South East Humps focus catchment report

A Hollick

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South East Humps Focus Catchment Report

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*Note*: Because of delays in publication of this report, references to costs and sources of other information may need updating.
Introduction and objectives

This report provides a record of the activities carried out by the Focus Support Team and the Catchment Group. It covers the results of the investigations and a summary of the group’s catchment plan. It covers the current best available information on soils, groundwater hydrology, surface water control, alternative crops and pastures, and revegetation options.

Catchment overview

The South East Humps Catchment comprises six landholders, five of whom are involved in group activities. The group has been active since 1994, and prior to selection as a focus catchment in 1997 had completed farm planning. The Focus Catchment process began in February 1998.

South East Humps is located between 5 and 19 kilometres east of Hyden along the Hyden-Norseman Road. It measures 18 km from the lake chain in the south to the catchment divide in the north, and 14 km from the ridgelines at the east and west. The area is approximately 12,600 ha. Total area owned by catchment group members is 14,750 ha.

The mean annual rainfall in Hyden is 335 mm, with 225 mm falling in the growing season between May and October. The five-year average for the catchment is slightly less at 305 mm, and 220 mm in the growing season.

Only a small area of salinity was observed in the catchment outside the salt lake system. Large areas of waterlogging have been noted on the lower catchment flats and depressions of the upper catchment following large episodic events. Groundwater levels are between 2 and 5 m on the valley flats and in some cases very salty. This is cause for concern and reason for large-scale change in catchment management practices.

The members of the catchment group are

- Joe and Carol Forrest, 890 ha, mostly within the catchment
- Ken and Cherith Smith, 2,286 ha, mostly within the catchment
- Vern and Jane Mouritz, 3,060 ha, entirely within the catchment
- Ian and Marielina Walton, 2,914 ha, mostly within the catchment
- Ron and Callum Payne, 5,600 ha, partly within the catchment.

The remainder of the area is owned by Russell Mouritz (2,880 ha) who is not part of the group, and part is covered by CALM Reserve #34295.

Lockhart Focus Support Team objectives

- To assist viable self-directed groups to develop effective catchment strategies that reduce the rate of land degradation through waterlogging and salinity.
- To provide focus catchment group members with the knowledge and skills that enable them to understand the impact of their farming activities on the catchment and to make decisions for implementing better management practices on their land.

These objectives were consistent with major group issues, to overcome:

- flooding of creeks
- waterlogging
- hillside and sandplain seeps
- soil resource decline, including structure and acidification.
Focus Catchment procedures

1. Coordination meetings

The Support Team needed to develop an understanding of the catchment and group, and for both parties to become clear on the purpose and activities involved in the coming 12 to 18 months; and decide on possible activities or information options and to schedule group focus catchment activities.

2. Field days
   - Lime and gypsum
   - Catchment hydrology.

3. The High Water Use Development Officer visited farmers who were trialling or intending to trial low recharge practices, and worked with one to set up comparisons of lime and dolomite, and another to trial lucerne and balansa.

4. The group developed a catchment soils map from previously completed farm maps.

5. The hydrologist and surface water specialist investigated the catchment from available information, bore data and on-farm visits. Nine bores were drilled and four were tested for groundwater level and salinity.

6. Farm and catchment strategies were developed at two planning meetings and accompanying farm visits.
Natural resources

Soils

A catchment soil map was created from each farm map with aerial photo interpretation and ground survey by a soil scientist (see Figure 1).

The soils were classified into 12 land management units: morrel, red clay/salmon gum clay, duplex slopes, sandplain soils, sandy gravels, red shallow loam, rock outcrops, dolerite soil, saline discharge soils, granitic sands, grey clay/hardsetting sandy loam over grey clay, and closely associated mixed soil types. The percentages of these soil types are shown in Table 1. More detailed descriptions are included in Appendix 3.

Table 1: Soils of the South East Humps Catchment

<table>
<thead>
<tr>
<th>Soil type</th>
<th>%</th>
<th>Soil type</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Morrel</td>
<td>5</td>
<td>6. Red shallow loam</td>
<td>10</td>
</tr>
<tr>
<td>2. Heavy red clay/Salmon gum clay</td>
<td>5</td>
<td>7. Dolerite soil</td>
<td>1-2</td>
</tr>
<tr>
<td>3. Duplex slopes</td>
<td>35</td>
<td>8. Saline discharge soils</td>
<td>&lt;1</td>
</tr>
<tr>
<td>4. Sandplain soil</td>
<td>5-6</td>
<td>9. Granitic sand</td>
<td>&lt;1</td>
</tr>
<tr>
<td>5. Sandy gravel</td>
<td>30</td>
<td>10. Grey clay</td>
<td>10</td>
</tr>
</tbody>
</table>

Hydrology

1. Recharge potential map

A recharge potential map was developed using the soils map, further aerial photo interpretation, satellite imagery and farm visits by the hydrologist (see Figure 2). How the recharge units relate to soil types (land units) is explained in Table 2.

Uniform, coarse-textured soils have a high to very high recharge potential. Water movement through deep sands and gravels is rapid due to the low water-holding capacity. Deep loamy sands or loamy gravels have high recharge potential, but hold water longer than uniform coarse sands or gravels. This even downward movement of water is referred to as matrix recharge.

Texture contrast soils such as sandy or loamy duplexes have a low water-holding capacity in the topsoil and high water-holding capacity in the subsoil, providing a medium recharge potential. The predominant mechanism of recharge in these soils is preferred pathway (i.e. saturated water flow through cracks, pores or old root channels). After water has moved through the topsoil it will perch on top of the subsoil and may move horizontally until it reaches a crack.

Medium to fine textured soils such as loams and clays have a medium to high soil water storage and low recharge potential. Where waterlogging or ponding occurs in these soils, recharge may be higher than expected due to long periods of saturation and decreased water use due to loss of plant vigour. Large episodic rainfall events can also increase recharge through surface ponding and waterlogging.
Figure 1: Recharge potential of catchment
### Table 2: Recharge potential of land units

<table>
<thead>
<tr>
<th>Recharge Potential</th>
<th>Land Units</th>
</tr>
</thead>
</table>
| VERY HIGH          | Deep sands and gravels  
                    |   mixed breakaway/gravelly sands  
                    |   acid wodjil  |
| HIGH               | mid and lower slope deep loamy sand  
                    |   deep sands in waterways  
                    |   sandplain seeps  |
| MEDIUM             | deep loamy duplex soils  
                    |   (over 10cms/4inches sand over clay)  |
| MEDIUM             | shallow duplex (less than 10cms sand over clay) and clay soils which are subject to waterlogging/flooding.  
                    |   Shallow sand and gravels subject to waterlogging  |
| LOW                | shallow duplex and clay soils  
                    |   red loams, morrell soils  |
| SALINE             | Salt lakes and secondary salinity  |

Figure 2 is a diagrammatic cross-section of a wheatbelt catchment showing where and how recharge occurs. Matrix recharge is generally confined to deep granite sands around rock outcrops, and deep sands and gravels of the catchment uplands.
Preferred pathway recharge occurs beneath sandplain seeps of the upper and mid-catchment, along quartz dykes, beneath duplex soils and flood-prone valley soils. This type is seasonal in nature occurring during winter ponding or waterlogging, or during large summer rainfall events when plant water use is minimal.

2. Groundwater drilling

A drilling program was carried out at sites selected as being of particular importance for groundwater monitoring.

