vitally important to undertake soil conservation measures such as contour banks, waterways, strip cropping (to slow down and spread the flow of water) and the retention of crop stubble (*see Chapter 9*).

8.4.1 Erosion in the alluvial plains

All cultivated alluvial soils of the plains (LRAs 1–5) may be subject to erosive flooding. The areas most vulnerable to high flood flows are those adjacent to the main creeks and streams, and at the outlets of creeks discharging onto the plains. Rocky Creek and Linthorpe Creek are examples where problems occur. Over time, floods have removed massive amounts of soil from paddocks causing siltation on lower lands, roads and in streams.

The construction of roads, fences and other infrastructure on the floodplains causes barriers to the even spread of floodwaters. Silt deposited against such structures, and the location of those works has caused floodwaters to be concentrated and diverted into adjacent land which in turn has suffered severe soil loss (*see Section 9.7.2*).

8.4.2 Soil erosion in the uplands

Aerial photography of the Central Darling Downs in the 1950s showed that widespread soil erosion existed on cultivated upland soils. It was not uncommon to find water erosion had caused soil losses to a depth of 30–60 cm. During the 1960s, when there was increased interest in constructing contour banks as an erosion control measure, many farmers stated that contour banks should have been installed 25 to 30 years previously. It is estimated that approximately 70% of the cultivated land requiring the protection of run-off control structures has now been treated (Carberry, 1995).

Run-off control structures alone (contour banks, diversion banks, waterways), are not sufficient to prevent soil erosion. There is a need for surface cover to prevent raindrop splash, sheet, rill and wind erosion.

Serious and widespread soil erosion by wind and water occurs when ground cover is lacking, particularly during the summer months when high intensity storms are more common. Practices such as increasing crop frequency and conservation farming allow for greater retention of summer and winter crop stubble and have contributed to more effective erosion control. Stocking rates should be controlled to prevent overgrazing of crop stubble which can lead to bare and vulnerable soil during fallow periods.

Cultivated lands in the upper catchments of the study area are generally too steep or have inadequate soil depth for continual cultivation (LRAs 6b, 6d, 7c). These lands are quite degraded and in need of a long period under pasture, to restore natural structure and fertility.

Many degradation problems in grazing lands are associated with the clearing of unsuitable land and with over-grazing and excessive burning of pasture. Pasture deterioration contributes to both wind and water erosion in the uplands (*see Section 8.9*). Rill and gully erosion has also occurred in grazing lands where roads, tracks, firebreaks, watering points and fencing have not been located appropriately. In some cases, these works have caused concentration and diversion of runoff water leading to severe erosion.

8.4.3 Soil erosion in the forest LRAs

The forested LRAs (10–14) generally have limited opportunities for cultivation development because the soils are too shallow, are infertile, or gravelly, or are too steep. Some soils (*Downfall, Combidiban, Drome, Nudley, Cutthroat, Flinton* and *Chinchilla*) have been developed mainly for winter grain and fodder crops.

There is a risk of erosion on these soils where they occur on sloping lands. Protecting with surface cover and the use of run-off control measures are important in these fragile soils.

The native and sown pasturelands of these forest areas are also subject to erosion if not managed carefully. Overgrazing, excessive use of fire and inappropriate clearing methods can cause severe sheet and rill erosion. Gully development has occurred through unsuitable location of tracks, fencing, firebreaks and watering points.

8.4.4 Streambank erosion

Streambank erosion is a problem along all the creeks and streams of the Central Darling Downs. Clearing, grazing or cultivation of banks and adjacent areas are major causes. Vehicular traffic up and down banks and the removal of soil, sand and gravel are also major contributing factors. Obstructions to stream flow such as fallen trees and sediment deposits, or trees growing on the inside of a bend, may deflect stream flow to vulnerable locations causing streambank erosion. Unstable banks often contribute large quantities of sediment to a stream and can threaten structures such as roads and bridges. Rapid changes in the course of a stream may have disastrous consequences for affected areas including adverse impacts on the aquatic ecosystems. Particular problem areas include Linthorpe, Rocky, Ashall, Oakey Creeks and Condamine River.

8.4.5 Wind erosion

Soil erosion by wind occurs when loose soil particles are transported along the soil surface or picked up in the wind. Soils prone to wind erosion are those that have a sandy or loamy surface or very finely structured clay soils. The potential for wind erosion is increased where there is an open landscape and little protective vegetation.

When soil particles are moved by wind, they build up against natural and artificial barriers such as fences and crops. Fine soil particles (silt and clay) lifted by wind can be deposited up to hundreds of kilometres away. As the natural fertility of a soil depends on the silt/clay content, the land is degraded when these soil particles are lost.

Vulnerable soils in the Central Darling Downs are those formed from mixed Basaltic and Sandstone alluvium on the Recent and Older Alluvial Plains (LRAs 1a, 2b, 2c, 2d), and possibly exposed Loamy Sodosol Alluvial Plains (LRA 3a). Open, disturbed areas of the Brigalow and Basaltic Uplands and Poplar Box Walloons (LRA 6, 7, 8) can be subject to wind erosion if the surface structure is badly degraded from excessive cultivation and left bare during periods of high winds.

After a heavy storm, bare alluvial sandy clay soils of mixed origin, (*Condamine, Cecilvale* and *Millmerran*), will often be eroded by wind, due to particle separation. Sandblasting of young summer crops can be a significant problem during hot, dry windy spells.

8.5 Mass movement

Mass movement is a form of land degradation that includes soil creep, earth flow, slumping, landslips, landslides and rock avalanches. It occurs when the force of gravity is greater than the resistance offered by the soil or rock material, so that the landmass moves down the slope. It is dependent on landform, rock and soil types, water content and vegetation cover. Mass movement may occur when moisture builds up in the subsoil layers, as a result of excessive clearing of vegetation that would otherwise maintain the soil moisture balance.

Mass movement is not a major land degradation problem in the Central Darling Downs, although it has occurred in the Toowoomba City area on the Eastern escarpment. There are potential landslip problems elsewhere along other very steep parts of the Great Dividing Range (LRA 7c).

Techniques for managing mass movement include developing stable vegetation cover at the site. Trees will help secure the soil. Other techniques include the establishment of interception banks or subsurface drains, which will divert water away from the site. Fencing the area will provide protection from stock and encourage vegetation regeneration.

8.6 Soil structure and fertility decline

The main cropping soils of the region are the broad level plains of basaltic alluvium or mixtures of basaltic and sandstone alluvium (LRAs 1a and 2a–d). Initially these soils were very fertile, with high levels of organic matter and friable surfaces.

Continuous cropping for at least 25 years has led to severe fertility decline and soil structural degradation. This has resulted in declining soil nitrogen levels and reduced yield and protein in grain crops. Common soil structural problems include compaction, hardsetting or cloddy surfaces, pulverisation of surface structure. These lead to poor seedling establishment, difficult workability, reduced infiltration and increased wind and water erosion.

Soil structural degradation varies with soil features such as clay type, structure, texture, moisture characteristics and organic matter. Mixed alluvial soils supporting poplar box woodlands (such as LRAs 2b, 2c) are typical of those prone to suffering a number of structural problems e.g. compaction and crusting. Heavy clay soils (LRAs 1, 2, 6, 7, 8) are prone to compaction, but usually repair themselves through cracking and swelling. The red non-cracking clay soils of LRAs 6a, 7a, 7b and 7d once compacted are more difficult to remedy as they lack natural shrink/swell properties.

There is widespread use of nitrogen fertiliser on the major cropping soils of the plains. Short-term rotations with lucerne or longer term rotations with grass/legume ley pasture are used to maintain soil structure and fertility levels in mixed farming enterprises, particularly in the uplands.

Soil structure decline

Soil structure decline is a widespread problem on the Central Darling Downs. It results in poor plant growth, as well as accelerated erosion by wind and water. Soil structure is related to the stability, porosity and infiltration characteristics of the soil. It essentially refers to the spatial arrangement of primary soil particles into aggregates such as peds, clods or crumbs. Structure may be described in terms of the grade, size and form of these aggregates. When soil structure breaks down, these aggregates separate into smaller units or into single soil particles.

The following soils of the Central Darling Downs are most prone to structural decline.

- Alluvial loamy soils in LRAs 1a-b.
- Alluvial soils in LRAs 2b-d and 3a.
- Sandy loam to light clay soils in the Brigalow Uplands, LRA 6a–d.
- Clay loam to light clay soils in the Basaltic Uplands, LRAs 7a–d.
- Loamy soils in LRAs 9a–b, 10a–b, and 12a–b.
- Clay loams in Traprock, LRA 14a

In soils with a high clay content, the clay particles may be held together by humus and/or other bonding agents (ionic, sesquioxidic etc). Some soils are naturally well structured, while others are not. Structureless soils (e.g. *Chinchilla, Davy*) may be single grain and loose in nature with no coherence between individual soil particles (sand). When they appear as a coherent, solid mass, with all soil particles firmly stuck together they are described as massive (e.g. *Nudley, East, Flinton*). Soils with a massive structure may be hard when dry, are poorly aerated and water does not infiltrate easily because of a lack of pore space.

Soils that have a high content of fine sand and silt in the surface, such as *Allan, Haslemere, Walker, Weranga* and *Oakey*, are naturally prone to hardsetting and crusting. Management practices such as excessive cultivation can increase the degree of hardsetting and crusting.

In some soils containing high levels of sodium, a change in the chemical balance of the soil can occur through the use of particular fertilisers or by reduction in organic matter. This can result in calcium being replaced by sodium, leading to structure decline in these soils.

Compaction by machinery or stock trampling also causes structural decline. Loss of organic matter results from continual overgrazing of pastures, or continual cultivation without stubble retention. In weakly aggregated soils, this loss of organic matter quickly leads to the separation of soil particles and a rapid breakdown of structure. Cracking and self-mulching clay soils with a strong structure are more resistant to particle separation, but compaction can cause temporary loss of pore space leading to reduced infiltration. The natural swelling characteristics of these soils allow the structure to be restored to its natural state as long as further compaction does not occur.

Local observations suggest that soil aggregates can break down during the high soil temperatures and low moisture levels, common in long-term droughts. The heaviest clay soils are susceptible to wind erosion when such conditions prevail.

Soil fertility decline

The top 10–20 cm of soil is chemically and physically the most fertile part of the soil, providing essential nutrients to growing plants (*see Chapter 4*). The loss of topsoil for a long period by erosion on the Central Darling Downs has been a major cause of reduced soil fertility.

Another major cause of reduced soil fertility is where agricultural, pastoral and forestry production occurs without the replacement of those soil nutrients that are taken up by plants. Large areas of the Central Darling Downs have been cropped continually for 50-100 years, without replacement of nutrients. Even the best soils subjected to such use, show deficiencies in nitrogen, phosphorus, zinc and sulphur.

The fertility of grazing land is also declining, as natural soil elements such as nitrogen, phosphorus and some trace elements are removed in the form of meat, milk or wool products. This is evidenced by changes in species composition, invasion of weeds and greatly reduced pasture growth.

8.7 Acidification in cropping lands

Increasing soil acidity leads to a reduction in plant growth and yield. Soil acidification can produce a dramatic decline in crop and pasture production due to nutritional changes such as calcium deficiency, and aluminium and manganese toxicities. Depending on the parent material of a soil, acidity problems increase when farming practices cause the soil pH to drop below levels suited to normal plant growth, i.e. pH <5.5. Such practices include use of high levels of some nitrogen-based fertilisers (e.g. sulphate of ammonia), or harvesting plant material that is high in alkaline nutrients. Applying superphosphate on legume based pastures and nitrate leaching over time from medic-based pastures can also lead to soil acidification.

Soils that originally had a neutral pH may suffer acidification. For example, in the older alluvial plains of the Central Darling Downs, the red-brown earths (e.g. *Oakey*) have become more acidic after several decades of grain cropping and application of nitrogen fertiliser. Soils with light textures, low organic matter, low buffering capacity (low ability to resist chemical change) and moderate acidity are susceptible to acidification and include:

- sandy loam to clay loam soils in Recent and Older Alluvial Plains (e.g. *Downfall, Haselmere, Oakey,*) and the loamy and sandy Sodosols (e.g. *Leyburn*);
- loams to light clay soils of the Brigalow Uplands and Poplar Box Walloons (e.g*., Acland, Diamondy, East, Toolburra, Walker*);
- red and red-brown clay loam to light clays of the Basaltic Uplands (e.g. *Aubigny, Burton, Nungil, Southbrook*);
- sandy loam to clay loam soils in the Poplar Box Sodosols (e.g. *Downfall, Leyburn, Haslemere, Nudley*);
- sandy loam soils in the Ironbark/Bull Oak Sodosols, Cypress Pine and Sandstone Forests (e.g. *Allan, Channing, Flinton, Hanmer, Leyburn, Nudley, Weranga,*);
- the gritty sands of the Granite Hills (e.g. *Banca, Cottonvale*); and
- the gravelly loams of the Traprock Hills, (e.g. *Gammie, Karangi*).

8.8 Salinity and sodicity

Salinity and sodicity issues in the Central Darling Downs relate to inherent characteristics of the geology and soils in the area. However, some problems can be related to mismanagement of the land through excessive clearing, unsuitable landuse or the over-use of poor quality irrigation water.

Salt-affected soil retards plant growth, reduces choice of crops or pastures, and when extreme, can be completely unproductive. Salt affected land is susceptible to wind and water erosion due to the lack of plant cover. Soils with a high salinity level have a tendency to disperse readily in water due to the high levels of sodium. This increases the risk of tunnel erosion.

Sodic soils contain high amounts of sodium attached to the clay particles. They are difficult to manage as they are often hardsetting, may be waterlogged, are poorly aerated, prone to erosion and compaction and have high bulk densities that inhibit root penetration.

8.8.1 Salinity

Salinity in soil refers to the concentration of soluble salts in the soil solution. A build-up of salts interferes with water and nutrient uptake by the plant roots, resulting in poor growth. As salts move to the surface and become concentrated, the plants die leaving denuded areas called scalds. Rehabilitation is difficult and costly.

Saline soils can result from the weathering of natural rocks that contain high levels of sodium which are frequently those derived from marine sediments, but also from some granites and volcanics.

In irrigation areas, yields of sensitive crops can be affected when poor quality groundwater is used, i.e. groundwater that contains salts. Irrigation may also upset the salt equilibrium in saline soils because of the increased moisture applied. This can result in salts, otherwise held in balance in the subsoils, being brought to the root zone in rising water tables.

Dryland salinity results from saline groundwater reaching the plant root zone or the soil surface, and affecting soil properties and plant growth. This can occur after a change in the landuse of the recharge areas (e.g. clearing of timber), leading to a rise in the groundwater levels. Salts can dissolve in groundwater where it flows through naturally saline rock or substrata. The areas affected by dryland salinity often occur at the interface between different geological units or at a break of slope.

In the Central Darling Downs, dryland salinity is often associated with groundwater seepages and natural springs at the interface between the Walloon Coal Measures and other units such as the basaltic uplands, Marburg Subgroup and alluvial areas (K.K. Hughes *pers. comm*. 1986). Knowles-Jackson (1987), conducted a detailed survey of dryland salinity occurrences in the Jondaryan and Rosalie shires, and found salinity on 63 farms, with a total affected area of 581 ha. Other affected areas have been reported in the Kaimkillenbun/Bell/Jimbour district (Molloy and McIntyre, 1986). On several farms in the Bell area, outbreaks range from 10 to 40 hectares in size. Small saline seepage areas of less than 1 ha occur in all shires of the Central Darling Downs.

Photo 15 An area near Dalby where trees have been killed by rising groundwater and salinity

Changes in the groundwater hydrology resulting from land development and management practices such as tree clearing and long fallowing may cause shallow watertables to rise within the root zone. Salinity problems may not be evident for up to 50 years or more after an initial change in landuse, because of the slow movement of water through the subsurface rock layers. This means new outbreaks of salinity can occur continually, and the area affected fluctuates seasonally, being greatest after a period of wet years. Carberry (1995) identified approximately 1500 hectares of salt affected land on the Darling Downs (i.e. Central Darling Downs plus parts of the Cambooya, Chinchilla, Clifton, Murilla, Tara and Warwick Local Authority areas). Another 3000 hectares was considered potentially at risk from salinity in the future.

The most common signs of dryland salinity are seepage areas, soil structure deterioration, crusting, finely flocculated (fluffy) clay, and zones of poor crop growth. Salinity levels can become high enough that even salt tolerant plant species cannot grow. In these extreme situations, white salt crystals are evident on the soil surface, and the area is devoid of all vegetation.

8.8.2 Sodicity

Sodicity is often associated with saline seepage, but some soils may be naturally sodic. Examples include *Cecilvale, Condamine* and *Kupunn* (*see Soil Summary Sheets*), all of which have sodic to strongly sodic subsoils below 30–50 cm. Sodicity is caused by the presence of sodium held on the surface of clay particles in a soil (*see Section 4.4.4*). Sodium weakens the bonds between soil particles when they are wet, causing them to disperse. Dispersed clay acts as a filler and binder, clogging the pores in a soil, reducing infiltration and drainage, and increasing the size and density of aggregates.

Symptoms of sodicity problems include poor infiltration and drainage resulting in waterlogging, increased runoff and poor water storage; surface crusting causing poor emergence of crops and pastures; gully erosion and tunnel erosion in sloping country (Rengasamy and Walters, 1994).

Sodicity is becoming an increasing problem on soils developed on the Walloon geological formation particularly in those areas identified by the presence of poplar box (*Eucalyptus populnea*) tree species. Sodic soils and texture contrast soils with sodic subsoils at less then 30 cm are susceptible to land degradation. These soils occur in all LRAs except the basaltic uplands (*LRA Map in back pocket*).

8.9 Degradation of grazing land

Land degradation has had an enormous impact on the productivity of the grazing lands and has greatly increased costs of production. Whilst the clearing of land and the provision of watering facilities has increased the number of some forms of wildlife it has had an adverse effect on many species of wildlife and native flora.

Table 8.1, extracted from Tothill and Gillies (1992), shows the assessed condition of the main pasture communities in the Condamine catchment (which includes the Central Darling Downs area). The pasture conditions were assessed at 3 levels:

A *sustainable*, ecologically desirable pasture condition; physical, chemical soil fertility maintained; reasonable economic output.

B: *deteriorating* degradation, undesirable change that can be reversed with appropriate management and normal rainfall.
C: *degraded*, probably irreversible change within limits of economic management.

