1-1-2003

Albany eastern hinterland: catchment appraisal 2002

A T. Ryder
L Crossing

Follow this and additional works at: http://researchlibrary.agric.wa.gov.au/rmtr

Part of the Natural Resources Management and Policy Commons, and the Water Resource Management Commons

Recommended Citation

This report is brought to you for free and open access by Research Library. It has been accepted for inclusion in Resource Management Technical Reports by an authorized administrator of Research Library. For more information, please contact jennifer.heathcote@agric.wa.gov.au, sandra.papenfus@agric.wa.gov.au.
IMPORTANT DISCLAIMER

This document has been obtained from DAFWA’s research library website (researchlibrary.agric.wa.gov.au) which hosts DAFWA’s archival research publications. Although reasonable care was taken to make the information in the document accurate at the time it was first published, DAFWA does not make any representations or warranties about its accuracy, reliability, currency, completeness or suitability for any particular purpose. It may be out of date, inaccurate or misleading or conflict with current laws, polices or practices. DAFWA has not reviewed or revised the information before making the document available from its research library website. Before using the information, you should carefully evaluate its accuracy, currency, completeness and relevance for your purposes. We recommend you also search for more recent information on DAFWA’s research library website, DAFWA’s main website (https://www.agric.wa.gov.au) and other appropriate websites and sources.

Information in, or referred to in, documents on DAFWA’s research library website is not tailored to the circumstances of individual farms, people or businesses, and does not constitute legal, business, scientific, agricultural or farm management advice. We recommend before making any significant decisions, you obtain advice from appropriate professionals who have taken into account your individual circumstances and objectives.

The Chief Executive Officer of the Department of Agriculture and Food and the State of Western Australia and their employees and agents (collectively and individually referred to below as DAFWA) accept no liability whatsoever, by reason of negligence or otherwise, arising from any use or release of information in, or referred to in, this document, or any error, inaccuracy or omission in the information.
Resource Management Technical Report 242

Albany Eastern Hinterland
CATCHMENT APPRAISAL 2002

Compiled by
Tim Overheu

Disclaimer
While all reasonable care has been taken in the preparation of the material in this document, the Western Australian Government and its officers accept no responsibility for any errors or omissions it may contain, whether caused by negligence, or otherwise or for any loss, however caused, sustained by any person who relies on it.

© Chief Executive Officer of the Department of Agriculture 2003
# CONTENTS

<table>
<thead>
<tr>
<th>SECTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUMMARY</td>
<td>v</td>
</tr>
<tr>
<td>1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2. NATURAL RESOURCE BASE</td>
<td>1</td>
</tr>
<tr>
<td>2.1 Climate</td>
<td>1</td>
</tr>
<tr>
<td>2.2 Geology</td>
<td>4</td>
</tr>
<tr>
<td>2.3 Soil-landscape information</td>
<td>4</td>
</tr>
<tr>
<td>2.4 Hydrology</td>
<td>7</td>
</tr>
<tr>
<td>2.5 Native vegetation</td>
<td>10</td>
</tr>
<tr>
<td>2.6 Land use and agricultural production</td>
<td>11</td>
</tr>
<tr>
<td>2.7 Infrastructure</td>
<td>12</td>
</tr>
<tr>
<td>2.8 Demographics</td>
<td>13</td>
</tr>
<tr>
<td>3. RESOURCE CONDITION AND FUTURE RISK</td>
<td>13</td>
</tr>
<tr>
<td>3.1 Climate change</td>
<td>13</td>
</tr>
<tr>
<td>3.2 Soil degradation risk</td>
<td>14</td>
</tr>
<tr>
<td>3.3 Hydrological risk</td>
<td>16</td>
</tr>
<tr>
<td>3.4 Vegetation condition and risk</td>
<td>18</td>
</tr>
<tr>
<td>3.5 Agricultural production</td>
<td>19</td>
</tr>
<tr>
<td>3.6 Infrastructure</td>
<td>20</td>
</tr>
<tr>
<td>4. MANAGEMENT OPTIONS AND IMPACTS</td>
<td>20</td>
</tr>
<tr>
<td>4.1 Land management</td>
<td>20</td>
</tr>
<tr>
<td>4.2 Water management</td>
<td>30</td>
</tr>
<tr>
<td>4.3 Productive use and rehabilitation of saline land</td>
<td>37</td>
</tr>
<tr>
<td>4.4 Economic analysis of management options</td>
<td>38</td>
</tr>
<tr>
<td>5. CONCLUSIONS</td>
<td>41</td>
</tr>
<tr>
<td>6. REFERENCES</td>
<td>42</td>
</tr>
<tr>
<td>7. APPENDICES - MAPS</td>
<td>46</td>
</tr>
<tr>
<td>A1.1 Soil-landscape map for the Albany eastern hinterland area</td>
<td></td>
</tr>
<tr>
<td>A1.2 Land monitor: Current salinity and unproductive land</td>
<td></td>
</tr>
<tr>
<td>A1.3 Land monitor: Potential waterlogging and areas prone to salinity</td>
<td></td>
</tr>
</tbody>
</table>
SUMMARY

Soil degradation on farmland reduces agricultural production and damages infrastructure and natural resources such as remnant vegetation, waterways and wetlands.

While dryland salinity, waterlogging and soil erosion cause serious environmental problems in Australia, several other forms of soil degradation are of concern such as water repellence, wind erosion and soil acidity. Dryland salinity will increase as watertables continue rising, decreasing the value of agricultural land and reducing agricultural production.

The objective of Rapid Catchment Appraisal (RCA) is to assess the condition of, and future risks to, agricultural and natural resources within regional geographic catchments. The process also attempts to identify the most suitable options to manage the risk.

- The study area covers approximately 105,000 hectares in the eastern portion of the Albany shire, on the South Coast of Western Australia.
- Geology is characterised by aeolian sands deposited over tertiary sediments overlying granites and granite-gneiss.
- The area is dominated by grey sandy duplex soils, duplex sandy gravels, pale deep sands and semi-wet soils also being common.
- The soils are susceptible to soil acidification, water repellence, wind erosion and prolonged waterlogging.
- Hydrology is influenced by the low hydraulic gradient underneath the sandplain, salt-lakes, granitic highs and landscape dissection along the Pallinup; the area is mainly affected by perched watertables.
- The degradation risks are:
  - Current salinity - 1,200 ha (1 per cent of the area).
  - Susceptibility to water repellence - approximately 75 per cent of the area.
  - Susceptibility to waterlogging - approximately 58 per cent of the area.
  - Susceptibility to soil acidity - approximately 55 per cent of the area.
  - Susceptibility to wind erosion - approximately 50 per cent of the area.
- Approximately 20 per cent of the original vegetation remains within the study area.
1. INTRODUCTION

The Albany Eastern Hinterland appraisal area is located to the far east of the Albany Shire, is approximately 104,770 ha in size and covers the Gnowellen, Pendernup and Sandplain East landcare subcatchments (Figure 1.2).

The area has a recognised history of innovative landcare activity.

Figure 1.2. The Study area illustrating the three landcare activity areas (Gnowellen, Pendernup and Sandplain East).

The western portion of the study area has subdued topography and sandplain soils, while the western portion of the study area has a more dissected landscape with many breakaways. The area is severely affected by the land degradation hazards of wind erosion, water repellence, soil acidity, and has a moderately high risk of salinity and waterlogging.

2. NATURAL RESOURCE BASE

2.1 Climate

The region has a Mediterranean climate with cool, wet winters and dry hot summers. The annual average rainfall on the coast (Albany East to Denmark West) ranges between 800 to 1100 mm, which then decreases with distance inland (Figure 2.1.1).

Climate change will have a significant impact on agriculture for the region. The changes that have already occurred (from Foster, 2002a and personal observation) include:
- below average seasonal rainfall;
- rainfall decline early in the growing season;
- fewer rain days and a greater proportion of rain from daily rain events of less than 10 mm (There has already been a trend of decreased winter rainfall in the southern portion of the region over the last 25 years. This may be associated with a climate cycle and not actually related to global climate change, but is a decreasing trend nonetheless); and
- decreased frequency of cold fronts and an increased incidence of high pressure cells during winter.

Figure 2.1.1. Rainfall distribution.

Rainfall
The yearly rainfall is quite variable in the region. Table 2.1.1 shows that there is a 20 per cent chance (or one out of five years) of rainfall above 526 mm* (wet year) and a 20 per cent chance of rainfall below 408 mm (dry year) or in other words an 80 per cent chance of more than 408 mm rainfall. Also shown are the driest and wettest years in these records since 1957. Figure 2.1.2 shows the total rainfall and growing season rainfall for each year back to 1957.
Table 2.1.1. Statistics for annual rainfall

<table>
<thead>
<tr>
<th>Location</th>
<th>Mean (mm)</th>
<th>20% Dry year</th>
<th>50% Median</th>
<th>80% Wet year</th>
<th>Minimum driest years</th>
<th>Maximum driest years</th>
</tr>
</thead>
</table>

Figure 2.1.2. Annual rainfall 1957-2000 showing proportion in growing season.

Temperature

Temperatures range from an average daily high in January of 27°C to average winter highs of 16°C. Frosts rarely occur because the area is close to the coastline and is influenced by humid afternoon sea breezes.

Figure 2.1.3. Average monthly rainfall and evaporation (left) and average monthly temperatures (right), showing the highest recorded temperature for the month, the average maximum daily temperature, the average minimum daily temperature and the lowest recorded temperature (since 1957).
Wind

The hours of strong winds (greater than 29 kph) for the four years 1997-2000 have been below average in the Wellstead area. (Figure 2.1.4 left). The predominant direction of strong winds in the region is west-northwest (Figure 2.1.4 right). Soil type is critical to wind erosion risk with lighter soils much more susceptible than heavy soils to erosion.

![Wind data from recording stations in the region, Department of Agriculture, Western Australia.](image)

2.2 Geology

*Ruhi Ferdowsian, Albany*

The area has aeolian sand deposits and deeply weathered mantles of laterite overlying thick Eocene and Tertiary sediments (up to 80 m in places) of the Pallinup and Werrilup formations (comprising spongolite, sandstone and low energy marine carbonate and siltstone). The basement geology (comprising granites and gneiss of the Albany-Fraser Orogen) rarely outcrops on the land surface. The tertiary sediments have been incised by the rivers, which in places have dissected to the basement rocks. The geology and other structural features are described in Cope (1975), Cockbain (1968) and Cruse and Harris (1994).

2.3 Soil-landscape Information

*Tim Overheu, Albany*

The dominant soils are grey sandy duplex, duplex sandy gravels, pale deep sands and semi-wet soils. These soils are aeolian in nature and are developing on weathered tertiary sediments (spongolite/siltstone). The subsoil clays are often alkaline, and their buffering capacity, subsoil structure, effective rooting depth, nutrient and moisture retention is good. This presents favourable growing conditions during average seasons.

With the low landscape relief, spatial distribution of the soils can be very uniform (for example; 70 per cent of the property known as Subasio Downs in the catchment has a dominant shallow sandy duplex (gravelly) soil.)
2.3.1 Soil-landscape units

The main soil-landscape systems (Table 2.3.1 and Appendix 3) are Chillinup and Lower Pallinup. The Chillinup-2 (Ch2) system consists of grey shallow sandy duplex and gravelly duplex soils on a level to very gently inclined landscape. The Chillinup-3 (Ch3) soil-landscape has deep sands and deep sandy duplex soils associated with linear sand dunes and a gently undulating sandplain. The Lower Pallinup system has distinctive slopes and valley floor area of the Pallinup River. The associated soils are duplex sandy and gravelly soils on valley slopes.

Table 2.3.1. Dominant soil systems (> 5 per cent of total area)

<table>
<thead>
<tr>
<th>Soil-system (%)</th>
<th>System description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chillinup (Ch)</td>
<td>The Chillinup system is a broad level to gently undulating sandplain that slopes gently to the south from about 180 to 100 m elevation (asl). Local relief within this system is less than 10 m and there are many internal drainage depressions, including lakes and swamps, some with lunettes. Clusters of deep sandy linear dunes occur across some parts of the system. These sand dunes are aligned in an east to south-easterly direction. Moderately deep sand sheets are also present.</td>
</tr>
<tr>
<td>Lower Pallinup (Lp)</td>
<td>This system is at the edge of the Chillinup plain where the Pallinup River cuts though the siltstone and lateritic-based Chillinup plain. Mostly a U shaped valley profile</td>
</tr>
</tbody>
</table>

2.3.2 Soil groups

The main soil groups (Schoknecht 2002) are presented in Table 2.3.2. Grey shallow sandy duplex (gravelly), grey deep sandy duplex soils and pale deep sands are the three most common soil groups in the study area. Associated soils include alkaline grey shallow loamy duplex, hard setting grey clays and semi-wet soils.