Nine sites were drilled, but only four were successfully completed and cased. All drill sites may be seen in Figure 3. Site 3 (Mouritz laneway) was drilled to 4 m, where it struck silcrete hardpan that the small auger rig was not able to penetrate. No watertable was reached, so the hole was not cased. Sites 4 and 5 were not completed, as the auger was not able to penetrate a ferricrete (ironstone) hardpan. Site 7 (along the main creek) was not completed, also due to silcrete hardpan. Site 8 was drilled to what was termed saprolite by the logger. It is possible that the drill auger reached a bedrock high, or the auger was not capable of penetrating a semi-solid hardpan. Successful drill logs are shown in Figure A1 (Appendix 4). SH1 was drilled into lower slope alluvial sediments, deposited during flood events from the stream, and the top of the mottled zone. SH2 comprised layers of grey-brown to brownish black sediments, possibly a combination of alluvial depositions and aeolian (wind-blown) drifts from nearby salt lakes, over richly mottled clays. SH6 was located in a mid-upper landscape position. It was drilled through about 1 m of pale alluvial sand, overlying thinly bedded layers of depositional sand and clay to mottled zone red to red-brown clays. SH9 was drilled on a valley flat into bands of sedimentary sands and clays. Soil layers were not easily definable at all bore sites as the auger-rig mixed the drill samples as they came up. This problem would have not occurred with a rotary air-blast drilling rig.

3. Groundwater levels and salinities

Watertable depths and groundwater salinities were measured from bores SH1, SH2, SH6 and SH9 (Table 4). SH1 and SH2 had watertable depths of 3.83 and 4.55 m respectively and high salinity. Although there are currently no surface signs of salinity in the immediate vicinity, the areas are at medium to high risk of salinisation within the next 10-15 years, assuming a rate of groundwater rise of 30 cm/yr. SH6 was also salty, with an electrical conductivity (EC) of 4000 mS/m. The watertable in this area is not an immediate threat to surrounding land, but the high EC reading indicates a high salt store in the upper catchment (remnant gravel hills to the north and north-west). These salts are could be mobilised and carried to the lower catchment where they are discharged. EC of SH9 was comparatively low compared to other groundwater measurements. The reason may be that it is being
recharged from a relatively small area below the major dyke. The high water level of SH9 is a concern. It is likely that capillary discharge is occurring in the clay soils in this area. Waterlogging of this valley floor site is adding to the problem and needs to be addressed.

Figure 3: Catchment hydrology map

4. Land salinisation

Visible signs of land salinisation have been found on all properties but the area is currently small. Severe salinisation is only evident in the salt lake system. These areas are saturated with saline groundwater at or near the surface. They are salt scalded and have a groundwater salinity range from 12,000 to 55,000 mS/m.

Moderate salinisation is evident surrounding the severe salinisation in the lower catchment, where dykes have formed groundwater barriers, and around saline seeps in the upper catchment. The watertable in these areas is likely to be within 5 m of the surface, varying
seasonally. Some tree species have died in the moderately saline areas, leaving only salt-tolerant shrubs including saltbushes, samphire and some melaleucas.

Reduced production is occurring in the lower catchment bordering areas of moderate salinisation. The watertable in these areas is likely to be between 3 and 5 m. Surface inundation and waterlogging may be a compounding problem.

Potentially all the lower catchment below an elevation of 300 m, apart from where there is micro-topographic relief, has a medium to high risk of becoming saline in the near future, given current land management. The major dyke, acting as a groundwater barrier across the main creek, is likely to be a site of increasing groundwater salinity as salts concentrate behind it and groundwater rises.

Rates of groundwater rise cannot be determined, as piezometers have only been installed since 1998. Rise for other 300 mm rainfall catchments in the wheatbelt is about 10 cm per year on the valley floor and 25-30 cm on the slopes. Figure 4 shows an example of a hydrograph of a valley and a hillside bore east of Merredin. Watertable rise was related to episodic flood events in the valley floor during May and October 1989.

Figure 4: Groundwater levels showing response to two major storms in May and October 1989

**Surface water hydrology**

Surface water management can play a significant role in reducing waterlogging and salinity. Appropriate management can reduce the extent of flooding and waterlogging by:

- Reducing the total amount of run-off
- Reducing the peak flow (measure of water flow rate when the flood is at its maximum, and the best indicator of potential flooding from a rainfall event)
- Assisting to remove water from flooded or waterlogged areas.

An investigation on Vern Mouritz' property, used a computer model called RAFTS to indicate the effect of a combination of grade banks, dams and tree alleys on peak flow and total water flow. Three situations were modelled:

- Before land clearing
After land clearing without surface water work

- After land clearing with grade banks at 200 m spacing, four rows of trees below each bank, and dams at strategic points.

Vern’s property is 2,578 hectares of mainly duplex soil, of which 1,625 hectares (63%) were suitable for grade banks. The assumed surface water control works were 65 km of banks with trees and 12 dams with a total capacity of 81,250 cubic metres. The situations were analysed using three ARI recurrence intervals, 10, 50, 100.

A recurrence interval is a measure of the chance of receiving a certain sized run-off events. For example, an extremely large flood can be expected once every 50 years (50 year recurrence or ARI), but much smaller events can be expected more regularly (say five times in 50 years or once in 10 years has an ARI of 10). Results of analysis are shown in Table 3.

Table 3: Comparative run-off volumes and peak flows for Vern Mouritz property

<table>
<thead>
<tr>
<th>ARI</th>
<th>1 in 10</th>
<th>1 in 50</th>
<th>1 in 100</th>
<th>1 in 10</th>
<th>1 in 50</th>
<th>1 in 100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before clearing</td>
<td>81,860</td>
<td>81,860</td>
<td>81,860</td>
<td>0.3</td>
<td>2.8</td>
<td>4.2</td>
</tr>
<tr>
<td>Cleared</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleared with banks and dams</td>
<td>2.6</td>
<td>3.7</td>
<td>4.7</td>
<td>7.1</td>
<td>36.4</td>
<td>50.8</td>
</tr>
<tr>
<td>Cleared with banks and dams</td>
<td>0.7</td>
<td>3.0</td>
<td>3.9</td>
<td>1.3</td>
<td>12.3</td>
<td>18.1</td>
</tr>
</tbody>
</table>

This analysis does not consider water entering the catchment from upstream but shows that:
- There is greater change in peak flow than total water run-off
- There have always been rare floods, but clearing has made them much worse
- A comprehensive surface water plan could greatly reduce frequency and intensity of flooding.

![Figure 5: Peak flows from RAFTS modelling](image)

The cost and other benefits (e.g. aquaculture, erosion) of any plan need to be considered.
Current Focus Catchment strategies

The main concern is flooding and waterlogging along the main drainage line. To alleviate this, they are interested in grade banks over large areas of the upper catchment. This will slow the water so that it doesn’t all arrive at once and cause flooding outside the main creek channel. Behind each grade bank two rows of trees will be planted to utilise any water that seeps through the bank, and intercept any sub-surface flow below the depth of the channel.

Given the position in the landscape and slope, the banks should be a maximum of 250 m apart, and less than 2 km long. By increasing height of the bank wall, longer grade banks can be built.

The usual height of a grade bank wall is around 50 cm. On some longer banks, the banks will start at this height at the top, and increase in size further down, in some cases to 1.5 m high. This is necessary due to the length of the banks needed to reach a safe disposal site in the natural creeklines.

The grade banks also continue on the sides of the catchment, again with the effect of reducing run-off and flooding. On the Payne farm to the east, the majority of the banks empty into dams for stock water and drought-proofing.

