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Catchment management report prepared for the Dalwallinu Pithara land conservation district

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SUSTAINABLE RURAL DEVELOPMENT
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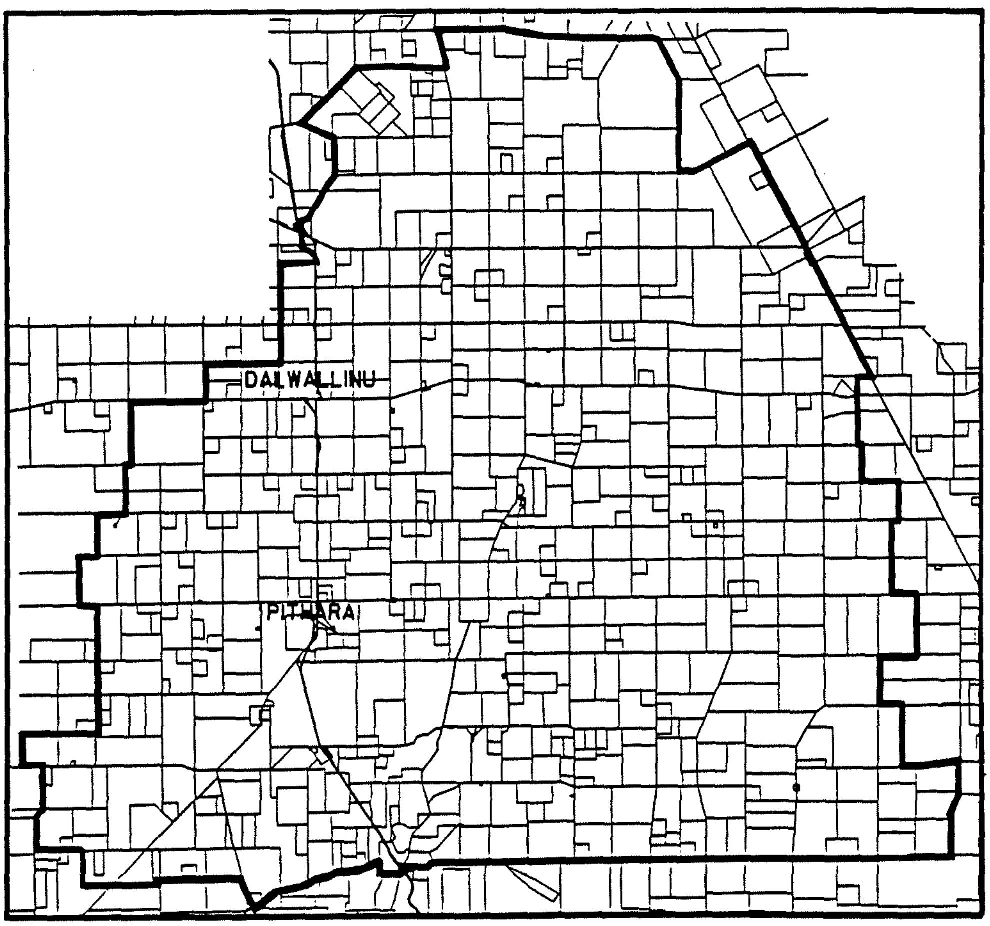
Catchment Management Report

prepared for the

DALWALLINU - PITHARA LAND CONSERVATION DISTRICT



**Report compiled by
Jenny Borger
1993**

DEPARTMENT OF AGRICULTURE
WESTERN AUSTRALIA

National
Landcare
Program

INDEX

FOREWORD

Mark Wilson
Chairman Pithara-Dalwallinu LCDC

The Pithara-Dalwallinu Land Conservation District was initiated in 1985. Over the past seven years the committee has carried out various trials, demonstrations and field days. It was decided in 1989 to go along the road of whole catchment planning utilising the Geographic Information System (GIS). It now gives me great pleasure to see the information collected over the last two years, presented as a workable document. I hope now that many farmers within the LCD will be able to use this report to aid in planning and future development of their most valued asset "The Land". The Catchment Report is designed to enable you to identify and solve common problems on a coordinated basis with guidance from the Project Officer.

The most current project being undertaken by the group is the treatment of the 240 (approx.) sandplain and hillside seeps. The funds for this project are being raised from rating landholders and some through Greening Australia. To ensure the success of the treatment of these areas I would ask all landholders to take a positive attitude and come forward.

The objectives of the Committee are to:

1. educate and demonstrate sustainable land use;

2. implement and co-ordinate reclamation programs;

3. increase water use on recharge areas and establish high water use vegetation on and upslope of discharge areas;

4. identify, map and protect all remnant vegetation;

5. encourage working on the contour and stubble retention;

6. encourage protective fencing of saltland and wind eroded areas; and

7. define and stabilise water courses.

I hope this report together with a positive attitude from you the farmer will help promote the benefits of developing good conservation practises as outlined in these objectives along with sustainable agriculture and increased farm profitability. I believe that every farmer with a positive attitude towards *caring for their land* will inevitably produce more from healthier hectares.

Finally, on behalf of the group I would like to thank Jenny Borger for her wonderful efforts over the last two years in getting us organised to completing the report. Jenny extended herself well beyond the call of duty and sometimes through somewhat difficult circumstances. Thanks Jenny!!

Acknowledgements

Howard Beer - former LCDC Chairman
Mark Wilson - current LCDC Chairman
Current members of committee
- John Fry
- David Roach
- Paul Gatti
- Gary Butcher
- Robert Sawyer
- David & Margaret McFarlene
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SECTION 1.

INTRODUCTION

1.1 PROJECT BACKGROUND AND OBJECTIVES

The Pithara-Dalwallinu Catchment Plan is a project developed between landholders, the National Soil Conservation Program (NSCP) and the Western Australian Department of Agriculture.

The Land Conservation District occupies the central and southern parts of the Dalwallinu Shire and a small portion of the north end of the Wongan-Ballidu Shire. Towns include Pithara and Dalwallinu which are situated 240 and 250 km respectively north-east of Perth on the Great Northern Highway. Rainfall decreases eastwards from 365 mm per annum to 300 mm per annum. There are 85 farms in the Land Conservation District comprising 160,550 ha.

The project was designed to:

- identify the major land classes within the catchments;
- develop management strategies for each land class;
- produce farm and catchment plans to integrate the management strategies.

The land degradation problems in the Land Conservation District include:

- increasing soil acidification;
- high water run-off;
- soil structure decline;
- rural tree decline;
- water and wind erosion;
- secondary salinity;
- waterlogging.

The following report describes the background of the existing practices and problems within the Land Conservation District and what can be done to overcome the problems. It is hoped this will give a better understanding of the situation so implementation of the plans proceeds smoothly.

1.2 HISTORY OF THE PITHARA-DALWALLINU AREA

Alice Roach

Dalwallinu means "a place to wait a while" and that is probably what the aboriginal inhabitants did as there was no permanent water here. However, there was an important commodity that they valued, red ochre, located in a cave at Wilgie Hills, south-east of Dalwallinu. There are still signs of the workings at the cave and markings of a ceremonial ground on a nearby clay pan. The ochre would have been traded to other aborigines many miles away.

The first white men using the area were most probably the monks from New Norcia shepherding their sheep through the area in the winter months. They made stone wells every ten miles or so for watering the animals. There are several existing wells just out of our Land Conservation District to the west and north. Sandalwood cutters also sought out the valuable trees in this area and many of their tracks were used by the early settlers.

The first settlers arrived in the south of the area around 1907. Messrs Michael Leahy and James Cole settled at Pithara in July and Mr W.J. Murphy settled at Wilgie Hills in October 1907. The Dalwallinu area was opened for selection in 1910. The land was dominantly clay and supported magnificent stands of Eucalyptus. Being highly fertile, the land was quickly taken up.

The lack of permanent water led to the government putting wells down, and in 1909 one was sunk near the future Dalwallinu townsite by the Ellison brothers. Although the water supply was not big, it did form a vital link in the area becoming settled. Some of the early settlers to make use of the well while clearing their selections, were Rayner, McNeill, Hyde and McLevie. The first crop (10 acres) was sown by C.E. Hyde and Sons in 1910.

Granite outcrops such as Petrudor and Xantippe rocks were also used as water reserves with dams built at Petrudor and a tank built at Xantippe storing water harvested off the rocks.

The arrival of the railway in 1914 reduced the need for settlers to make the long trek to Wongan Hills, Moora or Gunyidi for supplies. 1914 also saw the outbreak of World War 1 with many of the young men being called up, some never to return. A bad drought in that year, along with the reduction in labour led to a very poor year for farmers.

A building boom in the early twenties in Pithara and Dalwallinu and surrounding district, saw the construction of halls, churches, banks, shops and homesteads, many of which are still in use. The depression of the thirties slowed development to the point where many farmers walked off their farms due to very low prices for crops and animals, most farms not being large enough to be viable.

1939 saw Australia at war for six long years. In the fifties wool prices were very good and enabled most farmers to get back on their feet. About this time too the sandplain areas came into their own with use of trace elements, clover etc. This had been despised land which could grow the most wonderful wildflowers and not much else. Today it yields very good crops.

The introduction and spread of scheme water during the early sixties relieved many farmers of water carting chores during long hot summers. That and S.E.C. power at about the same time meant more comfort and security, making the district a much better place to live in.

1.3 SUB-CATCHMENT ISSUES

Farm planning workshops were held in October 1992 for the sub-catchments in the western, central and northern regions of the Land Conservation District. A question was posed to the participants. "What do you see as the major problems in the district?" The responses were collated.

Water management was seen by all groups as the major issue needing to be addressed, followed closely by wind erosion, acidity and soil structure decline. Participants were asked how they might overcome problems experienced - their answers are listed below each issue.

* Water management
  - contouring
  - trees
  - maximise water use
  - surface drainage
  - role of the Shire and Main Roads Department
  - stock management
  - growing better crops
  - stubble management
  - define water course
* Lack of water
  - suitable dam sites
  - selection and maintenance of catchments
  - reliability
  - scheme water
* Wind erosion/acidity
  - revegetation of fragile soils (e.g. Wodjil)
  - windbreaks/alley farming
  - use for fodder reserves
  - location of watering points
  - grazing management
  - crop management
  - lime
* Soil structure decline
  - gypsum
  - stock management
  - tillage operations (direct drill; minimum tillage)
  - working speed
  - time of working

* Non-participation/lack of co-operation

    - identify problem areas
    - tax incentives
    - communication
    - peer pressure
    - rating
    - using trials and demonstrations

* Decline of remnant vegetation

    - fencing
    - rabbit control

* Resistance

    - chemical management

* Yield potential (sustainable profitability)

    - farming to soil type
    - soil testing
    - rotations - legumes/medics
    - contour farming
    - variety selection
      (also covered under other headings)

SECTION 2.

PHYSICAL CHARACTERISTICS OF THE CATCHMENT

2.1 CLIMATE

The Pithara-Dalwallinu Land Conservation District experiences a dry warm mediterranean climate with 62% of rain falling in the period May to August (Table 1). Dalwallinu, with an annual average of 360 mm, has a slightly higher summer rainfall than Moora (466 mm p.a.) due to a prevalence of thunderstorms. Recordings by landholders during these events have included measurements of 50 mm (2 inches) in 30 minutes and commonly 75 mm in an hour. When these occur late in summer (when ground cover is at its minimum) serious damage can arise.

Rainfall decreases from 365 mm in the west of the Land Conservation District to approximately 300 mm in the north-east (see Figure 1). Five year rainfall averages are shown for Dalwallinu in Figure 2. Very high five year averages (above 440 mm) have occurred twice during the 80 year recording period, in 1916-20 and 1960-65. Rainfall data for other stations are included in Appendix 1.

Table 1. Climatic data for Dalwallinu (Dalwallinu Post Office)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall (mm)	15	17	23	22	45	69	60	45	24	18	12	10	360
Max. Temp.(°C)	35.3	34.5	31.5	26.3	21.5	18.0	16.8	17.9	21.0	25.0	29.1	32	
Min. Temp.	18.4	18.5	31.5	13.2	10.0	8.0	6.5	6.6	7.8	10.2	13.2	16.1	
Evaporation	339	287	255	162	106	71	79	99	138	206	256	313	700

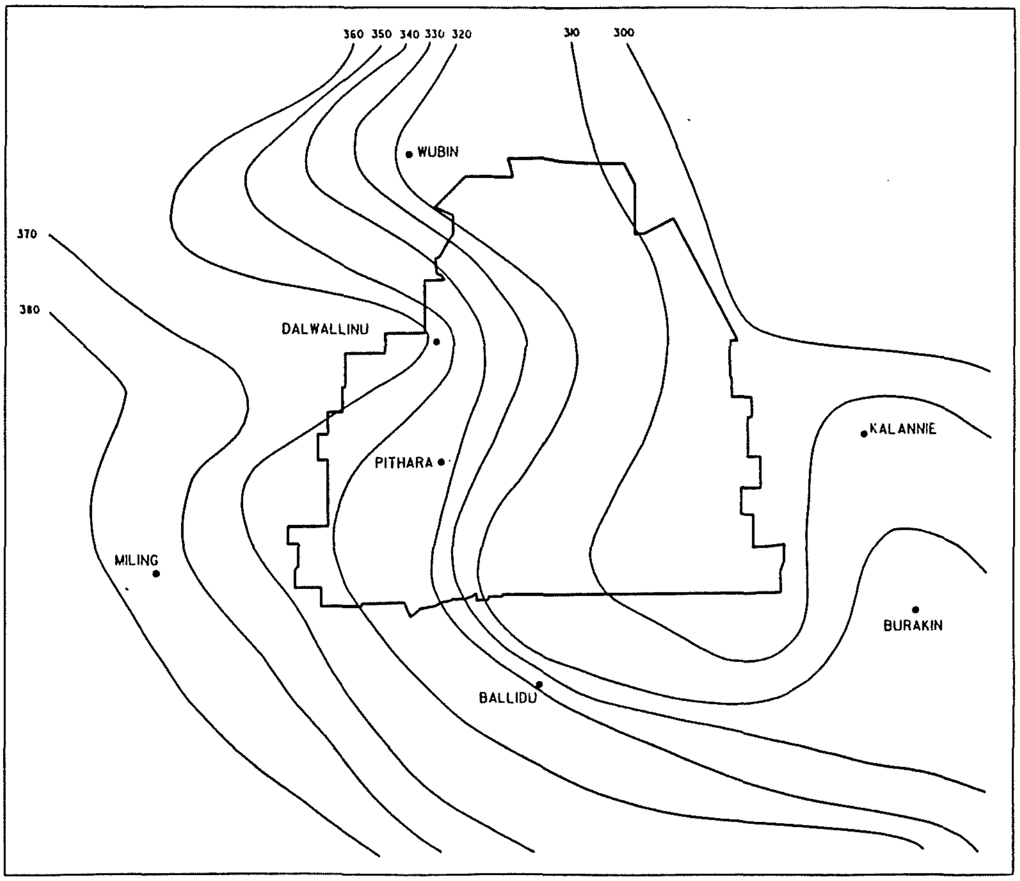


Figure 1: Rainfall isohyet map

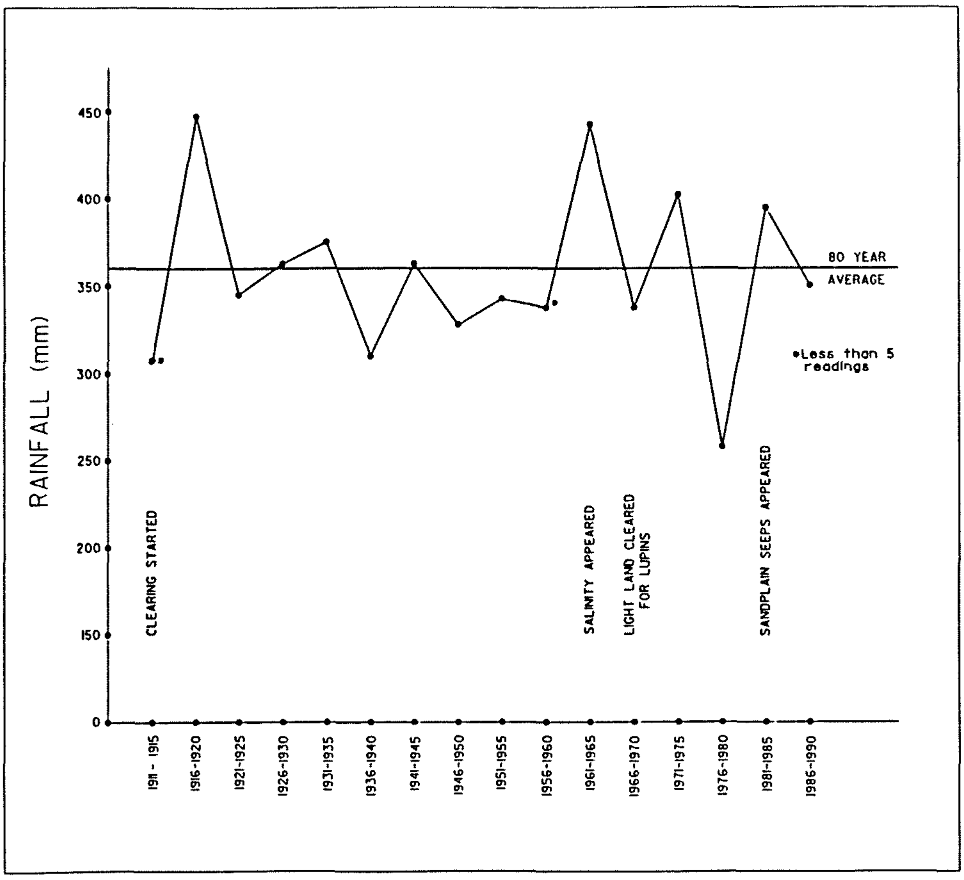


Figure 2: Five year rainfall averages for Dalwallinu

2.2 GEOLOGY

A concise description of the Dalwallinu area is found in the geological series - Explanatory notes (Moora SH/50-10). The Land Conservation District is located on the Darling Plateau with a general elevation between 300 and 400 metres above sea level. The present landform has developed on the Archaen rocks of the Yilgarn block, consisting primarily of granite, gneiss and migmatite. These rocks have been dated at between 2600 and 3000 million years. Intrusions by mafic dykes (chiefly composed of quartz, dolerite and gabbro) occurred between the last 2390 and 570 million years.

Banded iron formation outcrops in the central and eastern regions of the Land Conservation District, with Wilgie Hills being the largest formation. These rocks may include quartz, magnetite, haematite, hornblende, garnet and pyroxene.

Granite, gneiss and migmatite outcrops dominate in the east of the catchment with Petrudor Rocks being the best known example. Minor outcrops occur throughout the Land Conservation District, generally near ridgetops.

The drainage system on the Yilgarn block, of which the salt lake chain is a relic, probably started 200 million years ago but was most active between 160 and 110 million years when vast quantities of sediment were deposited in the Perth and Eucla basins. By 80 million years ago erosion and sedimentation had markedly decreased and the drainage system was becoming subdued. This landscape was largely laterised between 38 and 18 million years ago.

Laterite (gravel) is formed when water tables fluctuate concentrating iron and aluminium oxides near the surface. A period of high, seasonal rainfall from 38 to 18 million years ago caused the laterites to form. The layer of laterite sometimes forms a solid duricrust (conglomerate) which overlies mottled and pallid clay zones. Soils derived from this material are usually low in plant nutrients.

The pallid zone is deepest under the valley floors and shallowest under the watershed divides (ridges). Large quantities of soluble salts are stored in the pallid zone, with annual salt input (through rainfall) being 10-20 kg/ha. Accumulation over time has resulted in more than 600 t/ha being stored in the valley floors.

Another feature of the catchment which outcrops on John Fry's and Borrett's property, is a quartz dyke. The age of this is approximately the same as the dolerite dykes. These could be preferential recharge zones and have been used in the past for obtaining water.

The most recent geological formations are the saline lake deposits, aeolian sands (wind transported), alluvium and colluvium (water and gravity transported respectively) which are a product of weathering of the older units.

Soil related to geological units

Salmon Gum Loams and Crabhole soils
Salmon gum soils (red brown earths and crabhole soils) are derived from weathered dolerite. The high level of calcium carbonate can be attributed to the parent material. Calcium carbonate appear on the surface as white "stones" known as calcrete, where the soil profile is shallow.

Loamy Sand over Clay with Quartz and/or Gravel
These soils are characteristic of the transitional zone from the red brown earths to sandy gravels. They usually have a clay subsoil and have rock fragments (i.e. quartz) throughout the profile. These grade into the SG, SSL and DYS units.

York Gum Soils and Sands over Clays
York gum soils refer to those red loamy soils found in the drainage lines with less clay and more sand than Salmon gum soils. They are derived from weathering and alluvial

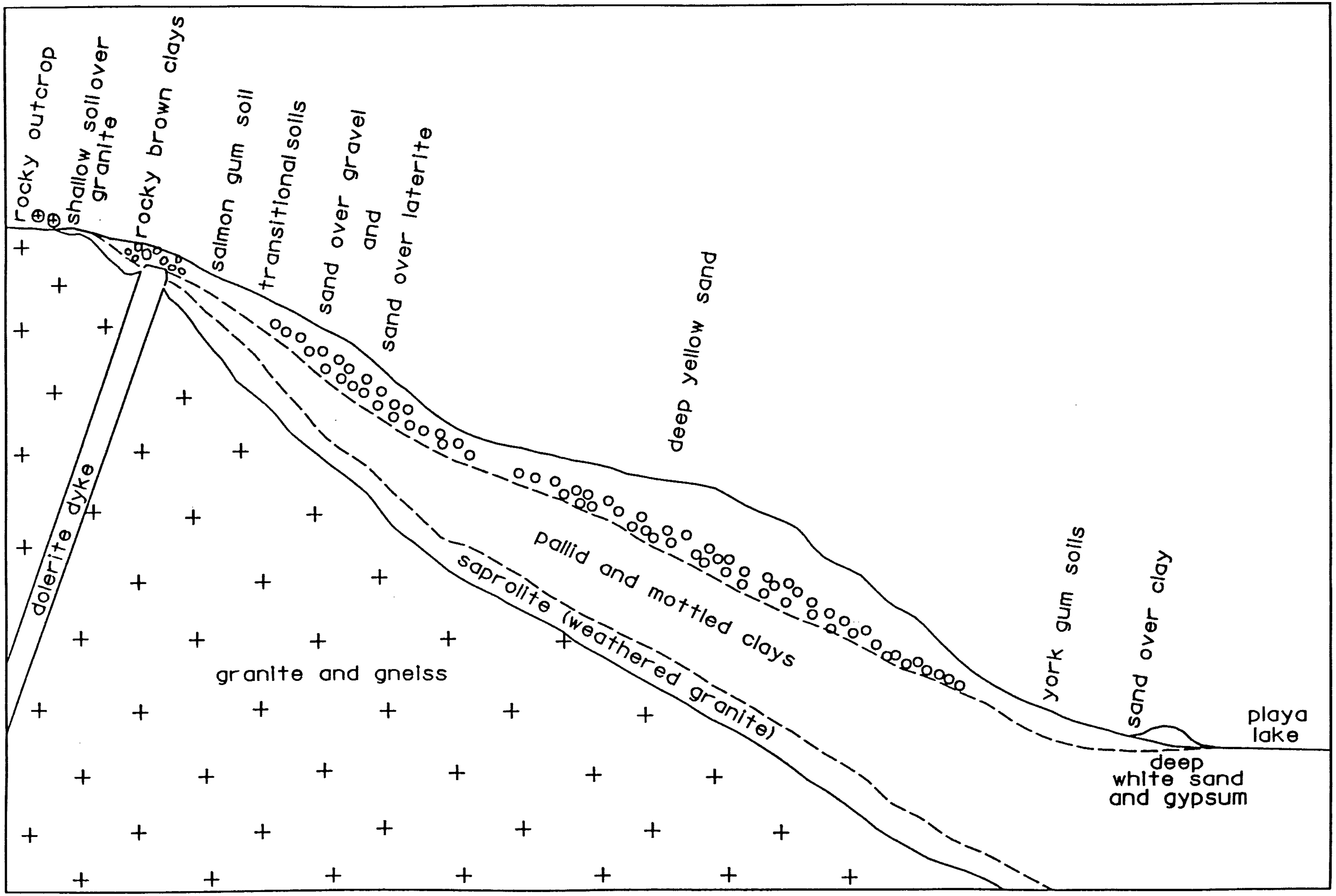


Figure 3: Relative position of soil units in the landscape.

transport of the Salmon gum soils. The sand over clay unit of the drainage lines generally have less clay in the surface horizons and a B horizon tending more to yellow and grey clays. They tend to support melaleuca (ti tree) vegetation rather than York gum.

Rocky Outcrops
Soils associated with rocky outcrops are generally young and shallow, showing little pedalogical development. They closely resemble the parent rock. These soils are generally found on the catchment divides or upper slopes.

The relative positions of these soils in the landscape are shown in Figure 3.

2.3 HYDROLOGY

Regional Drainage

The Land Conservation District incorporates the head waters of two major drainage systems - the Mortlock-Avon, and the Moore.

Seventy-five per cent of the Land Conservation District drains into the Mortlock River North with drainage lines being well defined in upper areas of the catchment particularly where there are large areas of rocky outcrop. Definition of the drainage line becomes less clear lower in the landscape with increased infiltration into the soils where gradient drops below 1%. Drainage in the lower reaches of the catchment is dominated by a series of saline lakes, the largest being Damboring Lake.

Drainage south of the lakes is intermittent and does not become a defined river until south of Lake Ninan. The Mortlock River North joins the Mortlock between Goomalling and Northam, below which it joins the Avon-Swan system.

The western subcatchments drain westward into the Moore River which meets the Coonderoo River at Moora, then flows south, emerging at the coast at Guilderton. The river is saline from its head-waters near Dalwallinu to Gillingarra, then becomes progressively fresher. Figure 4 shows the location of both systems.

The main catchment can be divided into five regions which are listed in Table 2 and illustrated in Figure 5. The remaining 3% (or 5220 ha) of the LCD drain into other catchments such as Lake Goorly and Lake Mongers near Kalannie

Table 2. Major regions in the catchment, area and rainfall.

Region	Area (ha)	% of LCD Main Catchment	Av. Rainfall (mm)
North Dalwallinu	37,745	23	320
Wilgie Hills	29,377	18	310
East Pithara-Dalwallinu	23,785	15	330
Damboring	25,553	16	315
Marne	11,972	8	340
Western Sub-catchments	30,000	20	350
TOTAL	158,432		

Water balance

The present water balance has been altered from its natural condition through widespread clearing of the woodlands for agriculture. When native vegetation is replaced by short-lived annuals (crops and pastures) water use by plants is decreased markedly. Interception of rainfall is reduced thus reducing evaporation from foliage, run-off increases where soil surface condition has deteriorated and infiltration beyond the root zone to the groundwater also increases (Figure 6).