Table 8.1 Condition of main pasture communities in the Condamine catchment

Pasture community	Condition
Aristida - Eragrostis (wiregrass, lovegrass, cypress) e.g. LRAs 10b, 12b	Sandy skeletal soils: 60% condition A, 30% condition B and 10 % condition C. [Pine density, due to lack of appropriate fire management, is the main cause for pasture deterioration.]
Queensland bluegrass (southern) e.g. LRAs 1a, 2a, 7	i. Darling Downs plains: 70% condition A, 25% B and 5% C. ii. Darling Downs uplands, 40% A, 50% B and 10% C. [Overgrazing in some areas.]
Brigalow-Belah (southern) e.g. LRAs 5, 6	45% A, 45% B and 10% C. Brigalow regrowth and soil nutrient decline are the main factors affecting pasture condition.
Bothriochloa-Stipa-Danthonia (bluegrass, speargrass) e.g. LRAs 10, 12, 13, 14	i. Traprock: 25% A, 60% B and 15% C. ii. Granite: 60% A, 30% B and 10% C. iii. Sandstone: 20% A, 70% B and 10% C. [Regrowth following clearing is the main degradation problem.]
Black speargrass (southern) e.g. LRAs 6, 7, 12	Minor areas along the Great Dividing Range: 60% A, 35% B and 5% C. [Overgrazing and timber regrowth are the main causes of pasture decline.]

Overgrazing has adverse effects on the condition of pastures by changing the pasture composition to less desirable species, accelerating soil erosion and invasion of weeds. Heavy pressure is often placed on pastures during and immediately following droughts. High populations of feral and native animals may contribute to degradation problems in grazing lands (*see Section 8.10*).

Continual overgrazing leading to loss of desirable perennial grasses is often accompanied by soil erosion, surface crusting and reduced infiltration (Scattini and Hall, 1987). Lack of protective surface cover, especially at the time of high intensity storms, leads to sheet and rill erosion. Gully erosion may occur where inadequately located tracks, fencelines, watering points and firebreaks cause runoff flows to concentrate. Many degradation problems in grazing lands are associated with the clearing of unsuitable land.

8.10 Weeds and pest animals

Pest plants fall into 2 categories: declared (under State legislation) and non-declared. Pest plants targeted for legislative control are species that have, or could have serious economic, environmental or social impact. Declaration imposes legal responsibilities for control. Under the *Rural Lands Protection Act 1985* (RLPA), all landholders, local government and state government agencies are required to control declared plants on land under their control. Declared plants are listed under different categories which reflect the level of control required by law:

- Category P1 — Plants whose introduction into the State is prohibited.

- Category P2 — Refers to plants that are to be destroyed throughout the State or the relevant parts of the State.
- Category P3 — Refers to plants whose numbers and/or distribution are to be reduced throughout the State or the relevant parts of the State.
- Category P4 — Refers to plants that are to be prevented from spreading from the places from in which they occur in the State or the relevant parts of the State.

Local governments can also declare weeds within their boundaries that are not declared under the RLPA, using a Model Law under the *Local Government Act 1993* A list of locally declared weeds can be obtained from the relevant local government.

Declared, agricultural and environmental weeds for the Central Darling Downs are shown in Table 8.2.

Table 8.2 Declared, agriculture and environmental weeds in the Central Darling Downs

Status	Common name
Declared weeds	African boxthorn, annual ragweed, bathurst and noogoora burr, giant rats tail grass, groundsel, fireweed, harrisia cactus, honey locust, mother of millions, Parthenium, salvinia, stramonium, tiger pear, tree pear and pest pear, water hyacinth, water lettuce.
Agricultural weeds	amaranthus, barnyard grass, bellvine, bladder ketmia, caltrope, climbing buckweed, cobblers peg, couch grass, deadnettle, docks, fat hen, hexham scent, Johnson grass, marshmallow, melons, mintweed, mustard, New Zealand spinach, nut grass, pigweed, sesbania, spiny emex, summer grass, staggerweed, thistles, turnip, urochloa, wild oats, wild radish, wireweed.
Environmental weeds	asparagus fern, broad-leaved pepperina, camphor laurel, cats claw creeper, Chinese elm, lantana, lippia, paulownia, privet, wandering dew, weeping willow, white moth plant.

Declared weeds

Declared weeds that have the potential for serious economic, environmental or social impact on the Central Darling Downs include:

Parthenium weed (declared P2)
This weed is a vigorous annual herb with white/creamy flowers that colonise weak pastures and areas of sparse ground cover. This pest plant is also a health risk, as contact with the plant or pollen can cause dermatitis and hayfever. Parthenium weed is a major problem in Central Queensland. Small infestations have occurred in the Central Darling Downs and are usually quickly brought under control. Parthenium is spread easily by machinery, vehicles, stock fodder, stock movement and pasture seed.

African boxthorn (declared P3)
African boxthorn is a spiny shrub growing to 5 metres and producing red berries. The plants can be an aggressive invader of pastures, forming impenetrable sharp spined thickets. Birds and animals disperse seed (when the fruit is ingested).

Tree pear and pest pear (declared P3)
Tree pear and pest pear is distributed throughout the Central Darling Downs, occurring in wooded areas and along fencelines. Birds and animals spread the seed

when the fruit is ingested. Pest pear is controlled by the introduced cactoblastis moth, which also controls seedling tree pear. The cactoblastis moth is widely distributed in this area. Mature tree pear can only be controlled with an appropriate herbicide.

Bathurst and noogoora burr (declared P3)
Bathurst burr and Noogoora burr are widely distributed throughout the Central Darling Downs. Bathurst burr is an erect annual herb growing to 1 metre. Mature plants are covered in straw coloured burrs with hooked spines. Noogoora burr is an erect annual herb growing to 2 metres. Mature plants produce numerous woody spiny burrs with hooked spines. The seedlings of both burrs are poisonous to livestock. Heavy infestations occur where the ground has been disturbed, e.g. roadsides, cultivation, irrigated pasture and water courses.

Mother of millions (declared P4)
Mother of Millions are erect, smooth, fleshy, succulent plants growing to about 1 metre. Tall flower spikes form in winter with clusters of orange/red bell shaped flowers. These plants are highly poisonous to stock and have caused significant cattle deaths. Infested areas need several treatments and should be monitored regularly for regrowth.

Weeds in cultivation (non-declared)

Major annual summer weeds in cultivation include liverseed grass, summer grasses, thornapple, noogoora burr, mintweed and wireweed. Winter weeds include turnip weed, wild radish, thistles, wild oats and climbing buckwheat. Perennial weeds posing serious problems in cultivation on heavier soils include nutgrass, johnson grass and bindweed. These weeds are controlled mainly through crop rotations and herbicide application. If a summer weed is a serious problem, winter cropping is carried out in that paddock and the weed controlled (through herbicide or cultivation) through the summer.

Pest animals

Pest animals impact on most primary production enterprises across the Central Darling Downs. Declared pest animals are: dingo/wild dog; feral pig; fox; rabbit, hare and locusts. Non-declared pest animals of concern are the house mouse, European carp and the feral cat. Under the Rural Lands Protection Act (RLPA) 1985, landowners are required to control declared animals on their land. The RLPA uses eight categories to indicate the standard of control required.

- A1 introduction of these animals are prohibited
- A2 animals non-native that must be destroyed
- A3 keeping and selling is prohibited
- A4 introduction subject to prescribed conditions and restrictions
- A5 numbers to be reduced and kept under restriction
- A6 keeping and selling subject to prescribed conditions and restrictions
- A7 Native animals that require a management program
- A8 plague species (locusts only)

Dingo/Wild dog (declared A1 A3 A5)
Dingoes and wild dogs are present throughout the Central Darling Downs, impacting on the grazing industry. They mostly occur in the forested hills on the western slopes of the Great Dividing Range and the sandstone forest west of the Condamine River. Controls include exclusion (electric fencing), shooting, trapping, and baiting. Baiting campaigns are carried out several times a year in the area to reduce populations. A high level of participation is required to dramatically reduce numbers.

Feral pigs (declared A1 A2 A6)
Feral pigs are significant pests in the grain growing areas of the Condamine Floodplain. They prefer habitats with surface water, such as watercourses. Feral pigs will also prey on lambs in the sheep growing areas. Control methods include trapping, baiting and shooting.

Fox (declared A1 A2 A3)
The European red Fox is widely distributed over the Central Darling Downs. Numbers are estimated to be 5–10 per square kilometre in agricultural areas. Foxes prey on newborn lambs in sheep growing areas, and frequently raid poultry. Foxes have been responsible for extensive environmental damage, preying on native birds, marsupials and reptiles. Control methods are poisoning and shooting.

Rabbit (declared A1 A2 A3)
Most of the Central Darling Downs is within the protected area of the Darling Downs and Moreton Rabbit Board fence (*see Map 1*). Parts of Millmerran and Wambo shires are not within the protected area, and rabbit numbers can build up and require control. Rabbit calici disease (RCD) has been released in these areas but control methods such as warren ripping and shooting may still be required.

Hares (declared A1 A2 A3)
Hares are widespread throughout the Central Darling Downs. Normally they do little damage, but can impact on newly established orchards and tree plantings by ring barking young trees. Controls include shooting and exclusion.

House mouse
Mouse plagues have become more prevalent on the Central Darling Downs cropping areas. The main contributing factors causing the increase in numbers include stubble retention and decreased soil disturbance from conservation farming practices, double cropping and poor farm hygiene around sheds and grain storage areas. Control methods include anti-coagulant mouse poisons around sheds and grain storage and the use of zinc phosphide in broadacre cropping areas. DNR monitors mouse numbers during the year and can predict the likelihood of plagues.

Feral cats
Feral cats are widespread throughout the Central Darling Downs. Although they do little direct damage to agricultural industries, they have been responsible for extensive environmental damage, preying on native birds, marsupials and reptiles. Control methods are cage trapping, poisoning and shooting.

European carp
Introduced European carp are an environmental pest that contribute to stream bank erosion and result in the loss of or displacement of many native fish and aquatic organisms. It is illegal to transport them alive and place them in any waterways.

Plague locusts (declared A8)
Locust plagues cause serious damage to crops, pastures and native vegetation periodically. DNR and Australian Plague Locust Commission (APLC) monitor locust numbers during the year and can predict the likelihood of plagues. Locusts are controlled with insecticides. Large numbers of young locusts should be sprayed as soon as they are found. Aerial spraying has been found to be the most effective method of control against the very mobile adult. DNR and APLC are researching possible biological control agents for locust control.

8.11 Degradation of water resources

The management of land, water and vegetation resources are inextricably linked. The nature and intensity of land management practices determine the extent to which water resources are affected. For example, soil erosion from an agricultural landscape results in the transfer of sediment into creeks. While sediment is suspended in the water, it can reduce penetration of light through the water and impact on aquatic plants which rely on energy from the sun for growth. Where sediment settles out it can smother aquatic animals, interfere with their feeding mechanisms or change the habitat in which they live. Deposition of sediment can also fill up river pools, which act as important refuge habitat for animals when flow in the river has stopped. Nutrients, most importantly phosphorus, and pesticides attached to sediment can be transported into waterways.

Groundwater contamination is another example of catchment activities impacting on water resources. For example, wastewater from intensive animal industries containing high concentrations of nutrients or irrigation tailwater containing high concentrations of agricultural chemicals can enter groundwater systems. Contaminants can enter groundwater systems in a number of ways including, direct leaching through the soil profile, interchange with surface water flows and transfer from a connected groundwater system. Once in the system, pollutants can be transported in both vertical and horizontal directions some distance from the source.

Table 8.3 presents an overview of the major relationships involved in problems arising from human pressures on water resources relevant to the Central Darling Downs.

The environmental issues of most concern associated with water resources within the Central Darling Downs are briefly described as:

- Increased nutrient loading in surface waters. Nutrient sources include sewage treatment discharges, intensive animal industries, urban stormwater and agricultural runoff.
- Contamination of water by pesticides. Important pesticide sources include runoff, drift and non-target applications associated with dryland and irrigated cropping, and urban uses.
- Decreased groundwater quality. Potential groundwater contaminants include saline waters, nutrients, pesticides and effluent.
- Water resource conflicts. There is a continuing demand for surface water and groundwater resource development in the study area. There is also an increasing recognition of the environment as a water user i.e. the need for environmental flows.

Table 8.3 Major effects of human pressures on water resources

Pressure / Problem	Agriculture, urban development, infrastructure	Flow regulation, water storage and diversion	Modification of water and sediment flow	Pollution	Channelisation and river works	Introduction of feral animals, fish and plants
Streambank and streambed instability						
Bank scour	✓				✓	
Bank slumping	✓					
Overbank erosion	✓					
Bed erosion		✓			✓	
Sedimentation		✓			✓	
Habitat Degradation						
Riparian habitat degradation	✓	✓	✓	✓	✓	✓
In-stream habitat degradation	✓	✓	✓	✓	✓	✓
Water quality and flow regime						
Degraded water quality	✓	✓	✓	✓		✓
Altered flood patterns	✓	✓			✓	
Socio-economic factors						
Loss of land and infrastructure	✓	✓	✓			
Reduced recreational value	✓	✓	✓	✓		
Reduced conservation value	✓	✓	✓	✓	✓	✓

Source: Anon. (1999).

Photo 16 Rabbits are a declared animal pest on the Central Darling Downs

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Photo 17 Pasture field day at Warra

Photo 18 Rainfall simulator field day at Pittsworth

9. LAND PLANNING AND MANAGEMENT STRATEGIES FOR SUSTAINABILITY

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9.1 Introduction

This chapter outlines some of the processes and strategies that may be used in property planning and regional/catchment planning to achieve sustainable landuse. Property planning provides for development and land management at a property level aiming at economic but environmentally sustainable production, while regional/catchment planning focuses on local government and catchment land use planning.

A basic planning principle is that land resources (i.e. soils, vegetation, landform and hydrology) should be used within its capability if sustainable landuse is to be achieved. This principle applies to all levels of planning, whether at the property scale, the broader catchment scale or for local government areas.

The first step in planning for landuse and land management involves a careful assessment of the natural features of the land. This involves assessing the capability and suitability of land resources for a range of different landuse and the inputs and management required for sustainable use. For example, in the case of property planning, an area of land could be suitable for grain cropping with the addition of fertiliser and run-off control measures. For local government planning, an area of land may not be suitable for residential development unless reticulated sewerage is provided.

Natural resource planning is an on-going process. Once a plan has been implemented, monitoring of its outcomes should occur to determine whether modifications to the plan are necessary.

The information contained in this *Land Management Manual* will provide a basis for developing landuse and land management plans at any scale. The *Land Resource Area Map* (*Map 1 in back pocket*) and *Resource Information Book* can be used to identify suitable landuses and management at a broad scale. The *Soil Summary Sheets* in the *Field Manual* provide more detailed information useful at the property level once more detailed surveys are carried out to identify different soil types.

9.2 Land planning

9.2.1 Statewide planning

Guidelines for natural resource planning at a state level are expressed in the form of state planning policies. The most significant state planning policy that influences landuse and management on the Central Darling Downs is State Planning Policy 1/92: Development and the Conservation of Agricultural Land (DHLGP 1992).

State Planning Policy 1/92 was formulated to allow good quality agricultural land to be identified and protected (DHLGP 1992). The policy requires both local and state governments to be aware of the location of good quality agricultural land and to protect it using local government planning schemes. To assist government with the policy, two sets of guidelines, *The Identification of Good Quality Agricultural Land* (DPI & DHLGP 1993), and *Separating Agricultural and Residential Land Uses* (DNR & DLGP 1997) have been prepared.

This state planning policy defines good quality agricultural land (GQAL) as 'land which is capable of sustainable use for agriculture using a reasonable level of inputs and managed without causing degradation of land or other natural resources'. Good quality agricultural land is a scarce resource in Australia and Queensland. Even though agricultural products are significant contributors to export income, only approximately 6% of Australia and only 4% of Queensland is regarded as productive cropping land. These, combined with the need to retain our rural heritage and provide a base for secondary industries, are the primary reasons why good quality agricultural land should be protected from non-rural uses wherever possible.

The guidelines for the identification of good quality agricultural land is a classification system to differentiate between land types and their suitability for agriculture. These guidelines define the agricultural land classes as follows:

Class A: Crop land
Land **suitable for current and potential crops**. All land suitable for cropping (*see Table 4.8*) is considered to be good quality agricultural land.

Class B: Limited crop land
Land **marginal for current and potential crops**; and **suitable for pastures.** Land suitable for particular crops of local significance is considered to be good quality agricultural land.