Many banks in the upper catchment run through several farms before discharging into a creekline. This is to ensure sufficient delay in water flow down the creek to prevent flooding.

The detail can best be seen from catchment maps, rather than written description. The current level of the plan is work that can reasonably be achieved in the next five years, rather than an ultimate plan for the future. The plan is necessarily flexible, and will evolve as the catchment changes (ideals of farmers, land use, physical attributes, etc.) over time.

Possible future changes, not on the plan at this stage, are revegetation areas on the major drainage line to use up the water that sits there for extended periods of time, and more upper catchment revegetation. These will be added to the plan only if necessary to reduce flooding, if the current earthworks-based strategy is ineffective.

This plan should have the following effects:

- reduced flooding
- slight reduction in recharge to the groundwater
- reduced soil erosion
- drought-proofing
- biodiversity enhancement.
**Recommendations**

It is vital that a monitoring system is put in place for the catchment group to know how quickly groundwater is rising, and to test the effectiveness of applied management strategies. It is recommended first that bore sites 3, 4, 5, 6, 7 and 9 are re-drilled. Site 7 should be drilled to obtain the depth to bedrock, while the other sites should be drilled to watertable level. Further, site 8 should be replaced with another site drilled to water level further up the creek from site 6. A rotary air blast drill rig should be hired because of the presence of silcretes, which can only be broken with compressive forces. Further bores should be drilled at sites where management is changing, to determine effect on groundwater.

- Bores should be monitored at least four times a year to obtain maximum information on seasonal trends.
- Drainage lines need to be revegetated and fenced.
- Sandplain seep control is already being carried out in some parts of the catchment. Small seepages which farmers do not intend to control with revegetation should be fenced to prevent further damage from stock trampling.
- Banks should include vegetation lines to use more water on the slopes.
- High water use plants need to be used in all recharge areas. This may include pastures for livestock grazing or productive tree crops.

The following section provides information on relative costs and benefits to aid decision-making. Figure 6 summarises components that must be considered.

**Table 4: Area of catchment occupied by each recharge potential unit**

<table>
<thead>
<tr>
<th>Recharge potential</th>
<th>Area (ha)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very high</td>
<td>2,982</td>
<td>18.6</td>
</tr>
<tr>
<td>High</td>
<td>624</td>
<td>3.9</td>
</tr>
<tr>
<td>Medium</td>
<td>4,884</td>
<td>30.4</td>
</tr>
<tr>
<td>Low</td>
<td>1,141</td>
<td>7.1</td>
</tr>
<tr>
<td>Waterlogged</td>
<td>2,510</td>
<td>15.6</td>
</tr>
<tr>
<td>Granite outcrop</td>
<td>271</td>
<td>1.7</td>
</tr>
<tr>
<td>Saline discharge</td>
<td>3,661</td>
<td>22.8</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>16,074</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

The entire catchment is contributing to recharge as the recharge potential map (Figure 1) indicates. Respective areas for each of the recharge units may be seen in Table 4.

It is not possible to accurately gauge the influence of flooding. Although the valley soils mostly have a medium to low potential, action is very important due to the high risk of salinity and the very low slope that enhances recharge.
**How to manage components of the water balance**

**Ridges and slopes**
- Direct recharge (matrix flow)
- Preferred flow recharge
- Runoff to valleys

**Valley floors**
- Flooding/waterlogging
- Direct recharge

---

**Figure 6: Possible tools available for managing water balance**

**Strategies for reducing direct recharge**

**Matrix recharge through soils**

Poor water use by annual crops and pastures is the major factor contributing to salinity. Achieving lower recharge involves using rainfall all year round and not just through the winter. Figure 7 shows how annual crops and pastures fail to use rainfall that occurs throughout the year. Annual crops and pastures do not start using significant quantities of water until about four weeks after emergence. Unfortunately by this time in the year, enough groundwater recharge has occurred to keep watertables rising.
Figure 7: Comparison of crop water use and rainfall through the year

**Lucerne**

<table>
<thead>
<tr>
<th>Best bet option</th>
<th>4 year lucerne/4 year phase cropping system. Any soil that has pH greater than 4.8–5.0 and does not waterlog. Good insect and weed control needed. Liming may be necessary.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>Can reduce recharge under the area planted to lucerne by up to 40% or more. Lucerne’s deep root system extracts soil moisture and being a perennial, summer/autumn/early winter rainfall is used instead of recharging groundwater.</td>
</tr>
<tr>
<td>Cost</td>
<td>Approximately $130/ha inclusive of machinery costs but excluding liming costs.</td>
</tr>
<tr>
<td>Other benefits</td>
<td>Nitrogen fixing, increased soil organic matter, disease break, weed control, year round green feed. Land can be re-cropped whereas tree plantings are ‘permanent’. Farm liming program can be incorporated.</td>
</tr>
<tr>
<td>More information</td>
<td>See Appendix 2, and/or contact WA Lucerne Growers on (08) 9821 3333.</td>
</tr>
</tbody>
</table>

**Tree alleys**

<table>
<thead>
<tr>
<th>Best bet option</th>
<th>At least 4 rows planted across the slope on soils with greatest recharge potential.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>On soils with watertables greater than 5 m deep, or saline/waterlogged situations, almost complete reduction of recharge within 10 to 30 m of the row. Where watertables are less than 5000 mg/L salinity and within 5 m of the surface, benefit is greatly increased as the trees can use water. Trees are more benefit below existing banks as they will use water seeping down and productivity losses associated with shallow roots will affect less paddock. Alleys allow for vegetation to be dispersed over large areas which generally use more water than dense blocks of trees over small areas.</td>
</tr>
<tr>
<td>Cost</td>
<td>About $250/km of row (no fencing). Direct seeding is about $500/ha. Some competition effects of alleys with inter-row crops and pastures expected. Ripping along edges every few years can reduce yield loss, however also reduces the range of effectiveness for reducing recharge between rows.</td>
</tr>
<tr>
<td>Other benefits</td>
<td>Possible opportunity for future oil mallee industry.</td>
</tr>
<tr>
<td>More information</td>
<td>Appendix 1. Oil Mallee information kit (Revegetation on Farms).</td>
</tr>
</tbody>
</table>
**Summer cropping**

<table>
<thead>
<tr>
<th>Best bet option</th>
<th>Forage sorghum and millet. Grain sorghum and millet are options, however grain production requires suitable summer rainfall.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>Dries out soil over summer and utilises any incidental summer rainfall. Reduces recharge in areas prone to winter waterlogging or where fresh seepage occurs. Can bring a waterlogged section of a paddock back into production by using stored soil moisture over summer.</td>
</tr>
<tr>
<td>Cost</td>
<td>Approximately $90-$140/ha.</td>
</tr>
<tr>
<td>Other benefits</td>
<td>Income from summer production. Weed control opportunity when killing summer crop (requires knockdown). Winter crop may not require herbicide applications. Disease break.</td>
</tr>
<tr>
<td>More information</td>
<td>High Water Use/Low Recharge Development Officer.</td>
</tr>
</tbody>
</table>

**Rock outcrops**

Although occupying only a minor proportion of ridges and slopes, the fractured nature of the rocks and limited run-off from them, indicate that these outcrops contribute to recharge in most years, several times greater than an equivalent area of sandy soil. This is primarily due to the coarse, gritty sands around the rocks allowing recharge directly into the groundwater.