These changes have resulted in erosion, waterlogging and salinity.

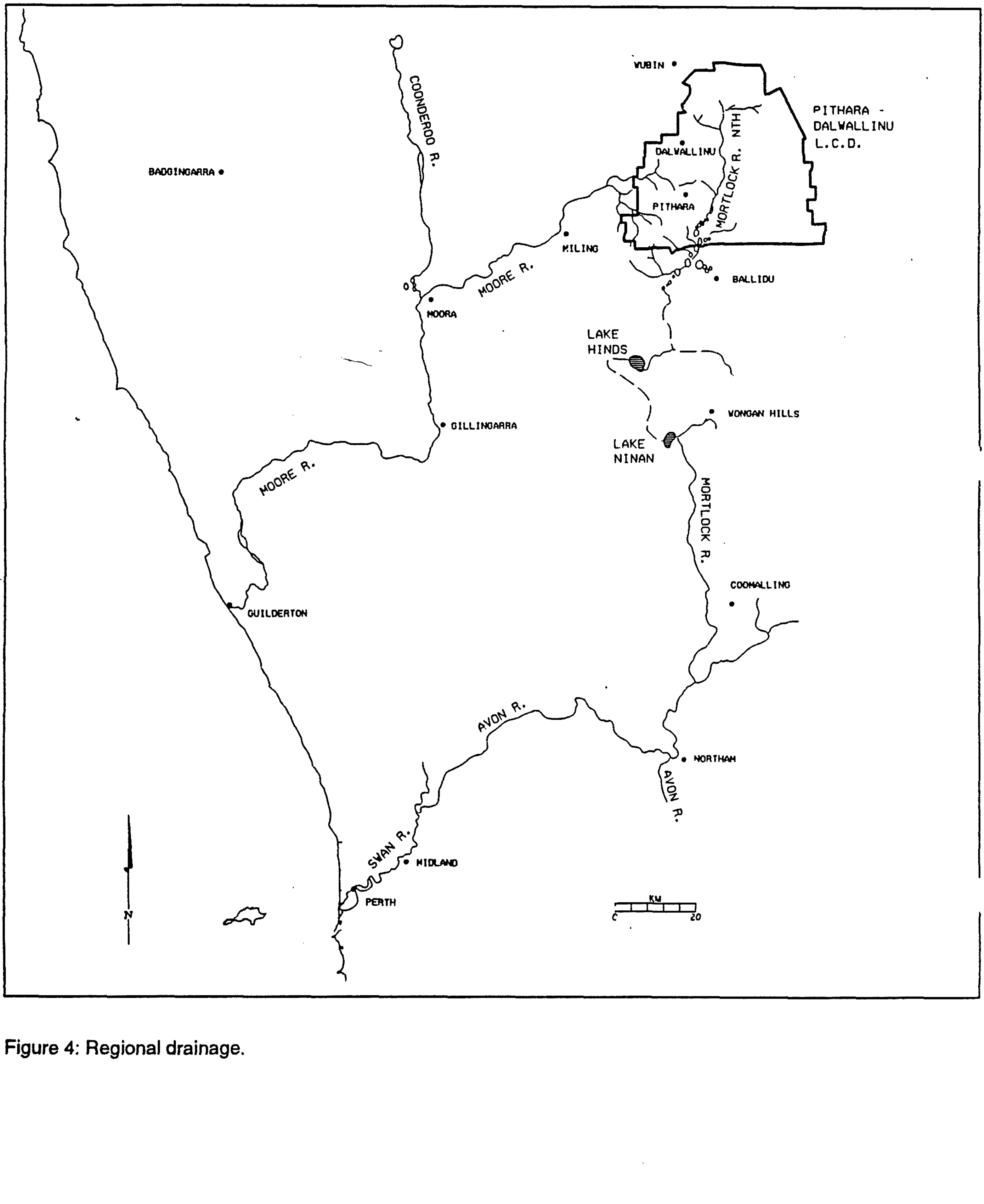


Figure 4: Regional drainage.

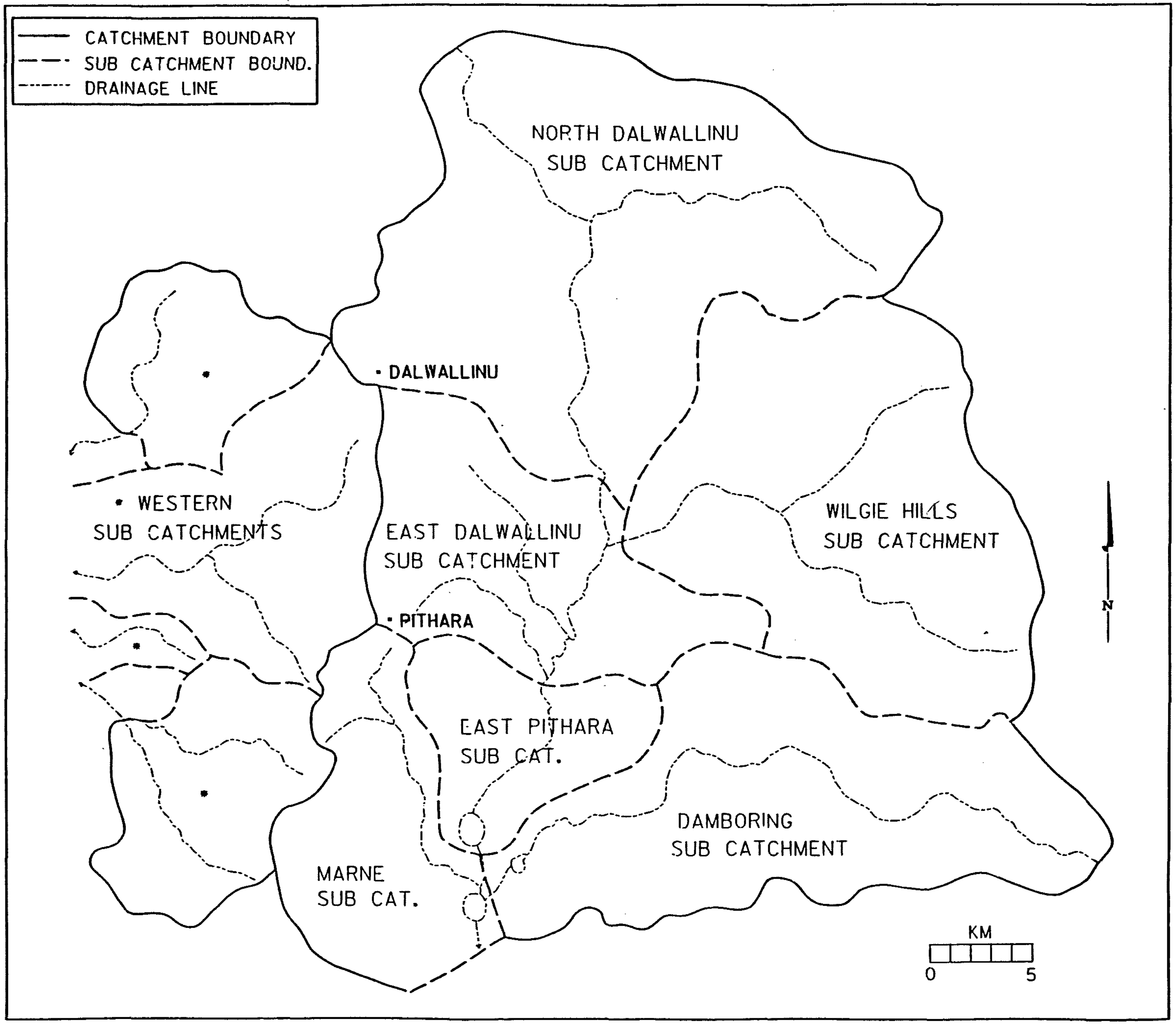


Figure 5: Pithara - Dalwallinu sub catchments.

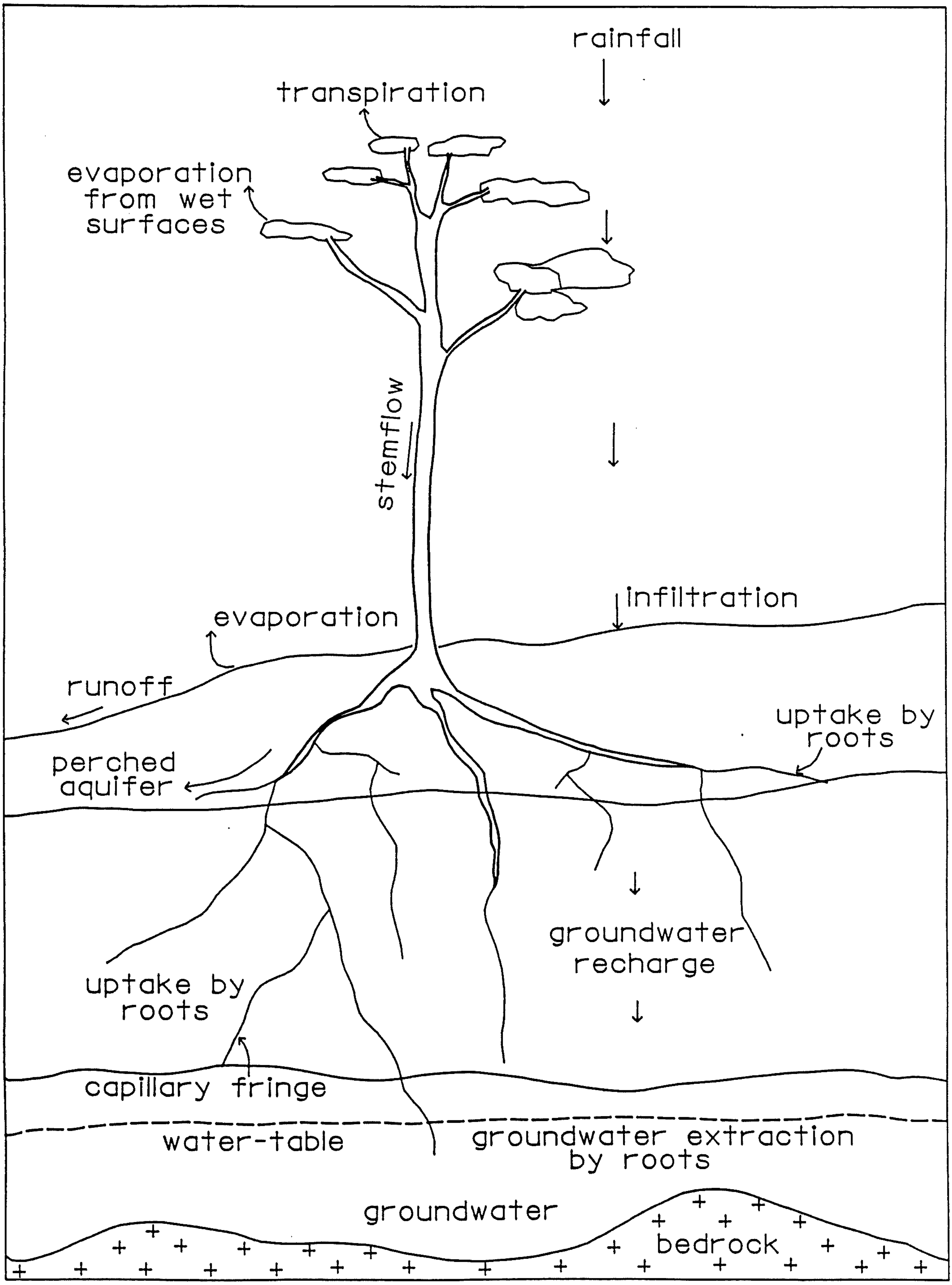


Figure 6: Fate of rainfall.

The water balance (inputs = outputs) of a catchment can be described by the equation

$$P = R + E + U + W \text{ (mm)}$$

where	P	=	precipitation
	R	=	run-off
	E	=	evaporation
	U	=	recharge to groundwater
	W	=	change in soil moisture storage

W is assumed to be negligible and its volume assumed to be zero.

Water balance for western areas

Pre-clearing	Cleared	Change
P = 350 (mm)	P = 350	Same
R = 1	R = 4	+3
E = 348	E = 321.5	-26.5
U = 1	U = 24.5 (7%P)	+23.5

Water balance for eastern areas

P = 310 (mm)	P = 310	Same
R = 1	R = 3	+2
E = 308	E = 285	-23
U = 1	U = 22	+21

Please note that these figures are based on work done in other areas.

What do these figures mean?

Example: For a cleared catchment of 12,000 ha and average annual rainfall of 340 mm (Marne sub-catchment) over one year:

P	=	340 mm	->	3,400 m^3 /ha/year
	=	40.8 million cubic metres over whole catchment		
R	=	4 mm	->	480,000 cubic metres
E	=	312 mm	->	37.5 million cubic metres
U	=	24 mm	->	2.85 million cubic metres

Clearing has taken place in the Marne sub-catchment since 1907 so there has been 85 years of increased recharge to the groundwater. Salinity first appeared in the valleys in the early 1960s following a number of years with exceptionally high rainfall. One could look at the situation as filling up a bath tub. The granite basement is impermeable not allowing water to drain out so the water level rises. Water flow through the clays in the weathered zone is extremely slow and obstructions such as dolerite dykes and basement highs exacerbate the problem even further.

This situation has been repeated throughout the LCD with salinity being one of the most visual problems accounting for approximately 15% of the landscape. Barriers to groundwater flow of significance occur in the western sub-catchments on the properties of Coyle, Falls, Peake, Gatti and Roach. (In the main catchment it is assumed that there are a number of barriers but on-ground evidence is negligible.) One of major impact (whether a dyke or bedrock high is uncertain) is that which cuts across the main drainage channel just north of Wilgie Hills. The impact of this has caused serious salinity and waterlogging problems on the properties of Roach, Wallis, McNeill and Annetts.

Also of significance is a quartz dyke running east-west through the Damboring sub-catchment, outcropping on John Fry's property at Jones Road. The dyke crosses Hourigan Road and may play a significant role in the groundwater hydrology east of there.

Salinity - Where has the salt come from?

Without salt the groundwater problems in the valleys would not be as severe because of the effect salt has on plant growth (see section on waterlogging).

Rain contains dissolved salt, the content ranging from very low amounts (1-2 mg/L) to more than 15 mg/L depending on the source of the rain. An average figure would be 5 mg/L.

North Dalwallinu Sub-catchment

Rainfall	320 mm
Area	37,745 ha

Rainfall Volume = $0.32\text{m} \times 10{,}000\ \text{m}^2$
= $3{,}200\ \text{m}^3/\text{ha/yr}$
= 3,200,000 litres/ha/yr

Salt input per hectare/year = 5 mg/L x 3,200,000 litres/ha/yr
= 16,000,000 mg/ha/yr
= 16 kg/ha/yr

Total salt input to the sub-catchment = 16 x 37,745 ha
= 603,920 kg/yr
or = 604 tonne/yr

Salt is stored in pallid zone clays. Some estimates for valley areas have been put at 600 t/ha. The rising water-table mobilises the salt bringing it to the surface. Evaporation concentrates salt on the soil surface. As the salinity in the topsoil increases the ability of most plants to survive rapidly decreases. Crop plants are replaced by more salt tolerant species such as bluebush and these in turn are replaced by samphire which are both waterlogging and salt tolerant. If the situation deteriorates further, the area will not support plants and becomes an erosion hazard.

Changing the water balance

To achieve a change in the water balance to somewhere nearer the natural condition, there are three alternatives which can be tried.

1. Reducing recharge (U) over the catchment will lead to an eventual decrease in water-table levels. This can be achieved through intercepting recharge in the upper catchment with higher water use crops, healthier crops and strategic placement of perennial plants (trees and shrubs) to maximise water consumption. Water harvesting for stock and domestic use is also an option and can be achieved with roaded catchments, banks and dams.

2. Increasing the water use on the discharge areas such as saline or waterlogged areas can lower the water-table locally. Establishing salt tolerant trees and shrubs and good management can turn low productivity areas back into productive areas.

3. Improving drainage out of the catchment will allow the increased amount of run-off a faster exit, decreasing ponding, waterlogging and salinity. This may be achieved through well designed surface drainage systems, bearing in mind a safe disposal point and downstream landholders.

An alternative which has been successful on soils with a highly permeable subsoil is deep drainage. Research on deep drains in the north eastern wheatbelt has shown that the subsoils are generally not permeable enough to allow more than limited reclamation.

Figure 7 illustrates the different types of seep which occur in the LCD. Sandplain seeps occur at the base of sandy rises. The water above the discharge area (scald) is usually fresh and could be harvested for stock use or used to grow a large range of trees and shrubs (see section 4.4).

Bedrock high seeps are generally high in the landscape with a small catchment and can be treated effectively with a block of trees above the discharge area.

Dolerite dykes form a barrier to groundwater flow, either as a solid wall of rock or an impermeable weathered red clay. Dykes can also behave as carriers of groundwater transmitting groundwater along their length, either in cracks associated with the dolerite or along the contact between the dolerite and granite.

Salinity generally breaks out on the upstream side of the dyke so it is important to accurately determine the position of the dyke as it is no use implementing management on the downstream side.

The "best bet" management option is to fence off the saline area and establish a block of trees on the uphill side. Shallow surface drainage can be considered to control waterlogging and assist tree establishment.

Quartz dykes can act in a similar manner but often have preferential paths for water flow and have been used successfully to find good quality stock water. Where the quartz outcrops higher in the landscape trees planted at the base will intercept water.

Change of slope seeps are fairly similar to sandplain seeps and can be managed much the same. Water quality may be more variable depending on the substrate upslope. Water testing for salt levels is recommended prior to choosing tree species to plant above the discharge area. Appendix three lists approximate upper limits for use by animals, plants and domestic situations. Conversion from grain per gallon to part per million (ppm) or millisiemen per metre (mS/m) are also included.

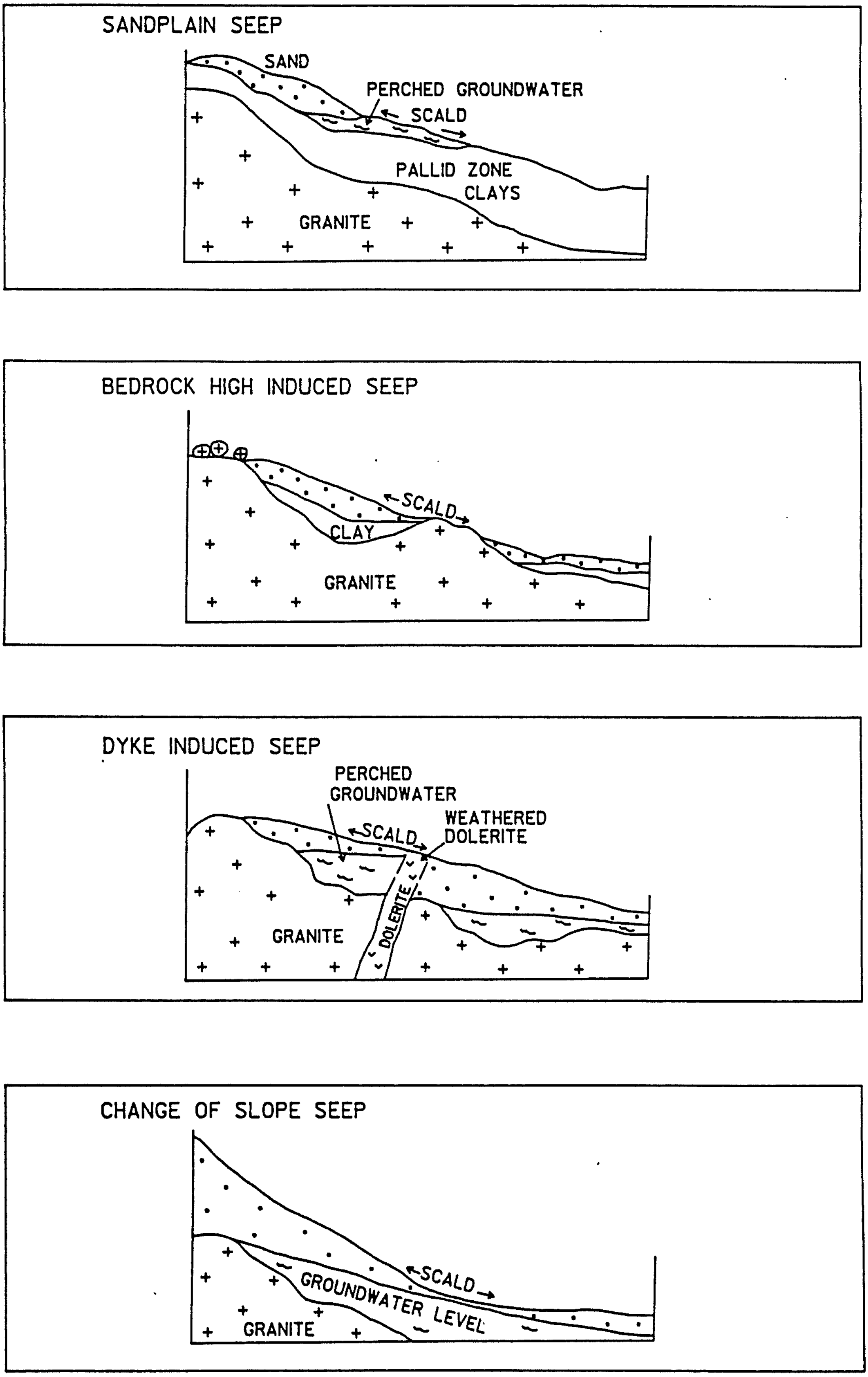


Figure 7: Influence of geology on subsurface water movement.

2.5 VEGETATION

The Land Conservation District occurs in the south-western Botanical Province (Beard 1979) and includes two vegetation systems - Jibberding and Guangan. The Jibberding system occupies the northern half of the LCD, whilst the Guangan covers the south.

Studies carried out in the LCD area include Beard (1976, 1979) Muir (1979) and a Main Roads Department survey (1987). Vegetation formations recorded in the area were:

1. *Woodlands* - open sclerophyll woodlands dominated by one or more of the following species - *Eucalyptus loxophleba* (York gum), *E. salmonophloia* (salmon gum) and *E. salubris* (gimlet). These have a woody understorey on red clay loam soils.

Low woodland to open mallee are also present. These are dominated by York gum and mallee species. Soils range from clay loams to transitional types (SCQ) underlain by a clay horizon. They are generally located in or adjacent to drainage lines.

2. *Shrublands* - This category includes a wide range of plant community type from shrubland with scattered trees (usually acacia dominant), closed shrub formation (dominant species include one or all of the following - *Allocasuarina* or *Melaleuca* (ti-trees) *Acacia* spp.). *Allocasuarina* spp. (tammar) were more prevalent before clearing and firing. Acacias respond better to burning. Melaleucas tend to dominate in wetter areas.

The other categories are open shrub (or scrub) and scrub heath formations. Members of the Proteaceae family (see Appendix 4) are prominent in the scrub heath community. Soil types are generally leached sands with gravel.

3. *Salt - country complex* - consists of small playa lakes, seasonally dry, with a band of samphire, *Halosarcia* sp., around the margin set in woodlands of York gum or salmon gum and sometimes ti-tree, *Melaleuca uncinata.*

4. *Rock Outcrops (Lithic complex)* - *Borya nitida*, annual grasses and everlastings are common in the shallow soils on the rock outcrop areas. Rocky outcrops are common along the eastern boundary of the LCD (e.g. Petrudor rocks) and also south of Pithara. York gums grow in deeper pockets of soil particularly where dolerite dykes have intruded increasing the amount of clay. *Allocasuarina huegliana* (rock sheoak) and several species of small shrubs may also be present.

2.6 FAUNA

The long term survival of wildlife populations will be directly influenced by the presence, vigour and size of vegetation remnants. The reduction in size and fragmentation of remnants is a major concern to the survival of insectivorous and nectivorous birds and mammals. The absence of large areas of mallee or woodland has contributed to the decline of arboreal (tree-dwelling) mammals such as the brush-tailed possum *Trichosurus vulpecula* and red-tailed wamberger *Phascogale calura.*

The Biological Survey of the WA Wheatbelt part 10 by the Western Australian Museum details and discusses the vegetation and fauna of Nugadong and East Nugadong Nature Reserves which are located in the North Dalwallinu sub-catchments. A Main Roads Department survey of the road verges was carried out in 1987 along the Great Northern Highway between Dalwallinu and Wubin. Birds and mammals recorded in both studies have been listed in Appendices 6 and 7 at the end of this report.

From the MRD survey, cleared areas with sparse plantings of eucalypts were observed as the richest habitats for birds. These locations had grassed areas with isolated trees and shrubs, gravel and sand-pits and narrow shelterbelts. Eighteen species of birds were recorded.

The second richest habitat was degraded York gum woodland with remnant *Acacia* sp. thickets, supporting 16 species. Birds which would usually have preferred open mixed woodlands of salmon gum, gimlet and York gum have been forced into York gum dominant woodlands because of the extremely poor condition of the former habitat.

Western grey kangaroos (*Macropus fuliginosus*) have been sighted throughout the LCD particularly around the ti-tree scrub in the valley floors. Euros (*M. robustus*) were found shot in the 1976 Museum surveys. Red kangaroos (*Megalea rufus*) were observed in both surveys. Bats are probably the most well-represented group of mammals being able to overcome the fragmentation of remnants by flying where they are safe from introduced predators such as cats and foxes. Four species of marsupial mice, the common dunnart (*Sminthopsis murina*), white tailed dunnart (*S. granulipes*), Mitchell's hopping mouse (*Notomys mitchellii*) and ashy grey mouse (*Pseudomys albocinereus*) were recorded during the Museum surveys.

Echidnas are sighted occasionally in both woodland and heath areas. Reptiles (skinks, geckos and snakes) are represented by 43 species (W.A. Museum records). Five frog species can be expected.

Fencing off remnant vegetation and linking areas by way of bush corridors is the most effective way that species diversity can be retained. Retaining old trees with hollows is also important as many animals and birds use them for nesting. Controlling fox and cat populations will also contribute to the long term survival of wildlife populations.

Further reading

Kitchener DJ, Chapman A, Dell J and Muir BG (1979) Biological Survey of the Western Australian Wheatbelt Part 10: Buntine, Nugadong and East Nugadong Nature Reserves and Nugadong Forest Reserve. Western Australian Museum.

Main Roads Department (1987) Biological survey of the Road Reserve between Dalwallinu and Wubin. Unpublished.