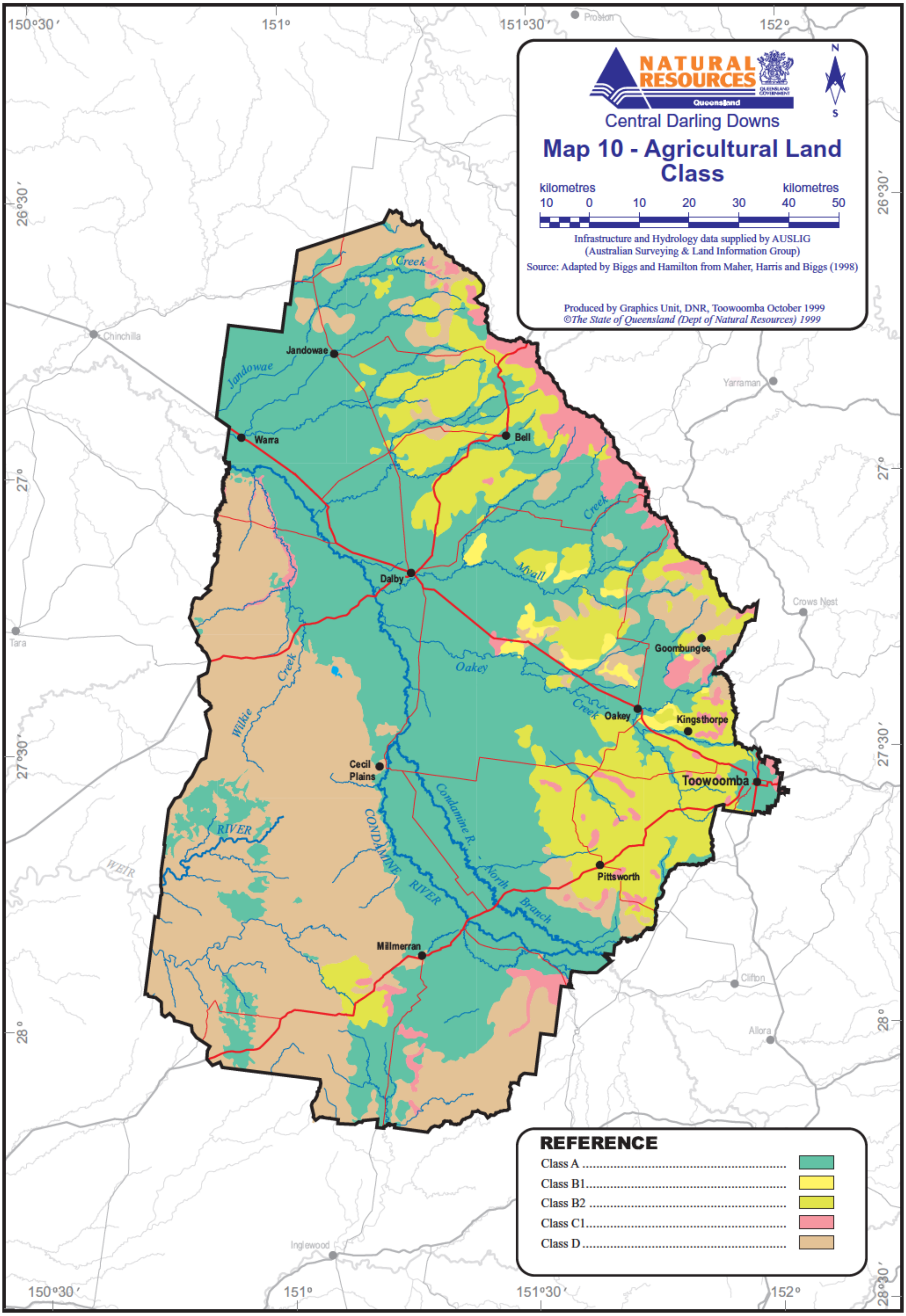
Class C1: Pasture land
Land **suitable only for improved or native pastures**. In areas where pastoral industries are predominant, improved pasture may be considered as good quality agricultural land.

Class C2: Pasture land
Land **suitable only for native pastures**. In areas where pastoral industries are predominant, native pasture may be considered as good quality agricultural land.

Class D: Non-agricultural land
Land **not suitable for agricultural uses.**

Table 4.8 identifies the suitability of each of the 14 LRAs (and their dominant soils) described in the Central Darling Downs for different agricultural uses and their dominant agricultural land class. This information may be used for regional planning. Map 10 displays the Agricultural Land Classes based on the Central Darling Downs LRAs.

The guidelines for Planning Policy 1/92 also outline the role of local government planning in protecting good quality agricultural land and principles to be used when assessing development applications which are located on good quality agricultural land. A review of these guidelines began in 1998.



NATURAL RESOURCES
Queensland
Central Darling Downs
Map 10 - Agricultural Land Class
kilometres
10 0 10 20 30 40 50
Infrastructure and Hydrology data supplied by AUSLIG (Australian Surveying & Land Information Group)
Source: Adapted by Biggs and Hamilton from Maher, Harris and Biggs (1998)
Produced by Graphics Unit, DNR, Toowoomba October 1999
©The State of Queensland (Dept of Natural Resources) 1999
REFERENCE
Class A
Class B1
Class B2
Class C1
Class D
Jandowae
Warra
Bell
Dalby
Goombungee
Oakey
Kingsthorpe
Toowoomba
Cecil Plains
Pittsworth
Millmerran
Chinchilla
Tara
Yarraman
Crows Nest
Clifton
Allora
Inglewood
Proston
CONDAMINE RIVER
Condamine R. North Branch
Myall Creek
Oakey Creek
Wilkie Creek
Jandowae
WEIR RIVER
150°30′
151°
151°30′
152°
26°30′
27°
27°30′
28°
28°30′

The reference, *Planning Guidelines: Separating Agricultural and Residential Land Uses* (DNR & DLGP 1997) provides technical advice and guidance to local government, developers, consultants and landholders on minimising conflicts between farming activities and residential uses. Conflict can arise from the use of chemicals, noise, dust and odour generating activities. Adverse impacts of residential development on farmlands include sediment and stormwater runoff. These planning guidelines outline measures to reduce these types of land use conflict.

9.2.2 Regional planning

Regional Planning is an exercise for which the Department of Communication, Information Local Government and Planning is lead agent and which is provided for in the Integrated Planning Act (1997). Regional planning addresses issues that extend beyond the boundaries of a single local government. It is co-ordinated by Regional Planning Advisory Committees and seeks to develop a framework for managing growth and for programming the provision of State and local infrastructure and services. (DNR, 1998).

The Central Darling Downs is partially covered by the Eastern Downs Regional Organisation of Councils (EDROC) which has a focus on regional planning in the study area. Only the local governments of Dalby Town and Wambo Shire are not covered by EDROC. In 1996, EDROC released a Regional Land Use Strategy which provided a framework for consistent land use planning and decision making by local governments in the area. This strategy addressed issues relating to settlement patterns, rural landuse, transportation, natural resources, facilities, infrastructure, social planning and cultural heritage.

The term regional planning is also used to describe any form of planning at the scale of a whole river catchment (e.g. the Condamine River catchment), a bio-geographical area (e.g. the southern brigalow belt) or an extensive area of distinctive economic activity (e.g. Eastern Darling Downs or Granite Belt).

9.2.3 Catchment planning

Integrated Catchment Management (ICM) is a framework for planning at a whole river or sub-catchment scale. The Central Darling Downs is covered by a catchment co-ordinating committee called the Condamine Catchment Management Association Inc. (CCMA). The main focus of this committee is to develop management strategies that help to achieve sustainable use of natural resources in the Condamine catchment from Killarney to Chinchilla.

Catchment committees can provide advice to both regional and local land planning authorities. This advice can ensure landuses are appropriately located and managed to maintain the condition of the natural resources. To achieve sustainable landuse local government, Catchment Co-ordinating Committees and regional planning groups need to work closely together.

Sub-catchment planning

Land use planning can also occur on a sub-catchment scale. Sub-catchment planning considers specific issues relevant to a part of a catchment in detail and the planning of on-ground solutions with land managers in a co-ordinated way.

Typically, sub-catchment planning has an integrated socio-economic and natural resource management approach focussing on achieving high levels of on-ground actions and attitudinal change to land management at a local community level.

For example, the Brigalow–Jimbour Floodplains Group Inc. has adopted a catchment approach to resolve runoff co-ordination and flood plain management issues in the Jimbour, Canaga, Jinghi, Jandowae, Jimbour and Cooranga Creek catchments.

Photo 19 Planning for runoff management on floodplains

Project planning and implementation has occurred at a sub-catchment scale to implement co-ordinated runoff control measures with land managers including farmers, local governments and state agencies.

9.2.4 Local government planning

Local Governments have a major responsibility for land use planning through the preparation and operation of their planning schemes. In 1997 the Integrated Planning Act was introduced which requires all Local Governments to prepare a new planning scheme for their local government area.

A local government's planning scheme co-ordinates and integrates local, regional and state matters related to landuse and development, infrastructure and valuable features (including significant ecological or natural resource areas) within its area. Planning schemes should integrate relevant matters identified in regional land use strategies and/or catchment management plans.

Local Government also have the responsibility for making decisions on the use and management of land at a site specific scale by assessing proposals for development of particular parcels of land. Local Government is required to assess these proposals under the Integrated Development Assessment System (IDAS). This system was established under the Integrated Planning Act (1997) to integrate state and local government development assessment and approval processes. In assessing development applications, local government is required to ensure that the effects of development on the environment can be managed and that natural resources are used sustainably.

9.2.5 Use of this manual for regional, catchment and local government planning

The Central Darling Downs Land Management Manual can provide useful information for all levels of land planning. The information in the manual can be used:

- As base information for strategies and planning schemes to determine the capability / suitability of the land resources for future landuses at a broad scale.
- To develop broad scale GQAL maps for planning scheme preparation.
- To assist the assessment of development applications and their possible impact on land resources.
- To assist catchment management and Landcare groups identify, understand and develop plans to resolve land resources management issues relevant to their locality.
- To create awareness of the physical limitations to the use of land, and provide strategies to prevent or minimise land degradation.
- To assess the impact of land development on other natural resources.

9.3 Property planning

A property plan can take many forms depending on the specific requirements of the landholder. Although property planning can be very much a voluntary process, particular types of plans may be required for specific purposes. Some examples include, soil conservation plans, vegetation management plans, land and water management plans and nature conservation plans. The DNR Fact Sheet (LC64) *Property Plans: when are they required* provides a brief outline of various plans for specific purposes.

Property mapping for landholders (DNR in press), is a guide to preparing property plans showing the component of a plan, sources and types of suitable base maps and where necessary, use of overlays for particular purposes.

A property plan combines the knowledge, experience and goals of a landholder with the technical knowledge and expertise of land management planners and advisers. The plan shows how the land can be developed and managed economically and at the same time allow for the sustainable use of resources. An understanding of limitations of the land resource and the potential for degradation through misuse helps to ensure sustainable production goals are possible. The degree to which these are included in a particular property plan can depend on the complexity of the land resource and/or property specific enterprise and the purpose of the plan.

Some natural resource components of a property plan include:

- resource plan (or resource inventory);
- a capability plan;
- land use plan; and
- property management plan.

9.3.1 The resource plan

Prominent features (such as watercourses, ridges, catchment boundaries and vegetation patterns) are identified from an aerial photo or other resource map, and marked onto an appropriate base plan. Other details are added such as existing landuses, fencing layout and access, water storages, watering points, buildings and yards. Opportunities for enhancing or further developing the natural resources should be assessed and noted, for example, value of timber for commercial use or for shelter, windbreaks, wildlife habitat or quantity and quality of water and the potential to irrigate. A landholder interested in managing the property efficiently and maintaining its productivity should consider natural environment concerns, such as the maintenance of wildlife habitats and the preservation of remnant vegetation.

9.3.2 The capability plan

There is a need to identify the capability of the different land types to ensure no part of the property is developed or used beyond its sustainable potential. Land capability assessment should include land slope, landform, vegetation patterns, and soils and their characteristics. This information helps to classify the land according to the limits of safe landuse, the suitable management techniques and the hazards attached to specific use of the land (Rosser *et al.*, 1974).

Guidelines for Agricultural Land Evaluation in Queensland (LRB Staff, 1990) provides details for determining land suitability for specific enterprise production. For example, the land suitability criteria for growing wheat, or for types of irrigation uses, or for intensive grazing by beef or sheep. Broad land suitability determinations are given in Chapter 4 for the Land Resource Areas in the Central Darling Downs as well as more detail for specific soils — see also Biggs, 1999b. In time, identified land classes or categories may be altered as economic conditions and/or technology change. This will allow for alternative, but safe use of the land.

For property planning purposes, either the land capability method described by Rosser *et al*. (1974) or the Land Resources Branch method (Land Resources Branch, 1990) for land suitability mapping, may be used. Both systems divide agricultural land into various classes based on limiting factors that can affect the land's ability for sustained production. The land characteristics that can limit the type or degree of agricultural production, are broadly grouped as follows:

- *Factors limiting choice of crops or crop productivity*, i.e. climatic, moisture availability, soil depth, soil physical factors, nutrient fertility, soil salinity or sodicity;
- *Factors limiting the use of agricultural machinery or accessibility*, i.e. topography, soil workability, stoniness, surface micro-relief or wetness; and
- *Factors related to land degradation,* i.e. susceptibility to water erosion, wind erosion, or flooding.

To determine land capability, it is necessary to identify those areas where obvious limitations occur. Examples of these may include:

- steeply sloping areas which make the use of farm machinery difficult, or which have a high risk of erosion;
- rocky or wet areas not suitable for cropping or pasture improvement; and

- areas where soil features (e.g. surface compaction, depth, dispersibility) result in limited agricultural potential.

After these have been identified and mapped, a detailed assessment can be made of the remaining land using the information given in the *Field Manual*. Once the land capability plan is completed, the land use plan is prepared, taking into account the managerial skills and the financial resources available for the preferred enterprise.

9.3.3 The land use plan

Depending on land capability, the following land use options can be available for each parcel of land in regard to its agricultural potential:

- Cultivation for grain (summer and winter), fodder and horticultural uses.
- Improved pastures, introduced grasses and/or legumes.
- Native pasture production.
- Limited agricultural use, but may be best suited to timber production, nature conservation, or watershed protection purposes.

Strategies for ensuring sustainable landuse for agricultural enterprises based on the above options, are outlined in Sections 9.7 and 9.8. Consideration should also be given to nature conservation benefits (*see Section 9.4*).

Different inputs may be required for each management unit, depending on the adopted enterprise. For example, the land capability study may define a parcel of land suitable for growing lucerne, or for a horticultural cash crop, but the inputs will differ depending on which crop is grown. Adding fertilisers and irrigation water may be sufficient to overcome the specific limitations for lucerne growing; but for a cultivated horticultural crop it may be necessary to implement an intensive runoff control system. Therefore, the land use plan should identify the particular requirements for each parcel of land according to the expected enterprise.

A land use plan for a property may need to co-ordinate its run-off control requirements with those works required on neighbouring properties. Often, the location and the time of installing these works on one property can affect related works on upstream or downstream properties. Cross-drainage structures on public utilities such as roads, railways or irrigation channels, should also be co-ordinated as part of an overall catchment plan.

9.3.4 The property management plan

The property management plan describes the measures and action required when changing a property from the current to the desired landuse, considering also the available financial constraints and resources. This plan should be flexible and modified as needs change and financial resources fluctuate according to economic influences.

Care is required to ensure timely and proper development. For example, excessive clearing early in development of a property may require additional time and costs in later regrowth control. Planning for areas to be cleared should give regard to the need to retain trees for shade, shelter and timber supplies and the risk of secondary salinisation. Indiscriminate clearing of native vegetation can result in loss of flora and fauna, which can lead to a build-up of pest populations affecting crops and pastures. Productivity can be reduced through lack of wind protection in pastures and crops (especially tree crops), and through lack of shade and shelter for grazing animals.

Key runoff control works should be located before clearing sloping land so runoff disposal areas are disturbed as little as possible. For example, for some landforms, the top contour or diversion bank may define the upper clearing limit. Drainage lines may require stabilising with grass before runoff can be directed into them. If defined channels do not exist, artificial waterways may have to be constructed.

9.4 Nature conservation

Nature conservation on rural land aims at achieving a balanced system which can sustain long-term productivity and ensure the protection of regional diversity.

9.4.1 Benefits of conserving wildlife on rural lands

Magpies, ibis, bustards and other insect eating birds can reduce numbers of pasture feeding insects considerably. Carrion feeders such as goannas will clean up rotting carcasses, which helps prevent disease. Mammals such as sugar gliders also consume substantial amounts of insects (Loyn, 1987). Predatory spiders, birds and reptiles can play an active role in reducing insect pest pressure and help remove disease-carrying organisms. Predatory insects can play a major role in controlling insects affecting the health of native timber (Loyn *et al*., 1983) and crop production such as cotton (Pyke and Brown, 1996). Microbes, reptiles, snails, worms, native mammals such as bandicoots and ground dwelling insects like ants and termites are known to have integral roles in keeping soils healthy. They break down organic matter, loosen the soil, increase moisture penetration and cycle nutrients. Both vertebrates and invertebrates depend on good habitat and a diversity of vegetation to function effectively.

Areas of retained wildlife habitat can act as firebreaks, or shelter crops from the wind. Wind protection can have great benefits for crops affected by frost, sand blasting or chemical spray drift. Native vegetation along watercourses provides some of the most valuable habitat on any property. This vegetation also protects banks from slumping and filters floodwaters as they enter the stream.

Remnant vegetation can provide resources for new industries not yet discovered. The more diverse the range of native plants and animals on a property, the greater the chance for future income diversification. For example, nature based tourism is being developed in many parts of Australia.

Recent research in Australia suggests that where there is a diverse population of plants and animals the environment is less likely to be subject to natural catastrophes such as insect plagues or disease outbreaks. This effect could benefit native wildlife as well as crops and pastures introduced by humans.

9.4.2 Management considerations

The application of the following wildlife management principles will maximise conservation efforts when incorporated into land use planning:

- The size of an area of bushland will influence its value for wildlife. A larger area will generally contain more species of birds and animals and more individuals than a smaller area of the same vegetation type. Larger areas are more likely to survive in the long term because they are less susceptible to damage by fire, weeds, wind exposure or tree dieback.

- Shape is important as the remnant with the smallest perimeter to area ratio is least affected by outside disturbances. The closer an area of bushland is to a square or a circle, the better are its chances of long-term survival.

- The proximity of bushland to other areas of natural vegetation is important in conserving diversity of plants and animals. Many species need continuous or near-continuous areas of habitat for breeding and for re-colonising areas after disturbances such as fire, drought or human activity. Small species in particular are not able to travel across large expanses of unsuitable habitat.

- Corridors of vegetation linking areas of remnant bushland allow movement of wildlife, and also provide habitat for some species. Shadelines can act as links between patches of retained bushland and can also provide habitat for some wildlife. Seemingly modest areas of property based habitat, roadside vegetation, stock routes, Crown reserves, state forests and national parks linked in turn to watercourses contribute to a mosaic of habitat extending across the catchment.

Habitat diversity is one of the major factors affecting the presence of wildlife on any property. Habitat considerations include the following.

- A range of layering in the vegetation because many birds and animals prefer to live in one or two levels only, while others range more widely.
- The composition of the vegetation, including different types of food, resources for breeding and shelter or resting sites for small species.
- The ground layer, including leaf and twig litter and fallen logs, which harbours many of the smaller animals such as insects, snails, spiders and microbes. These play major roles in maintaining soil fertility and nutrient cycling processes.
- Fallen logs, which provide shelter and sunbathing sites for reptiles and marsupials and a moist habitat underneath for certain burrowing reptiles and frogs.
- 'Habitat' trees which contain hollows suitable for hollow-dependent wildlife, (plus other important wildlife needs such as blossom, peeling bark, perching and nesting sites).

9.4.3 Conservation priorities

The native vegetation and associated wildlife has been extensively altered throughout the Central Darling Downs through agricultural and pastoral development and the introduction of exotic weeds and feral animals. The following actions are required to address key issues.