**Water harvesting via rock walls**

<table>
<thead>
<tr>
<th>Best bet option</th>
<th>Harvest water before it leaves rock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>Depends on water storage capacity</td>
</tr>
<tr>
<td>Cost</td>
<td>Depends on water storage capacity</td>
</tr>
<tr>
<td>Other benefits</td>
<td>Opportunity for intensive livestock, irrigation, aquaculture, bottling</td>
</tr>
</tbody>
</table>

**Strategic revegetation around rocks**

<table>
<thead>
<tr>
<th>Best bet option</th>
<th>At least four rows of trees planted at the base of rock where there is sufficient soil depth for survival, and in waterways leading from the rock.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>Not known, but expected to greatly reduce recharge in most years.</td>
</tr>
<tr>
<td>Cost</td>
<td>Approximately $250/km of row (does not include fencing). Cost of direct seeding is about $500/ha.</td>
</tr>
<tr>
<td>Other benefits</td>
<td>Possible opportunity for future oil mallee industry. As this is a water-gaining site, there may be opportunity for other perennials like grapes, nuts, olives etc. Detailed site and industry viability factors would need to be investigated.</td>
</tr>
<tr>
<td>More information</td>
<td>Appendix 1 contains information on suitable species.</td>
</tr>
</tbody>
</table>
Strategies for reducing preferred flow

Reverse-bank seepage interceptor drains

<table>
<thead>
<tr>
<th>Best bet option</th>
<th>Seepage interceptor banks preferably draining water into the dams (if water is fresh) or disposing it safely into the nearby creekline.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>Can reduce waterlogging and improve cereal yields where salinity is mild. On average, an effective interceptor can dry a strip 50 m wide downslope. Improved grain yields, averaging 1,000 kg/ha, have been measured in the drained strip.</td>
</tr>
<tr>
<td>Cost</td>
<td>Depends on sandy layer depth and design (width, depth and grade). May range from $800-1500/km.</td>
</tr>
<tr>
<td>Other benefits</td>
<td>May provide additional run-off into dams as a water resource.</td>
</tr>
</tbody>
</table>

Dykes, shear zones, bedrock highs, soil/slope change zones

These areas often accumulate water due to landscape and geological features/deformations. Faulting and associated intrusions (quartz and pegmatite veins/dolerite dykes) result in areas that are porous and allow massive quantities of water to flow along them. In addition, groundwater may accumulate at shallow depths (few metres below surface) and allow for better tree survival and water use. Such areas are termed ‘strategic revegetation sites’ which are shown as suggestions for exploration in Figure 8.

It is critical that trees be planted in areas that do not have very saline groundwater (greater than 1000 mS/m), or very shallow rock that restricts root development. The best locations have less than 3 m to the watertable and at least 5 m to bedrock/impermeable clay.

Strategies to reduce waterlogging/recharge from run-off to valleys

The strategic implementation of earthworks should reduce flood risk, inundation, waterlogging and minimise land degradation.

Shallow drainage

<table>
<thead>
<tr>
<th>Best bet option</th>
<th>Spoon and W-drains</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>Most flat valleys have a random pattern of shallow depressions which do not drain to a defined creek channel. Rainfall and flood water accumulate in these depressions. Surface drains are most effective where poor infiltration of water is the main cause of waterlogging. However, if the watertable is close to the surface, waterlogging will still occur even if surface waters are drained.</td>
</tr>
<tr>
<td>Cost</td>
<td>Depends on design parameters. About $600-1000/km.</td>
</tr>
<tr>
<td>Other benefits</td>
<td>Reduced waterlogging and increased production.</td>
</tr>
</tbody>
</table>
Figure 8: Strategic revegetation sites
### Agronomic options

**Raised beds**

<table>
<thead>
<tr>
<th>Best bet option</th>
<th>Raised beds allow rapid drainage of waterlogged soils and aeration for plant roots. Furrows can drain away excess water that can be stored as a fresh supply for stock.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>Reduces recharge caused by waterlogging/flooding to almost negligible quantity on heavy soils when furrow water is harvested. Makes use of winter waterlogged land that would otherwise not grow a crop.</td>
</tr>
<tr>
<td>Cost</td>
<td>Depends on area. Approximately $200/ha for 50 ha, $140/ha for 100 ha, $100/ha for 200 ha. With the right machinery farmers can form their own beds.</td>
</tr>
<tr>
<td>Other benefits</td>
<td>Prevent waterlogging by draining excess surface and soil water and aerating the root zone of plants. Possible yield increases of 10–20%. Increase the water-holding capacity of root zones and plant-available water. Raise production from poorly and/or highly variable productive areas. Provide opportunity to harvest excess winter water, which would otherwise evaporate and recharge groundwater systems. Control traffic by using furrows as traffic lanes and drains. Assure machinery access in the wettest periods.</td>
</tr>
<tr>
<td>More information</td>
<td>Contact Greg Hamilton on 9368 3276 or Derk Bakker, Albany on (08) 9892 8464.</td>
</tr>
</tbody>
</table>

**Waterlogging tolerant pastures**

<table>
<thead>
<tr>
<th>Best bet option</th>
<th>Puccinellia, tall wheat grass with nutritious annual pastures such as balansa clover (also mildly saline tolerant) for animals. Note that perennials MUST be a component of the system so as to dry out the soil over summer and utilise any summer rainfall.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>A permanent pasture system to provide &quot;year round&quot; green feed and eases the pressure of groundwater rise in the valley flats. Drought tolerant perennials like puccinellia are important if the area dries out over summer. If the area is constantly moist even in summer, perennials such as strawberry clover are an option.</td>
</tr>
<tr>
<td>Cost</td>
<td>Approximately $80/ha to $130/ha</td>
</tr>
<tr>
<td>Other benefits</td>
<td>Localised recharge and watertable control Good grazing management can result in stocking rates on saltland being as high as on non-saline land.</td>
</tr>
<tr>
<td>More information</td>
<td>Appendix 2.</td>
</tr>
</tbody>
</table>

**Saltland pastures**

<table>
<thead>
<tr>
<th>Best bet option</th>
<th>Puccinellia, tall wheat grass, saltbush (e.g. creeping, wavy leaf, old man) with annual companion pastures to provide bulk material for animals e.g. balansa clover. Alley layout appears most manageable.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>Using saltbush as perennial water pumps &gt;50 cm drawdown, the more palatable perennials for summer feeding, and annual clovers for winter feed. Aims for productive use of saline land, controlling local recharge and lowering watertables.</td>
</tr>
<tr>
<td>Cost</td>
<td>Approximately $80-130/ha.</td>
</tr>
<tr>
<td>Other benefits</td>
<td>Localised recharge and watertable control Good management can result in stocking rates as high as on non-saline land.</td>
</tr>
<tr>
<td>More information</td>
<td>Appendix 1; contact Saltland Pastures Association (Inc.)</td>
</tr>
</tbody>
</table>
Focus Group strategies

The main concern of group members is flooding and waterlogging along the main drainage line. To alleviate this, they are interested in grade banks over large areas of the upper catchment. This will slow the water flow, so that it doesn’t all arrive at once and cause flooding outside the main creek channel. Behind each grade bank two rows of trees will be planted to use water that seeps through the bank, and intercept any sub-surface flow below the depth of the channel.

Given the position in the landscape and slope, banks should be a maximum of 250 m apart, and less than 2 km long. By increasing the height of the bank wall, much longer grade banks can be built, but at greater cost.