Table 2.3.2. Soil groups

<table>
<thead>
<tr>
<th>Soil group</th>
<th>Hectares</th>
<th>Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pale deep sand</td>
<td>30,200</td>
<td>29</td>
</tr>
<tr>
<td>Duplex sandy gravel</td>
<td>22,900</td>
<td>22</td>
</tr>
<tr>
<td>Grey shallow sandy duplex</td>
<td>10,800</td>
<td>10</td>
</tr>
<tr>
<td>Grey deep sandy duplex</td>
<td>10,100</td>
<td>10</td>
</tr>
<tr>
<td>Deep sandy gravel</td>
<td>5,600</td>
<td>5</td>
</tr>
<tr>
<td>Other soils (40 groups) each representing &lt; 5% distribution</td>
<td>25,150</td>
<td>24</td>
</tr>
</tbody>
</table>
Figure 2.3.1. Soil systems.

2.3.3 Land management units

Land managers in the Wellstead and South Stirling area identified a set of land management units in 1994 and 1998 (Table 2.3.3).

Table 2.3.3. Ten land management units

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Associated landform element</th>
</tr>
</thead>
<tbody>
<tr>
<td>SS/C</td>
<td>Shallow sandy duplex clay (may have gravel through the profile)</td>
<td>Found throughout the landscape. Usually associated with level to very gently undulating landscapes; flats and sandplain landscapes</td>
</tr>
<tr>
<td>S/C</td>
<td>Deep sandy duplex (may have gravel through the profile)</td>
<td>Generally associated with level to gently undulating landscapes. Common to very gently undulating sandplain landscape positions</td>
</tr>
<tr>
<td>WSD</td>
<td>Poorly drained duplex</td>
<td>Found throughout the landscape. Common where slopes are usually &lt; 3% adjacent to swamp flats and low-lying sandplain</td>
</tr>
<tr>
<td>DS</td>
<td>Deep sand</td>
<td>Found throughout the landscape. Common to dunes, lunettes and deep sand pockets</td>
</tr>
<tr>
<td>Gr</td>
<td>Gravelly (ironstone) soils</td>
<td>Dominant on slopes, valley spurs and crests</td>
</tr>
<tr>
<td>GC</td>
<td>Grey loams and clays</td>
<td>Crab hole country; margins of lakes and swamps</td>
</tr>
<tr>
<td>Sa</td>
<td>Salt-affected land</td>
<td>Dominantly found on level landscapes. Common landform elements include valley floors, swamps and lakes</td>
</tr>
</tbody>
</table>
Table 2.3.3. (Continued)

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Associated landform element</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td><strong>RBL</strong></td>
<td>1. Valley slopes - adjacent Lower Pallinup River and associated tributaries (may include some alluvial loams).</td>
</tr>
<tr>
<td>2.</td>
<td><strong>RCL</strong></td>
<td>2. Associated with dolerite dykes. (Uncommon for Gnowellen-Pendernup study area)</td>
</tr>
<tr>
<td>R</td>
<td>Stony and Rocky soils</td>
<td>Rocky, stony or coarse gravelly (not ironstone) &gt; 60 per cent. Generally seen on hillcrests and slopes. May include outcrops of granite or hard ironstone.</td>
</tr>
<tr>
<td>AL</td>
<td>Alluvial sandy earths</td>
<td>Alluvial sandy earths, loams and some duplex soils deposited on an ancient flood plain adjacent the Pallinup River, and some of its tributaries.</td>
</tr>
</tbody>
</table>

- Lakes, swamps, dykes and rock outcrops, being largely non-arable / non-agricultural areas, have not been represented as Land Management Units.
- Incorporated with each unit is a correlation to the South Coast MIDAS economic model to assist with future economic analyses.

2.4 Hydrology

2.4.1 Groundwater and aquifers

*Ruhi Ferdowsian and Lisa Crossing, Albany*

The hydrology has been described by Ferdowsian (1996). The area can be divided into two categories, each having a unique type of aquifer:

- (a) dissected landscape and granitic rises; and
- (b) internally draining sandplain.

**The dissected landscape and granitic rises**

The dissected landscape close to and directly affected by the Pallinup River has a local scale flow system (local aquifer). Granitic rises in the north west of the study area are common.

Depth to bedrock in these areas is mostly less than 30 m, so aquifers are generally relatively thin and shallow. Most of the profile is low yielding because of clays in the regolith (often, kaolinitic white clays) but a thin layer of coarser material (saprock) usually exists just above bedrock that is a much better conduit for groundwater.

Problems with salinity and rising groundwater are likely to be confined to areas with a local scale flow system. Therefore, management practices outside the influence of these areas will have little or no effect on the extent of their salinity. However, the management of land with a local aquifer will affect others downstream. Salinity in these areas is in three forms: (i) creek lines; (ii) valley floors; and (iii) occasional hillside seeps. Well-defined and narrow creek lines will become salt-affected because they become discharge sites as well as the carriers of saline baseflow. A few hillside seeps occur in the lower parts of granitic rises, where basement rock obstruct the saline groundwater and bring it close to the soil surface.

**The internally draining sandplain**

Drilling under the sandplain has shown that the Tertiary sediments are between 35 and 64 metres deep with intermediate aquifers (recharge and discharge areas 2 to 10 km apart).
No watercourse takes surface run-off out of the sandplain areas but there is a gradual hydraulic gradient (slope of groundwater table) to the east and northeast. The coarser sand and rounded pebbles in the Werillup Formation have a higher hydraulic conductivity than the siltstone and clay above them.

The groundwater contained within the Werillup Formation is highly saline (greater than 3000 mS/m).

The Pallinup siltstone generally has a low hydraulic conductivity but does contain discontinuous sand lenses that can have higher groundwater flows. The intermediate aquifers, in some areas, are intersected by bedrock highs with local flow systems (recharge and discharge areas less than 2 km apart).

**Hydrology of swamps and lakes in the study area**

Swamps and closed depressions have formed in areas with very porous material at depth, associated with either granitic highs or Werillup Formation. The clays in the Pallinup sediments have gradually migrated downwards into the porous material and caused subsidence at the surface. Hydrology and salinity of these sumps depends on their interaction with the saline groundwater. Three types of sumps exist in the study area:

- **Fresh water sumps** in the study area, perching well above the saline groundwater, have seasonal water and dry out over summer (December to May). After heavy rain, water covers the sumps and their margins, inundating a large area. These sumps, and especially their margins, contribute recharge to the underlying groundwater flow system.

- **Brackish sumps** were fresh water sumps that recharged the regional groundwater prior to clearing and dried over summer. Due to rising groundwater, however, they have become periodic discharge sites and water now stays in them for long periods. As the levels of the groundwater rises, the natural vegetation in these sumps will die and they will change to saline sumps.

- **Salt lakes**, with rising groundwater levels in recent years, have become permanent discharge zones. Many active saline seeps along the fringes of the salt lakes confirm that they are permanent discharge areas. Very salty groundwater (30,000 TSS mg/L) is entering the salt lakes thereby increasing the salinity of water in the lakes. The flats that surround the salt lakes experience much higher water levels now than prior to clearing. The high surface and groundwater levels and increased salinity have already killed most of the natural vegetation on the flats and lake margins and will eventually denude these areas. The lakes receive run-off from the eastern parts of the Stirling Range as well as from agricultural areas.

Factors influencing groundwater flow in the area include hydraulic head and conductivities, and some regional or intermediate groundwater discharge through seeps along the Pallinup River. The granitic highs, lakes in the sandplain that have or may become windows to the groundwater table (such as in the cross-section shown in Figure 3.1.2) may also influence groundwater flow.

The groundwater salinity of bores in the area range from 417 mS/m (associated with a freshwater lake and large sand dunes) to 7,210 mS/m in the sandplain with an average of > 3,000 mS/m (Appendix 2). There is also a brackish water supply bore in the colluvial and alluvial sediments at the base of the Stirling Range. The deepest bores in the area have highly saline groundwater that is three times saltier than bores in shallower areas, suggesting the existence of a stagnant, highly saline basin under the sediments in this area.
2.4.2 Waterways and wetlands

River systems in the study area

Uplifting of the Darling Plateau tilted the Ravensthorpe Ramp and created a surface with a relatively high gradient, rejuvenated creeks and rivers flowing south. The rejuvenated drainage lines, with active headwater erosion and river-capture, cut through some ridges and catchments of some stagnant and westerly flowing watercourses. One of these ridges was north of the study area. The Pallinup River cut through this ridge and captured the Upper Pallinup catchment. Prior to this inclusion, the Upper Pallinup flowed west into the Gordon River.

The areas of the sand plain that have Werillup Formation have resisted the erosive processes and have kept their original surface. Therefore, the effectiveness of the Pallinup River in eroding and dissecting the landscape has been limited to the areas without Werillup formation at depth. Consequently, all creek lines and defined open depressions have shallow basement rocks or weathered material that affects the hydrology and salinity of the open depressions.

State of the waterways in the Pallinup River catchment

Kaylene Parker, Water and Rivers Commission, Albany

The Pallinup River and other waterways in the study area show signs of degradation. The riparian vegetation is degrading because of stock access, salinity, waterlogging and weed invasion. Catchment changes including rising groundwater levels, increasing salinity and nutrient levels draining from the catchment are affecting the health of the waterways in the sub-catchments and ultimately the Pallinup River and Beaufort Inlet. There are weeds proliferating along the Pallinup River and the river receives increasing volumes of water coming off cleared catchments, resulting in unstable banks and erosion and sedimentation of river pools. The two major flood events recorded on the Pallinup River (1955 and 1982) caused considerable damage to the banks and riparian vegetation along the river, and increased sedimentation of many river pools.

A survey conducted by the Water and Rivers Commission of the Pallinup River from Beaufort Inlet to south of Gnowangerup and the Pendernup Creek as part of the Pallinup River Action Plan in 2000/2001 (Parker 2002) recorded foreshore vegetation condition, habitat values, pool locations and condition, channel stability and sedimentation. Other data was collected for the river and estuary, including water quality, native fish, macro-invertebrates, and historical information (Table 2.4.1).

The survey rated sections of the lower Pallinup River as in excellent condition. In particular, the river south of Chester Pass Road was rated as pristine and in excellent condition. Many sections of the river north of the Chester Pass Road are rated as poor condition, where the banks were actively eroding and the understorey damaged by stock and weed invasion.
Table 2.4.1. Summary of the condition of waterways in the Pallinup River

<table>
<thead>
<tr>
<th>Waterway component</th>
<th>Rating</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrology and water quality</td>
<td>4</td>
<td>Water quality indicates high nutrient levels, increased salinity levels and an increase in flow from a cleared catchment. Evidence of eutrophication in Beaufort Inlet.</td>
</tr>
<tr>
<td>Foreshore vegetation</td>
<td>4</td>
<td>Good condition in the lower, poor in the upper. Excellent along Corackerup, Pendemup, Peenebup and tributaries draining off the Stirling Ranges.</td>
</tr>
<tr>
<td>Aquatic vegetation</td>
<td>3</td>
<td>Many pools in the lower section have various aquatic plants. There are some pools with increased algae and epiphyte growth - indicating high levels of nutrients.</td>
</tr>
<tr>
<td>Aquatic habitat</td>
<td>3</td>
<td>Good habitat, many pools, riffle zones and overhanging vegetation. Stock access and salinity are compromising some of these values.</td>
</tr>
<tr>
<td>Bank stability</td>
<td>4</td>
<td>The river shows signs of instability from increased catchment flows. Considerable damage done in 1955 and 1982 flood events.</td>
</tr>
<tr>
<td>Channel features and modifications</td>
<td>2</td>
<td>Few modifications except some farm dams on tributaries. Most of these have gone saline since.</td>
</tr>
<tr>
<td>Other pollutants</td>
<td>Unknown</td>
<td>Not monitored. There are community concerns about pesticides.</td>
</tr>
<tr>
<td>Cultural, historic and cultural values</td>
<td>3</td>
<td>The Pallinup River is important for Indigenous Australians. Lower Pallinup has high recreational use, commercial fishing, recreational fishing, popular camping ground.</td>
</tr>
<tr>
<td>Conservation values</td>
<td>2</td>
<td>High conservation values. Extremely rich botanical area surrounding Beaufort Inlet. Pallinup River and some of the tributaries form important vegetative corridors in the South Coast Region.</td>
</tr>
</tbody>
</table>

Key to ratings:
1. Pristine condition (no impacts).
2. Excellent condition - minimal evidence of changes to condition.
3. Good condition - some evidence of minor changes.
4. Poor condition - significantly impacting on the health of the waterways.
5. Very poor - affecting the health of the waterway.