- Landholders are encouraged to conserve representative areas of land types occurring across their properties as part of their normal property management planning.
- Wildlife corridors linking areas of native vegetation should be retained, or in cleared areas, be re-established through natural regeneration or native species planting.

- Management of remnant vegetation needs to allow strategic control, or even exclusion, of grazing where necessary to ensure regeneration of individual species or whole communities.
- Invasive weed species, which threaten the integrity of remnant areas, should be controlled through the actions of landholders, local authorities and local community groups, working together.
- Planning for development and maintenance work within road corridors should incorporate conservation of roadside remnants.
- Strategic plans prepared by local authorities offer the opportunity to conserve key remnant areas through zoning and planning guidelines.

9.5 Pests – animals and weeds

Property management and sub-catchment plans should include pest animal and weed control. Strategic planning and monitoring is necessary to obtain the best results. It is important for control activities to target key areas and coincide with the timing of agricultural enterprises.

9.5.1 Pest animals

Grazing enterprises should plan feral animal control activities prior to lambing or calving times.

Co-ordinated baiting campaigns for wild dogs or foxes are encouraged, and several Shire Councils on the Central Darling Downs assist in organising these with DNR at optimum times.

Feral pigs can cause major economic damage to winter and summer crops along the Condamine Floodplain. Once pigs are feeding in grain crops they are difficult to control. Control is best carried out between cropping periods. Feral pigs are a significant pest animal to sheep grazing enterprises, preying on lambs. Trapping is very effective and much safer than baiting. Trap designs are available from DNR. Baiting is restricted to large properties, as the risk of secondary poisoning to domestic dogs is high.

Mouse plagues occur every 2–3 years in the cropping areas of the Condamine Floodplain. Property management in these areas should include:

- Monitoring mouse numbers throughout the year using bait cards.
- Reducing mouse numbers around storage and machinery sheds using rodenticides.
- Slashing road verges.
- Stubble reduction when numbers increase.

DNR provides regular updates on mouse population trends on the Central Darling Downs throughout the year. A plague prediction service is also provided and this is advertised through the local media.

9.5.2 Weeds

Local Authorities in the Central Darling Downs have developed Pest Management Plans for their shires. These plans list locally declared weeds under both the Local

Government Act (1995) and the Rural Lands Protection Act (1985) and list the objectives for each Local Authority in relation to weed control. Landowners should be familiar with their Local Authority's Pest Management Plan and ensure timing of control activities to obtain optimum results.

Annual declared weeds need to be controlled prior to seeding to reduce the seed bank in the soil. Woody weeds can be controlled when time permits during the growing season.

9.6 Tree management

Tree management should be aimed at providing for multi-use purposes, including integrating agricultural and forestry production. Tree management on properties can be in several forms:

- Managing native forests for wood production.
- Retaining areas of native forest for land protection purposes.
- Planting trees for timber production or economic benefit.
- Planting trees for land protection.

For information regarding the dominant tree species found in the Land Resource Areas of the Central Darling Downs, refer to Chapter 4, the Land Resources Area map (*Map 1 in the back pocket*), and the *Field Manual*.

9.6.1 Wood production from native forests

In areas where commercial forestry is the main landuse, the process of logging is the most important aspect of its management. Trees should be carefully selected, or marked, so that:

- Poor quality (poor health, poor form) and competing trees are removed from the forest, as well as mature or over-mature trees, thereby concentrating growth on selected young trees for the next crop.
- Suitable trees are retained as seed trees (usually high-quality trees are kept at the rate of 3–5 trees per hectare for this purpose) and as habitat for wildlife (trees with hollows or obvious signs of wildlife use are usually retained at the rate of six per hectare).
- Gaps are created in the forest to allow regeneration to develop, ensuring sustained yield in the long term.
- Trees are selected for a desired end product (poles, girders, mill logs, sleepers and fence posts), utilising what is available for the best return.

9.6.2 Native forest for land protection purposes

Balanced retention of native forests has significant environmental and land protection benefits. While it is often necessary to clear or thin native forests to provide land for grazing or agriculture, it is also important to retain areas for stock shade, windbreaks, timber production, wildlife habitat and as part of an erosion control strategy.

Specific tree retention plans can be developed as part of a property plan, and in consideration of soil type and slopes (*see the Field Manual*). On leasehold land, tree clearing permits or vegetation management plans are required before clearing is undertaken. Similar plans may be required for freehold land. Advice on vegetation management can be obtained from the Department of Natural Resources, Environmental Protection Agency or local Landcare representatives.

9.6.3 Planting trees for timber production or economic benefit

Many producers are interested in having access to a timber enterprise because of the following advantages:

- Timber crops can be harvested within a wide time frame and can therefore be timed to supply income when other enterprises are less profitable.
- It can be a ready source of timber for on-farm uses, such as fencing and building.
- They can be established or retained on land with limited suitability to agricultural production.
- They can provide other benefits such as wildlife shelter, windbreaks, stock shade or screening.

Options for timber production on properties in the Central Darling Downs are limited and specialised. Planting trees on the Central Darling Downs, for direct commercial return, is unlikely to be highly successful, if viewed solely as a profit-making venture. However, timber plantations can also have aesthetic and environmental advantages. Integrating forestry plantations into property and business planning should be the first step to maximising the benefits this enterprise can offer.

There are presently significant changes under way in pricing structure and marketing for timber in Queensland. These changes are expected to make forestry a more stable and viable industry for producers. It is likely, however, that more effort will be required, in terms of management of the resource, and in evaluating value-adding options, such as on-farm milling, self-marketing products, home processing (e.g. seasoning, dressing or fabrication of saleable items).

Plantations of timber trees of any kind at the present time in Queensland must be considered as a high-risk, long-term investment. Predictions outlined in some commercial forest investment packages (of massive profits from short rotation plantations) are highly questionable, and investment in such schemes is extremely risky.

Other commercial uses for tree planting could include the following:

- Flower and foliage production occurs from plantations of native plants, including eucalypts and banksias. This industry has the potential to be quite lucrative but it is very specialised and requires high infrastructure and labour costs. It is highly advisable to seek accurate and reliable information on species selection and market suitability before investing in this industry (*see Section 7.2.2*).

- Crop or animal protection. Tree and shrub planting for windbreaks or shelter belts have been recorded as contributing significantly to improved profitability of plant and animal production.

Shelter belts are valuable for the protection of animals against wind. Shorn sheep, calves, lambs and sick animals have higher survival potential if climatic extremes are moderated by well located shelter from wind.

9.6.4 Planting trees for land protection

Tree planting for land protection is highly specialised and site specific. Whilst it may be economically feasible to retain large numbers of trees for land protection purposes, the costs involved in large scale tree planting are high enough to warrant very careful planning.

Tree planting costs in the Central Darling Downs are in the vicinity of $3.00 to $10.00 per tree (including site preparation, trees, guards, mulch and labour). This makes the planting of thousands or even hundreds of trees hard to justify. Consequently, this is done only when necessary for rehabilitation of valuable land, for landscaping or aesthetic purposes.

Planted trees can be used in a number of ways to protect land. These include:

- reduction of wind and soil erosion;
- creek bank and gully stabilisation; and
- re-distribution of nutrients from deep in the soil profile (due to trees' extensive root systems).

For each of these uses, the role of the trees must be set out as part of an overall strategy for land protection. Other activities such as grass establishment, stubble management, and property planning may be required.

Photo 20 Treeplanting for nature conservation and timber production on cropping lands

Advice on tree planting projects for any purpose can be provided by the Department of Natural Resources, the Environmental Protection Agency, Greening Australia and Landcare advisors. Local nurseries may also be able to provide advice on selection of species.

9.7 Management of grazing lands

Preparing a property plan for grazing enterprises is an important first step in reducing the risk of land degradation. The plan can be used to determine which areas may be cleared, where shelter belts should be located, whether any areas may require replanting, and what other special measures may be required. Guidelines on property development are provided in several references, e.g. Rowland (1987), DPI (1990), and Partridge (1992).

To ensure grazing land is managed sustainably, advice should be sought from local landholders familiar with specific land resource areas and technical experts. Sustainable land management requires a mix of skills and expertise combined with use of appropriate technology. The principles of grazing management include the following:

- Maintenance of effective ground cover (approximately 60% to 70%).
- Maintenance of adequate biomass prior to winter.
- Maintenance of biomass as a fuel load for strategic burning.
- Maintenance of a diversity of plant species that includes perennial plants, productive plants and palatable plants.
- Use of fire for the control of woody weeds.
- Careful control of stocking rates.

9.7.1 Grazing management

The most common and simplest system of grazing management is continuous grazing with careful control of stocking rates and spelling. Because of the rapid summer growth to maturity by most native grasses, excessive subdivision of paddocks beyond that necessary for herd and pasture management is not warranted. The more palatable species tend to be selectively grazed and can diminish in population over time if not allowed sufficient recovery time. Measures to counteract this should be taken, especially in poor seasons and in droughts. They involve periodic spelling of each paddock for 6 to 8 weeks during an autumn period to allow seed maturity and crown strengthening. Every 3 to 4 years is suggested as ideal spelling frequency but this depends on the occurrence of more bountiful seasons and/or the ability to temporarily concentrate stock elsewhere on the property. Grazing pressures can be reduced by increasing the number and distribution of stock watering points.

Important considerations to reduce the risk of land degradation are the location of watering points, timber belts or clumps and fencing layouts. Grazing pressure can be more evenly distributed if fencing is located to separate different land types. This ensures that better pastures species are not grazed out in preference to inferior species.

Fencing should be located so stock tracks will not cause diversion and concentration of overland runoff that may cause erosion. Watering points should not be sited on fragile areas where a concentration of stock may lead to land degradation either through higher grazing pressure or excessive soil disturbance or compaction. Additional watering points should be provided to draw stock away from the riparian zones of natural watercourses. The riparian zones should be fenced to exclude stock from continuous grazing. Occasional access for grazing purposes should be allowed to reduce fire hazard, and to provide weed control in such areas.

Stocking rates

Pasture condition may be improved by changing livestock management and reducing stocking rates. It is essential that livestock numbers be adjusted in response to growing season rainfall and pasture production. Recommended annual stocking rates for native and sown pastures for soil types in the Central Darling Downs are shown in Table 9.1 (*on page 188*).

Implementing sound animal husbandry practices and grazing good quality livestock will ensure high production per animal, and may allow less stock to be carried with no detrimental effect on profit. Spelling pastures during the growing season encourages seeding, but some knowledge of differential growth between species is needed for definite recommendations (Tothill and Hacker, 1983).

It is not possible to match stock numbers to the feed available each year. It may be more practical to compromise with a lower, but relatively constant, stocking rate. A general rule for calculating a constant stocking rate, for the sustainable grazing of native pasture, is to use 30% of the summer grass growth in 80% of years (Partridge, 1992). This requires the adjustment of stock numbers on the basis of an assessment of the pastures in March or April. For example, stock numbers can be adjusted to use no more than 30% of the standing feed before the next summer growing season. Winter rainfall can be discounted when calculating stocking rates, as it may produce a small amount of top-quality feed but the bulk of pasture growth still occurs during summer.

It is the long-term mean stocking rate that is most important. Healthy pastures can be heavily grazed for a short while, provided that management ensures:

- those pastures are spelled sufficiently;
- an assessment is made each autumn to confirm that the overall grazing pressure is appropriate; and
- future stocking rates are adjusted to reflect the pasture growth during the previous summer.

It is important to remember that significant changes in the condition of the pasture may only be apparent after 2 to 3 years (Partridge, 1992). Monitoring changes in pasture composition, condition and growth is an integral part of pasture management. Forge (1994) outlines a range of field methods for monitoring pasture changes.

9.7.2 Surface cover and erosion control

Overgrazing and excessive use of fire leading to a loss of protective cover can reduce rainfall infiltration and increase runoff. Lack of protective surface cover, especially at the time of high intensity storms, leads to sheet and rill erosion, which depletes the soil of nutrients valuable for pasture growth.

Ciesiolka *et al.* (1987) outlined the importance of adequate cover in preventing erosion in pasture lands. Truong *et al.* (1987) showed that 75% ground cover was critical at the time of storms with high rainfall intensity. That is, when cover was >75%, runoff was slight, but when cover was <75%, runoff amount accelerated rapidly. Consequently, grazing management should be aimed at maintaining adequate pasture cover for the periods when high intensity storms are expected, so that soil infiltration rates are maintained, and runoff rates minimised. Cover also provides protection against any runoff, which does occur. This helps reduce the risk of sheet and rill erosion.

9.7.3 Burning

Many native pastures have developed after thousands of years of occasional burning. This burning has enabled the pasture to remain as grassland. If managed as a prescribed burn, fire is a cheap and useful tool. Uncontrolled, it is destructive and dangerous. Woody weeds must be prevented from growing so tall that they can withstand fire, or suppress grass growth.

Fire, as a pasture management tool needs to be used carefully. Anderson *et al.* (1988) discussed the disadvantages of burning including, loss of nutrients, loss of forage, undesirable changes in pasture composition, increase in undesirable woody weeds and herbs, and an increase in erosion. Anderson *et al.* (1988) provided general guidelines on the use of fire as a management tool, and more specific guidelines for the pasture communities common in the Central Darling Downs. For these pasture communities they recommended that burning occur not more frequently than every 3-5 years .

Burning can be used to:

- alter pasture composition and control woody weeds;
- remove dead grass tops so stock can reach new growth;
- stimulate new growth, although selective grazing of fresh growth under heavy stocking after burning can bring about pasture degradation;
- reduce wildfire hazards;
- provide ashbeds for re-seeding; and
- attract animals to use areas not normally grazed.

In summary, the main aim of burning should be to reduce wildfire risk and to control regrowth. Provision of early green pick should not be the primary motivation as this commonly leads to pasture and soil degradation.

9.7.4 Managing regrowth

Landholders have devised a number of ways to control regrowth according to the scale of their operation and personal preference.

Planning

The clearing and/or chemical treatment of vegetation often results in undesirable regrowth. An important step in managing regrowth is to plan control measures and strategies carefully.

Requirements for shadelines and clumps should be planned before the initial treatment. If regrowth is left to form shadelines and clumps, it often consists of almost a monoculture of a certain species. The diversity is lost as slow growing and edible species such as cattle bush (*Pittosporum phylliraeoides*), red ash (*Alphitonia excelsa*), wilga (*Geijera* spp.) and others do not regrow. The shadelines and clumps must be of a sustainable size to withstand the heavy grazing, fire or chemicals used when treating regrowth or zero tillage of adjacent cultivation.

Treatments

The regrowth characteristics of some species and the economics of different treatments will have a major influence on the most appropriate method for tree clearing and regrowth control. For example, many farmers recommend selective chemical treatment of *Eucalyptus* and *Callitris* spp. in sandstone forests, and leaving the treated timber standing rather than mechanical treatment. Mechanical treatment without appropriate follow-up will often result in thick regrowth, preventing pasture growth. Similarly, due to the suckering nature of species such as brigalow, ongoing treatment may be required for many years. The following points outline treatment methods used within the Central Darling Downs.

- Some landholders pull the desired area and then immediately graze it very heavily. This practice is based on the theory that the supply of nutrients to the regrowth roots is depleted if leaves are continually removed, finally resulting in the death of the plant. Unfortunately the existing palatable pasture species suffer the same deadly fate. It is important to note that this method leaves the soil surface completely bare and open to erosion and may result in severe degradation if high intensity rainfall occurs at this stage. The high stock numbers used places a lot of pressure on surface soil structure and can lead to surface sealing and associated problems of reduced water infiltration and grass germination. The animals also grow very poorly when used in this situation.

- Another method is to pull the desired area and then destock it until it is well grassed up. Sometimes the firebreaks are burnt at night particularly around shadelines and clumps. The area is then subjected to a hot fire on a hot day, after firebreaks have been burnt in or raked in from the edges. Very heavy grazing follows for a short time to kill the suckers and seedlings. Some land may have thick wattle regrowth after fire. The area must then be rested until the pastures have regrown.

- Pulling the area and then stickraking into windrows is an alternative method. Some landholders stickrake the windrows onto the contour and do not burn them but regard them as shelter for stock and grasses, and allow regrowth in the contoured windrows. Any operations to improve pasture are then done on the contour, between the windrows. Most landholders control regrowth by cropping for 3-5 years on suitable soils before sowing to improved pasture or allowing native pastures to establish. Other landholders slash the regrowth as an alternative to the other methods.

- Another way is to use chemicals by individual application, aerial application, or by mechanical spreading. Individual application allows very selective treatment of timber. Aerial application takes careful planning to protect selected shadelines, and is not always successful if a dominant species is not controlled after a lot of expense. Some lateral movement of chemical may occur so shadelines should be very wide to allow for this.

- A common management system is to pull (leaving appropriate shade lines) and exclude stock (and kangaroos if possible) until the end of the summer. Grazing heavily with sheep and then cattle at normal rates can follow. The pasture may be rested in the latter half of the second summer and winter and then burnt in late spring to kill regrowth. Spot spraying of the missed patches of regrowth can occur thereafter.

9.7.5 Native pasture management

Many native pastures provide good grazing, which may not be improved in the long-term by ploughing them out and planting 'improved' species. Most remaining native pastures on the Central Darling Downs grow in areas where cultivation is not possible, because the soils are too infertile or too stony, the slopes are too steep, or the land is covered with timber or prone to flooding. Complete cultivation to reclaim degraded pastures on these lands is neither feasible nor economical. Grazing management is the major tool that is required. Renovating or otherwise disturbing native grasses on shallow, fragile soils should be considered only for the purpose of improving seed germination rate.

9.7.6 Sown pasture management

Where practical, sown pastures are used instead of native pasture because of superior animal productivity in terms of both quality and quantity. They demand a higher level of plant nutrition and a different management system than native pastures. They are confined either to the more fertile soils or to situations where a regular input of fertiliser or resowing is feasible. Important aspects of management of sown pastures include the following:

- Close attention to effective establishment. Small seeded species can be difficult to establish particularly on coarse and heavy clay soils (e.g. LRAs 1, 2, 5, 7).
- Limited grazing only (short and intense) during the first year of establishment.
- Subsequent grazing should be managed carefully to maintain pasture composition—especially any legume component.
- Providing adequate inputs of fertilisers as required.

Nutrient depletion in sown pasture swards may be reduced and temporarily reversed by adding nitrogenous fertiliser, by using legume leys, or by ploughing and re-sowing.