The usual height of a grade bank wall is around 50 cm. On some of the longer banks, the banks will start at this height at the top end, and increase further down, in some cases to 1.5 m. This is necessary due to the length of the grade banks needed to reach a safe disposal site in the natural creeklines.

The grade banks also continue on the sides of the catchment, again with the effect of reducing run-off and flooding. On the Payne farm to the east, most banks empty into dams for stock water and drought-proofing.

Many of the banks in the upper catchment run through several farms before discharging into a creekline. This is to ensure that there is sufficient delay in the water flowing down the creek to prevent flooding.

The detail of the plan can best be seen from the catchment maps. The current level of the plan is works that can reasonably be achieved in the next five years.

The plan is necessarily flexible, and will evolve as the catchment changes (ideals of farmers, land use, physical attributes, etc) over time.

Possible future changes are revegetation areas on the major drainage line to use up water that sits there for extended periods of time, and more upper catchment revegetation. These will be added to the plan only if necessary to reduce flooding, if the current earthworks-based strategy is ineffective.

V & J Mouritz

The plan for this property involves fencing off the remnant vegetation, various new dams, and grade banks to feed water into the dams. The main new dam is proposed on the creekline at the bottom of the property, near the boundary with Paynes. At the top of the property a network of grade banks feeds run-off into the creeklines, and there is potential for more tree planting above sandplain seeps.

There is a small trial of lucerne and balansa clover lower down the catchment, and potential to enlarge this to provide extra summer feed for the cattle as well as using water from summer rain and reducing groundwater recharge. He intends to plant a further 180 ha of lucerne higher in the landscape. The development of a ‘demonstration site’ involves the integration of block plantings of oil mallees and pines, direct-seeded revegetation, lucerne pasture, water control works, gypsum application and use of alternative pastures more suited to the soil types.
I & M Walton

Occupying an entire subcatchment of the main catchment, the Waltons are in the position of controlling all the water that falls on and flows over or through their land. The plan to date involves grade banks and tree plantings above seeps, but there is a lot of potential for planting the less fertile rocky, gravelly laterite soils to perennials (native trees and shrubs) to control recharge and waterlogging which may become a serious problem on the valley flats. They are intending to replant the native tamma scrub on shallow soils over caprock that are not viable to crop.

J & C Forrest

Situated right at the top of the catchment, there are few problems with this property. However, there are two sandplain seeps, and a lot of the soil is sandy and has a high recharge potential. Perennial species are the obvious solution, along with interceptor banks to collect run-off, and collect the water from the seeps and divert it to the creekline. However, banks on this soil type are never going to hold water. They will always leak, so there is need to plant additional woody perennials below the banks to use the water that flows through them. Local species of mallee are ideal in this situation as there is potential for harvesting them for use in an oil mallee industry in the future. However, the main bank planned runs through the pigpens, and there is no chance of getting trees to grow.

There is a waterlogging problem near the start of the main creekline, but rather than control it using perennials, Joe intends to dig a drain to take it into the creekline. But until someone can tell him 100% certain that this is the place to plant trees, he is not going to do it.

K & C Smith

A number of the banks planned for this farm are already in place, but need re-grading if they are to be of much use. There are also plans to place a number of new banks to control surface water both coming down off Joe Forrest’s place and the road. The bank below the road has the potential to run over the catchment divide and into a dam in the neighbouring catchment. Revegetation of the main creekline is also planned.

Another potential plan is to dig several large dams on the main creekline, or just off it, and collect water for either aquaculture (yabbies or trout) or irrigation of summer crops or lucerne. As there is no stock on the farm, the lucerne would be managed as a crop, and harvested for hay.

R & C Payne

Some banks were put in several years ago, and more have been constructed since the initial plan was drawn up. A number of the banks feed into dams, others are simply to control surface water. So far, there has been no tree planting or fencing.

Tree planting is planned for all the creeklines and a large number of the banks and fencelines. Block plantings will cover small corners of paddocks here and there and make working them a lot easier.

The catchment plan has gone through a number of changes since its inception, and will undoubtedly continue to evolve.
APPENDICES

Appendix 1: Trees, shrubs & perennial plants

Species detailed below are predominantly common wheatbelt species. Much is sourced from *Revegetation Guide to the Central Wheatbelt* by E.C. Lefroy *et al.* 1991. The list should be used only as a general guide. If increasing biodiversity is desired, consult CALM. It is important that tree and shrub selection be based on local knowledge of existing vegetation prior to clearing. Such information can be obtained from local nurseries.

Table A1: Selected trees, shrubs and perennial plants for various soils

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Trees</th>
<th>Shrubs</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Casuarina obesa</em> (salt sheoak)</td>
<td><em>Atriplex amnicola</em> (river saltbush)</td>
<td>Puccinellia (tolerates waterlogging)</td>
</tr>
<tr>
<td></td>
<td><em>E. sargentii</em> (salt river gum)</td>
<td><em>Atriplex paludosa</em> (marsh saltbush)</td>
<td>Tall wheat grass (tolerates waterlogging)</td>
</tr>
<tr>
<td></td>
<td><em>E. kondininensis</em> (blackbutt)</td>
<td><em>Halosarcia spp.</em> (samphire)</td>
<td>Salt water couch (tolerates inundation)</td>
</tr>
<tr>
<td>Saline</td>
<td></td>
<td><em>Maireana brevifolia</em> (old man saltbush)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Atriplex nummularia</em> (silver saltbush)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Melaleuca uncinata</em> (broombush)</td>
<td></td>
</tr>
<tr>
<td>Shallow sand over clay</td>
<td><em>E. salmonophloia</em> (salmon gum)</td>
<td><em>E. salubris</em> (gimlet)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>E. sargentii</em> (salt river gum)</td>
<td><em>E. loxophleba</em> subsp. <em>lissophloia</em> (smooth-barked York gum)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>E. ovularis</em> (small fruited mallee)</td>
<td><em>E calycogona</em> (gooseberry mallee)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td><em>Acacia hemiteles</em> (tan wattle)</td>
<td><em>Atriplex amnicola</em> (river saltbush)</td>
<td>Lucerne</td>
</tr>
<tr>
<td></td>
<td><em>Acacia colletioides</em> (wait-a-while)</td>
<td><em>Maireana brevifolia</em> (small-leaved bluebush)</td>
<td>Tall wheat grass (tolerates waterlogging)</td>
</tr>
<tr>
<td></td>
<td><em>Acacia merrallii</em> (Merrall’s wattle)</td>
<td><em>Santalum acuminatum</em> (quandong)</td>
<td>Strawberry clover (year-round moisture)</td>
</tr>
<tr>
<td></td>
<td><em>Cassia nemophila</em> (desert cassia)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Melaleuca adnata</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Atriplex amnicola</em> (river saltbush)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Maireana brevifolia</em> (small-leaved bluebush)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Santalum acuminatum</em> (quandong)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 20-70 cm duplex | **Trees** | Acacia acuminata (jam)  
E. sheathiana (ribbon bark gum)  
E. neutra (redwood)  
E. loxophleba subsp. Lissophloia (smooth barked York gum)  
E. eremophila (tall sand mallee)  
E. erythronema (white barked mallee)  
E. burracoppinensis (Burrawang mallee)  
E. annulata (open fruited mallee)  
E. calycogona (gooseberry mallee)  
E. argyraea (silver mallet)  
E. astringens (brown mallet)  
Melaleuca spathulata (swamp mallet) |
| **Shrubs** | Acacia hemiteles (tan wattle)  
Melaleuca uncinata (broombush)  
Melaleuca acuminata |
| **Other** | Lucerne  
Tall wheat grass (tolerates waterlogging)  
Strawberry clover (year-round moisture) |
| Loams /Sandy loam over granite | **Trees** | E. loxophleba subsp. Lissophloia (smooth-barked York gum)  
Acacia acuminata (jam)  
Allocasuarina huegeliana (rock sheoak)  
Acacia microbotrya (manna gum) |
| **Shrubs** | Kunzea pulchella (granite kunzea)  
Allocasuarina campestris (tamma)  
Melaleuca uncinata (broombush)  
Leptospermum erubescens (tea-tree)  
Hakea recurva |
| Sandy gravels /Sand over gravel | **Trees** | Allocasuarina acutivalvis (black tamma)  
Allocasuarina corniculata (grey tamma) |
| **Shrubs** | Allocasuarina campestris (tamma)  
Melaleuca uncinata (broombush)  
Melaleuca conothamnoides (wheatbelt honeymyrtle)  
Leptospermum erubescens (tea-tree)  
Hakea scoparia  
Grevillea paradoxa (bottlebrush grevillea) |
<table>
<thead>
<tr>
<th>Sands (&gt;70 cm over gravel)</th>
<th>Trees</th>
<th>Shrubs</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Allocasuarina huegeliana (rock sheoak)</td>
<td>Callistemon phoeniceus (lesser bottlebrush)</td>
<td>Tagasaste</td>
</tr>
<tr>
<td></td>
<td>Banksia attenuata (slender banksia)</td>
<td>Allocasuarina campestris (tamma)</td>
<td>Veldt grass</td>
</tr>
<tr>
<td></td>
<td>E. leptopoda (Tammin mallee)</td>
<td>Melaleuca conothamnoides (wheatbelt honeymyrtle)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Xylomelum angustifolium (sandplain woody pear)</td>
<td>Grevillea pritzelii (black toothbrush grevillea)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acacia acuminata (jam)</td>
<td>Leptospermum erubescens (tea-tree)</td>
<td></td>
</tr>
<tr>
<td>Shrubs</td>
<td>Callistemon phoeniceus (lesser bottlebrush)</td>
<td>Allocasuarina campestris (tamma)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Allocasuarina campestris (tamma)</td>
<td>Melaleuca uncinata (broombush)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E. leptopoda (Tammin mallee)</td>
<td>Grevillea huegelii</td>
<td></td>
</tr>
<tr>
<td>Breakaways</td>
<td>E. astringens (brown mallet)</td>
<td>E. capillosa (inland wandoo)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acacia acuminata (jam)</td>
<td>Grevillea pritzelii (black toothbrush grevillea)</td>
<td></td>
</tr>
<tr>
<td>Rock outcrop</td>
<td>E. loxophleba subsp. lissophloia (smooth-barked York gum)</td>
<td>Leptospermum erubescens (tea-tree)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Acacia acuminata (jam)</td>
<td>Allocasuarina campestris (tamma)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Borya nitida (pincushions)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Grimmea sp.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Parmelia sp.</td>
<td></td>
</tr>
</tbody>
</table>