LAND CLASS SUMMARY

Table 3. Soil Groupings

No.	Group Name	Soil Types
1	Red and brown clays	SAL, SSAL
2	Crabhole soils	CH
3	Valley duplex soils	YG, SC, ASSI
4	Sandy soils	SCQ, SG, CSG
5	Deep sands and sandy loams	DYS, DWS
6	Lithic complex	RO, GC, GR, RC, SSG, SSL, DDK, QTZ
7	Salt lake system	CP, DWS, SC
8	Acid soils	DYSW,
9	Saline soils	Mo

Soil Type	Abbreviation
Alluvial sand/silcrete	ASSI
Crabhole	CH
Clayey sand/gravel	CSG
Clay pan	CP
Deep white sand	DWS
Deep yellow sand	DYS
Wodjil	DYSW
Dolerite dyke	DDK
Grey clay	GC
Gravel	GR
Morrel	Mo
Quartz dyke	QTZ
Rocky clay	RC
Rocky outcrop	RO
Salmon gum	SAL
Sandy salmon gum	SSAL
Sand/clay	SC
Sand/gravel	SG
Shallow soil/granite	SSG
Shallow soil/laterite	SSL
Sand/clay with quartz fragments	SCQ
York gum	YG

1. Red and brown clay soils (SAL, SSAL)

Limiting factors: Hardsetting -> poor infiltration
High run-off
Low-moderate wind erosion hazard

Place in landscape: Mostly on upper slopes; can be associated with dolerite dykes. Dominant soil type in the central Dalwallinu area.

One of the most fertile groups of soils in the Land Conservation District with pH ranging from neutral on the surface (~ pH 7) to over 8.5 ($CaCl_2$) at depth. Where the soil profiles are shallow calcrete can be seen on the surface. Hardsetting properties do not affect all of the soils in the group, and small areas should be tested before gypsum is used to overcome these problems. (See section 3.6 on soil structure decline).

The soil can slump after particularly wet years leaving large holes in the surface. This can be attributed to rain water dissolving calcium carbonate lower in the profile and leaching it from the soil.

Management

1. Grade banks can be used to control surface water run-off if a defined waterway or dam is available for disposal, otherwise level banks are appropriate.

2. Maintain soil structure through minimum tillage and retention of stubble.

3. Hardsetting surface soils may respond to gypsum. Try test strips first.

4. Medic/wheat or pea/wheat rotation.

2. Crabhole soils (CH)

Limiting factors:	Micro-relief	-> water ponding
		-> machinery access

Place in landscape: Lower and mid-slopes mostly in the central Land Conservation District area.

Crabhole soils are areas of alkaline brown medium clay soils with pronounced micro-relief found associated with the Salmon gum unit. The swelling-shrinking properties of the clays have lead to the formation of the mounds and depressions (Figure 8). Water ponding in the depression can cause waterlogging problems, leading to patchiness in crop growth. Crabholes can be cultivated out over time, but this will not lead to even crop performance as removal of topsoil from the mounds exposes subsoil.

The swelling-shrinking nature of the soil type has caused problems in road maintenance between Dalwallinu and Pithara where the soil type is dominant.

Management

1. Position banks above these soils to divert surface water to overcome waterlogging problems.

2. Manage separately from the Salmon gum soils where possible. Medic/wheat or wheat/pea rotation.

3. Maintain soil structure through minimum tillage and retention of stubble. Test for gypsum responsiveness.

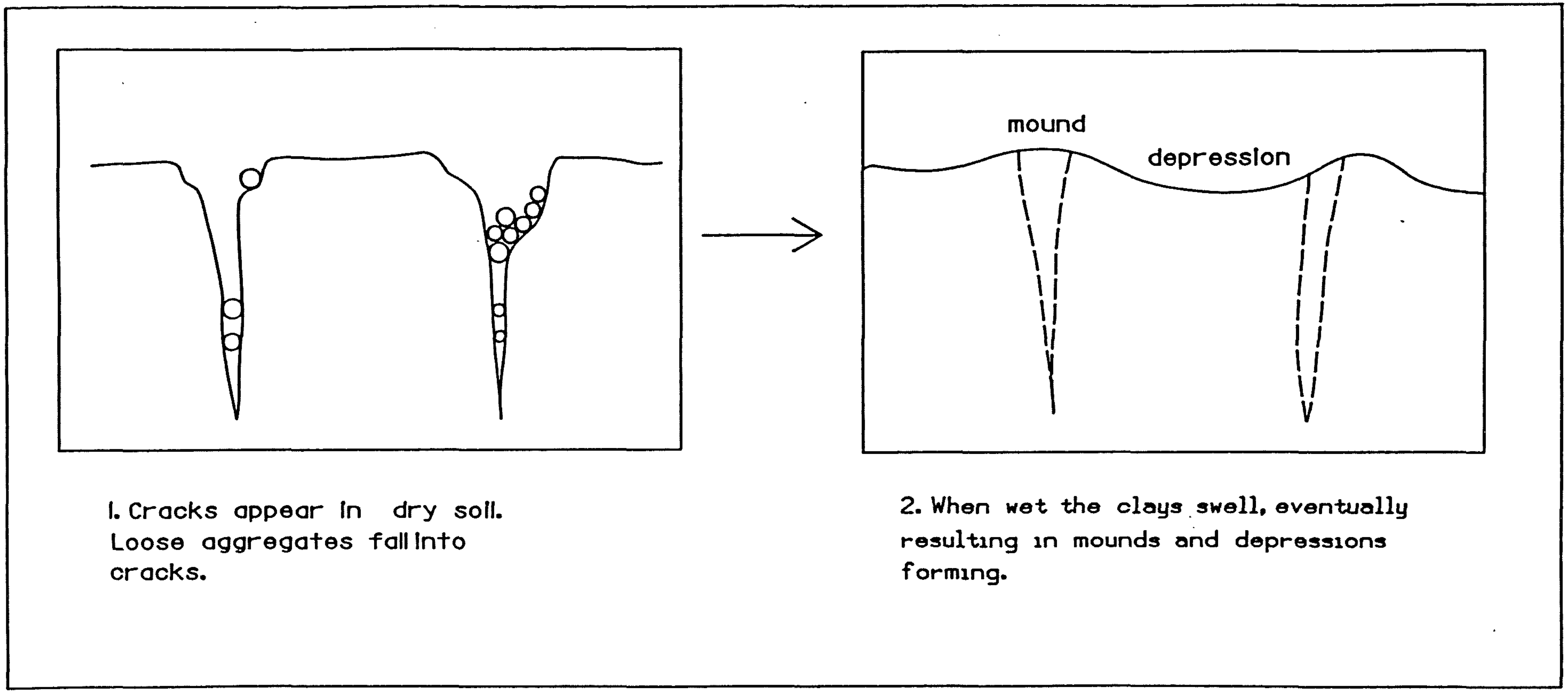


Figure 8: Crabhole formation.

3. Valley duplex (YG, SC, ASSI)

Limiting factors: Place in landscape (subject to waterlogging and salinity)
Water erosion
Subsoil compaction

Place in landscape: Lower slopes and valley floors, particularly in drainage lines.

The YG and SC soils have clay subsoils and ASSI has a silcrete pan which does not allow infiltration rates as fast as the surface horizon which range from sandy loam to sandy clay loam. This can lead to problems with waterlogging. Where the regional groundwater-table is high, salinity and waterlogging become the major limiting factors.

Management

Slopes:

1. Use banks to divert run-off away from low-lying areas.

2. Place trees to intercept discharge from upper slopes.

3. Minimum tillage and stubble retention to maintain or improve soil structure.

4. Deep ripping.

5. Test strips of gypsum if surface is hardsetting.

Valley floors:

1. Revegetate saline areas by fencing, planting to salt tolerant shrubs and trees and control grazing.

2. Drainage - surface (to alleviate waterlogging).
   - deep (to intercept groundwater e.g. reverse bank seepage interceptors on the change in slope disposing into natural waterway).

3. Deep ripping may improve crop growth where hardpans exist.

4. Sandy soils (SCQ, SG, CSG)

Limiting factors: Low moisture storage
Waterlogging
Nutrient status
Prone to wind erosion
Water erosion
pH (acidity)
Hardsetting

Place in landscape: Middle slopes.

All soils have some percentage of either lateritic or quartz gravel within the profile. The SCQ unit is a transitional zone from the Salmon gum unit to the sandy gravels and has some characteristics of each, but in nutritional terms is closer to the SG. There is a range of surface texture from loamy sand to clayey sand.

The infiltration rate may be diminished in some areas due to the subsoil compaction and lack of surface structure. Waterlogging problems can arise where clay or sheet laterite underlies the A horizons. Where sufficient cover is not maintained, wind erosion can become a hazard.

Management

1. Contour working and using level or grade banks to facilitate moisture storage and reduce the risk of water erosion.

2. Trees at the change in slope to intercept shallow groundwater.

3. Use of windbreaks and stubble management to reduce the risk of wind erosion.

4. Topsoil pH should be checked regularly and treated if necessary (see section on soil acidity).

5. SCQ soils can exhibit problems associated with dispersion leading to hardsetting problems. These soils may be gypsum responsive, and the subsoil must be tested along with the surface soil.

5. Deep sands and sandy loams > 1 m (DYS, DWS)

Limiting factors: Wind erosion
Low moisture storage
Surface acidity

Place in landscape: Mid and upper slopes.

The deep yellow and white sands have fairly uniform sandy profiles which allow rapid infiltration (and thus high recharge). DWS have less clay in the upper horizon than DYS, but at depth they are similar. The pH is usually 5 or less in $CaCl_2$ and problems can arise with acidity over the long term. The land class is more common in the west of the Land Conservation District nearer to Miling and also in the North Dalwallinu sub-catchment. Isolated patches occur throughout the rest of the Land Conservation District.

Management

1. Contour working and level banks to reduce the risk of water erosion (particularly sheet and rill).

2. Test pH regularly.

3. Reduce the wind erosion risk by the establishment of windbreaks and stubble management.

4. Deep ripping to alleviate root penetration limitation caused by cultivation pans.

5. Strategic placement of trees and/or fodder reserves to intercept groundwater.

6. Lupin/wheat rotation.

6. Lithic complex (RO, GC, GR, RC, SSG, SSL, DDK, QTZ)

Limiting factors: Low moisture storage capacity
High run-off
Depth

Place in landscape: Upper slopes and catchment divides.

There is a lot of variation in soil characteristics within this land class, but they have been grouped together because of their limitations, namely depth of soil (usually very shallow) and high potential for run-off. Often the amount of rock will not allow economical cropping, especially with the RO, RC, SSG, DDK and QTZ units.

Management

1. Limited grazing (maintain as much ground cover as possible to reduce run-off).

2. Use absorption banks or other earthworks to control run-off.

3. Where there are severe limitations to cropping or grazing, fencing out the area is the best option. Revegetation of the area will reduce run-off and will help those areas where salinity and waterlogging are a problem further downslope.

7. Salt lake system (CP, DWS, SC)

Limiting factors:	Salinity Waterlogging
Place in landscape:	Major drainage systems in valley floor.

The lakes and surrounding gypsum and sand deposits are part of an ancient drainage system of which the Damboring lakes are the major feature. Both saline and fresh lakes were present before clearing, seasonally drying to clay pans. Subsoils are saturated for much of the year and are highly saline. Since clearing the rise in the regional groundwater has led to all lakes becoming saline.

Management

1. Do not clear.

2. Fence off and control grazing (if already cleared).

3. Deep drainage is not practical as the fall along the drainage line is negligible. Some surface drainage may be required to reduce waterlogging to allow revegetation.

4. A strip of vegetation at least 50 m wide should be left alongside the lakes. This will provide a corridor for birds and animals, as well as intercepting groundwater.

8. Acid soils Wodjil (DYSW)

Limiting factors:	pH (and aluminium levels) Wind erosion susceptibility High infiltration rates
Place in landscape:	Mid-slopes generally in the eastern half of the Land Conservation District.

Wodjil sands are naturally acidic throughout the whole profile and it is usually aluminium toxicity which limits plant growth. Where areas have been cleared poor crop growth results leaving minimal cover leading to quite severe wind erosion problems. As the DYSW also allows high recharge, strategic tree/fodder plantings should be used to intercept groundwater.

Management

1. Do not clear.

2. Fence off and revegetate if it has been cleared. Revegetating with fodder shrubs such as tagasaste and *Acacia* spp. has had some success in the area. Rainfall seems to limit tagasaste production towards the east.

3. Establish windbreaks.

4. Treat sandplain seeps if they are associated with the area.

9. Saline soils (Mo)

Limiting factors: Salt content
Wind erosion susceptibility

Place in landscape: Upper slopes associated with Salmon gum soils and breakaways.

Morrel soils are not widespread and tend to occur as isolated patches through the central region of the Land Conservation District. The surface of the profile is often powdery with little structure and supports minimal crop growth often leading to wind erosion problems. Morrel soils are differentiated from the valley saline soils because waterlogging is not a limiting factor.

Management

1. Fence off and revegetate with salt tolerant plants.

2. Control grazing.

SECTION 3.

LAND DEGRADATION

As mentioned earlier in Section 1.3, water management was seen as the major issue needing to be addressed. The end result of poor water management is waterlogging, water erosion and salinity, which in turn result in reduced crop yields and returns. Salinity is by far the most visual problem in the LCD, however soil structure decline and fertility problems, which are not so easily observed, are present in larger areas of the catchment and cost just as much, if not more, in terms of lost production and input costs.

3.1 SALINITY

The processes behind salinity have been discussed in detail in Section 2.4 Hydrology. The main types of salinity present in the LCD are: 1) valley floor salinity, 2) sandplain seeps, 3) hillside seeps, 4) change of slope seeps, and 5) morrel soils.

The two major consequences of high soil salinity in a soil conservation context are: 1) the effect on plant growth, and 2) the effect on water quality relied upon for stock or domestic supplies. Lack of good quality water was seen as a very real issue over much of the LCD where many landholders have lost productive bores and dams to salty water. The arrival of scheme water to the district has relieved the pressure on some farms, but at a cost.

Morrel soils occur throughout the central area of the LCD, generally on mid and upper slopes, associated with Salmon gum soils. The source of the salt is assumed to be storage in pallid zone clays. Most morrel soils have a shallow profile so salt transfer from the clays to the surface is not unlikely. Another theory is that the salt has been blown there from salt lakes, but the distance from the lakes for most of the sites makes this an unlikely source.

Saltland reclamation

As mentioned previously there are three alternatives for tackling salinity:

1. Reducing recharge to the groundwater.
2. Using discharge from the groundwater.
3. Improving drainage out of the catchment.

Reducing Recharge

* improve crop management (healthier crops use more water)
* reduce run-off through contour farming → more water available for crops
* intercept rainfall, increase evaporation and reduce run-off from rocky outcrops and shallow soils by revegetating
* water harvesting - good maintenance of roaded catchments and dams; well designed bank systems

Using Discharge

* strategic tree planting above seeps
* appropriate choice of tree and shrub species
* fencing out degraded areas and encouraging regrowth
* use wildlife corridors as part of the overall water-use plan
* using interceptor drains to harvest fresh groundwater (such as above sandplain seeps) for stock or domestic use

Improving Drainage

* well designed shallow drains to relieve waterlogging and promote crop and tree growth
* deep drainage on well-investigated sites. NB - Permission is required from the Commissioner of Soil Conservation and downstream landholders.

3.2 WATERLOGGING

Waterlogging is often the precursor to salinity and reducing it will delay or relieve salinity. Waterlogging is a seasonal problem and will cause more damage in some years than others. Some parts of the catchment are also more prone than others.

Waterlogging is caused by excess rainfall, run-on from upslope areas, particularly rock outcrops and Salmon gum soils, but also subsurface lateral flow, poor surface drainage and poor internal drainage.

In duplex soils (those having a texture contrast such as sand over clay, or sandy loam over conglomerate) water infiltration through the sandy surface horizon is fast, but once the water reaches the clay or conglomerate layer water movement is slow thus causing water to build-up, saturating the soil upwards. This zone is usually the area of greatest root growth so waterlogging over long periods, particularly during germination and early stages of growth, can cause yield losses up to 100%. Yield loss and crop death occur because non-adapted plant roots cannot function in the absence of oxygen for extended periods (24 hours plus).

Treatment

Prevention of waterlogging is the most effective treatment. This can be achieved by intercepting run-off from upslope areas and diverting it to dams, waterways or creeks. Shallow sub-surface flow can be intercepted and diverted with reverse bank seepage interceptor drains or conventional grade banks. Level banks will not reduce a waterlogging problem. Waterlogging in valley floors can be relieved by shallow drainage with w-drains or spoon drains. Notes on construction of these banks and drains is detailed in Section 4.1.

3.3 WATER EROSION

Soil erosion by water is a function of the erosivity of rain and the erodibility of the soil. The ability of rain to cause erosion depends on the intensity and duration of a rainfall event. The erodibility of the soil depends on its texture (how much sand, silt and clay), structure, aggregate stability, slope and amount of vegetative cover. Plants, whether alive or dead, absorb much of the raindrop's energy, decreasing its ability to erode the soil.

Erosion starts when the soil particles become dispersed by the force of the raindrops impact. The fine soil particles remain in suspension, collect in natural or man-made channels and start flowing in rivulets forming rills in the soil. This stage is called rill erosion. When a rill becomes too large to be eliminated by cultivation, it is called gully erosion.

Splash erosion → Rill erosion → Gully erosion

Water erosion results in soil fertility loss, reduced crop yields, obstructions in paddocks, silting of dams and damage to fences and roads. Water lost off a paddock represents a significant potential crop loss and makes water erosion control a worthwhile practice.

Overcoming water erosion (See section 4.1 for detail on earthworks)

* Correct land use - maintaining soil structure and cover (either stubble or living), contour farming. Using land within its capability.

* Very steep slopes and areas just below high run-off zones (rocky outcrops) should be left under natural vegetation or revegetated.

* Construct earthworks to control run-off. These include level and grade banks, waterways and reverse bank seepage interceptor drains.

* Careful management of headlands, firebreaks and farm tracks.

* Location of watering points. Provide a watering point in each paddock, as close to the centre as possible for even grazing.

* Leave a belt of vegetation either side of a drainage line to stabilise stream banks.

3.4 ACIDITY

Louise Barton and Jenny Borger

The acidity of soil or water is a measure of the concentration of hydrogen ions (H^+) in the sample. A 'pH' scale is used to express this concentration . The scale ranges from 1 to 14, where 7 is neutral, below 7 is acidic and above 7 is alkaline. A pH of 5.2 (in water) or 4.5 ($CaCl_2$) is considered critical to plant growth.

ACID	NEUTRAL	ALKALINE
pH1	pH7	pH14

Soil acidity can occur in the surface or subsurface soil horizons. Both types of soil acidity limit plant growth.

What are the effects of soil acidity?

Lowering the pH of a soil not only increases the hydrogen ion concentration (or acidity) of the soil, but also changes the availability of some plant nutrients. Whilst both effects can be harmful, plant growth is more likely to be affected by factors related to acidity than by the acidity itself.

In Western Australia these factors include
* aluminium toxicity
* molybdenum, nitrogen, phosphorous, calcium and magnesium deficiencies
* nodulation failure.

Which soil types are likely to acidify?

A soil is more likely to be affected by soil acidity if
1. the soil is already acid.
2. the soil has a low "buffering capacity" (BC) i.e. the ability of the soil type to resist changes in pH is poor. A sandy soil BC is less than a loamy soil BC, and both have a BC less than that of a clayey soil.
3. the agricultural system on that soil produces a lot of acid.

Those soils having the greatest risk of acidifying include
* light soils supporting productive lupin/wheat rotations
* light soils supporting strong subterranean clover pastures
* light soils with a history of heavy nitrogen fertilisation.

Medium textured soils, such as red-brown sandy loams growing productive medic pastures are also at risk.

What are the causes of soil acidity?

Soil acidity is often a result of successful farming.

Topsoil Acidity (ie to 0-10 cm) has been attributed to a number of agricultural practices.

1. The use of acidifying fertilisers.
   Agras 1, Agras 2 and ammonium sulphate are the most acidifying, followed by DAP, urea, aqua ammonia, anhydrous ammonia and ammonium nitrate.
2. Legume dominant pastures, which fix high amounts of nitrogen in excess of pasture requirements.
3. The removal of alkaline products, such as grain and straw.
4. Increased amounts of organic matter (OM) under legume pasture.
   Note that this is not a problem if lime is applied. In fact OM can be a benefit because it has a higher buffering capacity than the sandy soil and retains nutrients against leaching. Both these effects will limit further acidity developing.
5. Application of sulphur and superphosphate.

Sub-surface acidity has generally not been induced by agricultural activities and occurred before clearing. 'Wodjil' soils, which carried acacias before clearing, are an example of a soil type that has an acid sub-soil.

HOW ARE ACID SOILS IDENTIFIED?

1. Soil Monitoring and Measuring
(Courtesy of Karen Connell, Soil Acidity Extension Officer)

Soil testing is essential if you want to confidently identify an acid soil. The following sampling techniques and tests are recommended by the Department of Agriculture.

Sampling Technique

Soil samples should be taken from the topsoil (0-10 cm), and the subsurface between 15-25 cm.

Topsoil
Identify the major soil types in each paddock. Within a representative area of each soil type, for example 100 m by 100 m, collect 30-40 pogo samples (0-10 cm). If there is a large area of one soil type in a paddock, take samples from several locations within it.

Subsurface
The subsurface may be difficult to sample in summer as the soil gets dry and hardens. Samples can be taken in the winter for ease of digging, provided the samples are put in the next mail after being taken. The soils to target the subsurface acidity are the loams or sands. From a uniform area take samples from five to ten places. This can be done by digging away the top 15 cm (6") and taking two or three pogo samples from the bottom of the hole.

Soil Test

A full nutrient analysis need only be conducted on the topsoil sample. The most important aspect for the subsurface is pH.

Soil pH is now measured in calcium chloride ($CaCl_2$) which is more reliable than the water method used previously. The pH ($CaCl_2$) is usually lower than the pH (water). Be aware which method was used when reading old soil tests!

Soil test kits can be obtained from private testing laboratories (for full analysis), or send samples into your local Department of Agriculture (for pH analysis only).

If you are on the fringe of the eastern wheatbelt and have deep yellow sandplain (Wodjil) the most effective test is the Aluminium Quick Test. This can only be done on the

subsurface sample. The quick test will indicate whether your yellow sandplain has high levels of toxic aluminium available to the plants and to what degree it is limiting yield.

The aluminium quicktest is available at the Dryland Research Institute, Merredin. Samples should be sent in well sealed and clearly labelled plastic bags for testing.

2. Plant Symptoms

No plant symptoms can be linked directly to soil acidity. However, the following plant symptoms may prompt soil tests for acidity to be conducted.

* poor nodulation because of poor colonisation by soil rhizobia
* pale green or red discolouration indicating a nitrogen deficiency
* poor regeneration in pastures
* slow growth and lack of plant vigour
* an increase in grass composition in the paddock.

Subsurface acidity may be suspected when a light area of soil on which wheat and other species produce lower than expected yields (even in good years), and tests on topsoil pH, phosphorus (P) and potassium (K) are adequate for plant growth.

What are the management recommendations for acid soils?

(from • Farmnote 3/89 by M. Lamond and P. Dolling and • Farm Monitoring Handbook by N. Hunt and R. Gilkes).

1. Soil sampling

Monitoring all soil types by testing for acidity is the best method for managing soil acidity. This will enable adoption of management strategies before reduced production can be seen, at which stage the cost of rectifying the problem becomes much higher.

The best time to sample is during the summer months. Sample soils every 2-4 years, and because the pH of a soil can vary across the paddock, return to the same sites every time.

It is important that a soil sampling program includes subsurface sampling. A high surface pH does not necessarily mean a high subsurface pH.

2. Choosing fertilisers

Nitrogen fertilisers are a major contributor to soil acidity, therefore using less acidifying fertilisers and sowing crops early to increase the use of the fertiliser will prevent nitrogen from being leached.

3. Select acid-tolerant species

Growing plant species that are more tolerant of acid soil is essential on the Wodjil soils, as it is uneconomic to lime subsurface soils. Oats, triticale, cereal rye and lupins are more tolerant of low pH conditions than most other crops.

4. Applying lime

Lime can be applied to acid soils to raise the pH of topsoil. There are two main points to consider when applying time:

- know the pH of the soil before spreading lime.
- when buying lime, compare different sources and types of lime and take into account the on-ground price, neutralising value and particle size.

Types of agricultural lime

- lime sand
- crushed limestone
- burnt lime

Particles of lime smaller than 0.6 mm diameter will react within the first year after being cultivated into the soil.

Particles larger than 1 mm will not react for more than five years and those larger than 2 mm will have little benefit.

How much lime?

1 t/ha lime (over 80% Neutralising Value) will change soil pH 0.3 to 0.5 units on loamy sands or sandy-loams.

On heavier soils use a higher rate, on lighter soil a lower rate.

Beware of over liming as it can cause manganese, zinc and iron deficiencies.

Lime - how often?

Monitor soil pH every two to four years.

Current research indicates that 100 kg lime/ha/year is needed in medium rainfall south-west of Western Australia to maintain topsoil pH. This is 1 t/ha lime every 10 years.

Possible liming schedule

Now	-	lime areas of the farm in the danger area (pH at or below 4.5 $CaCl_2$) and plan to lime every 10 years.
	-	monitor whole farm.
Future	-	as other areas drop into the danger zone include them in the 10 year plan.

If you are unsure if including a liming program is economic for your property try a test strip of lime across the paddock. Apply the lime at rates of 1 to 2 t/ha and incorporate in the top 10 cm. Monitor the strips, comparing the yield with those areas not limed.

5. Fencing

Consider removing severely acid wodjil soils from production, especially if they are located next to remnant bushland.

Further reading

Department of Agriculture Bulletin No. 4228 (1992). Monitoring and Managing soil acidity.

Journal of Agriculture (1984). Volume No. 4. "Soil Acidity".

Farmnote No. 3/89 (1989). Management of topsoil acidity in cropland.

"Farm Monitoring Handbook" (1992) by Natalie Hunt and Bob Gilkes. University of WA Press.

3.5 WIND EROSION

Wind erosion will occur on all soil types when the soils protective vegetative cover is reduced below a critical level and the soil surface is in a loose, dry state. Wind strengths exceeding 30 km/h cause the most damage. These generally come from a north-westerly direction.

The susceptibility of a soil to wind erosion can be reduced by modifying a number of factors.

Wind fetch - the distance the wind can blow uninterrupted. The longer the fetch the greater the wind velocity. Surface barriers such as windbreaks or cultivation ridges can greatly reduce the hazard.

Soil exposure - erosion tends to occur first on the higher parts of the landscape. In the Pithara-Dalwallinu area this is usually north-west facing upper sandy slopes.

Attached vegetative cover, dead or alive, protects the soil surface and reduces the wind velocity at ground level. The amount of stubble required to reduce the risk is discussed in Farmnote No. 90/91 by Paul Findlater.