Encouraging legumes

The black, self-mulching soils of the floodplains, and the heavier, upland soils originally supported an open grassland dominated by blue grasses and other tall perennial grass. For more information regarding soil types and original vegetation, see Chapters 4 and 6. During summer, a number of native legumes also grow on the Central Darling Downs; these include rhyncosia pea (*Rhyncosia minima*), emufoot (*Cullen tenax*) and native sensitive plant (*Neptunia gracilis*). Moderate grazing or fires encourage these legumes.

The most prolific legume growth occurs during winter and spring from naturalised, introduced medics. Medic growth is most prolific when a wet winter follows a dry summer and where the summer grasses are sparse. These medics have hard seed that can survive for years in the soil, but new plantings should be allowed to build up a seed bank in the first year. Medics growing on clay soils rarely need additional fertiliser, but the stony hills under mountain coolibah are often deficient in sulphur. The light sodosols in the Sandstone Forests (LRAs 12a-b) west of the Condamine river, are usually too infertile, and may be too acidic for medics to grow. Shading from the forest cover will also restrict medic growth.

9.8 Management of cropping lands

Strategies to effectively manage cropping lands in the Central Darling Downs should be aimed at maintaining or improving the productive capacity of those soils that are suitable for long-term cropping uses. These strategies should incorporate those measures that aim to:

- use the maximum available moisture;
- reduce or prevent soil losses caused by erosion;
- maintain or improve soil structure; and
- restore, maintain or improve soil fertility.

Various farming practices recommended for, and used in the Central Darling Downs apply to some aspect of these strategies. These practices include conservation tillage techniques, control and co-ordination of runoff, crop rotations, use of ley pastures, managing crop nutrition, weed management and controlled traffic farming.

9.8.1 Conservation cropping

Conservation cropping, including opportunity cropping, consists of growing crops that provide good ground cover; retaining stubble on the soil surface during fallow periods; and using herbicides with reduced tillage, or zero tillage, techniques. Other components include using crop rotations that provide high levels of protection throughout the year; and where practical, using ley pastures, and grazing animals for fallow weed control. At least 30% surface cover at planting time will minimise the risk of sheet erosion (Freebairn *et al*., 1997). Standing stubble is particularly useful, as it breaks down more slowly and may provide better protection from wind erosion and overland flows, particularly on the floodplains. Retaining crop stubble is now accepted in the Central Darling Downs as a necessary part of sustainable farming.

Conservation cropping includes special tillage techniques such as reduced tillage, minimum tillage, zero-till or no-till. These techniques aim to retain crop residue to protect the soil surface, maximise soil moisture levels, improve organic matter levels, control weeds, and provide suitable seedbed conditions relevant to specific crops. While conservation cropping is primarily aimed at retaining cover to minimise erosion losses, increased production can result through improved rainfall infiltration and increased PAWC. Improved soil moisture levels increases the cropping opportunities, which in turn increases the likelihood of having adequate surface cover.

Another important aspect of conservation cropping is the selection of suitable machinery, or modifying existing machinery, to handle crop stubble. Thomas et al. (1997) who showed that these requirements depended on soil types provides information about the selection of machinery suitable for conservation tillage, crop stubble and intended crop to be sown. Use of controlled traffic techniques provide other opportunities (*see Section 9.8.6*).

9.8.2 Runoff control measures

Suitable runoff control measures for the Central Darling Downs include construction of diversion banks, contour banks and waterways on upland areas, and strip cropping on floodplains (*see Section 9.8.7*). These provide a basic framework for controlling runoff and erosion upon which conservation cropping techniques and other measures can be applied. Regular maintenance of the mechanical erosion control measures is necessary to ensure their effective functioning. This includes:

- stable grass cover in waterway channels by slashing or grazing, and applying a maintenance application of fertiliser as necessary;
- maintaining the works to design capacity on a regular basis, e.g every 3–5 years;
- inspecting the works following storm rains and carrying out repairs as soon as practical;
- removing silt from the channels of contour banks, diversion banks and grassed waterways; and
- levelling out any interbank rills.

Runoff control measures require careful planning to ensure the co-ordination of runoff from property to property and across roads and railway lines (*see Section 9.3*). Types of structures and their design in relation to land form and soil type are described in references such as Titmarsh and Stone (1997), Stone *et al.* (1994), Titmarsh *et al.* (1994), Marshall (1988), Marshall *et al.* (1988) and DPI (1997).

9.8.3 Crop rotations

Rotating well managed winter and summer crops can provide higher net returns to growers by reducing costs and boosting yields. The use of different crops in sequence has the following advantages:

- It provides erosion control by ensuring adequate surface cover is available at critical rainfall/runoff periods, through either a growing crop or crop residue.
- It allows the choice of crops that may provide little surface cover to be grown in conjunction with others that produce adequate cover.
- It maximises the benefits of improved soil moisture levels.
- It assists in maintaining soil fertility by using crops with different nutrient requirements or if ley pastures are included in the rotation, fertility may be improved.
- It helps in maintaining, or improving soil structure by using crops with different growth patterns, or requiring different tillage techniques.
- It assists in the control of insect pests, diseases and weeds.

Freebairn *et al.* (1997) discussed measures and benefits of crop rotations relevant to the Central Darling Downs. Suitable crop rotations for the Central Darling Downs are listed in the Crop Management Notes DPI (1996, 1998).

Some important aspects of crop rotations are as follows:

Soil fertility

Soil fertility can be improved by including grain legumes in the crop rotation. Legumes help improve the general condition and nitrogen content of the soil because they are able to fix free nitrogen. Many grain legumes are now profitable crops in their own right, as more reliable, stable markets have developed. Grain legumes can produce their own nitrogen on nitrogen deficient soils. They do not increase soil nitrogen as much as pasture legumes because most of the nitrogen is removed in the grain. Nitrogen fertiliser may still be needed for the grain crops that follow in rotation, but application rates may be reduced. As a rule of thumb, an average grain legume crop such as chickpeas or mungbeans will add 20–40 kg/ha of nitrogen, compared to 80 kg/ha for a lucerne stand. Research has shown that rotations using pasture leys will improve soil organic matter levels (Dalal, 1989, Dalal *et al*., 1991).

Soil structure

Continuous cropping reduces the organic matter in the soil, leading to a decline in surface structure, which in turn hinders crop establishment. Using a range of crops where practical allows for improvement in soil structure particularly if reduced or zero-tillage techniques are applied, and where crop stubble is retained. The use of conservation cropping practices alone will not greatly increase the amount of organic matter in the soil, but will help slow further decline and can maintain current levels.

Weed control

Use of appropriate herbicides is an important aspect of conservation tillage aimed at minimising soil moisture losses particularly during a fallow. Summer Crop Management Notes (DPI 1998) described weed control strategies for the range of crops relevant to the Central Darling Downs.

Crop monocultures are relatively simple to manage, but weed populations can quickly build up to damaging levels. Rotations can help prevent this build up of weeds by stopping them seeding, thus avoiding the need for expensive herbicides (*see Section 8.10*).

Chemical residues

The following strategies will minimise a build up of chemical residues.

- Plan future rotations carefully when using residual herbicides for weed control in cropping systems, as low rates of breakdown in dry conditions and in high pH soils, can result in following crops being seriously damaged.
- Read the label on products and use accordingly.
- Some insecticides have long withholding periods before crops can be harvested, grazed or baled. These withholding periods may affect the marketing of the crop and/or grazing animals.
- Make every effort to reduce the incidence of spray drift.

Diseases and insects

Diseases, which survive in the soil or on crop residues, can be effectively controlled by crop rotations, which break their lifecycles. For example, diseases that occur in winter crops can be reduced by planting to a summer crop for several years, particularly to one that does not harbour the disease.

Sowing different crops can reduce insect numbers in the soil. Wireworms favour wheat, sorghum, barley and maize residue, but not oats, soybean and sunflower residue. Where root lesion nematodes occur, growers need to use other crops that are not hosts for these particular organisms. For more detailed information on diseases and insects refer to DPI (1996 and 1998).

9.8.4 Ley pastures

There is growing interest in the Central Darling Downs in the use of pasture rotations to rebuild the fertility of cropping soils that have been used for long-term cereal production, or have otherwise deteriorated in fertility and structure through erosion. Advantages of short-term legume or grass-legume ley pastures include the following.

- Increased soil nitrogen for future crops.
- Increased soil organic matter, which may improve the structure of many soils leading to improved infiltration and consequent higher soil moisture levels.
- Enhanced ground cover to protect the soil against erosion and improve rainfall infiltration.
- Better control of insects and disease by removing host plants and breaking the life cycle of insects and diseases.
- Better control of weeds, by not cultivating and/or preventing seeding opportunities.

Major constraints to ley pastures include the loss of grain production during the interchange phase and the lack of stock handling facilities on some farms, particularly in the floodplains of the Central Darling Downs. Some ley pastures, especially with lucerne-based mixtures, may deplete soil water reserves, making a suitable fallow period necessary to increase soil water before returning to cropping.

Pasture rotations, which include a grass, will improve soil structure, providing an improved surface tilth and the breakdown of plough pans of some soils. A badly depleted soil may need several years of a ley pasture rotation to recover. Legumes do not increase soil organic matter reserves as much as grasses do (Dalal *et. al*, 1991).

9.8.5 Forage crops

Where grazing beef or dairy cattle is practised in the Central Darling Downs, erosion of bare, fallowed soils during summer can be minimised by strategic use of forage crops. The following management practices can help ensure the long-term sustainability of farming systems relying on forage cropping.

- Leaving stubble standing through the fallow. Do not graze the last forage crop to ground level, but leave 15 cm of stubble as mulch through summer. Sow summer forage crops in other paddocks early to allow stock to leave this standing stubble. Herbicides should be used to control weeds in the fallow.
- Sowing of crops into stubble. Sow following crops into the slashed stubble with a stubble-handling planter. Where stubble-handling equipment is not available, the fallow should not be cultivated until immediately prior to sowing.
- Using adequate fertiliser. On soils with reasonable depth, pre-plant with a mixed fertiliser (such as DAP or Crop King 700) to provide around 50 units of nitrogen per hectare, as well as phosphate. Grow forage sorghum only on better soils, as it needs a good nitrogen supply, as well as moisture, to grow well. Black soil areas, regularly growing forage sorghum, could be rotated to lab-lab every two or three seasons.
- Rotate into pastures. After 3–4 years of forage crops, rotate the paddock into a grass–legume ley pasture for 3–4 years to build up nitrogen and improve soil structure.

9.8.6 Controlled traffic farming systems

The aim of controlled traffic farming (CTF) is to reduce the impact of tractor and machinery wheels by using the same tracks for all, or most, field operations, whether tillage, sowing, spraying or harvesting. This has the advantage of reducing tractor draught (and therefore fuel and machinery costs), and minimising damage to soil structure. On large enterprises the use of global positioning systems (GPS), can improve the ability and efficiencies in tracking machinery.

Controlled traffic farming can incorporate the added benefits of the techniques outlined above including conservation tillage, crop rotations, and the use of ley pastures and forage crops. Adoption of a CTF system into a co-ordinated runoff control layout is possible if care is given to the maintenance of the runoff interception structures (contour banks) providing for the proper functioning of these works.

CTF systems may be incorporated into strip cropping layouts on the Central Darling Downs floodplains, providing that flood flows remain dispersed and are not allowed to concentrate. Strip widths (*see Section 9.8.7*) may have to be adjusted to suit the nominated CTF track widths. Tulberg and Lahey (1990), and Lucy (1993) provided details on the application of this technique.

9.8.7 Floodplain management

Due to the nature of the floodplain topography, and associated overland flow, management practices require the involvement of all stakeholders. The following management practices ensure erosion control and high productivity on the floodplains of the Central Darling Downs.

- Use of strip cropping to spread flood flows.
- Minimal diversion and concentration of floodwaters by roads, fences, levee banks and irrigation structures.
- Management of problem areas such as melonhole country, natural stream levees, active gullies, concentrated flow areas and residual flow areas.
- Maintenance of natural drainage lines.

Crop rotations and stubble retention practices are vital for successful strip cropping. Strip cropping is a major tool for erosion control and for maximising moisture storage on the floodplains. The use of crops or crop stubble decreases water velocities and reduces erosion by increasing the spread of water. To be effective, strips need to run at right angles to the direction of flood or overland flows and be of correct widths. The design of strip cropping layouts and strip widths depends on factors such as machinery widths, land slope, crop rotation plan, velocity and depth of flow (*see Eacott, 1979; Crawford, 1975; Ruffini et al, 1988*). Runoff concentration problems on floodplains may be overcome by co-ordinating strip layouts between properties

Roads, levee banks, fences and irrigation structures may cause concentration of flood flows. Therefore, their location and design must take into account floodwaters. Roads (built approximately 300 to 600 mm above ground level) should be designed to run in the direction of flood flows to avoid damage to nearby cultivated land. When a road does not run in the direction of the flow, water often misses drainage structures such as culverts and inverts, and may damage cultivated land. Consequently, erosion from water breaking over the road may also cause damage. Long floodways and roads designed to be closer to the ground help maintain broad shallow flows.

Roadsides should be maintained to avoid build up of water, which can erode cultivated land. Location of farm roads and tracks should be carefully considered so that they do not affect flood flows. Access tracks should be regularly relocated, as they are susceptible to erosion damage. Fences cause flood flow problems due the material that may build up on them. Ideally, fencing in flood prone areas should be removed.

Grass can be used as an effective means of controlling erosion. Planting grass in strategic places such as flood breakouts helps to stabilise the area by catching silt, slowing down and spreading the overland flow. Grasses can also be useful in stabilising bare active gullies. Suitable grass species include African star grass, kikuyu and vetiver grass.

Levee banks have been used successfully to control flooding and erosion, especially in isolated areas, for small flood flows and to divert water to more stable areas. However, levee banks may counter the principle of spreading and slowing floodwaters. They often increase the velocity of overland flows causing significant scouring and gully erosion on lower lands.

Property infrastructure on the floodplains should be considered as part of the overall property plan and potential problems such as concentration of floodwater causing increased depth and velocity should be considered. Irrigation infrastructure such as head ditches, ring tanks and tail drains form levees and affect water management. A permit to construct a levee bank or similar structure may be required within some local authority areas. Flood irrigation structures intersect flow paths and special attention is needed to minimise diversion impacts and concentration of water. Alternative irrigation systems include spray irrigation and trickle irrigation.

Gilgai present a particular erosion problem on floodplains, particularly melonhole gilgai in LRAs 5a-b, if they have been levelled to improve management of cultivated land. Melonhole gilgai in their natural state act as small runoff retention storages, reducing the volumes of overland flows. When melonhole gilgai is levelled to improve cultivation practices, the frequency and amount of runoff is increased. Less intensive landuses, such as grazing enterprises are recommended for land with severe melonhole gilgai.

Other specific problems relate to residual flow and natural stream levees. Residual flow drains are used to reduce the effect of residual flow from springs or cultivated areas. Where residual flow drains are used, they should be incorporated into the overall floodplain plan. Modification of natural stream levees can significantly alter the flood hydraulics in the area, resulting in damage to adjacent lands. It is therefore recommended that natural stream levees not be modified.

The key to floodplain management on the Central Darling Downs is strategic planning and the co-operation of all the stakeholders. Further information can be obtained from (DNR, 1999b) and Marshall (1988).

9.8.8 Managing irrigation lands

Irrigated cropping is a major enterprise within the Central Darling Downs, particularly within the alluvial LRAs (1-5). Efficient and effective irrigation requires the use of a number of management principles, a knowledge of the soil and climatic properties of the area, and an understanding of crop requirements.

Relevant soil properties include soil structure, clay content, clay type, effective rooting depth, salinity and PAWC. Information on these soil properties are provided in Chapter 4, the soil summary sheets within the *Field Manual*, and the *Soil Chemical Data Book.* Other relevant factors include crop type, rainfall and evaporation, and irrigation method (Burt, 1995).

A key principle in irrigation management is to avoid excessive watering. This is costly from an economic sense, and can cause environmental problems such as rising groundwater, leaching of salts and nutrients or mobilisation of pesticides. The majority of the soils irrigated within the Central Darling Downs are cracking clays (Vertosols) such as *Waco, Anchorfield, Mywybilla* and *Condamine*. These soils have high PAWCs and need to be irrigated less frequently than lighter textured soils. They do however swell rapidly upon wetting. This means the rate at which water infiltrates into the soil is dependent on the soil moisture content.

Many of the commonly irrigated soils in the Central Darling Downs contain a natural salt bulge in the subsoil. Data concerning the dynamics of the salt when the soil is irrigated is limited. Under dryland conditions, evidence points to a leaching of the salt downwards (Dalal, 1986). Recent data for irrigated soils confirms similar leaching patterns, but the fate of the salt is unclear. If a barrier to downward movement exists, rising groundwater could bring salts back to the surface. A useful software package to determine likely leaching is SALFPREDICT (DNR, 1997).

Good irrigation scheduling should make use of available technology for measuring soil water status in paddocks e.g. neutron probes. This should be coupled with rainfall and evaporation data and crop growth requirements to make more accurate predictions about the timing and quantity of irrigation.

Construction of irrigation infrastructure should only occur after assessment of the suitability of the soils for irrigation. Calculations of water balances (using crop type) can be made to estimate the required amount of water. Practices such as land planing (to provide appropriate run within furrows) can cause problems, particularly on soils where gilgai occur. Removal of too much surface soil can result in the exposure of subsoils with properties that may restrict crop growth. Soil variations within a paddock (e.g. from a *Waco* to an *Oakey*) can also cause significant difficulties with furrow irrigation.

Some hardsetting and/or surface crusting soils e.g. *Haslemere,* should not be spray irrigated. The impact of water droplets on the soil surface causes breakdown of aggregates and the formation of a surface crust upon drying. If thick enough, this crust can reduce seedling emergence.

Gypsum can improve surface soil aggregation, resulting in reduced waterlogging and crusting and can improve surface soil drainage (DNR, 1997). Application rate of gypsum depends on sodicity levels. For ESP measurements between 5-10% approximately 2.5-3 t/ha is required; for ESP >10% 3.5-4 t/ha is necessary. Due to the low solubility of gypsum it may be more suitable to apply every second year (DNR, 1997).

Differences occur in the quality of bore water and surface water. Irrigation with poor quality water can lead to soil structural problems e.g. crusting. Mixing of surface and ground water may be used to alleviate water quality problems.