2.5 Native vegetation

John Bruce, Albany

The study area lies in the Eyre Botanical Region (Beard 1976). This stretches from the Stirling Ranges along the South Coast to the Bight and has mainly poor soils on plains covered with mallee-heath. Local vegetation communities form part of the Qualup and Cape Riche Vegetation Systems (Beard 1981). Common vegetation types include tallerack (*Eucalyptus tetragona*) mallee-heath on sandy duplex soils to the north of the catchment giving way to jarrah (*E. marginata*) mallee-heath in the south. Deep, linear sand dunes support proteaceous scrub-heaths, dominated by Banksia species (*B. baxteri, B. coccinea* and *B. attenuata*), while complex mallee communities occur on dunes adjacent to salt-lakes. Yate (*E. occidentalis*) woodlands commonly occur around loamy swamps and depressions, while more sandy depressions support redheart moit (*E. decipiens*). The Pallinup River
valley cuts into the plains and mixed woodland of yate, York gum (*E. loxophleba*) and jam (*Acacia acuminata*) occurs on the slopes adjacent to the river, with the river channel itself dominated by saltwater sheoaks and paperbarks. The main vegetation communities are described in table 2.5.1. The natural vegetation is described for the whole catchment, though 80 per cent of the original vegetation has been cleared.

### Table 2.5.1 Major vegetation communities

<table>
<thead>
<tr>
<th>Community (name)</th>
<th>Dominant species</th>
<th>Soil type</th>
<th>Proportion of catchment (Pre-clearing)</th>
<th>Proportion of catchment (Current)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tallerack mallee-heath</td>
<td><em>Eucalyptus tetragona</em>, <em>E. decipiens</em></td>
<td>Sandy duplex, sandplain, sandy depressions</td>
<td>56%</td>
<td>11%</td>
</tr>
<tr>
<td>Jarrah mallee-heath</td>
<td><em>E. marginata</em></td>
<td>Sandy duplex</td>
<td>23%</td>
<td>4%</td>
</tr>
<tr>
<td>Mallee scrub -black marlock/variou</td>
<td><em>E. uncinata</em></td>
<td>Various</td>
<td>8%</td>
<td>3%</td>
</tr>
<tr>
<td>Scrub-heath</td>
<td><em>Lambertia inermis</em>, <em>Banksia baxter</em></td>
<td>Deep sand</td>
<td>8%</td>
<td>1%</td>
</tr>
<tr>
<td>Other vegetation</td>
<td>Various: <em>E. occidentalis</em>, <em>E. loxophleba</em>, <em>Sarcoonia spp</em></td>
<td>Various</td>
<td>4.5%</td>
<td>1%</td>
</tr>
</tbody>
</table>

### 2.6 Land use and agricultural production

The land is mainly used for mixed cropping and livestock enterprises. Most farmers run sheep, though the number of cattle in the area has increased in recent years. The rainfall is too low for Blue gum plantations, except in the far south-eastern corner of the study area. The highest cropping yields are on alluvial sandy loams with an average of 3 t per ha for cereals. Highest stocking rates (six dry sheep equivalents per hectare on average) are often achieved on deep sandy duplex soils.

The following information is based on a random sample survey of land managers in early 2002.

Common crops include cereals - mainly barley and some wheat - followed by canola, lupins, some field peas and oats. Other less common crops include summer crops like millet and sorghum. Typical rotations include Barley or Wheat/Canola Barley or Wheat/Canola/Lupins, Barley or Wheat/Canola/ Pasture (legume based). Yields were very variable: barley ranged from 2 to 5 tonnes/ha; wheat from 1.8 to 5 tonnes/ha; canola from 0.5 to 2.5 tonnes/ha; and lupins from 1 to 2 tonnes/ha.

Farmers have always put in some crops but in the last ten years many have moved to bigger and more intensive cropping programs, due in part to low wool prices, but mainly to the development of no-till farming systems and better chemical control of weeds.

Prior to the introduction of no-till farming systems, the majority of the light textured soils were highly susceptible to wind erosion. With the (almost) total adoption of no-till or minimum-tillage systems across the study area in the 1990’s, land managers have been able to increase cropping while reducing the risk of wind erosion. In the last few years, however,
wheat has become less profitable due to Rhyzoctonia, waterlogging and herbicide weed resistance. The area sown to wheat has declined and more barley is now grown. Canola has also become a more profitable crop with the added advantage that it acts as a break crop.

Albany shire statistics for the period 1984-1996 show an increase in canola, wheat, lupins and oats and a reduction in sown pasture (Table 2.6.2). Although the statistical data covers the whole shire, the majority of cropping occurs towards the eastern portion.

Table 2.6.2. Land uses >350 ha in the Albany Shire for 1986 and 1996. (ABS, 1997)

<table>
<thead>
<tr>
<th>1986 Farm area: 257,544 ha (559 farms)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop</td>
<td>Pasture</td>
</tr>
<tr>
<td>Area (ha)</td>
<td>191,780</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1996 Farm area: 294,320 ha (507 farms)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop</td>
<td>Pasture</td>
</tr>
<tr>
<td>Area (ha)</td>
<td>131,480</td>
</tr>
</tbody>
</table>

* Pasture and ‘other’ occupy a large proportion because the statistical region covers the whole shire of Albany, including the high rainfall, pastured areas such as Redmond and Torbay.

Considerable interest has been shown in perennial pastures, with some farmers moving back to a more balanced crop/stock farming system. Stands of lucerne and Kikuyu are already present in the area and more are planned. Those with Kikuyu claim stocking rates of ten dry sheep equivalents per hectare throughout the year. Despite the interest towards incorporating more stock, there is still a core (including some of the biggest growers in the area) that depend entirely on cropping. These growers limit their risk by using contractors to harvest the crop early, and grain drying units. Most growers swath not only their canola but also their barley and wheat.

The main causes of land degradation are non-wetting soils, waterlogging and soil acidity. Many growers have started to experiment with claying, with varied though generally favourable results. Waterlogging is a major problem in this area. Also, summer rains can reduce the quality and price of canola and wheat. Many land managers have constructed several kilometres of contour drainage and other earthwork structures; however, waterlogging is still a problem on many farms.

Soil acidity is recognised as a problem and lime applications have increased since the early 1990’s to approximately 18,000 tonnes in 1998/99 (NLWRA 2001).

Other significant issues include subsoil acidity, erosion, soil structure decline, weeds (i.e. wild radish), pests (i.e. red mite) and low soil fertility.

### 2.7 Infrastructure

The main infrastructure includes the townsite of Wellstead (117 ha), the Wellstead and Kojaneerup grain receival bins, (which together handle more than 71,500 tonnes of wheat and barley) and the Pallinup river bridge.
The area has almost 150 km of gazetted roads, the majority of which are unsealed roads or tracks. The sealed road length includes a 75 km length of the South Coast Highway. The current impact of salinity on the roads and other assets is negligible.

2.8 Demographics
The median age of farmers is 47 years and increasing, while, in the Albany shire, the 15-24 year old population is declining.

The annual farm family income (from all sources) from 1996-1999 averaged around $35,000, and the average farm debt was around $260,000.

Some social statistics from the Australian Bureau of Statistics are given in Table 2.8.1.

Table 2.8.1. Demographics of the four shires that partly cover the study area. (ABS 2001)

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Albany</th>
<th>Plantagenet</th>
<th>Gnowangerup</th>
<th>Jerramungup</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>12,413</td>
<td>4,117</td>
<td>1,724</td>
<td>1,338</td>
</tr>
<tr>
<td>2001</td>
<td>13,896</td>
<td>4,329</td>
<td>1,521</td>
<td>1,208</td>
</tr>
<tr>
<td>% change</td>
<td>+ 12.0%</td>
<td>+ 5.1%</td>
<td>- 12.0%</td>
<td>- 9.7%</td>
</tr>
<tr>
<td>Median age</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>34</td>
<td>34</td>
<td>31</td>
<td>32</td>
</tr>
<tr>
<td>2001</td>
<td>35</td>
<td>37</td>
<td>33</td>
<td>35</td>
</tr>
<tr>
<td>Employment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-labour force</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not stated</td>
<td>5,739 (63%)</td>
<td>1,929 (62%)</td>
<td>878 (71%)</td>
<td>778 (79%)</td>
</tr>
<tr>
<td>Not stated</td>
<td>3,159 (35%)</td>
<td>1,076 (35%)</td>
<td>341 (28%)</td>
<td>190 (19%)</td>
</tr>
<tr>
<td>Individual education level:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Degree or higher</td>
<td>21</td>
<td>11</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Diploma</td>
<td>58</td>
<td>31</td>
<td>17</td>
<td>13</td>
</tr>
<tr>
<td>Vocational</td>
<td>87</td>
<td>50</td>
<td>23</td>
<td>20</td>
</tr>
<tr>
<td>Not stated</td>
<td>17</td>
<td>18</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

3. RESOURCE CONDITION AND FUTURE RISK
3.1 Climate change
Tim Overheu, Albany

International global climatic models suggest that higher temperatures and evaporation, combined with lower rainfall can be expected in this region. The climate will remain Mediterranean, but farmers may need new crop varieties and changes in management such as better systems of harvesting water, increased feedlotting and perhaps grain drying to cope with rainfall near harvest.

Some projections for the southern region of Western Australia (Bennet and George 2002; Foster 2002; Robertson 2001 and Ferdow sian, 2002) are:

- Land surface temperatures will increase by about 2 to 5 degrees by 2030.
Seasonal rainfall will decrease by at least 10-30 per cent for winter-spring by 2030.

Occurrence of sporadic summer storms will increase.

Low-pressure system activity/intensity will increase further south (with associated increased risk of flooding, wind damage and erosion).

The likely impact of these changes include:

- Cropping options in the medium to high rainfall areas will change. Cropping area may increase; however, summer rainfall could increase the risk of wet harvests. Summer cropping systems may also become more common.
- Waterlogging could be reduced in low-lying areas, but yields may also be reduced.
- Earthworks may be needed to improve surface water harvesting and storage.
- Reduced recharge and lower risk of salinity.
- Biodiversity change with species loss or migration.

### 3.1 Soil degradation risk

*Tim Overheu, Albany*

Salinity has visually disturbing consequences and, therefore, attracts more attention than the 'invisible' forms of land degradation such as soil acidity, water repellence and topsoil acidification. These less obvious forms affect far larger areas than salt in this region (Tables 3.2.1 and 3.2.2).