Soil surface roughness - this functions much the same as vegetative cover. Where there is sufficient surface roughness (vegetation, soil clods, ridges) wind velocity near the ground will be sufficiently retarded to reduce the erosion risks. Soil surface roughness is dependent on soil structure and texture and amount of organic matter. Well structured soils with a significant proportion of soil particles or aggregates greater than 0.85 mm diameter have a much reduced risk of being eroded.

Soil moisture - moist soil is not susceptible to wind erosion. Most wind erosion occurs in the LCD towards the end of summer (when plant cover is greatly reduced and soils are dry) as storms approach. These are preceded by gusty winds without rain and sometimes lightning. Fires started by lightning can reduce cover by up to 100% making the soil extremely prone to erosion. Well-designed fire breaks are essential for control of these events.

The other major risk period is just after seeding if initial rains are not followed up after working to maintain surface soil moisture.

Soil texture - the resistance of soil to erosion is highest in those soil types which form clods or aggregates. This is generally the case for soils with high clay or silt contents. However, wind erosion can still occur on clayey soils where the surface structure has deteriorated.

Management

* avoid clearing soils of light sandy textures
* leave sufficient trees to act as windbreaks
* if an area has been over-cleared establish windbreaks
* locate watering points and gates away from erodible areas
* use stubble retention farming systems
* maintain soil structure

Windbreak design

Location - at right angles to the direction of the most damaging wind. For Dalwallinu this is roughly north-east/south-west.

Width - a minimum of two rows, preferably three or more.

Length - a minimum length of 20 times the height of mature trees is recommended. (Tree species and heights are presented in Appendix 4). This should be increased to at least 30 times for breaks that are not at right angles to the damaging wind.

Pattern - most taller eucalypts shed their lower branches leaving a bare trunk. A row of shorter trees or tall shrubs which retain their foliage to ground level are needed in the front rows (See Figure 9).

- tree spacing 5 m.
  shrub spacing 4 m
- Distance between windbreaks should be 20 to 30 times the tree height. If mature height for the dominant species is 20 m then distances ranging from 400 to 600 m are suitable.

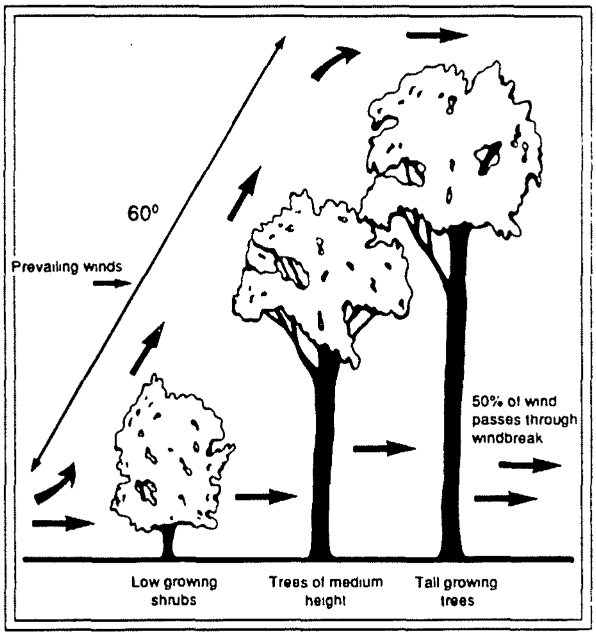


Figure 9: Foliage must extend to ground level. This can be achieved with a combination of trees and shrubs.

Ends of windbreaks

The ends can join onto other tree lines such as those below grade or level banks, or remnant vegetation. Using a mixture of shrubs and trees these can double as wildlife corridors.

If windbreaks end in an open area, the trees should be thinned out towards the end, or shorter trees can be used to taper it out.

Other shrub species such as grevilleas, hakeas and melaleucas (ti-tree) can be used in the first row.

Species

Select a compliment of 2-4 species that will give the desired height and perforation and that are suitable to the area they are going in. Appendix 4 provides a list of trees suitable for revegetating, their preferred soils, form, height and use

Maintenance

Tree windbreaks require little maintenance once they are established. Establishment is covered in Section 14.

Weeds may pose a problem for disease management (e.g. ryegrass toxicity) and fire hazards. Once trees have reached a height of 1.5 to 2 m, the area can be crash grazed with sheep. If ryegrass is present and ARGT is present in the area, graze early before flowering. Care must be taken to remove sheep as soon as they start to browse trees.

Further reading

Anon, (1991) Trees for farms, Department of Agriculture, Bulletin No. 4206, pp. 29-35.
Findlater, Paul (1991) Harvesting straw for paper pulp: Minimising wind erosion, Farmnote No. 90/91.
Chippendale, G. M. (1973) Eucalypts of the Western Australian Goldfields (and the adjacent wheatbelt). AGPS Canberra
Anon, (1990) Property plan manual, Soil Conservation Service of New South Wales.

3.6 SOIL STRUCTURE DECLINE

Several soil types in the Dalwallinu area exhibit soil structure decline either at the surface or at depth, or both. These include the red clayey loams (YG, SAL) which because of their fertility have had the longest history of cultivation, the transitional soils (SCQ) which often have a sodic[1] subsoil which can lead to hardsetting problems, and the deep yellow sands (DYS, DYSW) which form hardpans at depth.

([1] Sodicity refers to the amount of sodium in the clay. Where this is excessive the soil becomes dispersive when wet or hard setting when dry).

Factors contributing to structure decline include:

* loss of organic matter which helps bind particles into aggregates.
* working of the soil (cultivation) when it is too wet or dry (soil remoulding and/or smearing, and shearing).
* excessive vehicle or animal traffic.
* using inappropriate cultivation implements.
* mixing of dispersive clay subsoils with surface layers.

How can soil structure decline be avoided or improved?

1. Avoid all unnecessary tillage.

   Aim for minimum tillage. Use direct drill techniques, with herbicides to control weeds. Avoid discs or implements which invert the soil as this can lead to hardsetting problems on the surface of some soils.

2. Working the soil at the correct moisture content with narrow points.

3. Increase the amount of organic matter - maintain productive pastures; retain stubble; sensible grazing management.

4. Deep ripping to overcome hardpans and improve crop growth.

5. Controlled traffic.

6. Apply gypsum if the soil is gypsum responsive.

SECTION 4.

MANAGEMENT AND RECOMMENDATIONS

4.1 SURFACE WATER CONTROL AND EARTHWORKS RECOMMENDATIONS
Richard Kelly

Factors which increase the incidence of water erosion can be directly or indirectly related to the incorrect positioning of fences, gateways and stock watering points.

During early development of the land most paddocks were made either square or rectangular and it was the accepted practice to have good straight fences preferably running north/south or east/west in keeping with the location boundaries which were also surveyed mainly on the square.

Water erosion results in soil fertility loss, reduced crop yields, obstructions in paddocks, silting of dams and damage of fences and roads. As well it has been estimated that every millimetre of rain a crop receives represents a potential of 10 kg/ha of grain. Therefore water lost off a paddock represents a significant potential crop loss and makes water erosion control a worthwhile practice.

The Main Types of Water Erosion

1. *Headland Erosion*

Erosion of headlands is caused by run-off intercepted by combine furrows and channelled to a headland. The headlands are sometimes double worked and therefore have a poorer soil structure. The resulting run-off causes rill and gully erosion down the paddock and sometimes into a neighbouring paddock or two.

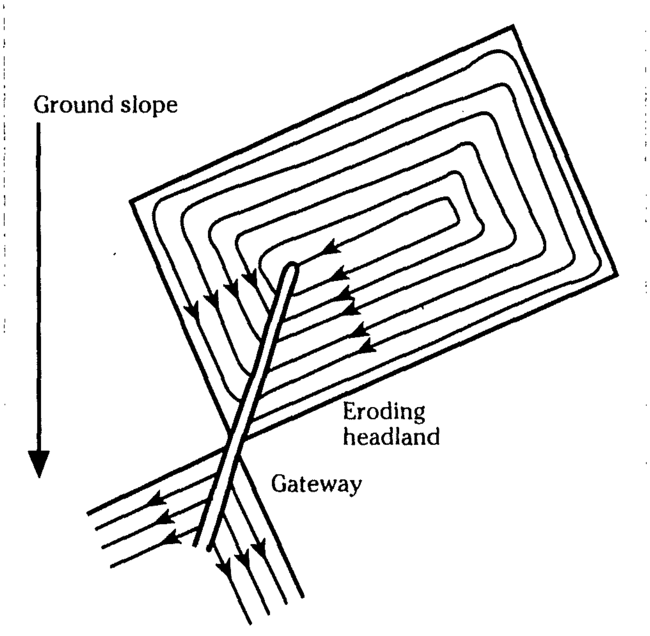


Figure 10. 'Funnel' headland.

1.1 Prevention

1. The overall remedy is to re-fence the farm to natural boundaries. For example waterways and ridge crests and along contour banks.

2. Do not cultivate and seed up and down headlands or seed headlands before the rest of the paddock if their position is known.

3. Reduce the length and position of headland by contouring the paddock.

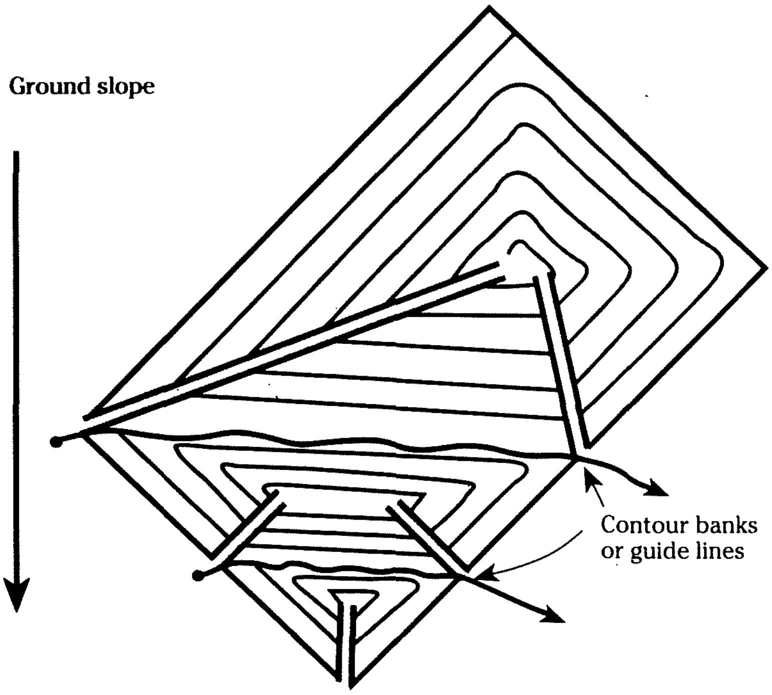


Figure 11. The result is a number of small headlands instead of one long one.

2. *Road and Firebreak Erosion*

When roads or firebreaks are sighted across a slope and not on the contour or a safe grade, they intercept run-off from the catchment above (Figure 12). The water is channelled in the bare wheel ruts or loose soil at unsafe velocities resulting in gully erosion.

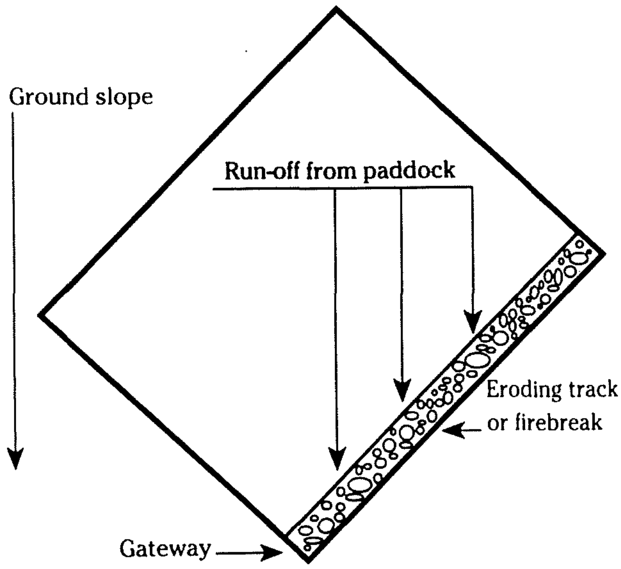


Figure 12.

2.1 Prevention

Locate roads or firebreaks along ridge crests or below contour banks. Do not site roads or firebreaks along waterways. Since roads or firebreaks often follow fence lines, fence

relocation may be advisable in some areas. If roads have to cross slopes it is better to place the road directly up and down the slope so that the only run-off the road has to intercept is its own catchment and not that of the paddock as well.

2.2 Cure

Intercept run-off at regular intervals along the road or firebreak (ie. 100 m) using spur drains or spreader banks. Or in the case of firebreaks, place loops in the break to intercept and slow down the run-off.

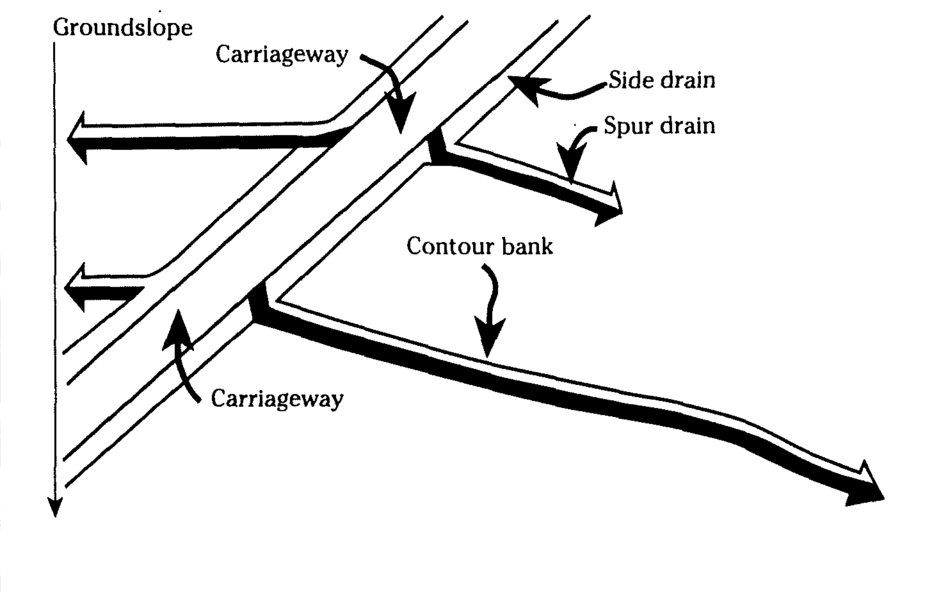


Figure 13. Run-off is shed into side drains and dispersed every 40-80 m with spur drains.

3. *Gateway Erosion*

Headlands, roads, firebreak and sheep pads all tend to concentrate run-off towards paddocks corners where gateways are usually sited. As the soil around the gateway is normally bare and often rutted or pulverised by stock, it is an ideal spot for erosion to start.

3.1 Prevention

Locate gateways on ridges or localised areas of higher ground where the natural drainage is away from the gateway.

If fences are located to prevent headland, firebreak and road erosion, then gateway erosion ceases to be a problem.

Cure of existing eroded gateway.m
Use the gateway as little as possible, construct a hump or spreader bank across the gateway and encourage pasture growth on the bare areas.

4. *Sheep Pad Erosion*

Sheep tend to follow a set track or pad to water. The soil structure of the pad quickly declines and the fine soil particles are then blown or washed away creating small channels for the water to collect which can result in dam siltation and gullying. This problem is increased when watering points are placed at the bottom of the slope and made worse if

upslope neighbouring paddocks do not have their own water and stock need to use water from the down slope paddock.

4.1 Prevention

Provide a watering point in each paddock. Site the watering point as close to the paddock centre as possible for even grazing and further up slope if sheep pad erosion is a real problem. However, this may only be practical if there is sufficient catchment above to fill the dam.

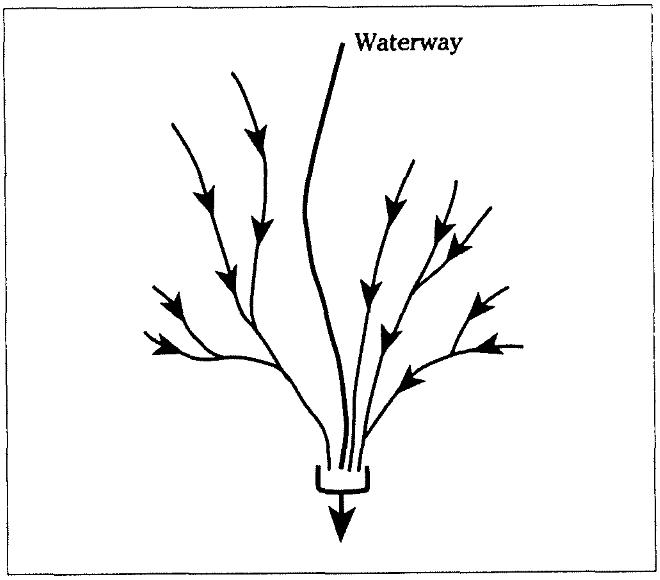


Figure 14. Water in pads converges into mouth dam sited low in a paddock.

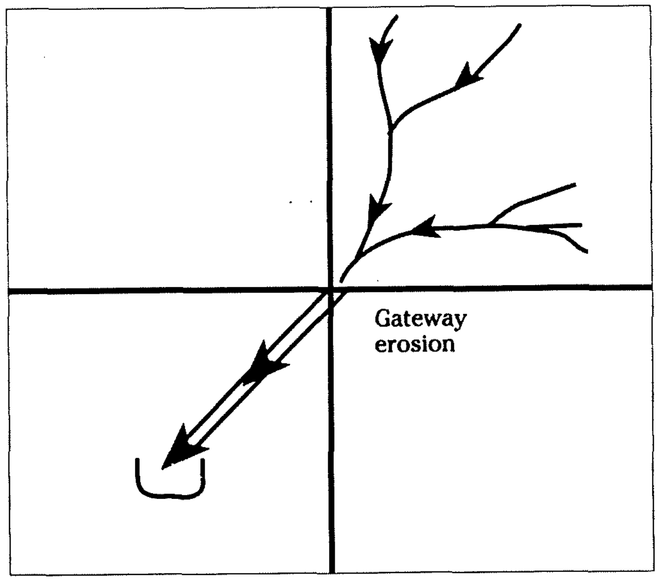


Figure 15. Sheep pad erosion due to of lack of a watering point in a higher paddock.

5. *Natural Drainage Lines Erosion*

Run-off concentrates naturally in minor and major depressions. After clearing most minor drainage lines are not recognised and are cultivated straight across. Any rill erosion in the first year of cropping, in some cases, was easy to fill in with the next cultivation. Following winters caused progressively more severe erosion until gullies occur which cannot be crossed with machinery.

5.1 Prevention

Protect natural drainage lines before they washout either by leaving them out of cultivation as permanent grassed waterways (this can be a problem if there are a lot of depressions in a paddock) or by diverting the run-off of most of the drainage lines by means of grade and contour banks and leading collected run-off at safe velocity to a grassed waterway preferably sited on the edge of the paddock and fenced out.

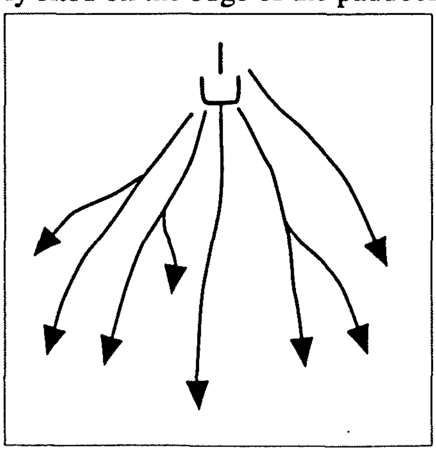


Figure 16. Water in sheep pads spreads downhill away from a dam sited higher in the paddock.

On new land initial development plans can be drawn up using air-photos to locate potentially erodible drainage lines. Earthworks plans can also be drawn up at this stage to fit into an overall farm plan.

The best approach for properties which already have extensive gully erosion is to develop a conservation farm plan which may be gradually worked towards.

i.e. Decide on which drainage lines are to be used as permanent waterways then fill in the remaining gullies, so that they can provide access to farm machinery. Construct contour banks to protect the new fill and plan fencing to fit in with the proposed erosion control measures and land classes.

6. *Sheet and Rill Erosion away from Natural Drainage Lines*

These are caused usually by high intensity summer rains on over grazed or fallowed land and run-off from completely waterlogged soils at or soon after seeding. Large areas of rock or virgin bush can also result in run-off erosion.

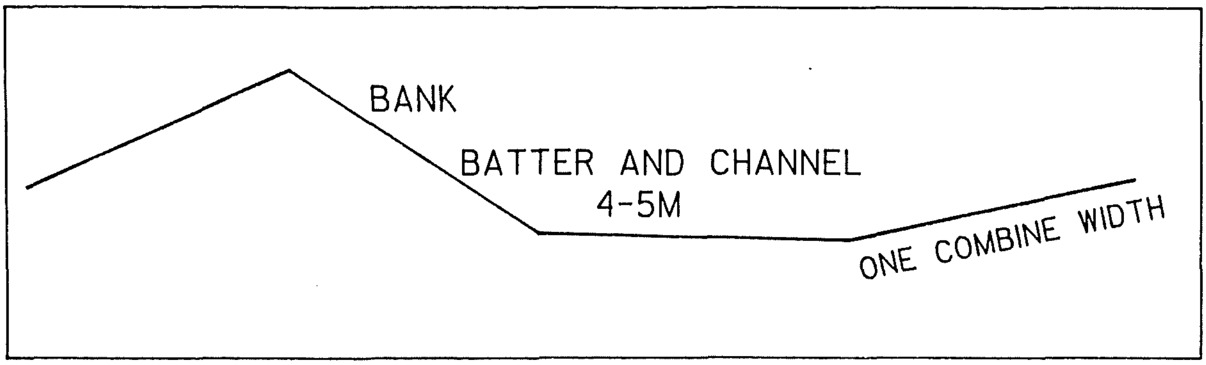
6.1 Prevention

Build up soil structure by minimum tillage and stubble retention practices where possible. Maintain productive pastures with a good ground cover especially at the times when summer thunderstorms or hot north winds are most likely to occur.

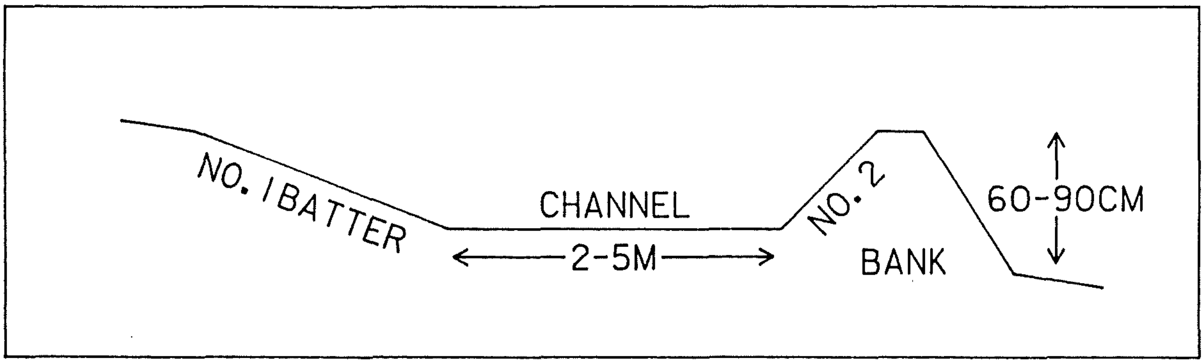
Cultivate sloping land on the contour. Do not use harrows after seeding. As this will increase the surface storage and encourage infiltration of rainfall into the soil.

If rilling is due to seepage flows it is an idea to contour cultivate between grade banks to remove excess soil moisture from waterlogged land. Use of seepage interceptors may be necessary on waterlogged land as level banks can increase the waterlogging of crops by concentrating run-off on a porous section of the channel where rapid seepage through the bank occurs.

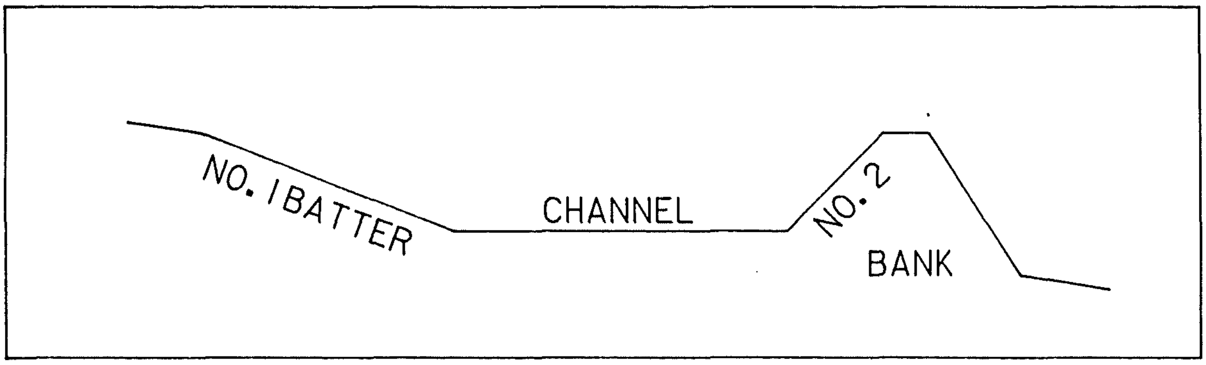
There are many different styles of banks used in agriculture for surface water control. (See diagrams on following pages).