9.9 Small rural holdings and their management

Issues concerning small rural holdings management are evident within the Central Darling Downs area and will only increase as more people are attracted to a small holding within the rural area as a preferred lifestyle.

There are many problems associated with small holdings and a great number of publications are available to answer questions and increase awareness as to what issues may confront owners of a small holding *(see Further Reading)*.

9.9.1 Things to consider before purchasing

Living on a small holding is quite different to living in a town. There are many questions that need consideration before purchasing.

- Will living in a rural environment suit the goals of all family members?
- Is the family prepared to become part of a rural community?
- Does the family have the necessary skills and time to manage the holding?
- What services do the family need and how accessible are they, for example how far are schools and shops?
- Will the existing infrastructure be sufficient or should it be upgraded, for example water supply, rubbish removal or connection of power and telephone?
- Is the land suitable for the family's purposes, particularly in relation to water supply, soil type, and slope?
- What does the local shire plan indicate regarding possible future uses for the land?
- Will the farming practices of neighbours cause concern?

The last question is particularly relevant. Some of the agricultural activities that occur in rural areas can interfere with the lifestyle aspirations that attracted the family to the area.

Potential residents of an area should be aware of seasonal variations of activities that commonly occur as a normal part of agricultural enterprises in the area.

For example:
- harvesting (24 hours) of cotton, wheat and other crops;
- associated truck movements and possible dust generation;
- aerial and tractor application of sprays and fertilisers;
- odours from intensive stock industries (e.g. feedlots, piggeries);
- occasional lucerne and hay cutting and bailing at night;
- stock mustering or grazing along roads, roads reserves and stock routes;
- the use of firearms at any time of the day or night for the control of feral animals;
- changes in water levels of streams due to irrigation demands.

9.9.2 Capabilities of the land

Each parcel of land will have unique physical characteristics. It is important that these characteristics are understood by a potential buyer to determine if the land is suitable for intended uses.

Important characteristics that may indicate what problems may arise include:

- degree of slope, affecting erosion control, crop productivity, machinery;
- aspect, affecting landuse and production;
- topography, determining machinery use, crop production and location of roads, fences, dams;
- soil type, affecting land use options, crop production and potential land degradation problems;
- area/size, affecting economic potential;
- existing land degradation (such as salting and erosion), farm production and cost of rehabilitation; and
- water supply (quantity, quality), affecting potential use and applications, production and fire control.

9.9.3 Planning the property

Planning the layout of a property should be a priority to ensure it is properly maintained and the goals of the owner are achieved. Landowners should seek professional advice from land planners before developing land.

The Department of Primary Industries, Department of Natural Resources, Landcare groups and consultants provide advice and practical workshops on property planning. One of the easiest ways to develop a basic property plan before seeking professional advice is to draw up a map of the property. For example, an enlarged aerial photo map provides a good base for planning (*see Section 9.3*).

Some of the main points to consider when planning the property and drawing up a map are:

- family goals - what are they and how should the land be developed and managed to meet these goals?
- where should buildings, roads and other permanent structures be located on the property?
- where are existing fences and dams located?
- what other farm infrastructure is needed?
- where should trees be on the property, where are they now?
- how do we incorporate nature conservation?
- what is the best location for particular uses, such as crops or orchards?
- where are the potential land degradation problems?
- what fire control measures are incorporated?

9.9.4 Land degradation and protection

If the property is not managed correctly, land degradation such as erosion, salinity and weed infestation can occur. Land degradation reduces the value and productivity of the property and can impact on neighbouring properties and the environment in general.

Small holdings in the Central Darling Downs can have the following land degradation problems.

- Erosion and over-grazing resulting from previous land mismanagement. Owners often over-estimate the carrying capacity of the land or under-estimate cropping limitations.

- Watercourse degradation caused by clearing of vegetation, over-grazing, pollutants, and increased water runoff from surrounding land. Small holdings can increase the amount of domestic waste reaching streams, such as detergents and sewerage. Not all soils are suitable for septic effluent disposal systems. Soils with impermeable clay subsoils are less suitable for the disposal of effluent.

- Pests and weeds need to be managed to maintain the productivity of the land, and to prevent spread to adjacent properties. Small lot landholders should practise pest and weed control as conscientiously as full-time farmers. If this is not achieved, community conflict can occur.

9.10 Managing water resources

Land and water are interactive components of the landscape. These interactions mean that change in one component often affects another. For example, soil erosion in the headwaters of a catchment not only affects the productivity of the land but also can seriously affect watercourses through decreased water quality and increased sedimentation. It is necessary to manage both components in unison.

Careful land management will help to ensure that water resources are not adversely impacted. Preparation and implementation of a land management plan will address inter-related land and water resource issues such as:

- the impact of landuse on water quality;
- soil erosion and sedimentation of watercourses;
- stability of bed and banks of watercourses;
- salinity induced through clearing of vegetation in upland areas;
- loss of habitat on land and in watercourses; and
- spread of plant and animal pests.

9.10.1 Integrated catchment management (ICM)

The purpose of ICM is to integrate the management of land, water, vegetation and related biological resources to achieve the sustainable and balanced use of resources. ICM provides the framework for fostering co-operation and co-ordination between the many landholders and other resource users, community groups and government agencies involved in the use and management of land and water resources.

9.10.2 Riparian land management

Riparian land is any land which adjoins or directly influences a body of water, including (LWRRDC, 1996):

- the land immediately alongside small creeks and rivers including the riverbank itself;
- gullies and dips which sometimes run with surface water;
- areas surrounding lakes; and

- wetlands on river floodplains which interact with the river in times of flood.

Riparian land can have broad biodiversity and high nature conservation values. It plays an important part in the lifecycle of many native animals and plants. Riparian lands are fragile by nature and due to their productivity are often vulnerable to overuse and poor management practices. Good management of riparian lands is needed in conjunction with good land management elsewhere in the catchment, especially of the adjacent floodplain.

The key measures in good riparian land management are (LWRRDC, 1996):

- retention of riparian vegetation;
- stock management; and
- revegetation of degraded riparian areas.

For further information refer to DNR River Fact sheets and Riparian Management Fact sheets (LWRRDC, 1996).

9.10.3 Surface water and groundwater management

More equitable allocation of surface water resources is being addressed through the Water Allocation and Management Planning (WAMP) process. As discussed in Section 5.2.2, existing licence arrangements will continue to apply until a WAMP is fully developed, with some restrictions expected on the issue of further licences.

District guidelines address the management of groundwater in the Central Darling Downs (*see Section 5.4*).

Photo 21 Constructing broad based contour banks for runoff control

Table 9.1 Recommended stocking rates for soils of the Central Darling Downs

Soil name	Stocking rate Native pasture	 Sown pasture
Acland, Toolburra	1 AE[1]/2ha	1 AE/1ha
Aberdeen, Anchorfield, Burton, Charlton, Craigmore, Drayton, East, Edgefield, Elphinstone, Irving, Kupunn, Langlands, Middle Ridge, Moola, Mywybilla, Purrawunda, Ruthven, Talgai, Toowoomba, Waco	1 AE/2.5-3ha	1 AE/1ha
Cecilvale	1 AE/2.5-3ha	1 AE/1-2ha
Gate, Mallard	1 AE/3ha	1 AE/1.5ha
Millmerran	1 AE/3ha	1 AE/2ha
Aubigny, Nungil, Southbrook	1 AE/3-3.5ha	1 AE/2ha
Belahville, Diamondy, Downfall, Formartin, Leyburn, Oakey	1 AE/3-3.5ha	1 AE/2.5ha
Walker	1 AE/3-3.5ha	1 AE/2.5-3ha
Clayburn	1 AE/3-4ha	1 AE/1.5-2.5ha
Condamine	1 AE/3-8ha	1 AE/1ha
Yargullen	1 AE/4ha	1 AE/2ha
Beauaraba	1 AE/4ha	1 AE/2ha
Calingunee, Kurumbul, Tandawanna	1 AE/4-8ha	1 AE/3-5ha
Arden, Tara, Wynhari	1 AE/4-8ha	1 AE/3-6ha
Haslemere	1 AE/4-8ha	1 AE/3-8ha
Flinton	1 AE/4-10ha	1 AE/3-8ha
Murra Cul Cul	1 AE/5.6ha	1 AE/2.5ha
Chinchilla, Combidiban, Davy, Drome, Nudley, Weranga	1 AE/6-12ha	1 AE/4-10ha
Moruya	1 AE/7-10ha	1 AE/3-5ha
Banca, Cottonvale, Gammie, Karangi	1 AE/8-10ha	1 AE/3-5ha
Kenmuir	1 AE/10-12ha	NR[2]
Allan	1AE/10-15ha	NR
Braemar	1 AE/10-15ha	NR
Channing	1 AE/10-15ha	NR
Cutthroat	1 AE/10-15ha	1 AE/10-12ha
Hanmer	1AE/10-15ha	NR
Binkey	1 AE/10-20ha	NR
Knoll	1 AE/20-30ha	NR

AE[1]: Adult Equivalent — standardised stock equivalent, — 1 cow, or 1 horse, 7 sheep, 7 goats or 10 kangaroos (Partridge, 1992).

NR[2]: Not Recommended.

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Appendix 1: A list of plants commonly found in the Central Darling Downs

Trees

Common name	Scientific name
Beefwood	*Grevillea striata*
Belah	*Casuarina cristata*
Belalie	*Acacia stenophylla*
Blackboy, Grass trees	*Xanthorrhoea* spp.
Black teatree	*Melaleuca bracteata*
Black wattle	*Acacia concurrens*
Black wattle	*Acacia leiocalyx*
Blue-leaved ironbark	*Eucalyptus fibrosa* subsp. *nubila*
Boonaree	*Alectryon oleifolium*
Bottle tree, Narrow-leaved bottle tree	*Brachychiton rupestris*
Brigalow	*Acacia harpophylla*
Broad-leaved ironbark/Broad-leaved red ironbark	*Eucalyptus fibrosa* subsp. *fibrosa*
Broad-leaved leopard tree	*Flindersia collina*
Brown's box	*Eucalyptus brownii*
Budgeroo	*Lysicarpus angustifolius*
Bull oak	*Allocasuarina luehmannii*
Caley's ironbark	*Eucalyptus caleyi*
Coastal banksia	*Banksia integrifolia*
Coolibah	*Eucalyptus coolabah (E. microtheca)*
Coughbush	*Cassinia laevis*
Crow's ash	*Flindersia australis*
Currawong	*Acacia sparsiflora*
Cypress pine, White cypress pine	*Callitris glaucophylla (C. columellaris)*
Dogwood	*Jacksonia scoparia*
Dusky-leaved ironbark	*Eucalyptus fibrosa* subsp. *nubila*
False sandalwood	*Eremophila mitchellii*
Flooded Gum/Rose Gum	*Eucalyptus grandis*
Fuzzy box	*Eucalyptus conica*
Gum topped box, Grey box	*Eucalyptus moluccana*
Gum-topped box	*Eucalyptus microcarpa*
Grey ironbark	*Eucalyptus drepanophylla*
Hairy oak, Thready-bark oak	*Casuarina inophloia*
Hop bushes	*Dodonea* spp.
Ironwood	*Acacia excelsa*
Kurrajong	*Brachychiton populneus*
Lancewood	*Acacia shirleyi*
Limebush	*Eremocitrus glauca*
Manna gum	*Eucalyptus nobilis*
Molly box, Mallee box	*Eucalyptus pilligaensis*
Moreton Bay ash, Carbeen	*Corymbia tessellaris*
Mountain coolibah	*Eucalyptus orgadophila*
Mugga, Red ironbark	*Eucalyptus sideoxylon*
Myall	*Acacia pendula*
Myrtle tree	*Canthium oleifolium*
Narrow-leaved ironbark	*Eucalyptus crebra*
Native olive	*Notelaea microcarpa*
New England blackbutt	*Eucalyptus andrewsii*
New England peppermint	*Eucalyptus nova-anglica*
Paper barked teatree	*Melaleuca nervosa* f. *pendulina*
Pink bloodwood	*Eucalyptus intermedia*
Poplar box	*Eucalyptus populnea*
Prickly pine	*Bursaria incana*
Privet	*Ligustrum lucidum*
Queensland blue gum	*Eucalyptus tereticornis*
Quinine bush	*Petalostigma pubescens*
Red ash	*Alphitonia excelsa*

River red gum	*Eucalyptus camaldulensis*
Rough-barked apple	*Angophora floribunda*
River sheoak	*Casuarina cunninghamiana*
Rusty gum	*Angophora leicocarpa*
Sally wattle	*Acacia salicina*
Sandalwood	*Santalum lanceolatum*
Scrub boonaree	*Alectryon diversifolius*
Silky oak	*Grevillia robusta*
Silver-leaved ironbark	*Eucalyptus melanophloia*
Spotted gum	*Corymbia citriodora*
Tumbledown gum	*Eucalyptus chlorocarpa*
Tumbledown red gum	*Eucalyptus dealbata*
Wattle	*Acacia ixiophylla*
Weeping pittosporum	*Pittosporum phylliraeoides*
Western teatree	*Melaleuca lanceolata*
White box	*Eucalyptus albens*
White cedar	*Melia azedarach*
Wild orange, Bumbil	*Capparis mitchellii*
Wilga	*Geijera parviflora*
Yarran	*Acacia omalophylla*
Yellow box	*Eucalyptus melliodora*
Youman's stringybark	*Eucalyptus youmanii*

Grasses & Herbs

Common name	Scientific name
Barbwire grass	*Cymbopogon refractus*
Black speargrass	*Heteropogon contortus*
Brigalow grass	*Paspalidium caespitosum*
Buffel grass	*Cenchrus ciliaris*
Couch	*Cynodon* spp.
Creeping bluegrass	*Bothriochloa insculpta*
Creeping saltbush	*Atriplex semibaccata*
Curly windmill grass	*Enteropogon acicularis*
Digit grass	*Digitaria eriantha* cv. *Premier*
Forest bluegrass	*Bothriochloa bladhii*
Galvanised burr	*Sclerolaena birchii*
Green panic	*Panicum maximum* var. *trichoglume*
Nardoo	*Marsilea hirsuta*
Kangaroo grass	*7hemeda triandra*
Pitted bluegrass	*Bothriochloa decipiens*
Poverty grass	*Eremochloa bimaculata*
Purple lovegrass	*Eragrostis lacunaria*
Purple pigeon grass	*Setaria incrassata*
Queensland bluegrass, slender bluegrass	*Dichanthium sericeum*
Rhodes grass	*Chloris gayana*
Rough speargrass	*Stipa scabra*
Saltbushes	*Atriplex* spp.
Sedges	*Cyperus* spp.
Sida	*Sida* spp.
Slender panic, belah grass	*Paspalidium gracile*
Urochloa	*Urochloa* spp.
Western rat's tail grass	*Sporobolus creber*
White speargrass	*Aristida leptopoda*
Wiregrasses	*Aristida* spp.

Appendix 2: A list of weed species commonly found in the Central Darling Downs

(Declared plants shown in bold type)

Common name	Scientific name
African boxthorn	***Lycium ferocissimum***
Alligator weed	***Alternanthera philoxeroides***
Balloon cotton	*Asclepias physocarpa*
Bathurst burr	***Xanthium spinosum***
Bellvine	*Ipomoea plebeia*
Bindweed	*Convolvulus arvansis*
Bishop's weed	*Ammi majus*
Blue heliotrope	*Heliotropium amplexicaule*
Burr medic	*Medicaso polymorpha*
Camphor laurel	*Cinnamomum camphora*
Castor oil plant	*Ricinus communis*
Cat's claw creeper	*Macfadyena unguis-cati*
Clock weed	*Gaura peruiflora*
Cobbler's pegs	*Bidens pilosa*
Common morning glory	*Impomea purpurea*
Creeping lantana	*Lantana montevidensis*
Cumbungi	*Typha* spp.
Curled dock	*Rumex crispis*
Current bush	*Carissa ovata*
Devils apple	*Solanum capsicoides*
Devils claw	*Ibicella lutea*
Dodder	*Coscuta* spp.
Dog burr	*Bassia tetracuspis*
Firethorn	*Pyracantha angustifolia*
Fleabanes	*Conyza* spp.
Foxtail grass	*Pennisetum villosum*
Galvanised burr	*Bassia birchii*
Gin's whiskers	*Solanum semiarmatum*
Gomphrena weed	*Gomphrena celosiodes*
Green cestrum	*Cestrum parqui*
Ground cherry	*Physalis angulata*
Groundsel	***Baccharis halimifolia***
Harrisia cactus	***Eriocereus martinii***
Harrisia cactus	***Eriocereus tortuosus***
Hemlock	***Conium maculatum***
Hexham scent	*Melilotus indica*
Honey locust	***Gleditsia triacanthus***
Johnson grass	*Sorghum halepense*
Khaki weed	*Alternanthera pungens*
Lantana	*Lantana camara*
Limebush	*Eremocitrus glauca*
Lippia	*Phyla canescens*
Maltese cockspur	*Centaurea melitensis*
Maynes pest	*Verbena tenuisecta*
Mexican poppy	*Argemone* spp.
Milk thistle	*Sonchus oleraceus*
Mimosa	*Acacia farnesiana*
Mint weed	*Salvia reflexa*
Mistletoe	*Amyema pendulum*
Mother of Millions	*Bryophyllum* spp.
Nodding thistle	*Carduus thoermeri*
Noogoora burr	***Xanthium pungens***
Nut grass	*Cyperus rotundus*

<u>**Common name**</u>	<u>**Scientific name**</u>
Parthenium	*Parthenium hysterophorus*
Pattersons curse	*Echium plantagineum*
Prickly pear	Opuntia inermis
Prickly roly poly	*Bassia quinquecuspis*
Privet	*Ligustrum* spp.
Ragweed perennial?	***Ambrosia artemisiifolia***
Saffron thistle	***Carthamus lanatus***
Salvinia	***Salvina molesta***
Sand burr	*Cenchrus incertus*
Scotch thistle	*Cirsium vulgare*
Sesbania pea	*Sesbania cannabina*
Silver leaf nightshade	*Solanum elaegnifolium*
Smartweeds	*Polygonum* spp.
Soft roly poly	*Salsola kali*
Speedy weed	*Flaveria australasica*
Spiny emex	***Emex australis***
Stinging nettle	*Urtica incisa*
Stinking roger	*Tagetes minuta*
Stramonium	***Datura* spp.**
Swamp dock	*Rumex brownii*
Tiger pear	***Opuntia aurantiaca***
Tree of heaven	*Ailanthus altissima*
Tree pear	***Opuntia tormentosa***
Verbena	*Verbena officinalis*
Variegated thistle	*Silybum marianum*
Water primrose	*Ludwigia peploides*
White moth plant	*Araujia hortorum*
Wild radish	*Raphanus raphanistrum*
Wild turnip	*Brassica tournefortii*
Wild zinnia	*Zinnia peruviana*