**Table A2: Major oil mallee species site preferences (from Revegetation on Farms Information Kit)**

<table>
<thead>
<tr>
<th>Oil mallee</th>
<th>Site preference</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Eucalyptus angustissima</em> subsp. <em>angustissima</em> (narrow-leafed mallee)</td>
<td>Best suited to moisture-gaining sites with sand over clay. Appears to have high degree of salt and waterlogging tolerance. Probably not suited to waterlogged grey clays.</td>
</tr>
<tr>
<td><em>Eucalyptus gratiae</em> (large fruited smooth barked York gum)</td>
<td>Good general species with performance like <em>E. loxophleba</em> subsp. <em>lissophloia</em>, growing on sands to duplex soils through to heavier clays. Some salt and waterlogging tolerance, but performs better on well-drained sites and heavier clay/loam soils. Suited to all areas within the present oil mallee program, but targeted closer to its home range.</td>
</tr>
<tr>
<td><em>Eucalyptus horistes</em></td>
<td>A good robust species, growing on reddish sands through to some heavier loamy clays. Limited salt tolerance, good drainage is important. Suited to all areas within the present oil mallee program.</td>
</tr>
<tr>
<td><em>Eucalyptus kochii</em> subsp. <em>kochii</em></td>
<td>Suited to the reddish sands of the northern and central agricultural areas. Little or no salt or waterlogging tolerance.</td>
</tr>
<tr>
<td><em>Eucalyptus kochii</em> subsp. <em>plenissima</em></td>
<td>Appears to prefer reddish sandy and sandy loam soils, though in some areas it has been proven tolerant of heavier clays. Little or no salt or waterlogging tolerance. Particularly suited to the northern wheatbelt, but all areas have examples of good plantings.</td>
</tr>
<tr>
<td><em>Eucalyptus loxophleba</em> subsp. <em>lissophloia</em> (Smooth-barked York gum)</td>
<td>A good generalist species, growing on sands to duplex soils through to heavier clays. Some salt/waterlogging tolerance but suited to well-drained sites and heavier clay/loam soils. Suited to all program areas.</td>
</tr>
</tbody>
</table>
Appendix 2: Maximising water use

Reductions in the rate of groundwater rise in catchments will be achieved by modifying farming systems in combination with other techniques (e.g. surface water control). High water use farming systems need to be widely adopted by farmers to succeed in the battle against dryland salinity in Western Australia.

Farmers have taken the initiative and planted millions of trees. Now we must take that extra step and use deep-rooted perennials and annuals to soak up groundwater on whole farm and catchment scales.

Vigorous, well utilised pastures, with high legume content increase livestock and subsequent crop productivity and profitability. Productive pastures and fodder shrubs contribute to improved catchment management by reducing recharge, wind erosion and improving soil structure. Perennial species within these pastures will greatly enhance their economic and environmental viability, and should therefore be used to complement annual pastures.

**Annuals**

In rotation, the pasture phase will increase organic matter, improve populations of soil fauna and delay the resistance of weeds to herbicides. Increased yields and grain protein levels are also experienced in crops following pasture phases.

Effective grass control can be achieved in the pasture phase of the rotation, allowing for early seeding and preventing the carry over of cereal diseases. Improving and maintaining pastures through spray-topping, pasture manipulation and careful management of stock will increase their value. Pastures should be managed to ensure that enough ground cover is maintained to avoid wind erosion and reduce recharge.

**Serradella** – a deep-rooted annual pasture legume able to grow and persist on poor deep acid sands. Both hard and soft-seeded varieties are available. Low germination in the first year of yellow serradellas (Santorini/Charano) is experienced but pink serradella (Cadiz) will have good first-year germination. Seed can be harvested with cereal harvester equipment. Phase cropping serradella instead of clover ley is an option.

**Biserrula** – this new species can be used in mixtures with serradella on sandy soils and on better soils where subterranean clover is grown. Biserrula will not tolerate waterlogging at all. It is deep rooted and has the ability to remain green long after other traditional pasture species have dried off. The variety Casbah (very hard seeded) should be suited to areas with more than 375 mm annual rainfall. Casbah appears susceptible to blue-green aphids.

**Medics** – a productive annual pasture that will grow on a variety of soil types from sandy soils to medium clays and from alkaline to moderately acidic soils. Careful selection of variety is important with special consideration for pH. Can be grazed heavily continuously over winter and regenerates well after cropping for several years because of high levels of hard seed.