#### Table 3.2.1. Summary of degradation hazards

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water repellence 75% at risk</td>
<td>Many of the light surface textured soils - sandy duplex, deep sands and gravelly slopes - are susceptible to water repellence.</td>
</tr>
<tr>
<td>Soil compaction 70% at risk</td>
<td>Many of the texture contrast soils have uniform, fine sandy surface and sub surface textures. Consequently under regular traffic (including tillage, liming and claying practices), the sandy sub-surface layers become compacted.</td>
</tr>
<tr>
<td>Waterlogging 58% at risk</td>
<td>The soils most at risk are the grey, shallow, loamy duplexes, grey clays and saline wet soils (particularly areas with low relief and impermeable sub-soils that develop perched watertables during winter.</td>
</tr>
<tr>
<td>Soil acidity 55% risk</td>
<td>Subsurface acidification, below the depth of normal cultivation (10-20 cm), occurs extensively in deep sandy duplex soils and pale deep sands, with neutral to slightly acidic topsoil, particularly along the southern (or lower) coastal plain. These soils also have low organic carbon content and low buffering capacity; they could reach a critical pH (&lt; 4.5) in less than 15 years (van Gool <em>et al.</em> 2001).</td>
</tr>
<tr>
<td>Wind erosion 50% at risk</td>
<td>Strong winds are common in the area, causing erosion, particularly in dry years. Most susceptible are the Sandy duplex soils and Pale deep sands with areas of unprotected loose sandy topsoils (with &lt; 5% clay content), dry soil, in higher landscape positions.</td>
</tr>
<tr>
<td>Water erosion</td>
<td>High-risk areas are river valley slopes and sloping areas adjacent to drainage lines within the sandplain. Sheet erosion is the most prominent form and causes loss of topsoil and nutrients. Most at risk are loose sandy topsoils with low organic carbon contents and dispensable clays (generally sodic soils) that favour dispersion.</td>
</tr>
</tbody>
</table>
Table 3.2.2. Land degradation hazards for each land management unit in the Albany Eastern Hinterland area

<table>
<thead>
<tr>
<th>Land management unit</th>
<th>Salinity risk</th>
<th>Waterlogging/inundation risk</th>
<th>Susceptibility to water erosion</th>
<th>Susceptibility to wind erosion</th>
<th>Susceptibility to subsurface (10-20 cm) acidification</th>
<th>Susceptibility to water repellence</th>
<th>Susceptibility to topsoil structure decline</th>
<th>Susceptibility to subsurface compaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow sandy duplex</td>
<td>Low to moderate*</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate to high**</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Deep sandy duplex</td>
<td>Low</td>
<td>Low to moderate</td>
<td>Moderate</td>
<td>Moderate to high</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Poorly drained sandy duplex</td>
<td>High</td>
<td>Moderate to high for lower slopes</td>
<td>Moderate</td>
<td>Low</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Deep sands, (lunettes and dunes)</td>
<td>No risk</td>
<td>Nil</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low to moderate</td>
</tr>
<tr>
<td>Grey/greyish brown loams and clays</td>
<td>Low</td>
<td>Moderate to high on valley flats</td>
<td>Moderate (on slopes)</td>
<td>Generally low</td>
<td>Low</td>
<td>Low</td>
<td>Moderate to high</td>
<td>Low to moderate</td>
</tr>
<tr>
<td>Gravels</td>
<td>No risk</td>
<td>Nil</td>
<td>Moderate</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Salt-affected land</td>
<td>Presently saline</td>
<td>Very high</td>
<td>High</td>
<td>Low</td>
<td>Variable***</td>
<td>Low</td>
<td>Not rated</td>
<td>Not rated</td>
</tr>
<tr>
<td>Red/red brown soils and dykes</td>
<td>Low*</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Stony and rocky soils</td>
<td>No risk</td>
<td>No risk</td>
<td>Low</td>
<td>No risk</td>
<td>Variable</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Alluvial sandy earths</td>
<td>Moderate to high</td>
<td>Moderate to high</td>
<td>High</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

* Salinity likely to develop as hillside seeps on the units where shallow bedrock forces saline groundwater close to the surface
** Highly susceptible to wind erosion on crests and upper slopes
*** Soil pH on saline soils is highly variable but they are not likely to be economic to lime.
3.3 Hydrological risk

3.3.1 Groundwater

Lisa Crossing and Ruhi Ferdowsian, Albany

Current salinity

Less than one per cent of the area was mapped as saline by the Land Monitor project. This is an underestimate as mildly affected areas densely vegetated in spring with salt-tolerant pastures or other vegetation often are not identified; nevertheless, salinity is not yet a major cause of land degradation in the area.

Groundwater trends

Trends in groundwater levels vary depending on landscape position, soil profile, management and rainfall. A typical cross-section along a flow line for the catchment is shown in Figure 3.1.2. This cross-section traverses sandplain country with deep saline lakes, breakaway country and down to the Pallinup River.

Hydrographs are graphs showing the water level in a piezometer or monitoring bore over time. To analyse the trends, a program called HARTT (Hydrograph Analysis using Rainfall and Time Trends - c.f. Ferdowsian 2002) has been used. The HARTT method is particularly good for hydrograph analysis because it removes the impact of above or below average rainfall events during the monitoring period, and presents the groundwater trend, as it would occur in an average rainfall period.

Some typical examples of groundwater hydrographs in the region are shown with respect to their position in the landscape. The analysis indicates that groundwater levels are generally rising in the region because of increased recharge under annual agricultural crops and pastures.

Summary of the hydrograph analyses (Figure 3.3.2)

**Hydrograph 1:** This hydrograph shows very shallow groundwater (1 metre or less) around the deep lakes. These deep lakes are essentially windows to the groundwater system. Groundwater here is close to the surface because of the topography. Water levels simply fluctuate within a metre of the surface due to rainfall and evaporation. Consequently, saline groundwater affects vegetation within 1 to 2 metres of the soil surface.

**Hydrograph 2:** In the middle of the sandplain piezometers have deep groundwater (20 to 30 m deep) that is steadily rising at a rate of 15 to 20 cm per year.

**Hydrograph 3:** This piezometer is positioned on the top of the breakaway where groundwater is still deep (> 20 m) and rising steadily at a rate of 0.29 m/yr.

**Hydrograph 4:** On the lower slope below the breakaway the groundwater is 5 metres below the surface and slowly rising 0.08 m/yr. Since groundwater is discharging at the river in some places, it partially reduces the rate of groundwater rise. The water level in these shallow piezometers also fluctuates due to variations in rainfall.
Potential salinity risk (Flowtube)
Flow tube is a two-dimensional groundwater calculator developed by the Department of Agriculture in collaboration with CSIRO Land and Water and the University of Melbourne. It is designed to predict long-term groundwater trends along a groundwater flow path and examine the effects of recharge and discharge management options. Flow tube can estimate both long-term trends in groundwater levels, and length of the Flow tube at risk of experiencing shallow watertables in any given number of years.

Flow tube analysis indicates the likely trends in groundwater levels and has been calibrated with actual bore measurements. However, as with all models, results should be treated with caution, as many simplifications, assumptions and estimates are included in the calculations.

Flow tube models a groundwater flow path, not a catchment. An entire catchment would have smaller proportions being affected by shallow watertables.
The main areas at risk of becoming saline are low points in the landscape such as creek lines, swamps and flats. Hillside seeps can also occur where there is shallow bedrock or other geological obstructions to flow. These areas then become groundwater discharge (saline) areas, which help to control the rate of rise in the rest of the catchment. However, it is not known how far the watertable will rise before an equilibrium is reached where extra recharge is matched by increased discharge to streams and evaporation. Equilibrium is reached much faster in higher rainfall areas.

In the scenario modelled above, the flow path reaches equilibrium under current agriculture in 150 years with 51 per cent of the flow tube being affected by shallow watertables. This is due to the watertable, currently greater than 20 m below the sandplain, rising until it is close to the surface and intersecting all low-lying and some flat areas of the catchment. It has not identified if discharge through other areas in the catchment will be enough to prevent this from occurring.

### 3.3.2 Surface water

There is one gauging station located, adjacent in the Albany eastern hinterland area, on the lower Pallinup River, which is still in operation. Comprehensive information associated with this gauging station can be sourced from the Water and Rivers Commission's Information Centre or via an online search via the following website:


### 3.4 Vegetation condition and risk

*John Bruce, Albany*

#### 3.4.1 Remnant vegetation

The location of remnant vegetation within the study area can be seen on the Vegetation map (Appendix 1.2).

Sixty five per cent of the catchment’s 19,000 ha of remnant vegetation is found on farmland, mainly in uncleared swamps, creek lines and sand dunes. Small, isolated remnants (less than five hectares) make up less than 15 per cent of the catchment’s total private remnant vegetation. Most occurs in significant blocks; with around 40 remnants in excess of 50 ha in area, of which at least five are over 250 ha in area.

Only seven per cent (1290 ha) of the catchment’s remnant vegetation is protected within CALM estate, including the Hassell National Park. The Stirling Range National Park borders the NW of the catchment. Other remnant vegetation is found in crown land reserves, including the Pallinup River Reserve, and various road and shire reserves.

#### 3.4.2 Rare flora

There are 23 populations of endangered flora known to exist in the area, comprising nine different species. Three of these species, *Caladenia bryceana* subsp. *bryceana*, *Grevillea maxwellii*, and *Myoporum cordifolium* are considered rare. The latter two are only known to occur within Pallinup region. Only two populations of rare and endangered flora are found in reserves protected for conservation, the remainder are mostly on roadsides and private property.

Further information can be sourced from Sarah Barrett, Department of Conservation and Land Management in Albany.
3.4.3 Biodiversity assets at risk

Vegetation at risk of salinity and waterlogging

Waterlogging and salinity are major threats to remnant vegetation in the agricultural landscape. Land monitor data suggests that only one per cent of the catchment’s remnant vegetation occurs in areas currently considered saline.

Vegetation at greatest risk occurs in low-lying areas of the landscape, such as yate swamps, creek lines, and poorly drained flats. Land Monitor (valley floor) maps show that 22 per cent (6,340 ha) of the study area’s native vegetation is in low-lying areas which may become waterlogged/saline if the water tables rise sufficiently.

Other risks to remnant vegetation

Other risks to our remaining revegetation include clearing, livestock grazing, weeds and feral animals.

Three of Australia’s top 20 weeds of national significance are known to exist within the study area. Blackberry (*Rubus fruticosus*) and gorse (*Ulex europaeus*) are only found in few isolated patches. These two species were considered to have the greatest economic impact of any weed on Australian agriculture and forestry. Bridal creeper (*Asparagus asparagoides*) is considered to be one of the worst environmental weeds in southern Australia, readily smothering out understorey vegetation. It is estimated that at least 500 ha of bridal creeper occurs with the area, though it is steadily invading roadsides and other remnant vegetation including the Pallinup reserve, Hassell Hwy and Chillinup Rd.

More information on Australia’s weeds on national significance can be found at:


Rabbits (*Oryctolagus cuniculus*) can severely degrade native vegetation and impede revegetation works. Over half of the catchments remnant vegetation is considered to be highly suited for rabbits, particularly the dense scrub heath found on the deeper sands (Bruce 2000).

3.5 Agricultural production

*Timothy Overheu, Albany*

The total value of primary production in the Albany shire peaked in 1996 to just over $70 million per annum. This was an increase of around $38 million over 14 years from 1983/84. In 1997 the Shire contributed approximately 30 per cent to the South Coast’s gross value of agricultural production (GVAP) which was about five per cent to the State of Western Australia’s GVAP (ABS, 1997). However, in 1999, the GVAP had decreased to around $51 million. It is assumed that trade liberalisation, uncertain rural commodity prices and land use change, have had the greatest impact on the GVAP for the shire.

Agricultural productivity in Albany is increasing, possibly because of the emphasis on innovation and market development in the region. Other reasons include: an increase in the area sown to canola from 1,800 hectares in 1993 to over 10,000 by 2001; and, diversification into a range of horticultural crops.

Over recent years there has been an increase in returns from cropping and horticulture and a decline in sheep and wool production - though recent increases in wool and meat prices
have reversed this trend to an extent. Factors limiting the area cropped are the likelihood of
damaging summer rains around harvest, and problems with herbicide resistance.

Among the diverse range of commodities produced in the region, the biggest contributors to
the economy are wheat and barley, followed by beef, sheep and wool. Other components
include canola, timber, oats, and legumes. Timber plantations have also in recent years
increased in contribution to the regional economy. The tourism sector also accounted for
about 10 per cent of the economic activity in 2001, in comparison to six per cent in 1996
(GSDC, 2001).

3.6 Infrastructure

*Timothy Overheu, Albany*

The road transport network within the area includes local gravel roads, sealed bituminised
main roads and a section of the South Coast Highway. Land monitor estimates indicate that
about 60 km of the road network (including about 13 km of the South Coast highway) occurs
in low-lying areas making the roads susceptible to waterlogging and, possibly, salinity. The
other major infrastructure within the study area also includes the town of Wellstead, which
comprises a total gazetted area of 117 ha. Land monitor topographical maps suggest that
around 40 ha (34 per cent) of the town area could be affected by waterlogging, as could the
Kojaneerup grain bin, which is also situated within a low-lying area.