<u>**Scientific Name**</u>	<u>**Common Name**</u>
Acacia farnesiana	Mimosa
Ailanthus altissima	Tree of heaven
Alternanthera philoxeroides	Alligator weed
Alternanthera pungens	Khaki weed
Ambrosia artemisiifolia	**Ragweed**
Ammi majus	Bishop’s weed
Amyema pendulum	Mistletoe
Araujia hortorum	White moth plant
Argemone spp.	Mexican poppy
Asclepias physocarpa	Balloon cotton
Baccharis halimifolia	Groundsel
Bassia birchii	Galvanised burr
Bassia quinquecuspis	Prickly roly poly
Bassia tetracuspis	Dog burr
Bidens pilosa	Cobbler’s pegs
Brassica tournefortii	Wild turnip
Bryophyllum spp.	Mother of Millions
Carduus thoermeri	Nodding thistle
Carissa ovata	Current bush
Carthamus lanatus	**Saffron thistle**
Cenchrus incertus	Sand burr

Scientific Name	**Common Name**
Centaurea melitensis	Maltese cockspur
Cestrum parqui	Green cestrum
Cinnamomum camphora	Camphor laurel
Cirsium vulgare	Scotch thistle
Conium maculatum	Hemlock
Convolvulus arvansis	Bindweed
Conyza spp.	Fleabanes
Coscuta spp.	Dodder
Cyperus rotundus	Nut grass
***Datura* spp.**	**Stramonium**
Echium plantagineum	Pattersons curse
Emex australis	Spiny emex
Eremocitrus glauca	Limebush
Eriocereus martinii	Harrisia cactus
Eriocereus tortuosus	
Flaveria australasica	Speedy weed
Gaura peruiflora	Clock weed
Gleditsia triacanthus	Honey locust
Gomphrena celosiodes	Gomphrena weed
Heliotropium amplexicaule	Blue heliotrope
Ibicella lutea	Devils claw
Impomea purpurea	Common morning glory
Ipomoea plebeia	Bellvine
Lantana camara	Lantana
Lantana montevidensis	Creeping lantana
Ligustrum spp.	Privet
Ludwigia peploides	Water primrose
Lycium ferocissimum	African boxthorn
Macfadyena unguis-cati	Cat’s claw creeper
Medicaso polymorpha	Burr medic
Melilotus indica	Hexham scent
Opuntia aurantiaca	**Tiger pear**
Opuntia inermis	*Prickly pear*
Opuntia tormentosa	*Tree pear*
Parthenium hysterophorus	Parthenium
Pennisetum villosum	Foxtail grass
Phyla canescens	Lippia
Physalis angulata	Ground cherry
Polygonum spp.	Smartweeds
Pyracantha angustifolia	Firethorn
Raphanus raphanistrum	Wild radish
Ricinus communis	Castor oil plant
Rumex brownii	Swamp dock
Rumex crispis	Curled dock
Salsola kali	Soft roly poly
Salvia reflexa	Mint weed
Salvina molesta	**Salvinia**
Sesbania cannabina	Sesbania pea
Silybum marianum	Variegated thistle
Solanum capsicoides	Devils apple
Solanum elaegnifolium	Silver leaf nightshade
Solanum semiarmatum	Gin’s whiskers
Sonchus oleraceus	Milk thistle
Sorghum halepense	Johnson grass
Tagetes minuta	Stinking roger
Typha spp.	Cumbungi
Urtica incisa	Stinging nettle

Scientific Name	**Common Name**
Verbena officinalis	Verbena
Verbena tenuisecta	Maynes pest
Xanthium pungens	Noogoora burr
Xanthium spinosum	Bathurst burr
Zinnia peruviana	Wild zinnia

Appendix 3: A list of Rare and Threatened plants of the Central Darling Downs

Scientific name	Conservation status
Acacia brunioides subsp. *granitica*	R
Acacia chinchillensis	V
Acacia curranii	V
Arthraxon hispidus	V
Bothriochloa biloba	V
Bothriochloa bunyensis	V
Callitris baileyi	R
Clematis fawcettii	V
Cryptocarya floydii	R
Cyperus clarus	P
Dichanthium queenslandicum	V
Digitaria porrecta	E
Dipodium pulchellum	R
Dodonaea biloba	R
Dodonaea macrossanii	R
Eleocharis blakeana	R
Eriostemon sporadicus	V
Eucalyptus curtisii	R
Eucalyptus infera	V
Eucalyptus rhombica	P
Fimbristylis vagans	R
Haloragis exalata subsp. *velutina*	V
Homopholis belsonii	E
Indigofera baileyi	R
Macadamia integrifolia	V
Macrozamia machinii	V
Notelaea pungens	R
Picris evae	V
Prostanthera spp. (Dunmore D.M.Gordon 8A)	V
Santalum lanceolatum	P
Sarcochilus weinthalii	E
Sophora fraseri	V
Stemmacantha australis	V
Symplocos harroldii	R
Tephrosia baueri	P
Thesium australe	V
Xerothamnella herbacea	E
Zornia pallida	P

Abbreviations

R = Rare
V = Vulnerable
E = Endangered
P = Pending possible declaration as R, V or E in the Nature Conservation (Wildlife) Regulation 1994

Appendix 4: A list of Rare and Threatened fauna of the Central Darling Downs

Scientific name	Common name	Conservation status
Mixophyes fleayi	Fleay's barred frog	E
Litoria pearsoniana	Cascade treefrog	E
Turnix melanogaster	Black-breasted button quail	V
Stictonetta naevosa	Freckled duck	R
Ephippiorhynchus asiaticus	Black necked stork	R
Accipiter novaehollandiae	Grey goshawk	R
Lophoictinia isura	Square-tailed kite	R
Rostratula benghalensis	Painted snipe	R
Calyptorhynchus lathami	Glossy black-cockatoo	V
Psephotus pulcherrimus	Paradise parrot	PE
Grantiella picta	Painted honeyeater	R
Dasyurus maculatus maculatus	Spotted-tailed quoll (Southern subspecies)	V
Petrogale penicillata	Brush-tailed rock wallaby	V
Chalinolobus picatus	Little pied bat	R
Conilurus albipes	White-footed rabbit rat	PE
Notomys mordax	Darling Downs hopping-mouse	PE
Diplodactylus taenicauda	Golden-tailed gecko	R
Delma torquata	Collared delma	V
Paradelma orientalis	Brigalow scaly-foot	V
Anomalopus mackayi	Long-legged worm-skink	V
Egernia rugosa	Yakka skink	V
Lampropholis colossus		
Aspidites ramsayi	Woma	R
Acanthophis antarcticus	Common death adder	R
Furina dunmalli	Dunmall's snake	V
Hoplocephalus stephensii	Stephen's banded snake	R

Abbreviations

PE Presumed extinct
E Endangered
V Vulnerable
R Rare

GLOSSARY

A horizon	See *Soil horizon*
A2 horizon	See *Subsurface soil; Bleach*
Acid soil	A soil giving an acid reaction throughout most of all of the soil profile (precisely, below a pH of 7.0; practically, below a pH of 6.5). Generally speaking, when the pH drops below 5.5 the following specific problems may occur – aluminium toxicity, manganese toxicity, calcium deficiency and/or molybdenum deficiency. Such problems adversely affect plant growth and root nodulation, which may result in a decline in plant cover and increase in erosion hazard. *See pH*
Adamellite	A variety of granite containing a calcium-bearing plagioclase, and a potassium feldspar, in roughly equal amounts.
Aeolian	A process whereby soil forming material is transported and deposited by wind.
Aggregate	A naturally occurring assemblage of smaller particles (mineral, organic and other) to make a larger one.
Agricultural Land Classes	Categories of land marked on their agricultural suitability based on selected properties that affect specific uses.
Alkaline soil	A soil giving an alkaline reaction throughout most or all of the soil profile (precisely, above a pH of 7.0; practically, above a pH of 8.0). Many alkaline soils have a high pH indicated by the presence of calcium carbonate, and are suitable for agriculture. However, others are problem soil because of salinity and/or sodicity. Soils with a pH above 9.5 are generally unsuitable for agriculture. *See pH*.
Alluvial plain	A plain formed by the accumulation of alluvium on a floodplain over a considerable period of time; this accumulation may be still occurring at present (recent alluvium) or may have ceased (relict alluvium).
Alluvium (plural. alluvia)	Deposits of gravel, sand, silt, clay or other debris, moved by streams from higher to lower ground.
Apiculture	Bee-keeping.
Aquatic macrophytes	Water plants large enough to be seen with the naked eye, living in or on water.
Aquifer	A body of permeable rock, for example, unconsolidated gravel or sand, that is capable of storing or transmitting significant quantities of water, is underlain by impermeable material, and through which groundwater moves.
Arenic	Soils in which at least the upper 0.5 m of the profile is non-gravelly and of

	sandy texture throughout. It is also loosely or weakly coherent (see *Consistence*), and may have aeolian (wind-blown) cross-bedding. This term is used in the Australian Soil Classification (Isbell 1996) to describe Tenosols (see *Tenosol*). Hence Arenaceous
Aureole	A zone surrounding an igneous intrusion in which contact metamorphism of the country rock has taken place.
B horizon	See *Soil horizon*
Backplain	Large alluvial flat occurring some distance from the stream channel; often characterised by a high watertable and the presence of swamps or lakes.
Base status	This refers to the sum of exchangeable basic cations (Ca, Mg, K and Na) expressed in cmol (+) kg^{-1} clay. It is used as an indicator of soil fertility and is calculated by multiplying the sum of the reported basic cations by 100 and dividing by the clay percentage of the sample. Three classes are defined: *Dystrophic* – the sum is less than 5; *Mesotrophic* – the sum is between 5 and 15 inclusive; and *Eutrophic* – the sum is greater than 15. It is used for some Great Group or Subgroup distinctions within the Australian Soil Classification (Isbell, 1996).
Bleached-Leptic	Soils with a conspicuously bleached A2 horizon which directly overlies a hard, continuous, discontinuous or broken layer of calcrete which may be massive, concretionary or nodular; or hard unweathered or decomposed rock or saprolite; or unconsolidated mineral materials. The term is used as a definition for a Tensile Sub-order in the Australian Soil Classification (Isbell, 1996)
Buffering capacity	Ability of a soil to resist change (usually chemical). It is affected by factors such as clay content, clay type, organic matter levels and pH.
C horizon	Layer(s) below the B horizon which may be weathered parent material, not bedrock, little affected by soil-forming processes.
Calcic	These soils have a layer containing 2–20% soft carbonate and <20% hard carbonate. This term is used to describe a number of Soil Orders in the Australian Soil Classification (Isbell, 1996).
Calcrete	A layer of cemented carbonate accumulation. The material must be hard.
Cation	A positively charged ion.
Cation exchange capacity (CEC)	The measure of the capacity of a soil to hold the major cations: calcium, magnesium, sodium and potassium (including hydrogen, aluminium and manganese in acid soils). It is a measure of the potential nutrient reserves in the soil and it therefore an indicator of inherent soil fertility. An imbalance in the ration of cations can result in soil structural problems. High levels of individual cations (e.g. aluminium and manganese) can also be toxic to plants.

Chlorotic	An abnormal yellow colour of a plant.
Chromosol	A Soil Order of the Australian Soil Classification (Isbell 1996). Soils have a clear or abrupt textural B horizon where the pH is 5.5 (water) or greater in the upper 0.2m of the B2 horizon.
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.
Cold fronts	The boundary where cold air moves to replace, and undercut, warmer and less dense air.
Concretion	See *Segregation.*
Compaction	The process whereby soil density is increased as a result of tillage, stock trampling and/or vehicular trafficking. Compaction can lead to lower soil permeability, poor soil aeration resulting in increased erosion hazard and poorer plant productivity. Deep ripping and conservation tillage can alleviate the condition.
Conservation farming practices	Integrated farming practices aimed at reducing land degradation and maximising production.
***Consistence* (of soil)**	Refers to the degree of resistance to breaking or deformation when a force is applied.
Cracking clays	See *Clays, cracking.*
Crusting	See *Surface crust*
Crusty	Soils with a massive or weakly structured surface crusty horizon 0.03 m or less thick, often of lighter texture than the underlying pedal clay which is not self-mulching. It is used as a Subgroup definition for Vertosols in the Australian Soil Classification (Isbell 1996).
Daily pan evaporation	The daily evaporative losses (in mm) from a free water surface (usually a wide, shallow pan of water).
Declared pests	
weeds	— plant species targeted for legislative controls under the Rural Lands Protection Act 1985 that have, or could have serious economic, environmental or social impact.
animals	— animal species targeted for legislative controls under the Rural Lands Protection Act 1985 that have, or could have serious economic, environmental or social impact..
Deep weathering	The process by which earthy or rocky materials are slowly broken down

into finer particles and soil by chemical processes over a long period of time. 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 quartz grains were relatively unaffected. See *Laterite.*

Dermosol — A Soil Order of the Australian Soil Classification (Isbell 1996). Soils with structured B2 horizons and lacking strong texture contrast between A and B horizons.

Die back — A progressive, usually protracted death of tips or branches in the crown of a tree. It may be caused by a variety of agents, acting singly or in combination, and may lead to tree death.

Dispersion — The process whereby soils break down and separate into their constituent particles (clay, silt, sand) in water. Dispersible soils tend to be highly erodible and present problems for earth works. Dispersion is associated with sodicity levels. See *Sodicity.*

Dissection — The process of streams or erosion cutting the land into hill, ridges and flat areas.

Drainage (soil profile) — The rate of downward movement of water through the soil, governed by both soil and site characteristics. Categories are as follows:
— Very poorly drained: free water remains at or near the surface for most of the year.
— Poorly drained: all soil horizons remain wet for several months each year.
— Imperfectly drained: some soil horizons remain wet for periods of several weeks.
— Moderately well drained: some soil horizons remain wet for a week after water addition.
— Well drained: no horizon remains wet for more than a few hours after water addition.
— Rapidly drained: no horizon remains wet except shortly after water addition.

Duplex soil — See *Texture contrast soil.*

Duricrust — A cemented layer at or near the surface resulting from the concentration of breakdown products of rock weathering.

Dystrophic — See *Base status.*

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 either to which salts have been leached and have therefore accumulated, or to an impeding layer. This represents the long-term depth of wetting.
Electrical conductivity (EC)	A measure of the conduction of electricity through water, or a water extract of soil. The value can reflect the amount of soluble salts in an extract and therefore provide an indication of soil salinity.
Endangered	A species is endangered if its numbers have been reduced to a critical level or its habitat has been so drastically reduced that it may be in danger of extinction; or, a species that has not been sighted in the wild for a period critical to its life cycle although no thorough search has been made for it.
Endohypersodic	Soils in which an ESP of 15 or greater occurs in some subhorizon below 0.5 m. It is used as a Subgroup definition for Vertosols in the Australian Soil Classification (Isbell 1996).
Epicalcareous	A soil in which the major part of the top 0.5 m of the profile is calcareous. It is used to describe Vertosols in the Australian Soil Classification (Isbell 1996).
Epipedal	Soils with a pedal A horizon which is either not or weakly self-mulching, and there is no surface crusty horizon. It is used as a Subgroup definition for Vertosols in the Australian Soil Classification (Isbell 1996).
Epihypersodic	Soils with at least one sub-horizon within the top 0.5 m of the profile having an ESP greater than 15. It is used as a Subgroup definition for Vertosols in the Australian Soil Classification (Isbell 1996).
Erodibility (soil)	The susceptibility of a soil to the detachment and transportation of soil particles by erosive agents. It is a function of the mechanical, chemical and physical characteristics of the soil, and is independent of the other factors influencing soil erosion such as topography, land use, rainfall intensity and plant cover. It may be changed by management.
Erosion Hazard	The susceptibility of a parcel of land to the prevailing agents of erosion. It is dependent on a combination of climate, landform, soil, land use and land management factors.

ESP Exchangeable sodium percentage. See *Sodicity.*

Eutrophic See *Base Status.*

Eutrophication Process by which water becomes enriched with nutrients, primarily nitrogen and phosphorus, which stimulate the growth of aquatic flora and/or fauna.

Feldspar Any of a group of alkaline aluminium silicate minerals, an important part of igneous rocks, such as granite.

Ferrosol A Soil Order of the Australian Soil Classification (Isbell 1996). Soils with B horizons which are high in free oxide, and which lack strong texture contrast between A and B horizons.

Fertility The capacity of the soil to provide adequate supllies of nutrients in proper balance for the growth of specified plants when other growth factors are favourable.
- — very low: the soil requires a high amount of nutrient input to achieve optimal plant growth. Major deficiencies in more than one nutrient.
- — low: the soil requires a moderate amount of nutrient input to achieve optimal plant growth. Moderate deficiencies in more than one nutrient.
- — moderate: the soil requires a low amount of nutrient input to achieve optimal plant growth. Minor deficiencies in more than one nutrient.
- — high: the soil only requires a very low nutrient input to achieve optimal plant growth.
- — very high: the soil does not need nutrient enrichment to achieve optimal plant growth.

Field crops Grain, fibre, pulse and other crops grown on an extensive scale.

Floating sandstone Loose sandstone rock fragments that are often found in the soil on a slope.

Floristic association The dominant or diagnostic species used to classify vegetation.

Floodplain Alluvial plains formed by flooding streams or rivers and prone to inundation from flooding.

Gilgai Surface microrelief associated with soils containing shrink-swell clays. Characterised by the presence of mounds and depressions.

crabhole — irregularly distributed small depressions and mounds, separated by a more or less continuous shelf. Vertical interval usually less than 0.3 m. Horizontal interval usually 3-20 m, surface almost level.

linear — long, narrow, parallel, elongate mounds and broader, elongate depressions more or less at right angles to the contour; usually in sloping lands.

melonhole — large depressions, usually greater than 3 m diameter and deeper than 0.3 m, which have a sub-circular or irregular shape and are separated by elongate mounds or set in an almost level surface.

normal — small, irregularly distributed mounds and sub-circular depressions, usually with less than 0.3 m vertical interval between the mound tops and bottom of depressions.