**Balansa clover (variety Frontier)** – a small-seeded annual clover highly tolerant of clover scorch disease but very susceptible as a seedling to red-legged earth mite. It can be grown on soils with pHca greater than 4.5 and tolerates mild to moderate salinity levels (less than 80 mS/m or 450 mg/L). Persian clover can also be added to the mix because of its waterlogging and salinity tolerance.

**Persian clover** – another small-seeded annual that can be grown on soils in the 5.5–8.5 pHca range. Particularly tolerant of waterlogging (similar to balansa) and tolerate low levels of salinity, which often occur in association with waterlogging. Management is similar to balansa clover.
Perennials

Perennial pastures have the capacity to use more water in comparison with annual pastures, addressing problems associated with excess water within the catchment. They provide a more even pattern of feed throughout the year, and can be used to reduce weed problems, alleviate soil erosion and decrease acidification rates. They should not be seen as a replacement to annual pastures, but as a complement to them.

Perennial pastures have different management requirements to annual. They can be quickly destroyed by set stocking, persisting best under rotational grazing systems. Grazing should only be carried out to control weeds in the first year. They should not be grazed over the first summer, as this does not allow for deep root development. Heavy winter grazing may be needed to keep annual weeds down.

Lucerne – a deep-rooted, high quality feed perennial legume pasture that is adapted to wheatbelt conditions. It is effective in extracting soil moisture over the summer and using up rainfall from the late-autumn/early winter. Will grow well on soils that have pHca >4.8, well drained (will not stand waterlogging), low salinity levels (less than 250 mS/m or 1,400 mg/L), and low weed burden. Phase cropping 3 years lucerne followed by 2-3 years cropping is the ideal way to limit groundwater table rise. Good first year establishment is critical.

Rhodes grass – a deep-rooted perennial able to reduce recharge and protect areas from wind erosion. It can regenerate by seed and runners, and controlled by herbicides or cultivation. Rhodes grass provides summer and autumn feed. It will grow on most soils but prefers light to medium soils as heavy soils can present establishment problems. It will not grow well on soils that experience prolonged waterlogging.

Veldt grass – another deep-rooted perennial well suited to sandy soil types. It grows predominantly through spring, summer and autumn, responding quickly to summer rains and applications of nitrogen. It is highly palatable and useful in stabilising drifting sands. It can be sown as a mixture with subterranean clover or serradella. Rotational grazing is recommended for long-term persistence. It can be a pest plant in the bush.

Strawberry clover – a perennial clover best suited to high rainfall areas or permanently moist soils. Has the capacity to grow well in summer waterlogged sites with low saline conditions. Winter growth is slow, but it grows vigorously during spring and summer providing moisture is available. It is tolerant of clover scorch disease.

Salt water couch – a perennial grass that grows actively during spring and summer. It requires plentiful moisture during summer and is best adapted to saline seepage that are wet during summer and waterlogged areas. Once established it may be grazed and can control erosion of salty seepages and gullies.

Puccinellia – a winter-active grass for saline and waterlogged areas. It may be grown on salt affected soils that are too wet during winter for saltbushes, but too dry in summer for salt water couch. Puccinellia requires annual rainfall of around 350 mm and can be sown with tall wheat grass. As a green plant, it has excellent feed quality (high protein concentration and digestibility) but should not be grazed during the first year, although stands can be grazed lightly in the second year.

Tall wheat grass – less salt tolerant than puccinellia, growing only where there is vigorous barley grass. It is slow in establishment and should not be grazed in the first year. It is most palatable in January, when it has fresh green shoots and a moist seed head, and is fairly bulky. Tolerates waterlogging and moderate salinity. Where surface soil (0-10 cm) salinity exceeds 2000 mS/m (11,000 mg/L) puccinellia should be planted instead.
**Fodder shrubs**

Shrubs for fodder have an important role in the farming system. They can be used as a valuable source of out of season feed, whilst providing shelter benefits for livestock, crops and pastures and reducing recharge. It is important to select the correct fodder shrub for the prevailing conditions and to manage them according to their requirements.

**Tagasaste** – a woody perennial legume well suited to deep sands. Tagasaste can grow up to 5 m high and survives well in areas with as little as 300 mm of annual rainfall. It can be planted in ‘alleys’ with serradella between and is excellent in minimising recharge in deep sandy soils. Provides fodder, windbreak, stock shelter, firebreak protection, and also acts as wildlife habitat. Good first year establishment is critical. Will require cutting to keep it within reach of sheep, but can be managed by grazing with cattle.

**Acacia saligna** – grows well on a range of soil types. Its deep root system will reduce recharge and its dense form will reduce wind erosion. It can be easily established by seedlings or direct seeding and can be expected to live for 10-20 years. It cannot be grazed in the year of establishment. After the first year grazing should be carefully managed to avoid ringbarking. Although high in protein (approximately 30%) its low digestibility and high tannin mean that sheep should not be fed a diet of this plant alone.

**Saltbushes** – a number are available for saline areas including old man saltbush (*Atriplex nummularia*), wavy leaf (*A. undulata*), small-leaved bluebush (*Maireana brevifolia*), and samphire (*Halosarcia spp*.). Saltbush plantations can be grazed 18 months after establishment. Grazing should be in autumn, which allows annual pastures to become established. When saltbush is grazed alone, loss of condition and stock body weight can be expected. Saltbush need to be supplemented by companion pastures (e.g. balansa clover) or hay and good quality water.

**Trees**

Catchment groups and farmers have implemented extensive revegetation programs. Trees and shrubs can be planted for both land conservation and production. Trees can be used for stock shelter, reduction of recharge, and wind erosion. Production of timber, honey and alternative tree crops of nuts, wildflowers and essential oils could be considered when undertaking a revegetation project.

**Recharge control** – wide selection of trees available depending on soil type, rainfall, depth to watertable (less than 3 m), water salinity (less than 1000 mS/m or 5000 mg/L). Locations require less than 5 m to rock or impermeable clay but enough soil for tree survival (no very shallow rock). Native revegetation, sandplain alley farming, windbreaks, shelterbelts, and strategic revegetation are major uses for trees. Good opportunities in catchments are above sandplain seeps; break of slope; behind dykes, quartz veins, shear zones (check salinity!); deep sands (tagasaste); sandy recharge areas around granite outcrops; acid wodjil soils; perched fresh water aquifers; permeable soils; zones of convergence (e.g. along upper slope drainage lines, gullies); below banks; and on contours. Local knowledge is important in tree selection.

**Watertable control** – wide selection of salt-tolerant trees available depending on soil type, rainfall, depth to watertable (less than 3 m), water salinity (less than 1000 mS/m or 5000 mg/L). Locations require less than 5 m to rock or impermeable clay but enough soil for tree survival (no very shallow rock). Native revegetation, salinity/watertable control alley farming, and strategic revegetation are major uses. Good opportunities exist along drainage lines: low-lying areas with shallow watertables (at least 1.5 m deep and not rising quickly) where salinity is still moderate (less than 2000 mS/m or 11,000 mg/L) and soils have a sandy surface. Hydraulic conductivity at depth is required for effective watertable control. Best results when soil salinity is less than 150 mS/m (825 mg/L) over at least 80% of the area.
**Tree products**

There is potential for future income by planting certain tree species now. Rainfall may limit the variety, although irrigation may (depending on cost and good quality water availability) alleviate this problem. Time lag between propagating trees and the first harvest income is also an influencing factor.