4. MANAGEMENT OPTIONS AND IMPACTS

4.1 Land management

Following is a series of tables based on the land management units (previously discussed in
section 2.3.3). These tables list potential degradation with each dominant land
management unit in the study area, with ‘best practice’ management options to reduce their
hazards.

The options have been suggested on the basis of minimising recharge and land degradation
over the study area. The information can be used as a guide; however, readers are strongly
encouraged to regularly seek further (current) information through relevant people and
organisations.
### Management units and management options

<table>
<thead>
<tr>
<th>Land management unit</th>
<th>Water and soil properties</th>
<th>General management options</th>
</tr>
</thead>
</table>
| MODERATELY WELL DRAINED SANDPLAIN DUPLEX (Deep sandy duplex) (15,000 ha) Pale grey sand or sandy loam over clay at 30-80 cm, seasonally perched water sometimes present on clay. Occurs level to gently inclined sandplain areas. | • Generally a moderate groundwater recharge risk; this may increase to a high risk in winter months, associated with perched watertables.  
• High risk of wind erosion on exposed crests and upper slopes, otherwise the risk is moderate.  
• Highly susceptible to topsoil acidification.  
• Water erosion is a high risk on exposed upper slopes.  
• Traffic and plough pans can be a risk.  
• Sandy topsoils may display water repellence, low soil water storage and poor nutrient availability.  
• Low to moderate risk of soil structure decline (surface crusting and hardsetting soils). | Soil management  
• This is a versatile and productive soil with a deep layer of sand over gravelly clay. However, all nutrients leach from these deep sands, especially potash which is deficient. A cereal/lupin/canola rotation or pasture/cereal rotation using minimum tillage and stubble retention would be suitable.  
• Minimum tillage and no-till operations will aid in reducing erosion and compaction problems, improving soil structure and maintaining levels of soil organic matter.  
• Liming may be necessary to achieve crop and pasture production potential and assist in the establishment of lucerne; regular monitoring of soil pH levels is advised  
• Practice stubble retention or aim to maintain > 50 per cent ground cover to control risk of wind and water erosion.  

**Cropping/pasture options**  
• Phase cropping with lucerne and cereals.  
• Canola/cereals and lupins on the deeper soils.  

**Recharge reduction and surface water control**  
• Grade banks are effective in controlling water erosion and waterlogging where interception of day is possible.  
• Phase cropping with lucerne and cereals will help reduce recharge rates.  

**Revegetation options**  
• Belts of oil mallees (four or eight rows) below grade banks, separated by crop pasture areas (suitable machinery width)  
• Deeper sand (> 50 cm) may be suitable for Maritime pines or tagasaste plots (must be cut or grazed hard.)  
• Fence off remnant vegetation and revegetate with species native to the catchment (seedlings)  
• Belts of farm forestry species may be suitable for medium to shallow duplex soils (< 50 cm) where there is no waterlogging *Corymbia maculata, Eucalyptus dactylyx, E. tricarpa.*
<table>
<thead>
<tr>
<th>Land management unit</th>
<th>Water and soil properties</th>
<th>General management options</th>
</tr>
</thead>
</table>
| **POORLY DRAINED SANDPLAIN**  
(Poorly drained sandy duplex)  
(12,000 ha)  
Sand or sandy loam over clay at 5 to 35 cm; clay may be blue/grey in colour or very mottled; very wet in winter months. Soils usually associated with low-lying landscapes and often seasonally inundated wet areas. The subsoils are usually dense, sodic and alkaline. Water movement through the subsoil is very slow and perched (and often saline) watertables are common. | • Moderate to high groundwater recharge—highest where water ponds.  
• High risk of salinity developing usually along drainage lines, on ponded areas and on valley floors.  
• Moderate waterlogging risk. Waterlogging is the major limitation in this area. ‘Boggy’ soils in wet years may hinder trafficability.  
• Flooding can occur on the valley floor.  
• Highly susceptible to sub-surface acidification.  
• Moderately susceptible to wind and water erosion, traffic and plough pans.  
• Clay subsoil may present a barrier to some deep rooted species | **Soil management**  
• Soils usually associated with low-lying landscapes. Suitable for waterlogging tolerant perennial pasture and tree species. Attention to waterlogging by drainage where suitable.  
• Liming may be necessary to ensure good establishment of lucerne, and to enable good growth of pastures. Regular monitoring of surface (0-10 cm) and subsurface (10-20 cm) pH is advised.  
• Reduction of traffic in paddocks and avoidance of traffic movement when soil is wet minimises soil compaction risk.  
• Minimum tillage and no-till operations will aid in reducing erosion and compaction problems in paddocks susceptible to these, improving soil structure and maintaining levels of soil organic matter.  
• Practice stubble retention or aim to maintain > 50 per cent ground cover to control risk of wind and water erosion.  
• Clayey subsoils may be sodic - surface sealing and hardsetting problems may result from day being brought to the surface by cultivation.  

**Cropping/pasture options**  
• Oats.  
• Summer crops.  

**Recharge reduction and surface water control**  
• Grade banks for controlling water erosion and waterlogging where interception of day is possible. Shallow relief drains (W) can be used to reduce ponding and promote drainage from valley floors.  
• Lucerne on the deeper soil and on areas with low risk of flooding.  
• Productivity may not be as good as soils, which are well drained.  

**Revegetation options**  
• Revegetation areas will need to be mound-aligned parallel to banks.  
• Windbreaks/shelterbelts of Farm Forestry species (eucalypt sawlogs) in four row belts—plant an extra row of hardy shrubs to maintain windbreak value. Over 500 mm or moisture gaining sites, *Eucalyptus botryoides*, *E. occidentalis* (leps can be problem).  
• Fence off remnant vegetation and allow to regenerate.
Land management unit | Water and soil properties | General management options
---|---|---
DEEP SANDS (30,000 ha) | • High groundwater recharge.  
• High risk of wind erosion on exposed crests, lunettes and upper slopes, otherwise the risk is moderate.  
• These soils are very highly leached do not retain nutrients, and are highly prone to sub-surface acidification.  
• Water erosion is a high risk on exposed upper slopes.  
• Sandy soils may display water repellence.  
• Soil water storage is generally low.  | Soil management  
• With reasonable annual rainfall, high yields can be obtained using high fertilizer input, especially potash and micronutrients. Suitable for cereal/lupin rotation using minimum till and stubble retention, or revegetated with trees for shelter belts or agroforestry.  
• Practice stubble retention, brown manuring or maintain approximately 50 per cent ground cover to control wind and water erosion and maintain soil organic matter.  
• Liming is likely to be uneconomical due to the characteristically low productivity of this soil.  
• Claying water repellent soils may be an option to consider where the problem is widespread.  
Cropping/pasture options  
• Lupins and wheat where wind erosion is not a problem.  
• Lucerne.  
• Veldt grass and serradella mix.  
Recharge reduction and surface water control  
• Grader built earthworks may alleviate soil erosion on slopes or inundation on flats, but have a high maintenance requirement. Interception of shallow seepage unlikely to be effective on downslope waterlogging. Waterlogging period may be reduced on valley floors by the placement of shallow relief drains (‘W’, ‘U’, etc.)  
Revegetation options  
• Maritime Pine plantation over entire area  
• Plots of tagasaste planted in rows three to six meters apart managed as fodder for cattle (will need to be cut for sheep) Acacia saligna can be direct seeded, but its value for fodder is questionable.  
• Some pastures (e.g. serradella) may be sown between rows if wide enough.  
• Fence off low production areas and remnant vegetation, allow regeneration or plant suitable Banksia, acacia species.  
• Seedlings usually grow best on deep sands, plant as early as possible.
<table>
<thead>
<tr>
<th>Land management unit</th>
<th>Water and soil properties</th>
<th>General management options</th>
</tr>
</thead>
</table>
| GRAVEL PLAINS AND SLOPES (23,000 ha)  | Ironstone gravel > 60 per cent overlying day or hard ironstone at varying depths. Occurs generally on, valley spurs, crests and slopes | • High groundwater recharge if cleared.  
• Sandy topsoils are moderately susceptible to sub-surface acidification, traffic and plough pans.  
• Moderate wind and water erosion on exposed sites where ground cover is < 50 per cent.  
• Low soil water storage.  
• May be susceptible to water repellence.  
• Generally good rooting depth. Effective rooting depth can be up to the clay layer. |  
• Liming may be necessary; regular monitoring of soil pH levels is advised.  
• High retention of Phosphorus may be a problem with these dense gravelly soils.  
• Maintenance of active growing plants is important here to prevent rapid drainage of soil water to below the root zone, contributing to problems lower in the landscape.  
• Cultivation should be carried out on the contour to reduce erosion risks and improve water conservation for crops.  
• Minimum tillage or no-till is encouraged to reduce the incidence of traffic and plough pans, improving soil structure, and maintaining soil organic matter. It may be worth examining deep cultivation to overcome current compaction problems.  
• Practice stubble retention or aim to maintain >50% ground cover to control risk of wind and water erosion.  

**Soil management**

**Cropping/pasture options**

• Canola, barley, oats and lupins.  
• Lucerne phase cropping.  

**Recharge reduction and surface water control**

• Soil profile and depth to clay need to be checked prior to commencing earthworks. Earthworks with grades should be used to move water off, prevent ponding and recharge.  
• Alley farming/strip planting system to reduce recharge rates.  

**Revegetation options**

• Direct seed native species-scalp areas with grader, scraper or chatfield.  
• Farm forestry species (eucalypt sawlogs) in four row belts (max. 30m wide)- plant an extra row of hardy shrubs to maintain windbreak value (see mallett hills)  
• Oil mallee alleys-unfenced four or eight meter row belts.  
• Fence off remnant vegetation and allow to regenerate.
**Land management unit**

- **GREY to BROWN LOAMS AND CLAYS**
  - **(5,000 ha)**
  - Shallow alkaline grey loamy duplex soils and non-cracking grey clays. Grey/greyish brown loamy surface layers over clay at < 30 cm, or clay at surface. These soils mainly occur on areas adjacent lakes and swamps, or flats and depressions. Also includes crabhole clays (gilgai country).

**Water and soil properties**

- Moderate groundwater recharge, highest where water ponds.
- Hardsetting topsoil limits root penetration and establishment of seedlings.
- Salinity may develop on valley floors and drainage lines with shallow watertables, or on ponded areas.
- Soil can be worked only over a narrow moisture range as it becomes too boggy when wet, and too hard when dry.
- Moderate to high risk of waterlogging and inundation, highest on flats and low-lying areas.
- Gilgai can be an obstacle to machinery.
- These clays are highly dispersible and sodic, and conditions are often made worse by cultivation.
- Clays can often be saline.

**General management options**

- **SOIL MANAGEMENT**
  - Green manuring of a high legume percentage pasture or a legume crop such as lentils or peas may improve organic matter content and soil structure and aid in improving yields.
  - Minimum tillage or no-till practices are preferred to maintain soil structure.
  - Adding gypsum may help improve soil structure and increase productivity. Investigate with a gypsum test and test strips first.
  - Avoid working the soil when excessively wet.
  - Activities which result in rapid loss of organic matter, such as long fallowing in a crop rotation and stubble burning, should also be avoided.

**CROPPING/PASTURE OPTIONS**

- Cereals.
- Medics on alkaline soil.
- Summer crops.

**RECHARGE REDUCTION & SURFACE WATER CONTROL**

- Shallow relief drains (‘W’) can be used to reduce ponding and promote drainage from valley floors.
- Hardsetting clay can be reliable run-off source for dam catchments.
- Raised beds may improve surface drainage and enable plant species to persist.