Gilt	A young sow.
Gradational	The term describes a soil with a gradual increase in texture (i.e. becomes more clayey) as the profile deepens.
Granite/granitic rocks	A coarse-grained, *igneous* rock formed beneath the earth's surface and consisting essentially of 20-40% quartz, alkali feldspars (which are a source of sodium and potassium) and very commonly a mica.
Granite tors	Tower-like blocks of unweathered granite rock standing above the surrounding area.
Green Chop	Silage.
Gully erosion	Process whereby the removal of soil is characterised by large incised channels in the landscape. Such channels are generally more than 30 centimetres in depth.
Gypsic	Soils with a gypsic horizon. This is one that contains more than 20% of visible gypsum that is apparently of pedogenic origin, and has a minimum thickness of 0.1 m. This term is used as a definition within a number of Soil Orders in the Australian Soil Classification (Isbell 1996).
Gypsum	A naturally occurring soft crystalline material which is a hydrated form of calcium sulphate. Gypsum contains approximately 23% calcium and 18% sulphur. It is used to improve soil structure and reduce crusting in hard setting clayey soils.
Haplic	A term used in the Australian Soil Classification (Isbell 1996) which indicates that the major part of the upper 0.5 m of the soil profile is whole coloured.
Hardsetting	Surface soil that becomes hard and apparently structureless on the periodic drying of the soil.
Horizon	See *Soil horizon,* also *Soil horizon boundary*
Humus	Dark organic material in soils, produced by the decomposition of animal or vegetable matter.
Hypercalcic	These soils have a B horizon or subsurface layer containing more than 20% of mainly soft, finely divided carbonate, and less than 20% of hard calcrete fragments and/or carbonate nodules, and/or carbonate coated gravel. The term is used as a definition for a number of Orders in the Australian Soil Classification (Isbell 1996).
Hypernatric	Soils in which the major part of the upper 0.2 m of the B2 horizon has an ESP greater than 25. It is used as a Subgroup definition for Sodosols in the Australian Soil Classification (Isbell 1996).

Igneous rock	Rock crystallised from molten rock material (magma). It may be extruded to the Earth's surface (volcanic) or cool at variable depths below the surface (intrusive, and plutonic).
Infiltration	The movement of water through the soil surface. Soils with a high infiltration capacity allow more rain to enter the soil than soils with a low capacity. Runoff will occur when the rate of rainfall exceeds the soil's infiltration capacity. Surface soil structure and texture are important determinants of the infiltration capacity of a soil.
Interbasaltic	Lying between layers of basalt.
Jump-ups	Local term used to describe stony, lateritised ridges and scarps.
Kandosol	A Soil Order of the Australian Soil Classification (Isbell 1996). These soils lack strong texture contrast and have massive or only weakly structured B horizons. The B2 horizon is well developed and has a maximum clay content in some part of the B2 horizon which exceeds 15%. They are also not calcareous throughout.
Kaolinisation	Breakdown of minerals (particularly feldspars) under intense weathering to form kaolinite clay (china clay).
Kurosol	A Soil Order of the Australian Soil Classification (Isbell 1996). Soils with strong texture contrast between A horizons and strongly acid B horizons. Many of these soils have some unusual subsoil chemical features (high magnesium, sodium and aluminium).
Land Resource Area	Broad landscape units made up of groups of different soils developed from related geological units with recurring patterns of topography and vegetation.
Laterite	A profile formed by intense weathering. Many deeply weathered profiles termed 'lateritic' exhibit a distinct series of layers including a surface duricrust, ironstone and mottled and pallid (kaolinised) zones. The word laterite is used for any profile in which ironstone is a major feature. See *Duricrust.*
Lateritised rocks	Rocks which have been partially or completely weathered to laterite.
Leaching	The removal in solution of soluble minerals and salts as water moves through the soil profile.
Levee	An embankment constructed to contain floods from a river. Can refer to natural embankments formed by deposition of sediments from flood flows.
Ley (pastures)	Pastures sown between cropping phases.
Lithology	Nature of rocks as seen in hand specimens, on the basis of colour, grain size and composition.

Local relief	The altitude difference between the base and crest of slopes in undulating or hilly areas.
Low hills	Landform pattern of low relief (30-90 m) and gentle to very steep slopes.
Low pressure systems	Masses of air with an atmospheric pressure lower than the surrounding air.
Magnesic	Soils with an exchangeable Ca/Mg ratio of less than 0.1 in the major part of the B2 horizon. This term is used as a definition within a number of Soil Orders in the Australian Soil Classification (Isbell 1996).
Massive earths	See *Earths, massive.*
Massive structure	See *Soil structure (apedal).*
Medics	Pasture species of the Leguminosae family.
Mesonatric	Soils in which the major part of the upper 0.2 m of the B2 horizon has an ESP between 15 and 25. Used as a Great Group definition for Sodosols in the Australian Soil Classification (Isbell 1996).
Metamorphic rocks	Rocks that were originally igneous or sedimentary that have been physically and / or chemically altered by high temperatures and / or pressures beneath the Earth's surface.
Mineralisation	The breakdown of soil organic matter and crop and animal residues by micro-organisms to inorganic (available) forms.
Mottle	Spots, blotches or streaks of subdominant colours different from the main soil colour.
Mycorrhizae	Soil fungi which act as rootlets and increase the amount of nutrients (particularly phosphorus and zinc) available to plants. Fallowing, excessive tillage and soil fumigation can cause mycorrhizae to die out. Plants growing with mycorrhizae are generally healthier and more resistant to disease, particularly root rots.
Natric	Soils in which the major part of the upper 0.2 m of the B2 horizon is sodic. Used as a Great Group definition for Kurosols in the Australian Soil Classification (Isbell 1996).
Nodules (in soil)	See *Segregation.*
Non-cracking clays	See *Clays, non-cracking.*
Orthic	Soils which usually have a weakly developed B horizon (in terms of contrast between A horizons above and adjacent horizons below), or a B horizon with 15% clay (SL-) or less, or a transitional horizon (C/B) occurring in fissures in the parent rock which contains between 10 and

	50% of B horizon material (including pedogenic carbonate).
Pans	A hard and/or cemented soil horizon e.g. cultivation pan.
Paralithic	A term used in the Australian Soil Classification (Isbell 1996) to define soil material which directly overlies partially weathered or decomposed rock or saprolite.
Parent material	The rock from which a soil profile develops.
PAWC	See Plant Available Water Capacity
Permeability	The capacity for transmission under gravity of water through soil or sediments.
Plain	Level to undulating or rarely, rolling landform pattern of extremely low relief (less than 9 m).
Plant available water capacity	The quantity of water held in a soil that can be extracted by plant roots. It is expressed as millimetres of plant available water within the root zone (PAWC).
pH	A measure of the acidity or alkalinity of a soil. A pH of 7.0 indicates neutrality, higher values indicate alkalinity and lower values indicate acidity. 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. Soil pH affects the amount of different nutrients that are soluble in water and therefore the amount of nutrient available to plants.
Plough pans	Zone of compaction and/or smearing at the base of the cultivated zone. Caused by the physical action of implements.
Porosity (of soil)	The degree of pore space in a soil (i.e. the percentage of the total space between solid particles). The extent and type of soil porosity indicates the ease with which water, air and roots can move through the soil. Without sufficient pores of the right size, soil is unproductive because plant roots cannot move through the soil easily, air and water movement are poor, and there is insufficient water for plant growth. There are two types of pores. Macropores are large pores, greater than 0.03 mm in diameter, and most can be seen by the naked eye. They include the spaces between soil aggregates caused by cultivation, shrinking and cracking, channels made by roots of plants, and earthworm and other animal and insect tunnels. Macropores are vitally important in allowing water and air to move freely, but provide little water for plant uptake because they are readily drained. Micropores are small pores less than 0.03 mm in diameter occurring mainly within aggregates. Water drains through them very slowly so they

act as water reservoirs for plant roots.

Rare	A species is rare if its population is represented by a relatively large population in a restricted range; or smaller populations thinly spread over a wide range.
Regolithic	A term used to describe soils with a layer of unconsolidated mineral material beneath the soil profile. The term is used in the Australian Soil Classification (Isbell 1996).
Rill erosion	The removal of soil by runoff from the land surface whereby numerous small channels, generally up to 30 centimetres deep, are formed. It typically occurs on recently disturbed soils and can be ploughed out.
Riparian lands	Are that part of the landscape adjacent to streams which exert a direct influence on streams or lake margins and on the water and aquatic ecosystems contained within them includes both the steambanks and the adjacent land.
Rises	Landform pattern of very low relief (9-30 m) and very gentle to steep slopes.
Root lesion nematodes	Small worms (eelworms) which feed on root cells, causing damage to the root.
Rudosol	A Soil Order of the Australian Soil Classification (Isbell 1996). This order is designed to accommodate soils that have negligible pedologic organisation. They are usually young soils in the sense that soil forming factors have had little time to pedologically modify parent rocks or sediments.
Salinity	The presence of sufficient soluble salts to adversely affect plant growth and/or land use. The main salt involved is sodium chloride, but sulphates, carbonates and magnesium salts occur in some soils. It is expressed as a level of electrical conductivity (EC). See *Electrical conductivity.*
Sands	Soils with a uniform sand (including sandy loam) texture throughout the surface soil and subsoil.
Saprolite	Decomposed rock that has maintained characteristics that were present as an unweathered rock.
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 (aeolian) or water (fluvial, marine). Sedimentary rocks have been classified according to grain size and constituent minerals: Clay-sized grains: Mudstone Sand-sized grains: Sandstone Silt-sized grains: Siltstone Gravel-sized grains: Conglomerate

Sandstone is further subdivided on the basis of the dominant minerals making up the clasts (solid inclusions) or the matrix which cements the clasts together:
90% or more of grains are quartz: Quartzose sandstone
less than 75% of grains are quartz: Labile sandstone

Segregation Discrete accumulations of minerals in the soil because of the concentration of some constituent, usually by chemical or ' biological action. Segregations are described by their nature, abundance and form.

1) nature for example, calcareous (carbonate), gypseous (gypsum), manganiferous (manganese) and ferromanganiferous (iron-manganese).

2)abundance

very few (trace or occasional)	<2%
few (slight)	2-10%
common (light)	10-20%
many (moderate)	20-50%
very many (heavy)	>50%

3) form

Concretions	- spheroidal formations (concentric in nature)
Nodules	- irregular rounded formations (not concentric or symmetric). Can have a hollow interior.
Fragments	- broken pieces of segregations.
Crystals	- single or complex clusters of visible crystals.
Soft segregations	- finely divided soft segregations accumulated in the soil through chemical action with water. They contrast with surrounding soil in colour and composition but are not easily separated from the soil as separate bodies.
Veins	- fine (<2 mm wide) linear segregations.
Laminae	- planar, plate-like or sheet-like segregations.

Self-mulching A condition of well-structured surface soil, notably of clays, in which the aggregates fall apart naturally as the soil dries to form a loose mulch of soil aggregates. In cultivated soils, ploughing when wet may appear to destroy the surface mulch which, however, will re-form upon drying.

Sheet erosion Movement of soil (by water) in a fairly uniform thin layer on the soil surface.

Silage	The preservation of green fodder in a pit or silo without drying.
Silicified	Materials in which silica dominant minerals e.g. quartz, opal, have permeated and filled pores.
Slickensides	Subsoil structural features which develop as a result of two masses moving past each other, polishing and smoothing the surfaces. These are common in Vertosols.
Snuffy	Soils with an A horizon having a very fine granular structure (,2 mm) and a dry consistence strength that is weak to very weak. The horizon usually has a low bulk density and may be water repellent.
Sodicity	A characteristic of soils (usually subsoils) containing exchangeable sodium to the extent of adversely affecting soil stability, plant growth and/or land use. It is measured as a percentage of the cation exchange capacity of the soil. The classes are defined as follows: non-sodic - less than 6% sodic - between 6% and 15% strongly sodic - more than 15%
Sodosol	A Soil of the Australian Soil classification (Isbell 1996). These soils have a clear or abrupt textural B horizon in which the major part of the upper 0.2 m of the B2 horizon is sodic and is not strongly sub-plastic.
Soft segregations	See *Segregation*.
Soil colour	The colour of soil material is determined by comparison with a standard Munsell soil colour chart. The colours are described for moist soils unless otherwise stated.
Soil concept	Identifies key features of the soil, including depth, surface characteristics, colour, texture, local relief e.g. gilgai, and parent material
Soil depth	The following depth ranges are used in this manual to describe the soil surface and soil profile depths

1) soil surface	Thin	0–15 cm
	Moderately thick	15–30 cm
	Thick	30–60 cm
	Very thick	>60 cm
2) soil profile	Very shallow	<25 cm
	Shallow	25–50 cm
	Moderately deep	50–100 cm
	Deep	100–150 cm
	Very deep	150–500 cm

Soil horizon	A layer of soil material within the soil profile with distinct characteristics

and properties produced by soil-forming 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 horizon).

Soil horizon boundary Boundaries between horizons take many forms. The terms used in the soil descriptions of the *Field Manual* soil photographs and Appendix 3 (Resource Information) 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 intergrade A soil which contains properties of more than one described soil type. They are common between two related soils.

Soil profile A vertical cross-sectional exposure of a soil, from the surface to the parent material or *Substrate.*

Soil reaction trend The general direction of the change in pH with depth.

Soil structure The arrangement of natural soil aggregates that occur in soil; structure includes the distinctness, size and shape of these aggregates.

1) distinctness

— *strong* The natural soil aggregates are quite district in undisplaced soil; when displaced more the two-thirds of the soil material consists of aggregates (i.e. well structured)
— *moderate* Natural soil aggregates are well formed and evident but not distinct in undisplaced soil; when displaced more then one-third of the soil material consists of aggregates (i.e. moderately structured).
— *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 (poorly structured).

2) size

— *coarse* The natural soil aggregates are relatively large; an average size of 20mm 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 5mm or less is fine for the purposes of this manual.

3) Shape

— *apedal* There are no observable natural soil aggregates (structureless); 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 multiangled.
— *lenticular* The natural soil aggregates are like large vertical lens shapes with curved cracks between the aggregates.
— *platy* The soil particles are arranged around a horizontal plane and bounded by relatively flat horizontal faces.
— *granular* The natural soil aggregates are rounded, porous, stable and less than 12 mm in diameter. They usually occur in the surface horizons.

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. It is generally related to the proportion of clay, silt and sand within a soil. Texture classes used in this manual are defined primarily by the total clay content:

	Group	Clay Content (%)
Coarse	Sand	Less than 5
	Loamy Sand	5 to 10
	Sandy Loam	10 to 20
Medium	Loam	≈ 25
	Sandy clay loam	20 to 30 + sand
	Clay loam	30 to 35
Fine	Sandy clay	35 to 40 + sand
	Light clay	35 to 40
	Medium clay	40 to 50
	Heavy clay	more than 50

Solodic soils Soils with strong texture contrasts between A horizons and sodic B horizons which are not strongly acid.

Stratigraphy The arrangement of layers within rocks.

Structural formation class (of vegetation) Vegetation grouping based on attributes of the tallest layer e.g. growth form, crown separation and height.

Structural soil conservation measures Any man-made device or thing adapted or designed, and constructed or earth, masonry or other material, for the purpose of soil conservation and the mitigation of soil erosion.

Structured earths See *Earths (structured).*

Subnatric A Great Group of the Australian Soil Classification (Isbell 1996). A major part of the upper 0.2 m of the B horizon has an ESP between 6 and less than 15. These soils are considered to be sodic (See *Sodicity).*

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. The B horizon.

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. The A2 horizon.

Surface crust Distinct surface layer, often laminated, ranging in thickness from a few millimetres to a few tens of millimetres, which is hard and brittle when dry and cannot be readily separated from and lifted off the underlying soil material.

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. The A horizon.

Tenosol A Soil Order of the Australian Soil Classification (Isbell 1996). These soils generally have weak pedological organisation throughout the profile apart from the A horizons.

Texture See *Soil texture.*

Texture contrast soil A soil in which there is a sharp change in soil texture between the A and B horizons (surface and subsoil) over a distance of 10 cm or less. Also known as a duplex soil.

Traprock A popular term used to describe a complex mixture of highly deformed sandstone and mudstone, interbedded conglomerate, limestone and volcanics.

Tunnel erosion The formation of tunnels and holes in soils and rocks through chemical (solution) weathering.

Uniform clays *See Clays.*

Vertic Soils with a B horizon in which at least 0.3 m has a clayey field texture or 35% or more clay, which cracks strongly when dry and has slickensides and/or lenticular peds. It is used as a Subgroup definition in the Australian Soil Classification (Isbell 1996).

Vertosol A Soil Order of the Australian Soil Classification (Isbell 1996). These are clay soils with shrink/swell properties that display strong cracks when dry and have slickensides and/or lenticular structural aggregates at depth.

Volcanic Rocks Igneous rocks which have cooled from magma extruded to the Earth's surface. The size of the rock crystals depends on its duration of cooling -

rapid cooling forms very fine crystals or even volcanic glass.

- acid Contain 10% or more quartz and proportions of magnesium, iron and calcium. Usually light coloured.

- basic Basalt or basaltic rocks containing minimal or no quartz. Usually dark coloured because of a high proportion of iron and manganese minerals.

- intermediate Contain less than 10% quartz and mixed amounts of other minerals that are intermediate between the typical acid and basic igneous rocks.

Vulnerable A species is vulnerable if: its population is decreasing because of threatening processes; or its population has been seriously depleted and its protection is not secured; or its population, while abundant, is at risk because of threatening processes; or its population is low or localised, or is dependent on limited habitat that is at risk because of threatening processes.

Waterlogging A situation in which all the pores in the soil have filled with water. Excess water may lie on the surface of the soil. All the air in the pores has been displaced by water, so no oxygen is available to plant roots or for soil microbial activity. If waterlogging continues for a long period, plants die. Under waterlogged conditions, nitrate, the most available form of nitrogen, breaks down and is lost as a gas.

Woody weeds Hard stemmed shrub and tree species (both native and exotic) that are considered to be weeds due to density or frequency and/or rate of regrowth

Workability The ease or otherwise of working the soil with machinery.