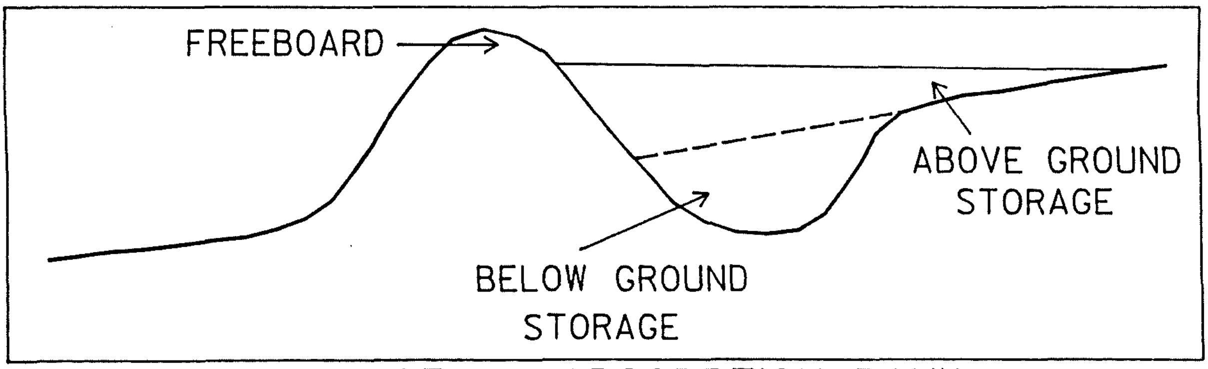
CROSS SECTION OF BROAD BASED BANK



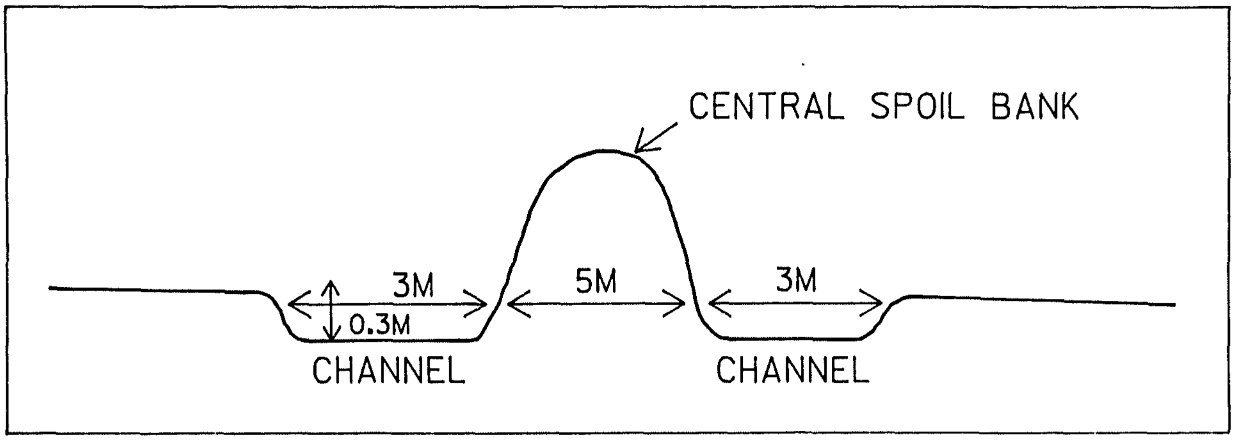
CROSS SECTION OF GRADE BANK



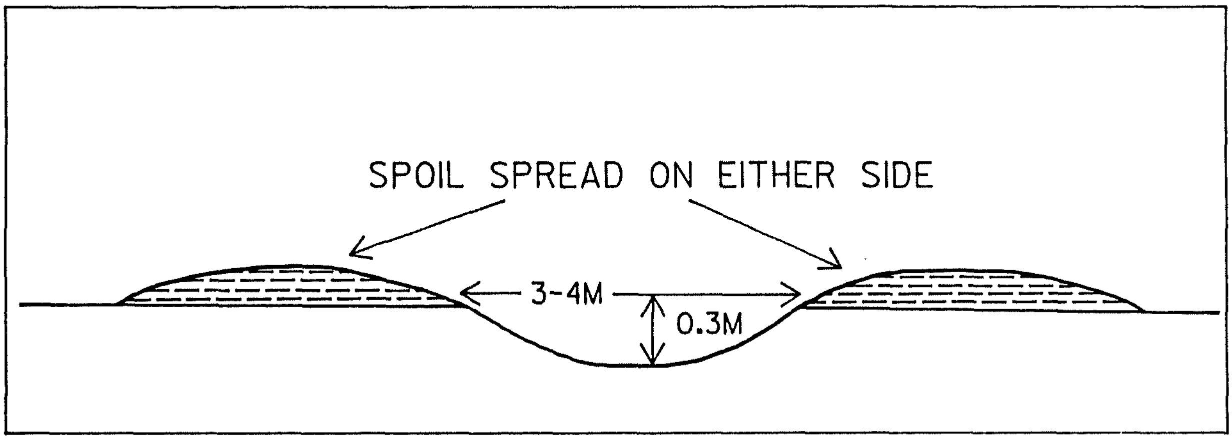
CROSS SECTION OF LEVEL BANK



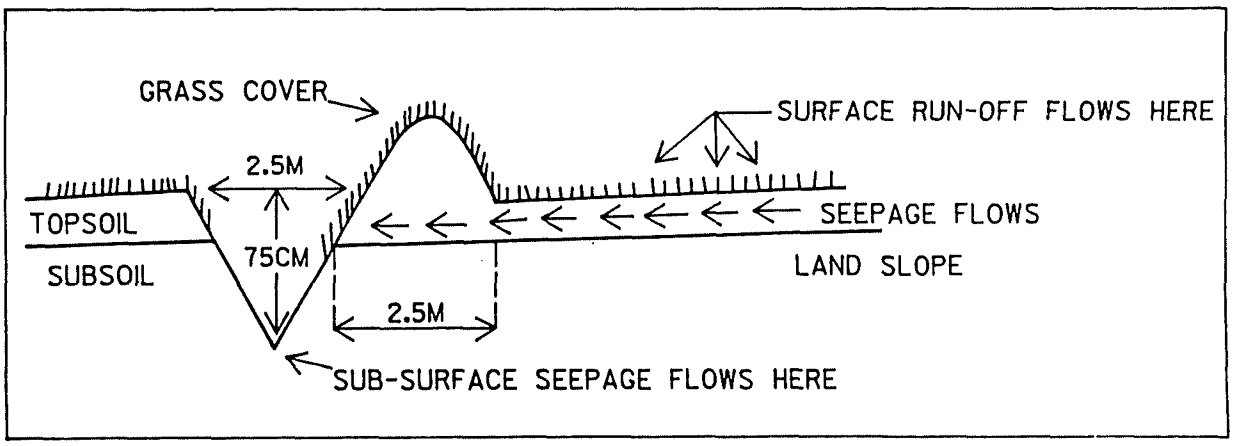
CROSS SECTION OF AN ABSORPTION BANK



CROSS SECTION W-DRAIN



CROSS SECTION SPOON DRAIN



CROSS SECTION REVERSE BANK SEEPAGE INTERCEPTOR

Water control for the upper and mid slopes

Absorption banks (Design period for 1 in 20 year rainfall event.)

Absorption banks are dozer built contour banks with the ends turned up in such a way as to provide above groundwater storage as well as allowing a safe freeboard. When water capacity is exceeded the banks overflow from the ends onto level sills or other safe disposal sites such as artificial or natural waterways.

These banks are used around rocky outcrops or on soil of low permeability where there are usually no available waterways to dispose of the run-off.

Level banks (Design period for 1 in 10 year rainfall event.)

Level banks are surveyed level without their ends being turned up so that they do not store any water above ground level. Level banks are used to control surface run-off that cannot be disposed of safely. These banks are grader built and when water capacity is exceeded they overflow along their entire length or out the ends of the bank.

The above banks are recommended for:

Erosion control
Flood mitigation
Contour working

Problems can occur where these banks cross intake areas as they increase water infiltration rates adding to the groundwater.

Increased groundwater infiltration mobilises the stored salts transporting them throughout the landscape where they can appear as saline groundwater in hillside or sandplain seeps. Increased infiltration also increases the hydrologic pressure which raises the deep groundwater pressure promoting upward groundwater discharge. This can lead to salt encroachment in lower landscape positions.

Average bank spacing

To avoid erosion between banks, bank spacings no greater than 200 m are used. On heavier soils where higher rates of run-off can be expected, a bank spacing of 100 m is used

Waterways

Waterways may be either natural or artificial. They are used to carry surface run-off from the upper slopes to creeks, lakes or drains. Artificial waterways should be designed for a 1 in 20 year rainfall event and be fenced off and pastured two years before use.

Grade banks (Maximum grade 0.5 % designed for a 1 in 10 year rainfall event.)

Grade banks are designed to intercept and divert run-off to waterways or dams at a non-erosive rate.

Broad based banks (Grade 0.25 %)

Broad based banks are grade banks which allow cropping on the entire bank. They can be used on slopes less than 4 %.

Reverse bank seepage interceptors (Grade 0.7 %-1 %)

Run-off from the paddock flows on the pastured top side of the bank. The seepage flows uninterrupted into the channel on the bottom side of the bank.

When the design periods of all banks are exceeded they over top. Plough or grader built banks which have an even construction height and are well settled do not pose any major erosion risks when this happens. On the other hand if dozer built banks over top they tend to break out in one or two places and add to the erosion hazard.

In summary contour banks can reduce and control run-off. They do this by restricting all cultivation to the contour, by diverting any run-off to a well grassed waterway, or by storing excess water in the bank channel. Banks break up sloping paddocks into smaller pieces, but in a well planned system each piece may be 50-100 hectares.

Water control on the lower slopes and flats

Surface drains

W drains are similar to two grade banks built back to back. They are constructed to channel surface water which lays in pools along drainage lines in flat country. They usually are designed to handle 1 in 10 year rainfall event peak flows. When the design peak flow is exceeded, the run-off then spreads out from the drain flooding adjacent country. When the peak recedes, water from the adjacent country flows back into the drain and away. W drains can be built with a wide middle ridge broad enough to provide vehicle access across otherwise flooded land.

Single sided levees are sometime used on flat sluggish drainage lines to contain surface flows. They are designed for a 1 in 20 year rainfall event. As with W drains when the rainfall event is exceeded, the excess run-off flows out from the drain and recedes again once the peak flow subsides.

Deep drains

Deep collecting drains 2-3 m deep are built with an excavator for the sole purpose of sub-surface drainage of groundwater. They are also used to collect flows from other types of sub-surface drainage (e.g. slotted pipes).

The walls of the deep drains need to be battered to avoid slumping. The excavated soil should be placed both sides of the drain to prevent any surface water washing in and eroding the sides or silting up the channel. The surface water may be let into the drain through controlled pipe inlets. Provision should be made so that any catchment peak flows are outside the deep drain.

4.2 WATER SUPPLY ISSUES
Wes Horwood

Maintenance of Roaded Catchments

A feature of a number of roaded catchments in the Dalwallinu area is they look more like nature reserves than roaded catchments. If a roaded catchment is to perform as it is designed then it must be kept free of vegetation. The presence of vegetation on a roaded catchment increases the amount of rain which must fall before run-off occurs. This is due to a number of factors such as:

1. The roots breaking up the surface seal and forming root channels. This increases the infiltration rate for the catchment and the initial loss will rise from something like 2 mm for a newly constructed catchment up to 20 mm or 30 mm for a poorly maintained catchment.

2. Foliage and associated limbs and debris. The foliage collects rainfall and channels it to the roots of the plant where it can enter the ground via root channels. Limbs and debris provide resistance to flow when run-off would otherwise begin. The water is forced to bank up to flow over or around the obstructions which increases the losses into the catchment due to the longer detention time.

Regular maintenance of roaded catchments is required to ensure they perform as designed. Newly constructed roaded catchments will need little maintenance for the first few years but once a build-up of debris (sand, manure, etc.) or the presence of weeds is noticed regular maintenance is essential. This maintenance could consist of a treatment with a herbicide (to kill weeds), scraping of the surface (to remove debris and kill weeds) or reconstruction (to remove significant plant growth which has become established and broken up the surface seal and resulted in significant accumulation of debris).

Herbicide treatments should be carried out early in the winter growing season. This fits in well with the spraying program already being carried out at this time of the year and ensures the catchment is free of weed growth during the winter when most run-off occurs. A list of appropriate herbicides and rates is shown in Table 4.

Table 4. List of herbicides and application rates which can be used to control weed growth on roaded catchments.

Water used for domestic purposes			**Water used by livestock only**		
Herbicide	**Trade name L/ha**	**Rate L/ha**	**Herbicide**	**Trade name**	**Rate**
Knockdown			*Knockdown*		
Paraquat + diquat	Spray.Seed	2.0-3.0	Paraquat + diquat	Spray.Seed	2.0-3.0
Glyphosate	Roundup CT Glyphosate	1.2-1.6	Glyphosate	Roundup CT Glyphosate	1.2-1.6
Residual			*Residual*		
Atrazine	Atradex Flowable	6.0	Atrazine	Atradex Flowable	6.0
	Gesaprim Flowable	6.0		Gesaprim Flowable	6.0
			Diuron	Flowable Diuron Diurex Flowable	6.0
			Bromacil	Hyvar X	5.0 kg
Knockdown + Residual			*Knockdown + Residual*		
Amitrole + atrazine	Vorox AA Flowable AA Tox	6.0	Amitrole + atrazine	Vorox AA Flowable AA Tox	6.0

If the weeds are too large for effective herbicide treatment, or there is a build up of debris (sand and manure) or if you do not wish to use herbicides the catchment surface will need to be scraped clean with a road grader. This treatment will result in the surface seal being broken and the catchment should be rolled with a rubber tyre roller to re-establish the seal. Scraping and rolling should be carried out during spring or autumn when soil moisture content is optimum for maximum compaction.

When a roaded catchment has fallen into disrepair, or it is of older design with smaller sharper vee's, reconstruction of the catchment should be considered. This may involve making one road from two existing roads or two roads from three existing roads. This process should also be carried out during spring or autumn to achieve maximum compaction.

For more detailed information on the use of herbicides and general maintenance of roaded catchments refer to Farmnote No. 58/86 "Roaded catchments - maintenance and reconstruction".

Different types of catchment

Many dams in the catchment rely solely on farmland catchment to provide the run-off to fill the dam and maintain a water supply. Depending on your definition of reliable using farmland catchment alone to fill dams will rarely succeed in providing a reliable water supply.

The current push towards farming on the contour, reduced tillage and stubble retention is aimed at reducing soil degradation due to wind and water erosion. All of these practices are aimed at getting the water to seep in where it falls rather than running off - contrary to what is required for a reliable water supply.

Depending on the type of soil, up to 40 mm of rainfall can seep into farmland catchment before run-off occurs. The rainfall events which occur every year are in the order of 10 to 20 mm, while events which are greater than 40 mm occur every 3 to 5 years. Run-off occurs from improved catchments after 8 to 10 mm of rain. Consequently most dams need some form of improved catchment to ensure a reliable supply of water. The run-off from the improved catchment maintains the supply until a large rainfall event occurs which fills the dam.

There are many different types of farmland catchment and some run water better than others. For example granite outcrops, breakaways, ironstone ridges and areas of heavy red clay run water long before sandplain or medium country. Steeper country will run water before flat areas but this type of country is often carefully farmed to try and reduce water erosion and minimise run-off.

If you have dams which rely solely on farmland catchment and are currently performing well, have you considered what effect soil conservation practices such as stubble retention and farming to the contour will have on the dam's performance? These types of soil conservation practices are designed to reduce the amount of run-off which occurs to reduce soil erosion.

If you do rely solely on farmland catchment to fill dams you must include high run-off areas such as granite outcrops, farm tracks, shire roads and areas around sheds in the catchment to gather as much run-off as possible. Sometimes if you have enough high run-off areas it can almost be as good as an improved catchment. However, farmland catchments will generally not produce sufficient regular run-off to maintain a reliable supply of water in a farm dam. Some form of improved catchment is necessary for most reliable on-farm water supplies in the wheatbelt.

Dams

Evaporation

Farm dams will lose up to 2 m, or about 6 feet, due to evaporation each year. Consequently the dams need to be a deep as possible with a minimum of surface area exposed to the sun to minimise the volume of water lost to evaporation.

Several different methods have been tried to reduce the amount of evaporation from farm dams. These include having a thin film of oil on the water surface, covering the water surface with polystyrene beads, old empty plastic bottles, covering the water with a plastic sheet, and building a roof over the dam. Unfortunately none of these methods have proven to be successful.

Some argue that you may be able to reduce the evaporation from dams by planting trees relatively close to the dam to reduce the speed of the wind over the water surface. By reducing the speed of the wind the evaporation is also reduced. Some factors to be careful of when adopting this approach are:

1. Trees using the dam water as their water source. The tree roots will seek out the most available source of water, the dam, and thrive on it.

2. Tree roots penetrating the base of the dam causing the dam to leak. If planted too close to the dam the tree roots may penetrate the base of the dam forming cracks and root channels for water the flow along. If this occurs the dam may leak making it unreliable.

Siting and Testing of New Dam Sites

There are three types of material which dams can be successfully built in:

Clay (grey and red),
Partially decayed granite
Hardpan (commonly referred to as Sandplain dams)

When looking for a new dam site there are a few features to look for. These features are shown in Tables 5 and 6.

Table 5: List of features which generally characterise poor dam sites.

Feature	Type of dam	Problem
The presence of ironstone or laterite on the ground surface	White to pink pallid dams	Leaks
Breakaways	White to pink pallid dams	Leaks
Calcium nodules in the soil the dam would be constructed in	Red/pale red clay dams	Leaks
Gimlet country (though not always)	Red/pale red clay dams	Leaks
Gravelly sands	White to pink pallid dams	Leaks
Soft fluffy sand		Deep sand
Sheet-like granite	Very shallow (<3 m deep)	Shallow soil over granite rock
Post wodjil		Deep sand
Tamma		The hardpan is often too hard to build dams. D9's can have trouble excavating the dam

There are other indicators which can be used to help locate good dam sites but those shown above are a good starting point.

Once you have located what you believe is a good dam site the next step is to drill the site. Always drill to one metre below the maximum depth of the proposed dam and it is wise to drill in a dice pattern, one hole in the centre and one in each corner of the proposed dam. By drilling in this way you get a fairly good picture of the material the dam is to be sunk in.

Table 6: List of features which can indicate a good dam site.

Feature	Type of dam
Change of soil type	Hardpan or clay dams
Jutting granite rock	Granite and clay dams
Sugar brother (*Acacia coolgardensis*)	Hardpan dams
York gum in association with sugar brother	Hardpan dams
Large mallee	Clay dams

When the holes have been drilled leave them for 24 hours and then check for the presence of water. You may not always notice the water when drilling but water may still come into the hole over a number of hours. Measure the salinity content on any water which comes into the holes. If the salinity reading is above 400 mS/m (150 grains/gallon) be aware that evaporation from the dam will concentrate the salts in the water over a number of months causing the dam to go saline. If the salinity reading is below 400 mS/m the water seeping into the dam is a bonus.

Further Information

For further information on topics related to water supplies the following publications are available from the Department of Agriculture:

Publication Number	*Title*
Bores	
4207	Selecting and developing Reliable Bores Sites in the Eastern Wheatbelt
Dams	
41/86	Dimensions and Volumes of Farm Dams
81/89	Control of Erosion Damage to Dam Walls and Spillways
103/89	Grass Filter Strips to prevent Dam Pollution
General	
13/86	General Principles for control of Erosion and Sedimentation in Special Rural Zones
43/86	Using Land Resource Surveys to Assist Rural Planning
MP11/87	Water for All Seasons
Government Assistance	
124/88	Farm Water Supply Assistance Scheme 1988

Regulations

9/91	Responsibilities of Landholders under Agricultural Acts: Water and Drainage
15/91	Notification of Draining or Pumping Saline Land

Reticulation

17/84	Pumping Water on the Farm
65/87	Selecting Pipes for the Farm
124/89	Sizing Solar Powered Pumping Systems

Roaded Catchments

56/84	How to Build Roaded Catchments with a Road Grader
109/84	Roaded Catchment Design and Construction
58/86	Roaded Catchments - Maintenance and Reconstruction
82/89	Roaded Interceptor Catchments

Soil Erosion Control

38/83	Level Sill Outlets

Water Quality

11/86	Clearing Cloudy or Coloured Water
11/87	Skimming Polluted Dams - A successful two stage system
59/88	Livestock and Water Salinity
10/90	Toxic Algal Blooms
46/90	Water Quality for Farm Domestic Use

4.3 AGRONOMIC CONSIDERATIONS AND FLEXIBLE PLANS FOR LONG TERM PROFITABILITY

Amir Abadi [1] and Jerome Gumley [2]

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Purpose

The agronomic considerations covered within this report are based on the land qualities of the major arable soil types. These qualities include rooting conditions, moisture availability and wind erosion hazard. It is important to be aware of these qualities so that future adjustments to the agronomic practice on your farm can be more easily assessed for its effect on the farms sustainability.

In attempting to develop a farm plan it is useful to distinguish between strategic planning and tactical planning. Strategic planning has a long term focus (three to five years) while tactical planning enables a rapid response (normally within a given season) to changing conditions. Both kinds of planning go hand in hand in a well thought out farm plan. A good farm plan can maintain such strategies as the correct rotations on various soil types while allowing tactical responses to fluctuating economic and seasonal conditions.

The first part of the report focuses on the agronomy of each major soil type. The second part refers to enterprise selection, rotations and the best level of cropping under the current medium to long term price outlook for various commodities. Benefits from adjusting crop area in response to seasonal conditions are also discussed in the second part.

1. Agronomic Considerations for the Major Soil Types

Summary

Soil	Rotations	Varieties	Yield	Management
DYS	LWLW LWWL WPPPW	Spear, Eradu, Cadoux Sub-clover	Wheat 1.4-2.4t/ha Lupins 1.2-2.0t/ha	Retain stubble. Deep rip if traffic compaction layer. Reintroduce pasture phase to reduce herbicide resistance. Control grazing on wind prone areas. Monitor for soil acidity.
Medium & Heavy Red Soils	WPP	Wilgoyne Medic	Wheat 1.6-2.0t/ha Field peas 0.6-1t/ha Pasture 7-9 DSE/ha	Special hard wheats after pea crop or medic pasture. Moisture stress in drier season. Control graze lighter loams to prevent wind erosion. Stored summer moisture may be used opportunistically.
Duplex	WPPP	Sub-clover		Sandy topsoils <60 cm could depress lupin yields. Use barley in areas prone to waterlogging.
Wodjil	PPP	Sub-clover		Poor wodjil, continuous pasture. Good wodjil will produce crop of triticale, cereal rye or oats. Retain stubble for wind protection and retention of moisture.

Deep Yellow sands

Deep yellow sands (DYS) predominate in the western Dalwallinu area. They are not to be confused with the wodjil soils which have a subsoil acidity problem. The soil has moderate fertility and has adequate moisture and nutrient retention.

The most economic rotation for this soil type is currently the lupin - cereal rotation. The key to the success of this rotation is that this soil type produces a consistent above average lupin yield. The lupin yield is in the range of 1.2 to 2.0 t/ha while wheat yields range from 1.4 to 2.4 t/ha. The rotation generally follows a LWLW type. However, where pleiochaeta root rot becomes evident in lupins, a LWWL would be the better alternative. Where there is known herbicide resistance in a paddock, a second cereal such as barley may be grown for its extra competitive ability against ryegrass and for its increased tolerance to alternative herbicides such as trifluralin.

Wheat profit would be maximised where long season varieties such as Spear are sown as close to the break as possible. Alternatively, the noodle varieties Eradu and Cadoux perform well on these soil types.

Stubble retention is vital on this soil type as

1. the risk of brown leaf spot in lupins is significantly reduced
2. germinating lupins are less prone to sand blast
3. there is improvement in seed bed moisture retention
4. the valuable nutrient load stored in the topsoil is protected

There are techniques available for handling cereal stubble. The stubble can either be treated at harvest by cutting the straw short (e.g. a second cutter bar) or by handling the straw at seeding time with cultitrash machinery or with wide spaced tined implements.

Wheat yield on the DYS can be improved by up to 30% with deep ripping. The yield improvement is due to the ripper breaking up the traffic pan occurring 20-30 cm below the soil surface. Yield improvement depends on the season but can be evident for four years following ripping.

Clover does establish and persist well on the deep yellow sands. With the increasing problem of herbicide resistance, the cereal - pasture rotation may need to be considered for some paddocks so that the grazing and spray topping options (in the pasture phase) can be added to the management strategies for ryegrass control. A three to four year clover pasture followed by a cereal would be necessary for the clover to persist.

Groundwater recharge is high under continuous pasture relative to a high water use system such as lupin - wheat. The pasture needs to be carefully managed otherwise weeds dominate the clover. Grazing any pastures on the deep yellow sand needs to be carefully managed to avoid wind erosion. The areas of poor sand will be those to drift first so these should be fenced off to allow an extended grazing period on the better sands without the risk of wind erosion.

Agricultural practices are increasing soil surface acidity on the DYS. It is best to monitor soil acidity by sampling the same sites in paddocks each year or two so that the extent of pH decline can be assessed. Generally, once the soil pH falls below 4.5 in $CaCl_2$, then clover, barley and some wheats begin to drop in production. Application of lime would ameliorate the soil acidity problem within one to two seasons.

The future:

Alley farming has promise on the deep yellow sands. By planting tree belts at 200 m intervals at right angles to the prevailing winds in a paddock would cut wind speed and provide the following effects:

a) provide lupins with protection against sand blast
b) slow the rate at which the soil dries out through the season.
c) reduce the amount of soil loss through wind erosion
d) reduce groundwater recharge

Extra profit could also be realised in terms of timber, firewood or fence posts as the trees mature.

Medium and heavy red soils (salmon gum & York gum)

Soils range from the medium red loams to the red and grey valley clays, originally supporting a native vegetation of salmon gum, gimlet and York gum.

Moisture storage and availability are higher on these soils than the DYS as the clay subsoil can retain large volumes of moisture from heavy rainfall providing the surface structure is not degraded. Potential yield increases markedly with summer rainfall. Crops and pastures do not suffer moisture stress during dry periods to the same extent as those growing on the valley clays, because root penetration is deeper allowing access to deeper stored moisture.

Internal drainage on the red loams is usually good, however, access can be limited for several days after a heavy rain. Drainage on the valley clays is much slower due to their position in the landscape. A high water-table can also increase potential waterlogging problems.

Over-cultivation (especially with continuous cropping) and compaction by sheep can damage the soil structure leading to slaking and eventually hard-setting soils. These soils are generally responsive to gypsum which improves soil structure. Samples should be tested first.

These soils are amongst the most fertile in the wheatbelt. The pH is generally alkaline although there is some risk of acidification of the topsoil under agriculture owing to its moderate pH buffering capacity.

The heavy red loams produce good cereal and field pea crops and medic pastures.

Pastures	7-9 DSE/ha (winter grazed)
Wheat	1.6 - 2.0 t/ha (potentially 3.0 in a good year)
Field peas	0.6 - 1.0 t/ha

This soil type can produce excellent cereal yields especially in the wetter years. The heavier the soil type, the less reliable is wheat yield owing to poorer moisture availability in the drier seasons. Field peas yield well, however, grazing on the lighter loams needs to be monitored because of wind erosion risk. The burr medics Serena and Santiago establish well with aphid control. These pastures are suited to the 'year in and then one or two years out' cropping system as the medic burr requires burial for it to germinate. The slightly spiny barrel medic 'Caliph' which flowers at about 70 days is a new variety which may be suitable. The advantage of Caliph is that the spines anchor the medic into the soil so that seed burial is not as critical as with the burr medics, allowing a longer pasture phase with a wider range of options for out of crop weed (especially ryegrass) control.

Special hard wheats can reach their protein potential on these soils. Wilgoyne, for example, can reach the hard category especially where it follows a field pea crop or medic

pasture. Local experience has shown that the nitrogen input form a good medic pasture is greater than that of a field pea crop.