**REVEGETATION OPTIONS**

- Belts of oil mallees (four or eight rows) below banks, separated by crop pasture areas (suitable machinery width).
- Fence off remnant vegetation/swamps and allow to regenerate, plant a buffer of suitable native/farm forestry species.
- Saline areas—see recommendations for Saline Soils.
- Eucalypt Sawlogs—*Eucalyptus occidentalis* (provenance important) contact farm forestry officer.
<table>
<thead>
<tr>
<th>Land management unit</th>
<th>Water and soil properties</th>
<th>General management options</th>
</tr>
</thead>
<tbody>
<tr>
<td>SALT-AFFECTED LAND</td>
<td>• Presently saline.</td>
<td>Soil management</td>
</tr>
<tr>
<td>(2,000 ha)</td>
<td>• Mainly groundwater discharge but recharge may occur during winter.</td>
<td>• Where possible, fence affected area to protect from compaction and erosion by stock and traffic.</td>
</tr>
<tr>
<td></td>
<td>• Very high risk of waterlogging, inundation, and in some areas, flooding.</td>
<td>• Maintenance of ground cover to reduce risk of water erosion is recommended.</td>
</tr>
<tr>
<td></td>
<td>• Highly susceptible to serious water erosion problems (gully and rill), particularly along saline drainage lines.</td>
<td>• Many of these areas are not suited to agricultural production due to waterlogging and salinity problems.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cropping/pasture options</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Not suitable for cropping.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Perennials such as tall wheat grass and tall fescue.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recharge reduction and surface water control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Appropriate shallow surface drainage is recommended (e.g. W-drains, grade banks, herringbone drainage and revegetation establishment). Notification of Intent to Drain will be required.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Grader built intercepting banks to clay installed above the salt-affected area may aid by draining water flowing on the clay subsurface before it contributes to saline areas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Increase water use off-site as well as on-site.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Groundwater options</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Drains to relieve groundwater and groundwater pumping are expensive options. Good design is essential and should be site specific.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Drainage effluent can be a problem with negative impacts.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• A Notice of Intent to Drain will be required.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Revegetation options</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• All revegetation areas should be mounded at 0.5 to 1% slope to reduce waterlogging-mounds with a distinct 'V' work best.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Mild saline areas four row belts of tolerant oil mallees, with tolerant pasture species (balansa, etc.) sown between-maintain grazing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Single rows of saltbush species (direct seeded or seedlings), separated by alleys of saltland pastures-managed for fodder.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Fence off creeks, waterways and adjacent bare/eroded areas. Allow regeneration of rushes, samphires, paperbarks and/or revegetate with tolerant native species/saltbushes-not grazed.</td>
</tr>
</tbody>
</table>
### Land management unit

<table>
<thead>
<tr>
<th>RED/ REDDISH BROWN SOILS (Including alluvial flats, red to brown clay loams, and dyke soils) (3,000 ha)</th>
</tr>
</thead>
</table>

Reddish brown sandy loam over day or grading to day at 10-20 cm (red loam); red or reddish brown day loam over red clay at <10 cm or grading to red clay at depth (red clay). Seen mainly on slopes and is often associated with dolerite dykes or the footslopes of breakaways.

### Water and soil properties

- Low to moderate groundwater recharge.
- Good water availability in most years - dry seasons may cause water stress.
- Fresh or saline hillside seeps may occur on or near these soils.
- Surface cracking may make stock and vehicle movement difficult.
- Low risk of waterlogging. Lighter soils upslope from this LMU may exhibit waterlogging due to the heavier red soils acting as a textural barrier to lateral water movement.
- Moderately susceptible to water erosion and decline of topsoil structure.
- Surface and subsurface soils may be alkaline and unsuitable for some crops and pastures, and may exhibit nutrient toxicity and deficiencies.
- Reddish/brown loamy soils associated with breakaways are often acidic through the topsoil and saline through the sub soil.

### General management options

- Cropping operations should occur on the contour and minimum tillage or no-till operations and stubble retention should be considered to aid in improvement of soil structure.
- Reduction of traffic in paddocks and avoidance of traffic movement when soil is wet minimizes soil compaction.
- Liming is recommended where top soil pH is < 5.0.
- Crop growth and yields can often be severely affected by the breakaway varieties of this soil. An EM survey is highly recommended across these soils, particular adjacent breakaway landscapes.
- The application of gypsum may reduce the crust forming or hardsetting nature of the topsoils. Incorporating organic matter may also be an appropriate action to improve the soil structure, drainage and organic matter content.

### Soil management

- **Cropping/pasture options**
  - Phase cropping with lucerne.
  - Cereals.

### Recharge reduction and surface water control

- Lucerne on areas that are not prone to waterlogging or seepage.
- Grade and seepage interceptor banks can reduce erosion and waterlogging. Care should be taken in siting of banks as striking rock may lead to increased recharge.

### Revegetation options

- Belts of revegetation 20 to 30 m wide placed below grade banks or interceptors.
- Farm Forestry species (eucalypt sawlogs) in four row belts-plant an extra row of hardy shrubs to maintain windbreak value (Eucalyptus dodocalyx, E. loxophleba ssp. loxophleba, E. occidentalis, E. triacarp, E. astringens, Allocasuarina huegeliana).
- Native species-hosts for Sandalwood production-direct seed or seedlings.
- Oil mallee alleys-four or eight row belts (unfenced).
- Fence large areas of remnant vegetation and allow to regenerate.
- Rip into clay layer to assist root penetration of seedlings.
<table>
<thead>
<tr>
<th>Land management unit</th>
<th>Water and soil properties</th>
<th>General management options</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHALLOW GRAVELLY AND STONY SOILS</td>
<td>• Very high groundwater recharge.</td>
<td>Soil management</td>
</tr>
<tr>
<td>(3,000 ha)</td>
<td>• Water erosion is a high risk on exposed upper slopes.</td>
<td>• Maintenance of active growing plants is important here to prevent rapid drainage of soil water to below the root zone, contributing to problems lower in the landscape.</td>
</tr>
<tr>
<td></td>
<td>• Water availability varies, depending on depth to clay.</td>
<td>• Cultivation should be carried out on the contour to reduce erosion risks and improve water conservation.</td>
</tr>
<tr>
<td></td>
<td>• Rocks may hinder cultivation and reduce trafficability.</td>
<td>Cropping/pasture options</td>
</tr>
<tr>
<td></td>
<td>• Moderate risk of wind erosion - rocks on surface lessen risk.</td>
<td>• Moderate performance of cereals and annual pastures.</td>
</tr>
<tr>
<td></td>
<td>• Generally good rooting depth but stones may hinder roots.</td>
<td>• Summer crops.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Recharge reduction and surface water control</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Kikuyu.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Phalaris and strawberry clover in seepage areas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Placement of earthworks is highly dependent on soil structure and clay depth. Grader built earthworks may alleviate soil erosion on slopes or inundation on flats, but have a high maintenance requirement. Unless the clay layer is reached, banks will be ineffective for waterlogging control.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Revegetation options</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Fence off and allow any existing vegetation to regenerate.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Sandalwood plantation-hosts required.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Revegetate with a mixture of native species around the rock areas-direct seed sandalwood after hosts are established.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Use direct seeding or seedlings as a method of establishing a buffer zone and extra habitat around these important nature conservation areas.</td>
</tr>
</tbody>
</table>

* Other minor land management units include alluvial loams and rock outcrops. These units are illustrated in an AGMAPS Land Manager CD-ROM available for the Albany Eastern Hinterland area.
Figure 4.1.1. Generalised landscape cross-section and associated land management units.

- Shallow sandy and loamy duplex soils
- Variable depth (aeolian) sand sheets
- Linear sand dunes (3 m)
- Shallow sandy and loamy duplex soils
- Shallow (gravelly) duplex soils
- Swamps
- Deep sand lunettes
- Breakaways
- Valley and alluvial flats

Mottled clays
/Spongeolite
Granitoid bedrock
4.2 Water management

4.2.1 Groundwater management

Arjen Ryder, Albany

Lucerne phase farming as an option

The economic and environmental benefits are important considerations before introducing perennials into the farming system. Phase farming with lucerne (three to four years crop, three to four years lucerne) is becoming widely accepted for its profitable contribution to the grazing and cropping systems with the added benefits of reducing recharge, increased soil nitrogen and providing winter cleaning as an option in managing herbicide resistance.

Estimating recharge through the AgET model

AgET is a model that provides an estimate of recharge based on soil, rainfall and plant species. The model was developed by the Department of Agriculture in association with the University of Melbourne. As with all models and mathematical assumptions, it is important to note that the model provides an estimate. Variations in the estimates will occur in the field.

Impact of introducing lucerne into the farming system

The example (calculated using the AgET model) below shows the estimated reduction in recharge across a 4,280 ha property, when lucerne plantings were increased from zero to 18 per cent of the property.

Property details

Property size: 4,281ha
Average rainfall: 450 mm (AgET rainfall records used from 1974 to 1993)
Property detail: Summary (under the existing land use of annual pasture and crop).

<table>
<thead>
<tr>
<th></th>
<th>1,800 ha</th>
<th>52%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual pasture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop</td>
<td>1,600 ha</td>
<td>48%</td>
</tr>
<tr>
<td>Total arable land</td>
<td>3,400 ha</td>
<td></td>
</tr>
<tr>
<td>Swamps</td>
<td>250 ha</td>
<td></td>
</tr>
<tr>
<td>Remnant bush + non-arable</td>
<td>630 ha</td>
<td></td>
</tr>
<tr>
<td>Total land area</td>
<td>4,280 ha</td>
<td></td>
</tr>
</tbody>
</table>

Recharge under existing the land use of annual pasture and crop is 55 mm (or 12.5 per cent of annual rainfall).

The above system then compared to having 18 per cent of the property under lucerne is observed as follows:

<table>
<thead>
<tr>
<th></th>
<th>1,320 ha</th>
<th>38%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual pasture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lucerne</td>
<td>635 ha</td>
<td>18%</td>
</tr>
<tr>
<td>Crop</td>
<td>1,445 ha</td>
<td>42%</td>
</tr>
<tr>
<td>Total arable land</td>
<td>3,400 ha</td>
<td></td>
</tr>
<tr>
<td>Swamps</td>
<td>250 ha</td>
<td></td>
</tr>
<tr>
<td>Remnant bush + non-arable</td>
<td>630 ha</td>
<td></td>
</tr>
<tr>
<td>Total land area</td>
<td>4,280 ha</td>
<td></td>
</tr>
</tbody>
</table>
Lucerne and other perennials could reduce recharge from 12.5 per cent of annual rainfall to 10 per cent (or 45 mm) by using water in summer.

Production benefits of lucerne and other perennial pastures include additional green feed after annuals have dried off, reduced autumn hand feeding, potential to fix 60 kg of soil nitrogen per hectare per year and increased protein levels in the following grain crop. Environmental benefits include recharge reduction, decreased soil moisture within the top two metres and lowered groundwater levels.

Lucerne roots have been found growing down to 3.5 m at Wellstead and dried the soil profile by approximately 200 mm compared with annual pasture. Growing lucerne will reduce recharge and decrease the potential extent of land at risk of becoming saline.

4.2.2. Surface water management

*Austin Rogerson, Albany*

**Surface water engineering options**

There are many engineering options for managing surface water before it contributes to erosion, eutrophication, sedimentation, waterlogging, flooding groundwater recharge and salinity.

Where the slope and soil characteristics of the land encourages water to shed off the land (‘shedding landscape’ c.f. Griffin, Verboom, Schoknecht, Gould and Cacetta 2002), surface water earthworks can reduce the velocity and volume (peak flow) avoiding serious soil erosion. Where there is little slope in the land, water flows from a shedding landscape and accumulates in an area (receiving landscape) causing waterlogging, flooding and adding to groundwater recharge.

Forty eight per cent of the slopes in the Study area are below 1.5 per cent (Figure 4.2.2). Where these flat areas occur adjacent to slopes in excess of 1.5 per cent, the area would be considered a receiving landscape. Fifty thousand hectares of the sandplain have low relief with slopes less than 1.5 per cent, have poor drainage and become waterlogged from 'in-situ' rainfall. Typically these are broad and internally draining flats of the gently undulating coastal sandplain and areas of the deep sand sheets within the Sandplain East, Gnowellen/Pendernup and Kojaneerup catchment areas.

Despite the deeper sandy soil profile, these landscapes benefit from engineering options such as 'W'drains and shallow relief drains that improve water movement and reduce waterlogging.
Subject to site survey, this map shows where surface water earthworks can be considered over five major soil-landscapes in the study area.