The amount of summer rainfall has a large bearing on the performance of the heavier loams. These soils should be cropped on an opportunistic basis depending on the amount of stored moisture at depth in the soil profile.

Wodjil (Acid Sands)

This description includes all deep yellow sandplain with an acid subsoil. The profile may contain ironstone gravel at depth. This soil type can be distinguished from the deep yellow sand by its pH, the wodjil vegetation, often heavier texture and poor crop and pasture growth. There is good wodjil and bad wodjil. The difference between the two is the amount of subsoil aluminium. It is the soils with high levels of subsoil aluminium which restricts root growth and plant productivity. The most productive management practice for this soil type is to pick the good from the poor. Aluminium soil tests can be carried out by the Agriculture Department. A profit can be made in a wodjil paddock through fencing off and/or not cropping the bad wodjil area (Table 11).

Soil acidity will also tend to make other nutrients such as copper, zinc, molybdenum and phosphate unavailable to plants. This means for example, that a phosphate bank will not form after years of super applications as the phosphate will be bound up within the soil.

Continuous pasture is currently the most economical option for the poor wodjil. For the good wodjil, cropping in a cereal lupin rotation may be viable. Alternative cereals such as triticale, oats or cereal rye should be considered as these varieties generally yield higher than wheat on these soil types. Cereal rye grown on contract with a feed mill makes the crop more profitable. Retaining all the straw seems to be an important management factor to improve the wodjil soils. By retaining stubble, the organic matter builds up in the topsoil which improves the moisture retention. Cereal rye and triticale have good straw strength properties. This assists in stabilising the wodjil soil against wind erosion especially in blow out areas.

The future:

Serradella should be the legume for the wodjil soils in the future. Seed costs are still high as there is a costly process of de-hulling involved.

Research is still advancing on the wodjil soils with Dr Bill Porter's work on the use of lime and gypsum to ameliorate subsoil aluminium toxicity. After two seasons, there has been no definite response to these treatments.

Duplex soils

This includes sand over clay, sand over hard laterite, sand over gravel and sand over rock.

This group of soils varies widely in their agronomic merit. The major factor would be the effective rooting depth for lupins. Generally any duplex soils shallower than 60 cm would restrict lupin growth and most likely depress yield. Sand over a loose gravel, should yield better lupins as the roots would be able to penetrate the subsoil.

The majority of these soils seem to lie to the east of the Great Northern Highway. The lower rainfall associated with these soils tends to make these soils less productive than the West Dalwallinu yellow sandplain.

Clover pasture and cereals perform reasonably on these soils. Clover pastures, should remain at least three years in pasture before a crop so that the clover has a chance to persist. Where sand over clay exists lower down in the valleys, some localised

waterlogging may be experienced. Barley is a more suitable crop for these areas. Soil pH should be monitored to assess the need for lime.

Wherever the rooting depth allows, grow the most productive crop so as to maximise water use. For all crops, a record of yield versus growing season rainfall should be kept so that an estimate of water use efficiency can be made. This not only allows a high productivity of the soil to be realised, but reduces groundwater recharge as well.

2. Flexible Plans for Long Term Profitability

To determine the enterprise mix and profitable rotations, the MIDAS (Model for Integrated Dryland Agricultural Systems) was used.

Since it was not possible to study each farm individually, this study concentrated on a farm with characteristics similar to most farms in this catchment.

All possible alternatives available to farms in this catchment were evaluated with the aim of finding a combination of activities that results in a profit maximising farm plan. To do this a large amount of local data were gathered from several farms in the catchment. Department of Agriculture advisers with local knowledge were involved in the study.

Assumptions

- In this farming system there are four major soil types.

- On each soil type there are around 13 possible rotations to choose from, each differing in the crop and pasture yields and also in the level of inputs required.

- Different sheep classes and selling times are included, allowing the choice of a flock structure which maximise farm profits.

- Seasonal finance is available with a borrowing limit of $150,000 per year. Machinery requirements and annual replacement costs were also accounted for. For instance, seeding capacity was assumed to be 105 ha/day for 20 days from the break of season.

- The important relationships between crop, pasture and sheep were also included. These consisted of grazing sheep on crop stubbles, disease break effect of lupins on cereal, nitrogen fixation by crop and pasture legumes, and higher spraying costs in a cereal after a year or more of pasture. In addition the cereal yield loss due to delayed seeding as a result of prolonged weed control or sowing lupins after the break is also taken into account.

- Soil conservation was accounted for by limiting the extent of stubble and pasture grazing.

- Long term sustainable crop yields on each soil type are listed in Table 7.

Table 7. Examples of crop yields used in the study.

Soil type	**Cereal crop yield (kg/ha)** Nitrogen not limiting	**Notes**
Acid Wodjil sands	900	After three years of volunteer pasture
Deep Yellow sands	1700	After a year of lupin crop
Duplex soils-sand over gravel/sand over clay	1300	After two years of legume pasture
Red loams-medium heavy soils	1850	After two years of legume pasture

NB: Contents of this table do not indicate the best rotation on each soil. These are representative yields of wheat crops in one rotation only and are provided as an example of yield assumptions. Yields of crops vary for different rotations.

- Setting up a long term viable farm strategy requires an assumption of likely expected commodity prices within a foreseeable medium term outlook (e.g. 5 years). For the purpose of this analysis prices were assumed to remain around the historical (last 8 years) average levels (Table 8).

Table 8. Medium term commodity prices net on farm after freight.

Commodity	Price
Wheat	125 ($/t)
Lupin	145 ($/t)
Barley	114 ($/t)
Oats	73 ($/t)
Wool	300 (¢/kg)

- In the West Dalwallinu area the proportion of each soil type varies for different farms. In this study three farm types were analysed each with a different mix of soil classes (Table 9).

Table 9. Soil type mix of three farms in West Dalwallinu (ha).

Soil Type	Farm 1	Farm 2	Farm 3
Acid Wodjil sands	300	300	300
Deep Yellow sands	1500		2100
Duplex soils-sand/gravel, sand/clay	300	900	
Red loams-medium heavy soils	900	1800	600
Total arable farm area	3000	3000	3000

Results

Rotations

A key factor in farming profitability is to distinguish between different soil types and select appropriate rotations on each soil class. In practice, farming to soil type means considering the balance of soils in a paddock and choosing the most profitable option for that paddock. Leaving out patches of soils might be a possibility in some circumstances.

Results (shown in Table 10) indicate that **the most profitable rotations for each soil type remain the same regardless of the proportion of soil types on each farm**. However, results indicate that each soil class should be managed separately by practising appropriate rotations which result in highest crop and livestock production by utilising the direct and indirect interactions between enterprises on the farm.

Table 10. The most profitable rotations for each soil type in the Dalwallinu region on a farm with the of soil type mix as specified in Table 9.

Soil Type	Farm 1	Farm 2	Farm 3
Acid Wodjil sands	Continuous or long term volunteer pasture followed by an occasional crop.	Continuous or long term volunteer pasture followed by an occasional crop.	Continuous or long term volunteer pasture followed by an occasional crop.
Deep Yellow sands	Two years of cereal crops followed by one year of lupin crop.		Two years of cereal crops followed by one year of lupin crop.
Duplex soils-sand over gravel/sand over clay	Three to four years of legume pasture followed by one year of wheat crop.	Three to four years of pasture followed by one year of wheat crop.	Not applicable.
Red loams-medium heavy soils	One or two years of legume based pasture followed by one year of wheat crop.	One or two years of legume based pasture followed by one year of wheat crop.	One or two years of legume based pasture followed by one year of wheat crop.

For the **acid wodjil** continuous or long term pasture with infrequent single crops is the most profitable option because the direct and indirect costs of growing crops is not outweighed by the returns on this soil type.

On **deep loamy sands**, lupins in rotation with cereal produce good crop yields relative to other soils.

On **duplex soils** cereal crops following three years of legume based pasture are more profitable than continuous pasture because the nitrogen input and disease break from the pasture for the crop outweighs the negative effect of cropping on pasture production.

On the **red sandy loams**, cereals yield well due to nitrogen fixation by previous legume species in pasture and a cereal disease break. The similar profitability of most cereal/pasture rotations on this soil type makes it suitable for tactical adjustments to cropping in response to seasons. Field peas may also be profitable, however, the yields achieved on-farm are highly variable and consequently considered high risk.

In many situations, a paddock will consist of both acid wodjil sands and yellow sands. It was calculated that if these two soils could not be managed separately and as a result such mixed soil paddocks were continuously cropped within cereal/lupin rotation, the paddock profit is low. Where part of the paddock is left out of crop, however, the paddock profit can be lifted considerably. (Table 11).

Table 11. Wheat Yield for a deep yellow sand (DYS) with an area of acid wodjil soil.

	Yield (t/ha)	Costs and Returns (Average over 3 years)	
All cropped 70 ha good DYS 30 ha acid Wodjil	 Lupins 0.85 Wheat 1.18 Wheat 0.93	Return Working capital Fixed Machinery Costs Profit	$13,006 $8,166 $4,000 $ 840
Only DYS cropped 70 ha good DYS cropped 30 ha acid Wodjil fenced and grazed continuously (occasional oats or triticale crop)	 Lupins 1.00 Wheat 1.30 Wheat 1.00 Sheep=2 DSE/ha	Return Working capital Fixed Machinery Costs Profit	$10,616 $5,716 $2,800 $2,100

For each sample farm, the most profitable range of cropping % can be determined. Where soil mix is predominantly deep yellow sands and duplex soils the most profitable level is around 60-80% of farm in crop (Table 12). This is because continuous cereal/lupin cropping is by far the most profitable rotation on the deep yellow sands. It is important to note that herbicide resistance has not been considered and appropriate strategies should be adopted to minimise risk of resistance.

Table 12. Most profitable range of cropping % on each farm type in the West Dalwallinu LCD.

Soil Type	Farm 1	Farm 2	Farm 3
Most profitable range of cropping #	60-80%	40-60%	70-80%

#: (Expressed in percentage of arable area of farm in crop.)

For farm 3, where around 70% of farm consists of deep yellow sands it is profitable to put even larger areas into crop. Farms with a high % cropping can maintain long term profitability if direct drilling and appropriate weed control strategies to reduce herbicide resistance are employed.

In practice, undertaking such large cropping programs depends on availability of seeding, harvesting and spraying machinery. In addition availability of permanent and seasonal

labour, seasonal finance, attitude to risk and personal preference determines the ability of the farmer to expand cropping.

Note that those rotations shown in Table 10 as being the most profitable rotations for each soil type are also those rotations which correspond to cropping levels that maximise farm profit.

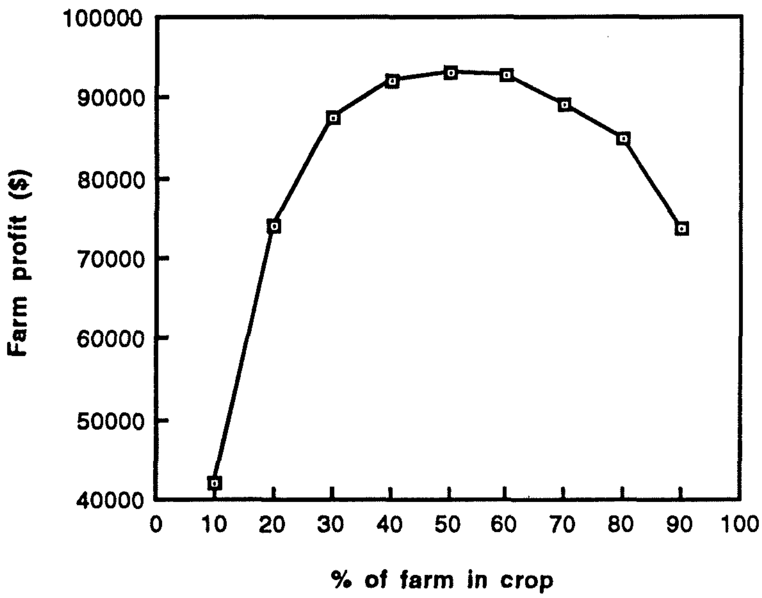

Figure 17: Change in farm profit in response to increasing the size of the cropping program.

An analysis of the effect of a wide range of wheat and wool prices has highlighted that, on farms in this catchment, profit is maximised when the arable area in crop is between 50% to 80%. These findings are confirmed by the Australian Bureau of Statistics survey results. The survey shows that more farmers in Dalwallinu are at a 60 to 70% cropping level.

Seasonal tactics

As far as long term farm profitability is concerned, making the most of seasonal conditions as they unfold is more important than changing farm plans in response to commodity prices. Adjusting crop area according to climatic events experienced up to the date of seeding is one of the most important year to year decisions that needs to be made. These within season changes to the cropping program are termed "tactical" area adjustments.

Flexibility in area cropped

Although it is valuable to identify optimal rotations, in practice it is not advisable to stick rigidly to a rotation from year to year. Flexibility in response to the seasonal conditions can help to generate extra income in good seasons or reduce losses in bad years. In seasons with an early break or in seasons with significant summer rains and an average break, it is likely to be profitable to increase the area of crop above the planned area. This is especially true on heavy and medium-heavy soils where yields are more sensitive to season type. Of course even with good conditions at the start of the season, there is no guarantee of good yield. Nevertheless over a run of seasons, the usual benefits of responding to a good start more than compensate for the years when a good start is not followed by adequate finishing rains.

Note that given a good start to the season, relatively high cropping can be profitable even if the grain price is poor. Even if the income gain from higher yields is not sufficient to compensate for lower prices, increasing crop area can still increase income above what it would be with low prices and average crop area.

On the other hand in years with a late break, it pays to cut back the area of crop on the medium to heavy soils. This avoids growing unprofitable crops, a significant risk on heavy soils if the break is late. It also provides pasture to carry sheep, which is likely to be much needed in these poor seasons.

If the season looks bad it is also advisable to cut back on any lupins planned for the poorer lupin country (wodjil, poor white sands and duplex soils). Wheat is less likely to fail in poor conditions than lupins.

Note that the rotation strategies identified as those most profitable on each soil type, on the case study farms in West Dalwallinu LCD, will be flexible enough to respond to seasons as outlined here. On the medium-heavy soils, the two pasture - one cereal rotation can be reduced in crop area by leaving cropping paddocks out of crop in years with a bad start. Conversely, in seasons with an early start, on good sandy soils the two cereal - one lupin rotation can be adjusted to one cereal - one lupin rotation by sowing a paddock prepared for a wheat crop with a lupin crop.

Simple adjustments to the areas of different enterprises such as those outlined above can have a significant impact on profits. On a typical farm (such as farm 1 shown in table 12) the benefits of adjustments to very poor years and very good seasons can average out to around $15,000 per year, over several seasons.

The area cropped in any season should be determined primarily by the season start, not prices. However, if the season start proves to be neither "good" nor "poor" then these crop area adjustments become less important.

Timing

There are yield penalties associated with late-sowing. The benefits of an increased cropping program in a good season may be out-weighed by the yield decreases resulting from a drawn-out seeding program. Hence sowing should commence as soon as seasonal conditions permit. If seasonal conditions are good, crops should be sown early, cropping the best paddocks first. Some early and late wheat variety should be kept on hand in order to allow effective response to season start.

Preparation

Good farm management requires the preparation of budgets and programs for good, average and poor seasons well ahead of seeding time. Thus the decision on how much crop to put in is only taken at just before seeding. It is therefore important to keep track of rainfall events and soil moisture status over the summer period.

Conclusions

These results highlight the importance of a systems approach to farm planning. It is crucial to know the potential of your major soil types, and select those rotation strategies on your farm that not only maximise your farm profits but are also flexible enough to let you adjust tactically to changing commodity prices and seasons.

Further Reading:

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4.4 REVEGETATION STRATEGIES

4.4.1 Introduction

Farmland can be more productive and/or less prone to land degradation problems if a proportion of it is under perennial vegetation. In the West Australian wheatbelt the commonly accepted area of perennial vegetation is around 10% of the farm.

Many cases have now been documented about the benefits of perennial fodder on saltland and gutless sands, the safeguarding of wind erosion prone sands and the protection given to lambs and off-shears sheep by windbreaks and use of water by trees on hillside seeps and saline valley floors. Many observations have been made about the values of vegetation for erosion control, wildlife habitat and improving the appearance of a farm and there are also many prospects of direct production from trees and shrubs through honey, wildflowers, wood, ethanol and eucalyptus oil.

A revegetation strategy therefore can take many different forms and can be designed to enhance the farming operation. With the many options available, revegetation should be seen as an opportunity not a liability.

The aim of the following section is to outline some of the perennial vegetation systems and the plants that could be used to enhance the productivity or reduce the degradation on your farm.

Blocks, Strips or Alleys?
Revegetation on farms usually takes the form of blocks, strips and more recently alleys, depending on the purpose of the planting and the location. The following table is a brief summary of this.

FORM	BLOCKS	STRIPS	ALLEYS
USE/PURPOSE	LOCATION		
Fodder (to stabilise and get production off waste or degraded land.)	Saltland Gutless sand areas		Gutless sand paddocks with low cropping potential.
Water use (to use up water at discharge sites and provide fodder where possible.)	Hillside seeps	Contours behind banks. Change of slope edge of saltland.	Flats (mild-moderately saline.)
Wind control (to control wind erosion and shelter stock.)	Wodjil soils Loose sandy hills	Paddock boundaries Along ridgelines Laneways.	Paddocks too fragile to crop safely or that are susceptible to overgrazing.
Alternatives and aesthetics (for alternative income and farm appearance.)	Wildflowers Honey Specialty timbers Oils	Entrances Road verges	

4.4.2 Species, their use and location

Tagasaste *(Chamaecytisus palmensis)*

Under natural conditions tagasaste is a medium sized legume tree which grows to a height of 5 m and up to 4 m wide. It will grow on a wide range of well drained, non saline soils. It grows in rainfall zones as low as 350 mm and up to 1100 mm and very well on deep infertile sands but will not tolerate waterlogging.

The leaves of tagasaste have up to 20 % protein, while the fine stems (up to 5 mm) can be as high as 9 %. Stock will eat both leaves and fine stems and the combined overall level of protein is generally 15-20 %. The leaves are as digestible as green leafy pasture (70-80 %).

Tagasaste can be grown as a forage crop or as part of an effective windbreak and hence seed source. Other uses include a coloniser of stony and waste areas (to control erosion), to assist in lowering water-tables in sandplain seepage areas, to restore fertility to impoverished soils through nitrogen fixation and nutrient recycling, and shelter for livestock.

Establishment

Large areas can be direct seeded into a cultivated seed bed using a modified combine, or direct drilled using a specialised seeding machine. The sowing rate is 0.5-1 kg/ha using pre-treated inoculated seed. With direct seeding good weed control is essential. Machines that scalp the soil at seeding give the best results.

Seedlings, potted or bare rooted, can be planted just as economically using a tree planter at 2-3m spacings. At these spacings the trees will put out more lateral growth that will prevent ringbarking of the main stem. During the establishment year, control of insects and vermin are essential. Lucerne flea, redlegged earth mite, cutworm and rabbits will attack tagasaste in the seedling stage.

Superphosphate, copper, zinc and molybdenum applied during planting will improve plant establishment and vigour. Depending on the break of the season and weed control, tagasaste can be sown from autumn to spring. Seedlings are best planted mid-winter for successful establishment.

Tagasaste can be control grazed within 12 months of establishment and then used as a valuable autumn feed source. Under ideal conditions its ability to recover from grazing gives a living haystack with very low input and advantageous returns.

Most measurements indicate that a good stand will produce up to 50 % more than will traditional pasture in the same environment. High stocking rates for short periods should be used to minimise physical damage. The best practice is to heavily graze (e.g. 70 DSE/ha) for two weeks, then mechanically cut the tagasaste. The sheep should then be left in for a further two weeks to eat the cut material.

Once established, tagasaste is likely to have greatest feed value during summer/autumn when all other paddock feed is dry and low in quality. The Midas model has shown that an extra tonne of feed in spring returns a farmer $20, while an extra tonne of feed in autumn/early winter returns $200.

Further reading

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Saltbush

Salt tolerant plants (*Atriplex* sp.) are now widely accepted as the forage shrub to establish on salt-affected land. There are at least six different species which are suitable for the north-eastern wheatbelt for revegetation and forage production. Although saltbush are highly salt tolerant in the adult growth stage, many are less tolerant during germination and establishment. Adaptation of these species to any given site is affected by soil type, climatic conditions, and the severity of salinity and waterlogging at the site.

Most saltbush species provide good nutrition. Protein levels are 7-8 % or higher and digestibility between 60-70 %. Some established saltbush sites can carry up to 5 dry sheep equivalents (DSE)/ha in 300 mm rainfall areas for short periods of the year.

Establishment will vary at each site, therefore it is important to sow a mixture of shrub species. A selection for the area should include, in order of dominance:

* River saltbush (*Atriplex amnicola*)
* Wavy leaf saltbush (*A. undulata*)
* Small leaved bluebush (*Maireana brevifolia*)
* Quail brush (*A. lentiformis*)
* Old man saltbush (*A. nummularia*)
* Grey saltbush (*A. cinerea*)
* Creeping saltbush (*A. semibaccata*)

Steps to consider when revegetating saltland:

1. Treat site for surface water control, contour if necessary and drain any waterlogged areas.

2. Plan site
   - Decide and budget for most economical option i.e. seedlings, directseeding.
   - Select suitable species (shrubs and grasses) to suit soil type.
   - Plan layout for future grazing consider water points, easy access.
   - If possible plant proportion of area for future seed source.
   - Consider fence layout in regard to expansion.
   - If in doubt seek specialised advice regarding your saltland.

3. Site preparation
   - Plan layout of the seeding lines and pre-rip them.
   - Cultivating improves leaching and provides a niche for wind blown seed to lodge and germinate.
   - Weed control (up to 12 months in advance). Do not use residual herbicides.
   - Control vermin, if necessary.

4. Seeding
   - Under saline conditions seeds/seedlings must be mounded.
   - Avoid wet and badly scalded areas.
   - Use the appropriate seeding machine.
   - Seed as close as possible to the optimum sowing time (moist soil, follow-up rain).

Seeds: Sow when there is adequate moisture and rising soil temperatures. However, site accessibility will also determine sowing time. If you have to sow early, seeds will remain dormant under ideal conditions i.e. no waterlogging. Do not skimp on seed, ensure good seed viability.

Seedlings: Plant out into moist soil during late winter. Avoid waterlogged conditions.

5. If in doubt, have work done by a specialist contractor who guarantees their work.

6. Regular post seeding observation - control insects if necessary. Redlegged earth mites and lucerne flea cause extensive damage.

7. Fence the area off so that grazing can be managed properly.

Alternatively you can adopt the low-cost method of revegetating your waterlogged and heavy clay saline areas. If the area has small leaved bluebush (*Maireana brevifolia*) or samphire (*Halosarcia* spp.) then a reduction in grazing pressure by fencing it off will allow regeneration.

If the vegetation cover is sparse the area can be cultivated lightly so that seed will lodge in the barer areas.

There are several Statewide saltbush seeding operators that are all reputable and contract costs vary according to the type and extent of service you require. Cost vary from machine hire only ($45-$50/ha) to full contract ($200-$250/ha) which includes up to 35 seeds of a shotgun mix seeded on a 2 m x 3 m grid.

Saltbush seedlings are readily available from local farm nurseries; ranging in price for peat pots (30c-50c) or bare rooted seedlings (as low as 10c) for large orders. A good idea is to compare prices.

Once the saltbush/forage shrubs are well established it can provide up to two months valuable grazing for sheep during autumn and early winter. Maximum benefit is gained by allowing stock access to non saline forages i.e. grasses, stubbles or hay at the same time. If the sheep have access to plenty of fresh water (up to 10 L/day) saltbush pastures will minimise the effects of drought on on-farm feed supplies.

Golden wreath wattle *(Acacia saligna)*

Acacia saligna has been established successfully on many different soil types including moderately saline areas throughout the state. It will grow on poor sandy as well as heavy clay soils. It is an excellent drought fodder shrub which can grow up to 10 m high in less than 350 mm rainfall areas and will tolerate waterlogging. However, it is frost sensitive.

Acacia saligna can be direct seeded using the same methods as tagasaste at a cost of 10 c/tree or less. It also has a hard seed coat and therefore needs to be treated before sowing. Where direct seeding is not feasible, seedlings (potted, 30c-50c ea. or bare rooted, 6c-10c ea.) can be planted.

The feed value of *Acacia saligna* is lower than tagasaste or saltbush and is therefore best used in combination with other fodder plants. *Acacia saligna* will eventually outgrow the browse height of stock but is still valuable as a fodder shrub because of leaf and seed fall which all gets grazed.

Further reading

Wilson, G. (1992) *Aust. Farm Journal* **1**(11): 79-80.

Trees

Most trees on farms are planted in order to:

1. use water,
2. provide wind protection, and
3. improve appearance.

There are any number of trees that will do these jobs, it is just a matter of selecting a species that will tolerate the conditions it is being planted into.

A list of popular species recommended for planting in this area is in appendix 4. This list was compiled by Max and Angela Waters of the "Kalannie Tree Supplies". The list is gradually being modified as results from various plantings come in but provides a good base to choose from. Other plants local to the Dalwallinu-Pithara area are listed in Appendix 5. Many of these species will not be commercially available but may be grown by collecting seed and growing in the home nursery or by giving the seed to the local nursery to grow.

NB - A seed collectors licence is required if collecting seed from reserves and crown land; available from CALM.

Alternative uses for trees are highly speculative but if planting trees for farm improvement there is no harm in planting species that may also have a commercial value in the future. Possible alternatives include:-

- Essential oils (*Eucalyptus* spp. with high oil content)
- Seed (higher demand for local popular species)
- Firewood (only if within economic carting distance of town)
- Specialty timber (tools, fencing, craftwood)

Common Name	Scientific Name	Use	Habitat	Comment
Inland wandoo	*Eucalyptus capillosa*	flooring fencing		Good insulating properties. White ant resistant.
Jam tree	*Acacia accuminata*	fencing craftwood	York gum soils Red sandy loams	Good at regenerating. Very durable for fencing.
Sheoaks	*Allocasuarina* spp.	craftwood	Rock outcrop perimeters. Creeks, flooded areas. Saline areas.	Species to suit most conditions. Very attractive grain.
Banksias	*Banksia* spp.	wood turning	Poor white sands	Brittle wood. Attractive grain.
Quandong Sandalwood	*Santalum accuminatum* *Santalum spicatum*	Nuts; fruit for jam. Wood for incense.	Sands over clay. Loams.	Slow growers. Sandalwood has high value and a fragrant scent.

4.4.3 Alley Farming - The Union of Agriculture and Environment

Alley farming applies lessons learnt from the natural bush, a self sustaining system, to agriculture. It is the first major step attempt at integrating nature into a traditional wheatbelt farming system.

One way to look at alley farming is it is compressing the bush into rows. Traditional farming, in some cases is going on between the rows but the tree rows are also playing a role in fodder production, stock shelter and wind erosion control.

The natural bush has limited productive value to humans, but it is self regenerating, it is perennial, it has a whole range of plants and animals, it is diverse, it requires no inputs (e.g. fertiliser, chemicals), there is no land degradation and through evolution everything has its place. The elements of the system, the plants and animals, have adapted to the conditions.

Traditionally farmed land is totally focused on production but requires inputs of fossil fuels, fertiliser and chemicals, the plants are only annuals and there is one type of animal, the system is very prone to invasions of weeds, pests, disease and the elements. Some of the signs that this system is not working and does not suit the wheatbelt landscape are soil acidity, ryegrass resistance, soil structure decline, soil erosion and salinity.

There are benefits and problems with both systems, the challenge is to marry the two so that they compliment each other thereby production of the land is increased and land degradation is reduced.

Row Spacing

The width of the alley's vary according to the soil type. This means that soils determine the type of alley farming system.

The gutless white sands (i.e. lupins 3 bags/acre) have very low productive potential for cropping. There is little or no lost opportunity cost by having larger areas under perennial vegetation at any stage of the system development. Therefore row spacings are narrow, the emphasis is placed on perennial fodder and the feed comes from the trees. The amount of feed on the ground may even be reduced because of competition from the trees but the system as a whole has a greater stock carrying capacity (3 times). With an emphasis on stock feed the alley paddock may best become permanent pasture in which case perennial grasses can be introduced into the alleys. Rhodes grass has been used.

The level of activity of Rhodes grass is proportional to nitrogen input. This nitrogen may be added to the system by other winter active crops and pastures because the grass is summer active. Lupins and clovers are being trialed at present as this is a more complementary system than just adding fertiliser.

On the break even soils i.e. lupins 5-7 bags/acre the alleys become wider. The trees are still necessary for wind erosion control and providing some fodder but larger areas are utilised for cropping and annual pastures.

On the good soils the spacing becomes wider again for the same reason i.e. more production coming off the ground than off the trees.

On saline land the spacing of trees will be dependent on the distance that the trees effect drawdown of the water-table.

Row Alignment

Alignment of the tree rows varies according to the position in the landscape and the soils.

Deep sands and sandy gravels generally have high infiltration rates and therefore are not prone to water erosion but the soil particles have low cohesive forces and therefore are low in nutrients and prone to wind erosion. The low productivity and susceptibility to wind erosion emphasises the need to protect them from the wind. The tree rows therefore are best placed perpendicular to damaging winds.

Heavier soils have lower infiltration rates and therefore are more prone to water erosion. These soil types are less prone to wind erosion and therefore emphasis is placed on water control both above and below the surface. On slopes a system of grade banks and contour working may be required to control surface water in which case the trees would be best placed along the contour banks and the middle of the workings and in difficult corners.

Often there are large areas of heavy ground on flats which, because of their position in the landscape, are subject to valley floor salinity. The emphasis here becomes water use in order to prevent groundwater rise. Row alignment in this situation would be north-south aimed at getting maximum sunlight for maximum evapotranspiration from the trees and production of crops and pastures from the alleys.

Alley Paddock Composition

On gutless sands the alleys are narrow and the trees and shrubs are mainly fodder species tagasaste, saltbush and *Acacia saligna* because they have higher fodder value in this system plus some Eucalypts for greater windbreaking effect and higher water use.

The alleys will consist of what grows best on that soil and may include annual ryegrass, sub-clovers and even so called weeds, brome grass and capeweed. To get more year round production of the alleys Dean Melvin of Dowerin has included Rhodes grass which is summer active perennial grass and very adaptable to different soil conditions.

Productivity

The following figures are observations from Dean Melvin's first alley paddock.

June 1989 trees and shrubs planted.

Autumn 1990 1400 dry sheep equivalent put in the paddock for ten days, i.e. 1 dse/ha. There was still fodder in the paddock but the sheep were taken off for fear of losing the eucalypts.

Autumn 1991 1500 dry sheep equivalent were put in for twenty days i.e. 2 dse/ha.

In the summer of 1992 a lot of unseasonal rain fell which boosted the perennial pasture in the alleys.

Autumn 1992 3100 dry sheep equivalents were put in the paddock for 60 days (2 months) i.e. 12 dse/ha.

A conservative estimate of the long-term carrying capacity of this system would be 6 dse/ha. Previous to the establishment of this alley farming system the unimproved pasture had a carrying capacity of 2 dse/ha. The increase to fodder production has been tripled.

On heavier soils there is more productive value in the crops and pastures therefore the emphasis for the composition of the treebelts is on enhancing production of the alleys by reducing wind speeds and lowering groundwater tables. On the heavier soils the alleys should have some high water use cropping strategy. Rhodes grass may also be able to be used here which would increase water use during summer months.

The treebelt requirement will be for tall species that give a windbreaking effect over a longer reach or for species that have high rates of water use or will tolerate salty water.

The rate of draw down on the water-table will be dependent on the density of trees planted per hectare. At Boundain, tree densities of 0, 80 and 160 trees per hectare were tested. It was found no drawdown occurred in the first four years whilst the trees got going, but in the subsequent three years the water-table was drawn down from the critical level of 1.5 metres to 2.5 metres.

If the site is moderately saline, i.e. patchy barley grass, the whole area would be more productive as a permanent saltland pasture. In this case both the tree rows and the alleys will contain salt tolerant trees and shrubs. The alley formation is not necessary in this system but may be beneficial for convenience of moving stock and fertilising the shrubs.

4.5 TRIALS AND DEMONSTRATIONS IN THE LAND CONSERVATION DISTRICT

Demonstration 1 - Sandplain Seepage Reclamation

East Pithara Sub-catchment

Landholder: Malcolm Mills Melbourne Location No. 527

Funding source: State Assistance Funding 1986

An assessment of the effectiveness of an intensive tree planting program to control saline/waterlogged areas in seepage situations that occur frequently in the north-eastern agricultural area..

Rainfall in excess of that utilised by the covering vegetation percolates through the permeable sands and gravels to form a perched aquifer over less permeable clays.

Catchment area: 63 ha
Discharge area: 14 ha
Rainfall (per annum): 325 mm
Estimated annual recharge: 23 mm (7% annual rainfall)
Tree water use: $10m^3$ /yr

1992 recommended:

Expected discharge	=	recharge x catchment area
	=	23 mm x 630,000 m^2
	=	0.023 x 630,000
	=	14,490 m^3 /year

(assuming a tree uses 10 m^3 /yr)

No. trees required:	=	14,490/10
	=	1449 trees

In the original submission recharge was assumed to be higher (35 mm), and tree water use was also assumed to be higher (18 m^3 /yr). The recommended number of trees in 1986 was 1200.

1987 actual number planted: 1336

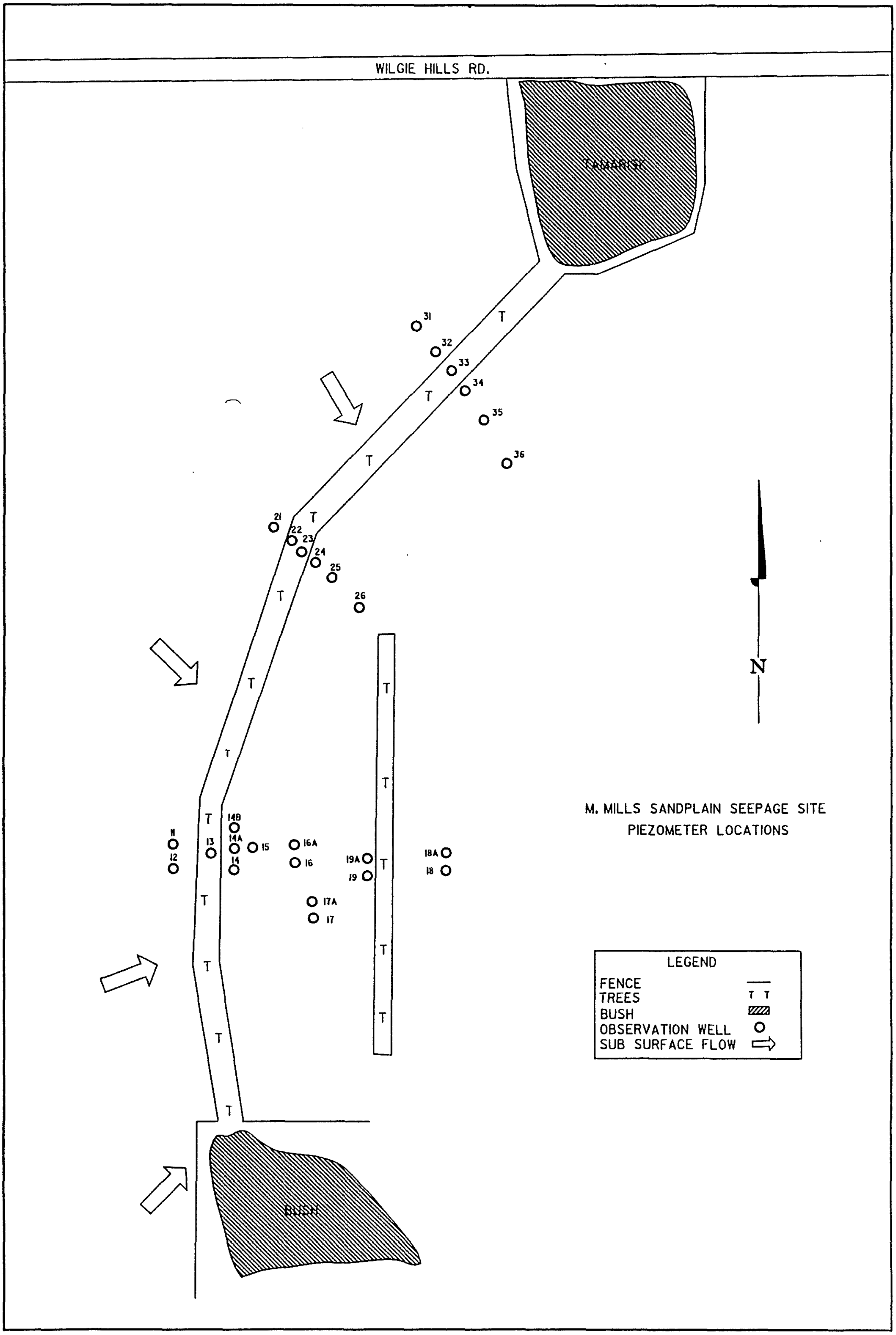
NB: Existing bush and tree plantings would account for use of some discharge, so the number of trees planted should be adequate to use up most of the excess discharge. However, the tamarisks on Wilgie Hills Road are old and do not use much water. Replacement of these trees with eucalypt species would be recommended.

Water-table monitoring

Twenty-nine piezometers were placed above, within and below the tree planting (see diagram). Twenty-four of these are monitoring the shallow water-table (less than 5 m), four are monitoring groundwater movements from 8.8 m to 14 m, and one is placed in the deep groundwater (26 m) above the tree planting.

Results

The water level in the deep piezometer (11b) showed small fluctuations between 1.3 m and 1.7 m to mid 1991. Readings taken in November 1992 show that the water level has now decreased to 2.1 m. Rainfall recordings near the site indicate a reduction in rainfall


WILGIE HILLS RD.
TAMARISK
BUSH
M. MILLS SANDPLAIN SEEPAGE SITE
PIEZOMETER LOCATIONS
N
LEGEND
FENCE
TREES
BUSH
OBSERVATION WELL
SUB SURFACE FLOW
31
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14B
14A
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16A
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17A
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19A
19
18A
18

during 1992, but whether this has had any effect on the deep groundwater is too early to tell. Rainfall over the wider area indicate an above average year.

Piezometers in the middle range (8.8 m - 14 m below ground level) have shown a slight downward trend dropping an average 40 cm in three wells, but remained the same in 18A which is 100 m downslope from the trees. The other three are just above and below the trees (within 10 m). A conclusion could be drawn that the trees at five years of age are having a localised effect on this deeper groundwater.

The piezometers measuring fluctuations in the perched aquifer between 0 and 3 m below ground level have become dry. These showed considerable seasonal fluctuations in the first three years, but have been consistently dry except for short periods over winter in the last two years.

Piezometer measuring levels between 5 m and 3 m below ground level have shown reductions in water level to 1.5 m. M21, which is located immediately up-slope of the trees recorded the maximum decrease, while piezometer 19A (which is 200 m downslope) has shown little change over the five years. M26 has dropped 80 cm and is located 100 m downslope. M17, located 150 m downslope, has not significantly decreased.

Demonstration 2 - Broad Based Banks

North Dalwallinu Sub-catchment

Funding source: NSCP 1991

Location: Bob Jackson's Melbourne Location No. 1892

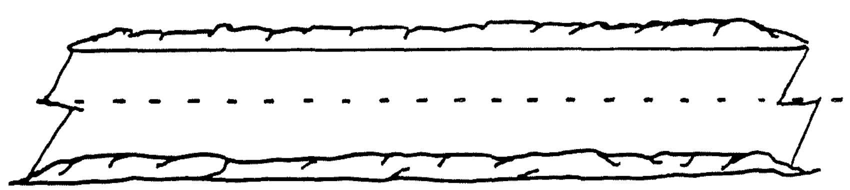
Grade banks are used in soil conservation to intercept and divert run-off into waterways or dams at non-erosive rates. Broad based grade banks have gently sloping batters and channel bottoms, which allow cropping of the bank and channel.

A bank, 600 m in length, was constructed at Bob Jackson's farm near the McLevie Bin. Water is discharged into a dam, the overflow from which leaves the property via culverts under the Great Northern Highway.

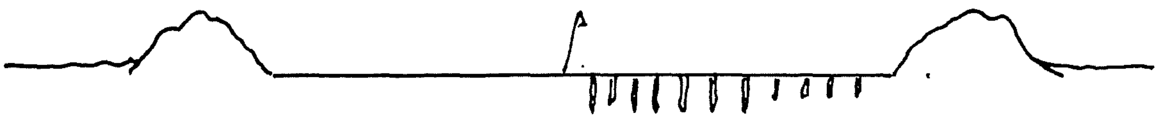
The bank has been under pasture during 1992. Monitoring of crop performance should take place in the near future.

Construction Method

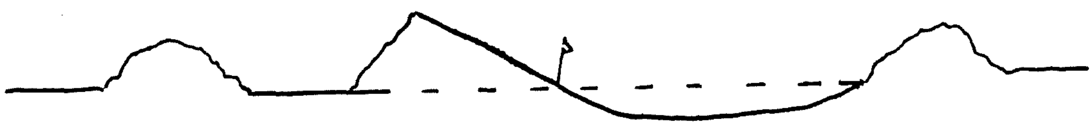
1. The grader is used first to stock pile the topsoil both sides of the surveyed line to a distance of 10 metres.



2. The dozer is then used to rip the channel area of the BBB (i.e. the top side of the survey line).



3. Depending on the size of the dozer the first push (or the first and second push for smaller dozer) is used to push the ripped area in above to the bottom side of the survey line forming the first batter.



4. A second rip may be required at this stage. Again, depending on the size of the dozer, the second or third push, which ever is the case; is pushed up over the first batter supplying soil to form batter two.

5. The grader is then used to shape batter two and smooth and compact the other batters.

6. The grader is then used to respread the topsoil over the construction.

Construction costs for a 600 m broad based bank

CONSTRUCTION PHASE	HOURS DOZER	HOURS GRADER	RATE/HOUR	COST
STOCKPILE TOPSOIL		0:45	$74.00	$55.50
FIRST RIP	0:10		$87.00	$14.50
FIRST PUSH	2:02		$87.00	$176.90
2ND RIP	1:15		$87.00	$108.75
2ND PUSH	3:50		$87.00	$333.51
SHAPE BANK		1:40	$74.00	$123.33
RESPREAD TOPSOIL		1:08	$74.00	$83.87
TOTALS	7:17 =7.28HR	3:33 =3.55HR		$896.36 $896.06

600 m B.B.B. costs $896
1000 m B.B.B. costs $1493

Other broad based bank demonstrations in the area include one at Ballidu (R. Harrington) built with an angle bladed dozer only and one at Buntine (A. Fitzsimons) built with a grader only.

Demonstration 3 - Alley Farming

Damboring Sub-catchment

Funding source: Greening Australia and Landholder

Landholder: M. Quain

Location: Ninghan Location No. 1532 and 91

Area: 80 ha

Aim of project: Demonstrate to neighbours that saltland can be reclaimed using trees to lower the water table.

Background: The land was taken up for agriculture in 1910 by the current owners family. While drilling for water in the early 1920s, the water-table was measured at 22 m b.g.l. on the eastern side of the project area. It has now risen to less than 1 m b.g.l. Salt encroachment became a problem in the 1960s. The southern area was planted unsuccessfully to saltbush by two different contractors in 1988 and 1989 using the Mallen niche technique. Trials with *Atriplex undulata* (wavy leaf saltbush) in 1990 have proved successful.

Current project: Trial plots of various trees were planted to compare suitable species. *Eucalyptus occidentalis* (flat topped yate) *E. kondininensis* (Kondinin blackbutt), *E. loxophleba* (York gum), *Acacia saligna* (golden wattle) and *Atriplex undulata* (wavy leaf) established well. Unfortunately, a locust plague during the summer of 1990/91 ate out these trials.

Rows of *E. occidentalis*, *E. platypus* (coastal moort) and *Acacia saligna* were planted in double rows, 42 m apart in April 1991. Initial growth has been healthy, and the landholder has found that cropping between rows has not been a problem.

Monitoring of the long term effect on the groundwater level will take place with two piezometers that were put in place at the start of the project. It is hoped that the impact of the trees will extend to the East Damboring Road which is currently being damaged by the presence of a high water-table.

4.6 Recommendations

To all landholders

It is evident from section 1.3, sub-catchment issues, that during the farm planning workshops the participants discussed all land degradation issues, the options for their treatment and ways of improving production.

I fully support all of the options for overcoming the farm management problems listed in section 1.3 and recommend them to all landholders in the LCD. During the visits to each property Jenny Borger, myself and others have been putting these options to farmers for consideration in their farm plans. We thank all farmers we have visited for the opportunity to do this.

Most of the work needs to be done on an individual farm basis. However, some work will need the co-operation of neighbours, especially where drainage is concerned.

It is important therefore for landholders to:

- Seek any further information required that will assist implementing the farm plan or help decide on a plan of action.
- Communicate to the LCDC your thoughts on the directions of landcare in this LCD.
- Report your successes and failures in landcare with others at field days and open meetings.
- Seek the LCD committees support for funding of community based and multiple farmer projects.

To the Committee

The committee already has its own set of objectives, as outlined in the foreword, which are completely in line with the recommendations of this report and is actively carrying them out.

I commend the committee on its initiative to start the "Sandplain Seeps Project". Sandplain seeps are a major contributor of water in the regional groundwater which makes this an issue for the whole LCD.

The following recommendations may help the committee to further its objectives.

1. Support farmers in the district with the implementation of their farm plans through providing a knowledge base by:
   - Holding field days and demonstrations that address the practicalities of overcoming the various degradation and management issues.
   - Setting up a resource base whereby landholders can be given the relevant information or a contact.

2. Co-ordinate and implement reclamation programs by:
   - Involving the school and community in propagation and planting of seedlings
     on road reserves and public reserves and sports grounds.
   - Involve the school through Ribbons of Blue to monitor groundwater levels.

3. Identify and protect all remnant vegetation by:
   - Encouraging farmers to fence off remnants either through the Remnant Vegetation Protection Scheme or through a local fence recycling scheme.
   - Coordinating a periodic vermin control program for the whole LCD so that eradication is more complete and effective.

4. Encourage working on the contour and stubble retention by:
   - Applying for a grant to subsidise a landcare technician in the area to survey proposed level lines and earthworks.

5. Define and stabilise water courses:
   - Involve the Dalwallinu Shire Council in planning and improvement of drainage out of the catchment.

APPENDIX 1. AVERAGE MONTHLY RAINFALLS FOR NORTH-EASTERN WHEATBELT CENTRES

KOKARDINE
Mean rainfall for the period 1907 to 1991.

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
12	16	20	22	45	61	56	42	23	16	10	9	332

DAMBORING
Mean rainfall for the period 1936 to 1947.

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
8	23	19	18	42	61	45	36	16	13	11	9	301

PAYNES FIND (NINGHAN STATION)
Mean rainfall for the period 1905 to 1991.

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
17	19	22	22	41	49	42	30	14	11	10	10	287

BALLIDU (POST OFFICE)
Mean rainfall for the period 1910 to 1989.

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
13	16	19	22	45	64	59	43	23	18	10	9	341

MILING (POST OFFICE)
Mean rainfall for the period 1924 to 1991.

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
12	17	19	24	52	73	66	50	26	19	9	9	376

KALANNIE (POST OFFICE)
Mean rainfall for the period 1928 to 1989.

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
12	17	21	23	43	59	48	38	18	14	9	9	311

WUBIN (POST OFFICE)
Mean rainfall for the period 1922 to 1991.

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
11	15	20	21	44	63	54	41	19	14	9	8	319

PITHARA
Mean rainfall for the period 1936 to 1985.

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
11	19	17	22	43	72	62	44	20	14	11	9	344

DALWALLINU (POST OFFICE)
Mean rainfall for the period 1912 to 1991.

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
15	17	23	22	45	69	60	45	24	18	12	10	360

APPENDIX 2. SOIL PROFILE DESCRIPTIONS
(NB. pH estimated with CSIRO pH kit)

Salmon Gum Soil SAL

Northcote:	Gn 2.13 (Calcareous red earth).
Place in toposequence:	Upper slopes, hill crests.
Vegetation:	Salmon gum, York gum, gimlet, *Acacia* sp., Quondong and bluebush.
Location:	Dalwallinu townsite.

Depth (cm)	*Soil Profile Description*
0-7	Dark reddish brown fine sandy clay loam, disturbed layer, massive structure, pH 7.5. Abrupt boundary to
7-15	Dark red light clay with fine sand. Weak sub-angular structure, pH 9. Clear boundary to
15-70	Dark red light clay with many calcium carbonate (lime) concretions, pH 9. Structure grading to
70-120+	Red medium clay pH 9, with fewer carbonate concretions.

Notes:
The soil profile is dominantly red with an increase in clay at 7 cm. The third horizon (15-70 cm) has an increasing amount of carbonate material and has the appearance of pink clay.

The colour and absence of mottling indicate that waterlogging does not occur in this profile. Surface horizons reach depths of 30 cm at some locations.

The surface structure declines under machinery and stock traffic leading to a reduction in infiltration and subsequently more run-off.

The estimated water holding capacity is 130 mm for the top 90 cm.

Colluvial Flat, York gum Soils YG

Australian Great Soil Group:	Red Brown Earth
Northcote:	Dr 2.13
Place in Toposequence:	Lower slopes, upper areas of drainage lines on colluvium.
Vegetation:	Salmon gum, York gum, *Acacia* spp., saltbush and bluebush, few quondong.

Depth (cm)	*Soil Profile Description*
0-3	Dark reddish brown loam, fine crumb structure, pH 6, clear boundary to
3-15	Reddish brown fine sandy loam, massive, pH 7.5 clear boundary to
15-70	Yellowish red sandy clay loam, weak sub-angular blocky structure, with calcium carbonate, pH 9, clear boundary to
70-200	Reddish yellow silty clay, pH 9, grading to
200+	Reddish yellow sandy clay

Notes:

The absence of mottled colours in the upper soil profile indicates that waterlogging does not commonly occur. Even though the profile is classified duplex, the change in texture from loam to sandy loam at the surface to sandy clay loam at 15 cm through to silty clay at 70 cm does not impede drainage to cause waterlogging.

Available moisture for the top 1 m is estimated at 140 mm. In cases where the soil is closer to the bottom slope problems may arise through salts stored in the profile. There is some evidence of salt damage at this site with decreasing viability of the acacias.

The soil structure is aggregated in the surface horizon under natural conditions, but under cultivation structure would be degraded and become massive. At lower depths in the clayey B horizon some peds are evident allowing moderate infiltration of water.

Organic matter levels are good under natural conditions but most cultivated soils would have very low contents. Phosphorus and nitrogen are also low, but potassium levels are usually adequate.

The decline in surface structure under cultivation may lead to emergence problems for crops and pastures. Gypsum response is not predictable and trial areas should be tested first. This soil type should respond well to reduced cultivation techniques, stock control and improved pastures.

Alluvial Sand over Silcrete ASSI

Northcote:	Gn 1.25
Place in Toposequence: with	Valley floors in upper drainage areas, associated catchments dominated by deep yellow sands.
Vegetation:	*Eucalyptus transcontinentalis, Melaleuca* sp., tussock grasses - Low open woodland.

Depth (cm)	*Soil Profile Description*
0-5	Dark brown clayey sand, fine crumb structure, pH 6 clear boundary to
5-15	Yellowish brown clayey sand massive, pH 6.5 clear boundary to
15-40	Yellowish brown sandy loam pH 6.5 weak crumb structure, grading to
40-70	Yellowish brown light sandy clay loam pH 6, massive structure, grading to
70-170	Yellowish brown LSCL with layers of lateritic gravel cemented with silcrete
170	Silcrete with some nodules of iron and magnesium

Notes:

Drainage in this profile would be rapid in the top 70 cm, but impeded after 70 cm due to the cemented silcrete and lateritic layers. Root penetration is also impeded by these layers. Waterlogging is a problem seasonally.

The non-wetting characteristics of the surface horizon may become more pronounced under cultivation, reducing infiltration rates and leading to poor crop growth.

Deep Yellow Sand **DYS**

Australian Great Soil Group: Yellow Earth
Northcote: Uc 5.22
Location: Dalwallinu West Road rubbish dump
Place in Toposequence: Generally upper slopes
Vegetation: Mallee - *Eucalyptus pyriformis* (Dowerin Rose) *Casuarina* sp., *Dryandra* sp., acacias, *Callitris* (native pine) and woody pear

Depth (cm)	*Soil Profile Description*
A1 0-5	Dark brown loamy sand, pH 6 fine crumb aggregates, clear boundary to
A1 0-10	Yellowish brown sand, massive, pH 7 clear boundary to
B1 10-30	Brownish yellow clayey sand pH 6, massive, diffuse boundary to
B2 30-300+	Yellow clayey sand pH 6.5 with layers of gravel at 1 m and 2 m

Notes:
High in organic matter in the surface horizon, rapidly decreasing in the lower horizons.

The A1 is non-wetting and results in high run-off initially.

Drainage throughout the profile is good. Plant available water in the top 170 cm is estimated at 171 mm, of which 73 mm is in the top metre of soil, which is low.

Soil structure is massive throughout except for fine aggregates in the surface. These would breakdown under cultivation.

The soil is typically very low in organic matter, phosphorus and nitrogen. Potassium levels are generally adequate pH is only slightly acid and does not indicate problems for crops and pastures.