![Distribution of slope classes across the study area.](image)

Figure 4.2.2. Distribution of slope classes across the study area.

Table 4.2.2. Area (ha) suitable for surface water earthworks

<table>
<thead>
<tr>
<th>Soil-landscape</th>
<th>Slope Class</th>
<th>Total ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gently undulating coastal sandplains between small rises in the Sandplain East catchment area. Common soils grey deep and shallow sandy and gravely duplex</td>
<td>23,600 18,700 2,280 330</td>
<td>44,910</td>
</tr>
<tr>
<td>Sandy and gravelly coastal sandplain. Typically within the Kojaneerup and Penderup/Gnowellen catchment areas. Common soils are grey shallow sandy duplex</td>
<td>12,900 12,440 1,050 150</td>
<td>26,540</td>
</tr>
<tr>
<td>Long linear dunes and deep sand sheets in the Chillinup system. Common soil types are pale deep sand and grey deep sandy duplex</td>
<td>10,300 9,100 860 70</td>
<td>20,330</td>
</tr>
<tr>
<td>Alluvial soils of the valley floor where the Pallinup River cuts through the Chillinup Plain. Common soils are grey sandy duplexes, sandy gravels and deep red and grey loamy duplex</td>
<td>430 1,790 1,320 540</td>
<td>4,080</td>
</tr>
<tr>
<td>Crabholes, lunettes and seasonally filled depression and swamps</td>
<td>2,950 3,220 1,200 400</td>
<td>7,770</td>
</tr>
<tr>
<td><strong>Total (ha)</strong></td>
<td><strong>50,190</strong></td>
<td><strong>103,630</strong></td>
</tr>
</tbody>
</table>
Surface water engineering for shedding landscapes

Within shedding landscapes water erosion can be controlled by intercepting, diverting or slowing run-off rather than permitting it to flow uninterrupted down the slope. Grade banks control water run-off by increasing the flow path length, therefore increasing time of concentration or slowing the velocity of the run-off thus preventing soil erosion. Grade banks are placed in the midslope and upper water shedding landscape areas.

To be most effective grade banks should be deep enough to allow the sub-surface clay to be cut and placed on the downhills bank to provide a seal against seepage.

The deep sandy duplex soils make the placement of grade banks difficult, and depth to clay needs to be surveyed before work commencement.

Due to the deep sandy profiles, it is difficult to estimate the area that grade banks and waterways may be installed. Subject to clay depth, there may be opportunities to install grade banks and waterways on up to 9,100 ha with slopes up to 10 per cent. The most suitable soil-landscapes for grade banks, and waterways are within the Gnowellen/Pendernup and Kojaneerup sub-catchment areas.

Surface water engineering for receiving and limited self-draining landscapes

Receiving areas have lower relief than the adjacent shedding slopes causing accumulation of run-off, leading to waterlogging and flooding.

Landscapes with low relief and no defined drainage, but have no adjacent shedding slopes are 'not receiving areas'. There areas are be defined as limited self-draining landscapes and are susceptible to waterlogging, ponding, flooding and increased recharge.

Within receiving or limited self-draining landscapes, waterlogging, excess surface water or barriers to surface water movement can be alleviated by shallow relief drainage; i.e. channels cut into the soil surface which allow surface water to enter and drain at a nominated grade to maintain a safe water velocity preventing soil erosion.

For the sandplain areas that have limited self-draining potential, shallow relief drains are the most cost effective engineering option for reducing waterlogging and inundation.

Landholders within these sandplain areas should use differential global positioning system data (DGPS) to accurately map paddock contours and develop strategic surface water drainage plans that include permanent waterways (non cropping drainage lines) and shallow relief drains that may be cropped over.

The areas where drains are most likely to be effective are the sandplains of Kojaneerup, Pendernup and Gnowellen and the undulating coastal sandplain of Wellshead Sandplain East. Areas under 1.5 per cent grade may benefit from shallow relief drains to alleviate waterlogging. Whilst these deep sandy soils are highly permeable, if they are saturated and subject to ponding, crops will benefit from drainage.

Table 4.2.2 cannot be used to identify specific locations suitable for shallow relief drainage, but the table does show that large areas are suitable. Land managers should assess their own land to determine its suitability for shallow relief drainage, and attempt to define and improve natural drainage.
Earthworks require careful planning because inappropriate and poor designs can cause soil degradation. Suitably qualified people need to be consulted for the legal aspects, design and construction. The following points need to be addressed.


- **The annual recurrence interval (ARI):** is the frequency an earthwork is designed to fill or safely fail. Important earthworks, such as dams, waterways and absorption banks are designed for at least a 20-year ARI. The minimum design of most drains and banks is a 10-year ARI (Bligh 1989).

- **Legal aspects:** there are legal aspects that must be considered before earthworks are constructed. Diversion of flows, increasing flow velocities or increasing quantity of flow, could cause damage to neighbouring properties for which the drainage proponent may be responsible (Keen 1998). Catchment planning and discussing planned earthworks with potentially affected neighbours is recommended.

After defining the problem and carrying out land assessment, the type and design of earthwork to construct can be selected. The design criterion for earthworks commonly used in Western Australia is listed in Table 4.2.3. Earthworks alone cannot halt the rising watertable and need to be used in conjunction with other conservation farming strategies. For more information visit: [www.agric.wa.gov.au/environment/land/drainwise/options/index.htm](http://www.agric.wa.gov.au/environment/land/drainwise/options/index.htm)

<table>
<thead>
<tr>
<th>Earthwork design</th>
<th>Land slope (%)</th>
<th>Soil type</th>
<th>Grade (%)</th>
<th>Landscape position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade bank</td>
<td>Up to 10</td>
<td>SD / L</td>
<td>0.2-0.5</td>
<td>Upper &amp; mid-slope</td>
</tr>
<tr>
<td>Seepage interception</td>
<td>Up to 10</td>
<td>SD / DD / S</td>
<td></td>
<td>Lower &amp; mid-slope</td>
</tr>
<tr>
<td>bank</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broad-based banks</td>
<td>2-6</td>
<td>SD / L</td>
<td>0.15-0.3</td>
<td>Upper, mid &amp; lower-slope</td>
</tr>
<tr>
<td>Shallow relief drains</td>
<td>Up to 0.2</td>
<td>C / SD</td>
<td>Up to 0.2</td>
<td>Valley floor</td>
</tr>
<tr>
<td>Levee waterways</td>
<td>Up to 10</td>
<td>C / S / DD / SD</td>
<td>Up to 10</td>
<td>Valley floors and hillslope</td>
</tr>
<tr>
<td>Raised bed</td>
<td>0.1-2</td>
<td></td>
<td>0.1-2</td>
<td></td>
</tr>
<tr>
<td>Evaporation ponds</td>
<td>Site-specific</td>
<td></td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Dams</td>
<td>Up to 10</td>
<td>C / SD / DD / L</td>
<td>Up to 10</td>
<td>Not in valley watercourse</td>
</tr>
<tr>
<td>Roaded catchment</td>
<td>Up to 6%</td>
<td>C / SD</td>
<td>Up to 6%</td>
<td>Good day required close to surface</td>
</tr>
</tbody>
</table>

* Further information about the above structures can be found out by an on-line search through the following web page. [www.agric.wa.gov.au/environment/land/drainwise/options/engineering](http://www.agric.wa.gov.au/environment/land/drainwise/options/engineering)

** Key to soil groups**

- C: Clay
- S: Sand
- L: Loam
- G: Gravel
- SD: Shallow duplex
- DD: Deep duplex
Conservation earthworks

Comprehensive descriptive information about various conservation earthworks and their placement in the landscape, is available on-line through the Department of Agriculture’s Internet site (Table 4.2.4, Figure 4.2.3). Similar information can be sourced through several other Department of Agriculture technical publications.

![Diagram of contour earthworks](image)

**Figure 4.2.3.** Schematic representation of some typical surface earthworks (after, Negus and Lefroy n.d.).

**Table 4.2.4.** Web links to follow on design, description and placement of conservation earthworks

<table>
<thead>
<tr>
<th>Valley floors and lower-slopes</th>
<th>Web Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levee and leveed waterways</td>
<td>Sh_relief.htm</td>
</tr>
<tr>
<td>Raised beds</td>
<td></td>
</tr>
<tr>
<td>Lower to mid-slopes</td>
<td></td>
</tr>
<tr>
<td>Mid to upper-slopes</td>
<td></td>
</tr>
<tr>
<td>Grade banks</td>
<td>Gr_bnk.htm</td>
</tr>
<tr>
<td>Upper-slopes</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.2.5. Other earthworks

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No dam site should be selected without drilling for soil suitability.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Evaporation basin design is based on the criterion that no leakage occurs to any groundwater that has an existing beneficial use or a potential beneficial use, nor should there be any overflow to environmental sensitive areas.</td>
</tr>
</tbody>
</table>

4.2.3 Groundwater management

There are only a few options for managing groundwater before it contributes to waterlogging and salinity. The effectiveness of these options is limited due to the local and intermediate groundwater flow systems that typically have low permeability and gradients and therefore have a low ability to move groundwater. Table 4.2.6 offers some options that may be suitable in the study area.

Table 4.2.6. Groundwater management options

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Deep drains are used to lower the watertable close to the surface, reducing waterlogging of the topsoil while allowing rainfall to leach salt from the upper profile.</td>
</tr>
<tr>
<td></td>
<td>Deep drains are expensive and have limited application in the study area. Open drains remove land from production and their effectiveness is variable according to soil type. Careful planning and site assessment is required to ensure deep drains are effective.</td>
</tr>
<tr>
<td></td>
<td>Deep drain construction cost are estimated between $3000-$6000 kilometre (based on 2mtr depth)</td>
</tr>
<tr>
<td></td>
<td>Farmers must notify the Commissioner of Soil Conservation of their intention to construct deep drains at least 90 days before undertaking the earthworks.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pumping is most often used to protect sites in recovery catchments (nature conservation), rural towns and other areas where high value assets are at imminent risk.</td>
</tr>
<tr>
<td></td>
<td>Groundwater pumping is most effective in permeable aquifer systems. These include deep sandy profiles, thick saprock over basement rocks with coarse material and in some geological faults and shear zones.</td>
</tr>
<tr>
<td></td>
<td>The Commissioner of Soil Conservation must be notified at least 90 days before undertaking groundwater pumping with associated earthworks.</td>
</tr>
</tbody>
</table>

Farmnote 20/2001 Agriculture Western Australia.
Table 4.2.6. Groundwater management options (continued)

<table>
<thead>
<tr>
<th>Relief wells (artesian bores)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A relief well is a 'free flowing' groundwater bore driven by artesian pressure.</td>
</tr>
<tr>
<td>A typical relief well with a drilling diameter of 100 mm, installed using 50 mm diameter casing, to a depth of 20 to 30 m, is estimated to cost $2000.00.</td>
</tr>
<tr>
<td>When planning to install relief wells, a notice of intent (NOI) is required to be submitted to the Office of the Commissioner for Soil and Land Conservation at least 90 days prior to installation.</td>
</tr>
</tbody>
</table>

**Farmnote 42/2001 Department of Agriculture Western Australia.**


**Legislation: Notice of intent to drain or pump**

Management of surface and sub-surface water through constructed drainage is recognised, as one of the legitimate tools available to fighting salinity, waterlogging and inundation, although increased use of water through vegetation or farming systems remains the preferred option.

Regulations established under the Soil and Land Conservation Act require that, 'When an owner or occupier of land proposes to drain or pump water from under the land surface because of salinity of the land or water and to discharge that water onto other land, into other water or into a watercourse, the owner or occupier shall, at least 90 days before the draining or pumping commences, notify the Commissioner in writing in the manner set forth in Form 2 Schedule 2'.

Landholders need to understand that they have a duty of care to ensure their management actions do not lead to land degradation.

A penalty will apply to the owner or occupier who fails to notify the commissioner.


### 4.3. Productive use and rehabilitation of saline land

**Ronald Master, Albany**

The area of existing salinity in the study area is small, however, many of the prominent areas are increasing.

The area currently receives an annual average rainfall of about 470 mm. This combined with a reasonably reliable summer rainfall provides several options for the productive use of saline land.

Severe waterlogging is in many cases exacerbating the effect of the salinity. Where this occurs, earthworks should be considered in an effort to remove surface water. In some areas, particularly around the lakes and wetlands this may be not possible. On some of the broad flats, raised beds are also an option that could allow cropping or the establishment of perennial pastures.

In areas of severe waterlogging and low salinity, which are often dominated by barley grass pastures, there are several alternative pasture species that could be considered.

- Tall wheat grass is active in both summer and winter and should be grown in sites with a surface salinity of less than 15 mS/m (Barrett-Leonard et al. 1995).
- Balansa clover, while not as salt tolerant as tall wheat grass, is very tolerant of waterlogging (Nulsen 2001). It will grow in wet, mildly salt-affected areas and has a long growing season. The two grasses combined will provide good quality feed, help to fill the autumn feed gap and will utilise excess stored soil moisture.
More severely affected sites greater than 15mS/m could be planted with puccinellia (Barrett-Leonard et al. 1995) and in even more saline areas, saltbush alleys. Puccinellia is palatable and responds well to grazing but must be left for at least 12 months after planting (Runciman and Malcolm 1989).

In areas less prone to waterlogging but with moderate levels of salinity, perennials like Rhodes grass could be considered. It is a palatable running grass and will utilise large amounts of soil moisture. Tall wheat grass and Puccinellia are also options.

Some hillside seeps do occur within the study area, particularly in the northeast. For mildly to moderately affected sites, the above-mentioned options are suitable, particularly a tall wheat grass or balansa mix. An additional strategy is to sow the sites with a ‘shotgun-mix’ of balansa, tall wheat grass and Puccinellia. This would ensure that a broad range of saline environments could be covered through one application. For the more severely salt-affected sites, revegetation with highly salt tolerant natives and saltbush may be the only option.

The options for severely affected lakes and wetlands are limited. The best course of action is most probably to fence the site off and allow samphire to establish. Where possible, highly salt tolerant species like *M. thyoides*, *C. obesa*, saltbush and other salt tolerant native species could be established to stabilise these sites and possibly provide habitat areas for native wildlife.

### 4.4 Economic analysis of management options

*Michael O'Connell, Albany*

**Guiding principles**

Decisions about salinity management are often complex. Deciding on what to do, when to do it, and how much of it to do, are big decisions. In order to minimise the chance of costly mistakes, the following process is recommended:

- Identify the problem, its causes and impacts on the farm business.
- Identify the various courses of action that are technically feasible.
- Analyse the economic and financial feasibility of the options available.
- Implement your chosen solution(s) to the problem.
- Monitor, control and revise for unexpected developments.
### Table 4.4.1. Selected enterprises for salinity management—summary of some important costs, benefits and cash flow implications

<table>
<thead>
<tr>
<th>Option</th>
<th>Costs/disadvantages</th>
<th>Benefits/advantages</th>
<th>Cash flow implications</th>
<th>Main profit drivers</th>
</tr>
</thead>
</table>
| Perennial pastures (e.g. lucerne, kikuyu) | Establishment costs are usually similar to cost of planting a crop.  
Ongoing costs are similar to annual pasture.  
Removal can require several sprays and careful management. Dead plants can create problems for seeding following crops.  
Soil profile will be very dry after a perennial pasture phase. Crop yields may suffer if growing season rainfall is low.  
Potential for animal health problems on lush green feed, but risk can be managed. | Reduced recharge.  
Supply of quality feed during autumn feed trough.  
Disease break for following crops.  
Nitrogen fixation by legumes (e.g. lucerne). | Usually negative cash flow in year one, but cover cropping can help recoup costs.  
Positive cash flow from year two onwards.  
Anticipate full cost recovery after two to seven years. | Livestock and wool prices.  
Flock structure.  
Success of establishment (failed establishment is expensive).  
Quality and quantity of out of season feed.  
Availability and cost of other feeds.  
Yield and protein boost in following crops.  
Area grown (average value declines as more area is sown). |
| Balansa dover | Should cost less than a crop to establish.  
Careful grazing management is required.  | Can be grown in areas where traditional pastures perform poorly.  
Waterlogging allows growing season to be extended. | A well-managed balansa pasture can be very profitable. | Quality of dry feed in summer.  
Livestock and wool prices.  
Flock structure.  
Area grown. |
<table>
<thead>
<tr>
<th>Option</th>
<th>Costs/disadvantages</th>
<th>Benefits/advantages</th>
<th>Cash flow implications</th>
<th>Main profit drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Saltbush pasture system (e.g. saltbush, puccinellia, tall wheat grass, balansa clover)</strong></td>
<td>Establishment costs vary enormously, typically ranging from $75/ha to over $200/ha. A good supply of fresh water must be provided for stock. New fences might be needed. Musterings can be a problem. Generally not suitable for lambing ewes and young sheep.</td>
<td>Reduced recharge. Reduced water erosion. Saltbush dries soil profile enough to allow salts to be flushed from topsoil. Other pasture plants can then establish (e.g. balansa clover, grasses). These other pasture species form a large part of the grazing value. Can last for many years if managed well.</td>
<td>Some grazing available in the first year. Cost recovery period will depend a lot on cost of establishment. Have been demonstrated to be profitable, especially when a good understorey of highly nutritious pasture is established.</td>
<td>Livestock and wool prices. Success of establishment (failed establishment is expensive). Quality and quantity of out of season feed. Availability and cost of other feeds. Area grown.</td>
</tr>
<tr>
<td><strong>Tagasaste</strong></td>
<td>Establishment cost typically in the order of $100-150/ha. Require ongoing management to prevent plants getting too big. New fences might be needed. Musterings can be a problem.</td>
<td>Stabilises soil. Reduced recharge. Provides year round feed.</td>
<td>Depends strongly on how well the plants are utilised. Well-managed stands can be profitable.</td>
<td>Feed must be utilised in order to realise benefits. Livestock prices. Success of establishment. Availability and cost of other feeds. Area grown.</td>
</tr>
<tr>
<td><strong>Tree crops in blocks, such as sandalwood</strong></td>
<td>Often costs over $1,000/ha to establish, plus ongoing maintenance. Livestock must be excluded for at least the establishment phase, often longer. Future prices and yields are uncertain. Recharge benefits restricted mainly to land on which trees are planted.</td>
<td>Stabilises soil. Reduced recharge.</td>
<td>Depends strongly on how well the plants are utilised. Well-managed stands can be profitable</td>
<td>Success of establishment. Availability and cost of other feeds. Area grown.</td>
</tr>
</tbody>
</table>
5. CONCLUSION

The greatest natural resource management threats to farming systems in the study area are:

- non-wetting soils affect approximately 95,000 ha (75 per cent);
- subsurface soil compaction affects approximately 88,600 ha (70 per cent);
- waterlogging affects approximately 73,400 ha (58 per cent);
- soil acidity currently affects about 69,600 ha (55 per cent); and
- wind erosion susceptibility is approximately 63,300 ha (50 per cent) of the area.

Surface salinity currently affects about 1,200 ha (1 per cent) of the area, (although this figure is considered to be under-estimated). It is important to note that in some locations within the study area, the groundwater levels are rising at 20 cm a year or more. In other areas, the groundwater levels are deep (20 m) and the trend is static with minimal increases. The potential for rising groundwater tables and associated salinity in the study area should not be ignored.

There are still many areas of high biological value in the study area, particularly along the Pallinup River and its tributaries. These areas are at a greater risk of salinisation and are likely to exhibit symptoms earlier than some of the surrounding agricultural landscapes. It is possible to reduce the impact on remnant vegetation and the wider landscape provided that measures are taken to improve water-use efficiency across the landscape by such means as reducing recharge, improving crop and pasture yields.

Land managers are addressing many of the natural resource issues:

- Surface clay spreading is practised, but not as widely as needed because suitable clay is not readily available.
- There has been a major shift to no-till or minimum-till, which will help mitigate erosion and subsoil structure decline. Progressive tillage is being trialed in an attempt to overcome soil compaction.
- Liming to ameliorate soil acidity is widespread, although application rates are still less than what they should be to lift soil pH to satisfactory levels.
- Earthworks are being implemented where possible to reduce waterlogging and erosion. However, many areas remain waterlogged and return poor crop and pasture yields.
- Perennials (e.g. Kikuyu and lucerne) are increasingly being established to increase production while reducing waterlogging, recharge and salinity. Phase cropping with lucerne will help reduce the impact of resistant weeds and help utilise stored soil moisture.
6. REFERENCES


6.1 References for alternative perennial pasture species

**Lucerne**

Farmnote No. 4/98 'Dryland lucerne - establishment and management'.
Farmnote No. 53/89 'Insect pests in lucerne'.
Farmnote No. 79/89 'Diseases and their control in lucerne'.
'Success with dryland lucerne': Contact Crop Monitoring Services 018 838 103.
WA Lucerne Growers Association C/- Roy Latta, Department of Agriculture, Katanning.

**Kikuyu**

Perennial pastures, Sudmeyer *et al.* 1994, Bulletin 4253 AgWEST.
Perennial pasture establishment technique, Buchanan *et al.* Esperance LCDC.
Perennial grasses for animal production in the high rainfall areas of WA, Greathead *et al.*
1998, Misc Pub 2/98, AgWEST.
Farmnote No. 11/95 'Kikuyu – the forgotten pasture?'.
Farmnote No. 11/98 'Well adapted perennial grasses for the Esperance sandplain'.

**Rhodes grass**

Perennial pastures, Sudmeyer *et al.* 1994, Bulletin 4253 AgWEST.
Perennial pasture establishment technique, Buchanan *et al.* Esperance LCDC.
Farmnote No. 20/99 'Perennial grasses-there role in the Ellen Brook Catchment.'
Farmnote No. 12/98 'Niche perennial grasses for the Esperance sandplain.'

**Tall fescue**

Perennial pastures, Sudmeyer *et al.* 1994, Bulletin 4253 AgWEST.
Perennial pasture establishment technique, Buchanan *et al.* Esperance LCDC.
Perennial grasses for animal production in the high rainfall areas of WA, Greathead *et al.*
1998, Misc Pub 2/98, AgWEST.
Farmnote No. 12/98 'Niche perennial grasses for the Esperance sandplain'.
Phalaris
Perennial pastures, Sudmeyer et al. 1994, Bulletin 4253 AgWEST.
Perennial pasture establishment technique, Buchanan et al. Esperance LCDC.
Perennial grasses for animal production in the high rainfall areas of WA, Greathead et al. 1998, Misc Pub 2/98, AgWEST.
Farmnote No. 11/98 'Well adapted perennial grasses for the Esperance sandplain'.

Perrenial veldt grass
Perennial pastures, Sudmeyer et al. 1994, Bulletin 4253 AgWEST
Perennial pasture establishment technique, Buchanan et al. Esperance LCDC
Farmnote No. 11/98 'Well adapted perennial grasses for the Esperance sandplain'
7. APPENDICES

Three maps are presented with the report.

A1.1. Soil-landscape map for the Albany eastern hinterland area

The mapping was compiled by field sampling, aerial photograph interpretation (at 1:50,000) and use of Landsat TM and Digital Elevation Models (at 1:100,000) to refine line work. Field sampling was undertaken with broad observation density.

A1.2. Land monitor: Current salinity and unproductive land

This map illustrates areas of assumed current salinity and unproductive land for two time periods (1990 to 1992 and 1996 to 1997).

A1.3. Land monitor: Potential waterlogging and areas prone to salinity

This map illustrates areas potentially susceptible to waterlogging and possibly salinity if the watertable were to rise above 1 m in the low lying and valley floor areas. It is illustrative only. There is no associated time inference.

An AGMAPS LandManager CD ROM is also available for the Albany Eastern Hinterland appraisal area. This CD provides:

- Soil-landscape maps for every farm in the district.
- Management Information to help you with your farming issues.
- Representative images of the Frankland-Gordon area.
- Over 180 Farmnotes relevant to land management issues.
- All maps include zoom, pan, search and print capability.
- Management options and degradation risks to watch out for with every soil type.
- Photographs, profile diagrams and descriptions for over 50 soil types.
- Links to detailed explanatory text.

Contact the Albany Office of the Department of Agriculture, Western Australia for to access a copy of the CD.