A hard pan will often form as a result of cultivation practices and is usually present at 10-15 cm below the surface. Root penetration is impeded, and water infiltration may be reduced. These problems can overcome by deep ripping, minimising cultivation and good management of stock.

Pediment **SG**

Earthy sand-gravel variety - Gravelly sands over truncated laterite.
Australian Great Soil Group: Lateritic Podzolic?
Northcote: Ks Uc 5.23
Local Name: Sandy gravels
Location: Rob Sawyers, Dalwallinu - Kalannie Road
Place in Toposequence: Midslopes derived from colluvium
Vegetation: *Eucalyptus leptopoda, Acacia* spp.

Depth (cm)	*Soil Profile Description*
0-20	Dark yellowish brown sandy loam, cultivated layer, apedal with many lateritic gravel pH 5 gradual boundary to
20-25	Yellowish brown fine sandy loam, apedal with much gravel pH 4.5 abrupt boundary to
25-35/70	Unconsolidated gravel pH 5.5 abrupt boundary to
35/70 - +	Duricrust

Notes:
Roots following pockets of unconsolidated laterite down to duricrust.

Data (Park feeds - similar site)
(Surface)

pH	P	K	Mg	Ca	Na
4.6	18	74	280	1600	650
	Deficient	Marginal	Normal	Optimal	>Optimal <Toxic

Cu	Zn	Fe	Mn
0.5	0.5	25	2.9
Latent Deficiency	Latent Deficiency	Normal	Deficient

Organic Matter - low
Total N - very low (440)

These soils are porous, becoming massive when dry. The high content of loose gravel (>60%) lends to rapid infiltration in the upper horizons. Internal drainage may be restricted by the underlying laterite causing occasional saturation above.

These soils have formed on old strongly weathered parent materials and are usually low in phosphorus nitrogen and potassium. Trace element deficiencies are likely in Molybdenum and copper.

Gravel Pit **SSL, SG**

Place in Toposequence: Upper drainage line

There are a number of phases here ranging from shallow soil over laterite to sand over gravel. This grades into a deep yellow sand eventually.

The laterite is very close to the surface on the southern side of the road.

The presence of a shallow water-table is indicated on the eastern side, with water and evaporite (salts) at 2-3 m, exposed on the base of the excavated gravel.

This area would be underlain by the pallid zone which is clay and high in stored salts.

Wodjil **DYS-W**

Australian Great Soil Group: Yellow Earth
Northcote: Uc 5.22
Place in Toposequence Upper Slopes
Location: Park Feeds
Vegetation: Wodjil (*Acacia* sp.) and sugar brother (*Acacia* sp.)

Depth (cm)	*Soil Profile Description*
0-5	Dark yellowish brown sand, cultivated, apedal pH 5, gradual boundary to
5-15	Dark yellowish brown loamy sand, weak crumb structure, pH 5 abrupt boundary to
15-70	Yellowish brown clayey sand, massive structure, earthy fabric, pH 4.2 gradual boundary to
70-200	Brownish yellow clayey sand, massive structure, with few red mottles and faint white mottles pH 4.5

Note:
Some profiles may have more clay in the lower horizons up to a texture of sandy clay loam. However, this will have minimal impact on drainage which is moderately rapid at the surface and good in the lower profile.

The soil can hold an estimated 200-220 mm of plant available water in the top 2 metres. The bright soil colour and absence of significant amounts of mottled colours confirm that the soil has good internal drainage and therefore not subject to waterlogging.

The soil profile is apedal throughout except for minimal aggregation within the A horizon. The soil is strongly acid in reaction throughout the profile. These acid conditions are natural and present in the virgin state. Fertiliser application can accentuate the acidity problem.

Data (Compliments of Park feeds)
(Surface)

pH (water)	P(ppm)	K	Mg	Ca	Na
4.4	19 Deficient	32 Acute Deficiency	260 Normal	1300 Normal	720 >Normal

Cu	Zn	Fe	Mn
0.2	0.4	Normal	1.1
Deficiency	Latent Deficiency	21	Acute Deficiency

Organic Matter - very low 7%
Total N - very low 210

(Hardpan - Park Feeds) **RBE**

Upper slope - Eastern Face
Australian Great Soil Group:
Northcote: Duplex
Vegetation: Eucalyptus woodland, *Grevillea* spp.

Depth (cm)	*Soil Profile Description*
0-10	Yellowish brown loam, fine sandy with fine crumb structure pH 6.5 clear boundary to
10-20	Yellowish brown loam, fine sandy with weak lenticular structure pH 7 abrupt boundary to
20-40	Compacted gravelly layer gradual boundary to (Man induced)
40-65	Yellow light clay pH 8. Gradual boundary to
65-120	Yellowish red light clay with many carbonate concretions pH 10
120+	Reddish brown light clay (no Ca CO_3 concretions) pH 8.5

Note: Few roots occur below compaction layer.
The soil type is not typical of any classification group and appears to be a buried red brown earth typified by the red clays at depth and prominent Ca CO_3 layer.

The loamy A horizons and yellow colour in the light clays beneath the compaction layer could be derived from wind blown material from the yellow earthy sandy (wodjil) from the other slope.

The compaction layer is mostly gravel which has cemented at depth, and has formed through cultivation techniques. It impedes root penetration as well as water infiltration. The compaction layer would respond well to deep ripping improving drainage and root penetration. Soil moisture storage would also be improved.

Alluvial Flat - Alluvial sand over clay SC

Australian Great Soil Group:	Solodic over truncated laterite
Northcote:	Dy 5.13 (5.43)
Location:	Roach's - Dalwallinu-Kalannie Road
Vegetation:	*Melaleuca, Eucalyptus* spp.

Depth (cm)	*Soil Profile Description*
0-7	Dark brown loamy sand apedal, cultivated layer, pH 7, gradual boundary to
7-20	Yellowish brown loamy sand apedal pH 6.43 clear boundary to
20-40	Olive grey sandy clay loam weak sub-angular blocky to lenticular structure pH 7.5 red mottles clear boundary to
40-180+	Light grey sandy clay, weak structure with cracks forming upon drying pH 8. Water entering profile at 180 cm may indicate laterite close by (~200 cm)

Note:
The soil profile changes sharply in texture at 20 cm. Mottled soil colours increase with depth and are indicative of waterlogging, caused by impeded drainage through the soil and saturated conditions at depth due to a high groundwater table.

The profile would have 100-120 mm of plant available water, but high concentrations of salt in the subsoil would reduce this considerably.

From figures collected at a similar site at Kalannie organic matter is generally low, phosphorus was deficient, potassium was normal and nitrogen (nitrates) low)

APPENDIX 3. APPROXIMATE UPPER SALINITY LIMITS FOR THE USE OF WATER FOR ANIMALS, PLANTS AND DOMESTIC USE

Animals and Domestic Use Upper limits	mS/m	mg/L-ppm TSS	gr/gal. TSS	Plants
				Pecan Nuts
	50			
	80	440	30	White Clover
	100			
	200			Lovegrass, Oats,
	210			Wheat, Lucerne
	220			
	230			
	240			
Humans	250	1375	96	
	260			Barley
	270			Tall Wheat Grass,
	280			*Eucalyptus spathulata,*
	290			*E. camaldulensis,*
	300			*E. loxophleba,*
	400			*E. kondininensis*
	500			
	550	3025	212	
Pigs	600			
	700	3850	269	
Horses,	800			
Lambs,	900			
Weaners,	1000	5500	385	
	1100	6050	423	Puccinellia,
	1200			*Eucalyptus sargentii,*
	1300			*Casuarina obesa,*
	1400			Tamarisk,
Beef Cattle	1500			Saltbushes,
	1600			*Acacia saligna*
	1650	9075	635	
	1700			
Adult Sheep	1800			
	1900			
	2000	11000	770	
	2100			
	2200	12100		

Results of water analysis are quoted at 25°C.
mS/m x 5.5 = mg/L (ppm) TSS
mS/m x 0.385 = gr/gal. TSS

APPENDIX 4. RECOMMENDED TREE SPECIES FOR REVEGETATING THE FARM.
Courtesy Max and Angela Waters

HIGH WATER USE - SEEPAGE AREAS	HEIGHT	NOTES
Eucalyptus botryoides (Bangalay)	20m	Sandplain seepage areas
Eucalyptus rudis (Flooded Gum)	12-15m	Favours poorly drained soils - salt
Eucalyptus camaldulensis (River Gum)	15-20m	Versatile - fast growing
Eucalyptus cladocalyx var *nana* (Sugar Gum)	6-7m	Shelter
Eucalyptus leucoxylon (SA Bluegum)	7-10m	Good shade & shelter
SALT TOLERANT		
Casuarina obesa (Swamp Sheoak)	10-15m	Tolerates swampy conditions
Eucalyptus spathulata (Swamp Mallet)	8m	Rapid growing attractive tree
Eucalyptus sargentii (Salt River Gum)	10-12m	Good shade - Wide range soils
Eucalyptus occidentalis (Flat Topped Yate)	10-12m	Rapid growth - Saltland reclamation
Eucalyptus kondininensis (Kondinin Blackbutt)	12m	Extreme salt & drought tolerance
Eucalyptus platypus var *heterophylla* (Coastal	5m	Bushy low windbreak
Moort)	10-12m	Grows around our local saltlakes
Eucalyptus salicola (Salt Gum)	6-7m	Tolerates wet feet
Melaleuca cuticularis (Saltwater Paperbark)	3-4m	Local - grows in saltlakes
Melaleuca thyoides	3-4m	Local - grows around saltlakes
Melaleuca uncinata		
CLFe COLLUVIAL FLAT - RED BROWN EARTH		
Eucalyptus yilgarnensis (Yorrel)	8m	Mallee or tree form - Shade
Eucalyptusbrachycorys	6-8m	Grows well in wet depressions
Eucalyptus salmonophloia (Salmon Gum)	20-30m	Shelter belt - Handsome
Eucalyptus loxophleba (York Gum)	10-12m	Shallow soil - Fast growing
Eucalyptus transcontinentalis (Redwood)	8-12m	Shade & shelter
Eucalyptus myriadena	5-8m	Some salt tolerance
Eucalyptus erythronema (Red Flowering Mallet)	5m	Light shade - Showy
Eucalyptus salubris (Gimlet)	10m	Elegant tree
Eucalyptus torquata (Coral Gum)	5-8m	Low windbreak - Attractive
DYS DEEP YELLOW SAND & WODJIL		
Eucalyptus leptopoda (Tammin Mallee)	2-3m	Excellent windbreak
Eucalyptus burracoppinensis (Burracoppin Mallee)	2-4m	Spreading tree - Windbreak
Eucalyptus eremophila (Tall Sand Mallee)	5m	Slender stems - Bush crown
Eucalyptus kochii (Oil Mallee)	5m	Oil potential - Bushy crown
Eucalyptus capillosa var *polyclada* (Mallee Wandoo)	5-8m	Variable soil - Local
Eucalyptus *hypochlamydea* (White Flowered Mallee)	5m	Windbreak - local
Acacia SPECIES		
SG SAND OVER GRAVEL		
Eucalyptus burracoppinensis (Burracoppin Mallee)	2-4m	Spreading tree - Windbreak
Eucalyptus ceratocorys	5-7m	Mallee - Umbrella crown
Eucalyptus oldfieldii (Oldfields Mallee)	2-4m	Similar to Burracoppin Mallee
Eucalyptus capillosa var *polyclada* (Mallee Wandoo)	5-8m	Variable Soil - Local
SSg & SSI SHALLOW SOIL OVER GRANITE		
Eucalyptus stowardii (Fluted Horn Mallee)	5-8m	Hardy & attractive
Eucalyptus capillosa var *capillosa* (Inland Wandoo)	5-8m	Shelter belt - Handsome
Eucalyptus capillosa var *polyclada* (Mallee Wandoo)	10-15m	Variable soil - Local Mallee
Eucalyptus astringens (Brown Mallet)	12m	Tall tree with erect branches
RBE RED BROWN EARTH		
Eucalyptus salmonophloia (Salmon Gum)	20-30m	Shelter belt - Handsome
Eucalyptus salubris (Gimlet)	10m	Elegant tree
Eucalyptus loxophleba (York Gum)	10-12m	Shallow soil - Fast growing
Eucalyptus yilgarnensis (Yorrel)	8m	Shade - Mallee or tree form
Eucalyptus brachycorys	6-8m	Local Mallee - Shade windbreak
Eucalyptus transcontinentalis (Redwood)	8-12m	Tall shade & shelter
Eucalyptus torquata (Coral Gum)	5-8m	Low windbreak - Attractive
Eucalyptus brockwayii (Dundas Mahogany)	15m	Tall windbreak & shade
ASC ALLUVIAL FLAT - SAND OVER CLAY		
Eucalyptus loxophleba (York Gum)	10-12m	Shallow soil - Fast growing
Eucalyptus longicornis (Morrel)	up to 30m	Tough - some salt tolerance

APPENDIX 5. PLANT LIST FOR PITHARA-DALWALLINU LCD

GYMNOSPERMS	
CUPRESSACEAE (cypress)	*Actinostrobus arenarius*
ANGIOSPERMS (flowering plants) Monocotyledons	** introduced species*
POACEAE (grasses)	*Amphipogon debilis* ** Briza maxima*
CYPERACEAE (sedges)	*Chrysitrix distigimatosa* *Gahnia affin polyphylla* *Lepidosperma gracile* *L. tenue* *L. resinosum* *Mesomelaena sp.* *Schoenus affin compressus* *S. affin sub bulbous* *Schoenus sp.*
RESTIONACEAE (sedges)	*Ecdeicolea* *monostachya* *Harperia laterifolia* *Lepidobolus preissianus*
LILIACEAE (Lilles)	*Borya nitida* *Borya sphaerocephala* *Dianella revoluta* *Lomandra effusa*
IRIDACEAE	*Patersonia drummondii*
ORCHIDACEAE (orchids)	
DICOTYLEDONS	
APIACEAE	*Platysace effusa* *Platysace commutata* *Platysace maxwellii*
APOCYNACEAE	*Alyzia buxifolia*
ASTERACEAE	**Arctotheca calendula* ** Dittrichia graveolens* *Helipterum sp.* *Olearia muelleri* *O. revoluta*
BORAGINACEAE	*Halgania sp.*
CAESALPINIACEAE (cassias)	*Cassia charlesiana*

CASUARINACEAE	*Allocasuarina acutivalvis* *A. campestris* *A. corniculata* *A. huegliana*
CHENOPODIACEAE (saltbush)	*Atriplex semibaccata* *Enchylaena tomentosa* *Maireana tomentosa* *Maireana brevifolia* *Rhagodia preissii*
CHLOANTHACEAE	*Pityrodia terminalis*
DILLENIACEAE	*Hibbertia aff. eatoniae* *H. glomerosa*
EPACRIDACEAE	*Astroloma serratifolium* *Leucopogon humulosus*
EUPHORBIACEAE	*Beyeria lechenaultii*
GOODENIACEAE	*Lechenaultia sp.*
GYROSTEMONACEAE	*Condonocarpus cotinifolius*
HALORAGACEAE	*Glischrocaryon aureum*
LAMIACEAE	*Hemigenia sp.* *H. west ringiodioides* *Westringia discipulorum*
LAURACEAE	*Cassytha glabella*
MALVACEAE (hibiscus)	*Alyogyne hakeifolia*
MIMOSACEAE (wattles)	*Acacia assimilis* *A. aff bidentata* *A. acuminata* *A. acuraria* *A. colletioides* *A. coolgardiensis* *A. daviesioides* *A. densiflora* *A. desertorum* *A. dielsii* *A. erinacea* *A. fragilis* *A. graffiana* *A. hemiteles* *A. heteroneura* *A. aff flabellifolia* *A. lineolata* *A. mackayana* *A. aff microbotrya* *A. microbotrya* *A. merrallii* *A. neurophylla* *A. neurophylla* *A. resinomarginea*

A. signata
A. steriophylla

MYOPORACEAE	*Eremophila clarkii* *E. aff alternifolia* *E. aff decipiens* *E. oppositifolia*
MYRTACEAE	*Baechea crispiflora* *B. aff cryptandroides* *B. muricata* *Calothamnus gilesii* *Calytrix angulata* *Eucalyptusdrummondii* *E. erythronema var marginata* *E. foecunda* *E. leptopoda* *E. loxophleba* *E. oldfieldii* *E. redunca var subangusta* *E. salmonophloia* *E. salubris* *E. stowardii* *E. transcontinentalis* *Leptospermum erubescens* *Malleostemon roseus* *Melaleuca conothamnoides* *M. cordata* *M. eleuterostachya* *M. filifolia* *M. laxiflora* *M. aff pentagona* *M. aff scabra* *M. subtrigona* *M. uncinata* *Micromyrtus imbricata* *Thryptomene kochii* *T. australis* *Thryptomene cuspidata* *V. brownii* *Verticordia brachypoda* *V. monodelpha* *V. chrysantha* *V. drummondii* *V. spicata*
PAPILIONACEAE (peas)	*Davesia cardiophylla* *D. hakeoides* *Gastrolobium spinosum var grandiflorum* *Jacksonia foliosa* *J. rhadinoclada* *Leptosema tomentosum* *Mirbelia trichocalyx* *Pultenaea capitata* *Templetonia sulcata*
PROTEACEAE	*Banksia benthamiana* *Conospermum brownii* *Grevillea eriostachya* *G. eryngioides*

	G. excelsior
	G. integrifolia
	G. paniculata
	G. paradoxa
	G. petrophiloides
	G. tenviloba
	Hakea circumalata
	H. coriacea
	H. falcata
	H. minyma
	H. scoparia
	H. sukata
	Isopogon divergens
	I. scabriusculus
	Persoonia coriacea
	P. rufiflora
	P. saundersiana
	P. striata
	Petrophile drummondii
	P. incurvata
	P. macrostachya
	P. ericifolia
	P. shuttleworthiana
	P. seminuda
RHAMNACEAE	*Cryptandra nutans*
	Spyridium complicatum
RUTACEAE	*Drummondita hassellii*
	Eriostemon deserti
	E. thryptomenoides
	Phebalium ambiguum
	P. microphyllum
	P. fifolium
	P. tuberculosum
	Philotheca drummondita
	P. hassellii
SANTALACEAE	*Choretum pritzelli*
	Exocarpus spartcus
	Leptomeria sp.
	Santalum acuminatum
	S. spicatum
SAPINDACEAE	*Dodonaea bursarifolia*
	D. viscosa ssp angustissima
SOLANACEAE	*Solanum hoplopetalum*
	S. lasiophyllum
STERCULIACEAE	*Keraudrenia integrifolia*

APPENDIX 6. BIRDS OF THE DALWALLINU AREA

Compiled by Gordon McNeill from "Birds of the Central Wheatbelt of Western Australia" - a survey conducted by Dr Denis Saunders, CSIRO; and "Biological Survey of the Western Australian Wheatbelt" Part 10 by the Western Australian Museum.

Common Name	**Scientific Name**
Emu	*Dromaius novaehollandiae*
Hoary-headed grebe	*Poliocephalus poliocephalus*
White-necked heron	*Ardea pacifica*
White-faced heron	*Ardea novaehollandiae*
Mountain duck	*Tadorna tadornoides*
Black duck	*Anas superciliosa*
Grey teal	*Anas gibberifrons*
Pink-eared duck	*Malacorhynchus membranaceus*
Wood duck	*Chenonetta jubata*
Black-shouldered kite	*Elanus notatus*
Whitstling kite	*Haliastur sphenurus*
Brown goshawk	*Accipiter fasciatus*
Collared sparrowhawk	*Accipter cirrhocephalus*
Wedge-tailed eagle	*Aquila audax*
Little eagle	*Hieragetus morphnoides*
Black falcon	*Falco subniger*
Peregrine falcon	*Falco peregrinus*
Little falcon	*Falco berigora*
Nankeen kestrel	*Falco cenchroides*
Mallee fowl	*Leipoa ocellata*
Stubble quail	*Coturnix pectoralis*
Little button quail	*Turnix velox*
Banded plover	*Vanellus tricolor*
Australian dotterel	*Charadrius ruficapillus*
Red-capped dotterel	*Peltohyas australis*
Pied stilt	*Himan topus himantopus*
Red-necked avocet	*Recurvirostra novaehollandiae*
Domestic pigeon	*Columba livia*
Crested pigeon	*Ocyphaps lophotes*
Red-tailed black cockatoo	*Calyptorhynchus magnificus*
Galah	*Cacatua roseicapilla*
Long-billed corella	*Cacatua tenuirostris*
Cockatiel	*Nymphicus hollandicus*
Budgerygah	*Melopsittacus undulatus*
Port Lincoln parrot	*Barnardius zonarius*
Mulga parrot	*Psephotus varius*
Elegant parrot	*Neophema elegans*
Pallid cuckoo	*Cuculus pallidus*
Black-eared cuckoo	*Chrysococcyx osculans*
Horsfield's bronze cuckoo	*C. basalis*
Boobook owl	*Ninox novaeseelandiae*
Barn owl	*Tyto alba*
Tawny frogmouth	*Podargus strigoides*
Owlet-nightjar	*Aegotheles cristatus*
Spotted nightjar	*Caprimulgus guttatas*
Red-backed kingfisher	*Halcyon pyrrhopygia*
White-backed swallow	*Cheramoeca leucosternum*
Welcome swallow	*Hirundo neoxena*
Tree martin	*Cecropis nigricans*
Fairy martin	*C. ariel*
Richards' pipit	*Anthus novaeseelandiae*
Black-faced cuckoo-shrike	*Coracina novaehollandiae*

Red-capped robin	*Petroica goodenovii*
Yellow robin	*Eopsaltria australis*
Rufous whistler	*Pachycephala rufiventris*
Golden whistler	*P. pectoralis*
Grey shrike-thrush	*Colluricincla harmonica*
Crested bellbird	*Oreoica gutturalis*
Grey fantail	*Rhipidura fuliginosa*
Willie wagtail	*R. leucophrys*
Southern scrub robin	*Drymodes brunneopygius*
White-browed babbler	*Pomatostomus superciliosus*
Western warbler	*Gerygone fusca*
Brown songlark	*Cinclorhamphus cruralis*
White-winged wren	*Malurus leucopterus*
Weebill	*Smicrornis brevirostris*
Chesnut-rumped thornbill	*Acanthiza uropygialus*
Brown thornbill	*A. pusilla*
Yellow-rumped thornbill	*A. chrysorrhoa*
Red wattlebird	*Anthochaera carunculata*
Redthroat	*Pyrrholaemus brunneus*
Yellow-throated miner	*Manorina flavigula*
Shy hylacola	*Hylacola cauta*
Singing honeyeater	*Lichenostomus virescens*
White-eared honeyeater	*L. leucotis*
White-fronted honeyeater	*Phylidonyris albifrons*
Calamanthus	*Calamanthus fuliginosus*
Blue breasted fairy wren	*Malurus pulchirrimus*
Brown honeyeater	*Lichmera indistincta*
Brown-headed honeyeater	*Melithreptus brevirostrus*
Spiny-cheeked honeyeater	*Acanthagenys rufogularis*
Grey-breasted silvereye	*Zosterops lateralis*
White-fronted chat	*Ephthianura albifrons*
Striated pardalote	*Pardalotus striatus*
Zebra finch	*Peophila guttata*
Australian magpie lark	*Grallina cyanoleuca*
Masked wood swallow	*Artamus peronatus*
Black-faced wood swallow	*A. cinereus*
Grey butcherbird	*Cracticus torquatus*
Pied butcherbird	*C. nigrogularis*
Australian magpie	*Gymnorhina tibicen*
Grey currawong	*Strepera versicolor*
Australian raven	*Corvus coronsides*
Little crow	*C. bennetti*
Black-tailed native hen	*Gallinula ventralis*
Rainbow bee-eater	*Merops ornatus*

APPENDIX 7. MAMMALS OF THE PITHARA-DALWALLINU LCD

	F	RR	NR	BUR
Echidna *(Tachyglossus aculeatus)*	*	*	*	*
Western grey kangaroo *(Macropus fuliginosus)*	*		*	*
Euro *(M. robustus)*				* *skull*
Red kangaroo *(Megalea rufus)*	*	*	*	
Common dunnart *(Sminthopsis murina)*	*		*	*
Mitchell's hopping mouse *(Notomys mitchelli)*	*		*	*
Lesser long-eared bat *(Nyctophilus geoffroyi)*			*	
Gould's wattled bat *(Chalinolobus gouldii)*				*
Little broad-nosed bat *(Nycticeius greyi)*			*	
White striped mastiff bat *(Tadarida australis)*				*
House mouse *(Mus musculus)*	*		*	*
Fox *(Vulpes vulpes)*	*	*	*	*
Domestic cat *(Felis catus)*	*	*		*
European rabbit *(Oryctolagus cuniculus)*	*	*	*	*
Dingo *(Canis familiaris dingo)*		*		

F = farm sighting
RR = road verge
NR = Nugadong Reserve
BUR = Buntine Water Reserves

APPENDIX 8. REPTILES AND AMPHIBIANS OF THE PITHARA-DALWALLINU LCD

Amphibia	NR	BUR
Burrowing frog *(Heleioporus albopunctatus)*		*
Trilling frog *(Neobatrachus centralis)*		*
Humming frog *(N. pelobatoides)*		*
Shoemaker frog (N. *sutor)*	*	
Gunther's toadlet *(Pseudophryne guentheri)*	*	*

Reptilia	NR	BUR
Gekkonidae (Geckos)		
Crenadactylus ocellatus		*
Diplodactylus maini	*	*
D. pulcher	*	*
D. granoriensis	*	*
Tree Dtella *(Gehyra variegata)*	*	*
Bynoe's Gecko *(Herternotia binoei)*	*	*
Reticulated velvet gecko *(Oedura reticulata)*		*
Pygopodidae *(Snake-like lizards)*		
Delma australis		*
D. grayii		*
Burton's snake lizard *(Lialis burtonis)*	*	
Agamidae (Dragons)		
Dwarf bearded dragon *(Amphibolurus minor)*		*
Lozenge-marked dragon (A. *scutulatus)*	*	*
Thorny devil *(Moloch horridus)*	*	*
Scincidae (Skinks)		
Cryptoblephanus plagiocephalus	*	*
Ctenotus schomburgkii	*	
C. uber	*	
Desert skink or Rosen's skink *(Egernia inornata)*		*
Gidgee skink *(E. stokesii)*		*
Lerista distinguenda		*
L. muelleri		*
Minitia greyii	*	*
Western blue-tongued lizard *(Tiliqua occipitales)*		*
Shingle-back *(Trachydosaurus rugosus)*	*	*
Elapidae (Snakes)		
Western brown or guardar *(Pseudonaja nuchalis)*	*	*
Rosen's snake *(Denisonia fasciata)*		*
D. monachus		
Bandy bandy	Farm sighting	