**Oil mallees** – oil mallees planted as block or alleys perform well in most situations, but they need a reasonable depth of soil and do not perform on shallow ironstone or rocky areas. Planting densities need to be lowered in free-draining sandy areas. The oil (cineole) is an industrial solvent and harvesting, extraction, and marketing of oil mallee products is still in the development phase. Oil mallees can be harvested every second year from year three and provide windbreaks and recharge control.

**Sandalwood** – a parasitic tree that requires a host to survive. It is slow growing (20–100 years) and will grow well in areas with ~350 mm annual rainfall (faster growth with higher rainfall). Sandalwood prefers lighter textured soils derived from granite. It is most common on neutral to slightly acid soils (to pH 4.5), but will tolerate alkaline soils. Heavy clay soils and waterlogged areas are not suitable. The aromatic oils contained in sandalwood heartwood, butt and roots make it a valuable commodity in Asia.

**Melaleuca** – broombrush (*Melaleuca uncinata*) has the potential to be a multi-purpose revegetation species in catchments. It can be used to produce brushwood fencing and high cineole oil. It can be used for lowering saline watertables on the flats, as shelterbelts for stock and crop protection, and as wildlife habitat. It can be grown from margins of salt lakes to gravely ridges but usually grows in areas with sandy topsoil over clay. Like oil mallees it may be necessary to cut the plants to stimulate growth.

**Olives** – self-fertile, long-lived, hardy evergreen trees growing 4–7 m tall with similar spread. Olives will grow in a rainfall of 450 mm or less, but perform best above 500 mm. Irrigation will aid establishment and yield. They will not tolerate waterlogging or poorly drained soils. Trees tolerate neutral to slightly alkaline soils, with best performance seen on moderately alkaline soils. Olives have a low to moderate salt tolerance. With irrigation, production should begin after year three, with a good crop after year five. Without irrigation, yield will start after year five, with reasonable yield after year seven, although the yield will never be as high as irrigated olives.

**Cut flowers** – cut flowers and foliage can supplement farm income. Banksias and dryandras, the mainstay of the cut flower industry, grow particularly well on free-draining soils and can therefore contribute to recharge control. When choosing species, investigate flowering times to ensure flower harvest will not conflict with other farming operations. Also seek advice from wholesalers as to current market trends.

**Carob** – evergreen trees with a height and spread of 9 to 12 m. Trees will grow in as little as 250 mm rainfall but 500 mm is considered necessary to achieve commercial production without irrigation. Well drained, neutral to slightly alkaline soils are best. If protected from grazing they keep their foliage down to ground level, making excellent windbreaks. Foliage is also fire retardant.

**Pistachio nuts** – relatively slow growing, small, spreading deciduous tree about 5 to 10 m round. Pistachios will grow with as little as 125 mm rainfall, but crop is erratic under these conditions. Soils need to be well drained, and pistachios are tolerant of moderately acid to highly alkaline soils. Parrots are a major problem.
Appendix 3: Catchment inventory survey

Total area of land owned by group members: 14,750 ha
Average farm size: 2,950 ha
Non-arable land with reduced grazing potential: 7%
No grazing value: 2.9%
1997 annual rainfall: 290 mm
1997 growing season rainfall: 193 mm
Average rainfall outside growing season: 73 mm
18% of the cropped area of the catchment is rotated one year in one year out cereal crop and pasture, by one farmer.
36% of the cropped area is rotated legume crop-cereal crop, on three farms.
28% of the cropped area is rotated legume-cereal-oilseed-cereal, on one farm.
18% of the cropped area is rotated pasture-legume-cereal.

One farmer uses more than one rotation on the farm.

1997 cropping
Three farmers grew wheat on 5,370 ha of land for an average yield of 1.15 t/ha.
Three farmers grew barley on 396 ha of land for an average yield of 1.04 t/ha.
Four farmers grew lupins on 1,185 ha of land for an average yield of 0.65 t/ha.
Two farmers grew canola for an average yield of 0.81 t/ha.
This added up to 96% of the yearly average cropped area.

Table A3: Potential crop yields

<table>
<thead>
<tr>
<th>Crop</th>
<th>5 year target (t/ha)</th>
<th>% of target achieved</th>
<th>1997 target (t/ha)</th>
<th>% of target achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat</td>
<td>2.3</td>
<td>78</td>
<td>1.9</td>
<td>60</td>
</tr>
<tr>
<td>Barley</td>
<td>2.7</td>
<td>62</td>
<td>2.3</td>
<td>45</td>
</tr>
<tr>
<td>Lupins</td>
<td>1.8</td>
<td>47</td>
<td>1.5</td>
<td>42</td>
</tr>
<tr>
<td>Canola</td>
<td>1.5</td>
<td></td>
<td>1.3</td>
<td>64</td>
</tr>
</tbody>
</table>

Stock

Sheep: 5000, one farm; shorn in spring.
Average DSE per winter-grazed hectare: 3.0

Cattle: One farmer, with a feedlot
481 cows, 9 bulls, 54 heifers, 311 yearlings/steers, 470 calves

Pigs: 2100 pigs, 202 hectares
Seeding practice
Two farmers work up, work back and then seed, on 1930 ha
Four farmers work up, wait and then seed, on 2605 ha
Two farmers direct drill, on 2052 ha
Two farmers use no till, on 1891 ha
On average, the farmers use two seeding methods.

Management practices
Five farmers have used lime on the farm
Two farmers have used gypsum, on 440 ha of land
500 ha of land is worked on the contour by one farmer
52 ha have been deep ripped on two farms.

Stubble handling
Three farmers graze stubble
One farmer bales stubble
Two farmers rake the stubble
Two farmers cut the stubble short
One farmer uses a double cutter bar
Two farmers spread the straw at harvest
One farmer hot burns
Two farmers cold burn the stubble
Three farmers use seeding machinery with improved trash handling capabilities.

Water control works
Four farmers have grade banks in place for a total of 32 km
One farmer has one kilometre of deep drain
Two farmers have grassed waterways
One farmer has WISALT banks.
Appendix 4: Soil survey report

Paul Galloway, Soil Research Officer, Narrogin

The survey was done by digitising individual farmers’ soil maps that were then ground-truthed from aerial photographs. The soils were grouped into 12 land management units.

Table A4: Soil types and descriptions

<table>
<thead>
<tr>
<th>Land Management Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morrel</td>
<td>Fluffy, highly calcareous greyish brown silty clay loam over highly calcareous brown medium clay. Found as dune deposits south-east of salt lakes. Soil 4 in Soils of the Lake Grace Advisory District.</td>
</tr>
<tr>
<td>Red clay/salmon gum clay</td>
<td>Dark greyish brown clay loam over calcareous brown to red clay. Usually found in broad valleys, downslope of duplex soils and further away from the salt lakes than the morrel soils. Soil 8 in Lake Grace Advisory District.</td>
</tr>
<tr>
<td>Duplex slopes</td>
<td>This unit incorporates both the sandy and loamy-surfaced duplex soils. The sandy variants often have deeper topsoil, and usually better surface characteristics (i.e. infiltration is better, no hardsetting). The loamy duplexes are often associated with grey clays (often near each other). Incorporates soils 3 and 7 of the Lake Grace Advisory District.</td>
</tr>
<tr>
<td>Sandplain soils</td>
<td>Usually yellow, but sometimes pale deep sands and sands grading to loams at depth. These are found in depressions and depositional areas of the upper landscape, just below gravelly uplands, ridges etc. Soils 5 and 6 of the Lake Grace Advisory District.</td>
</tr>
<tr>
<td>Sandy gravels</td>
<td>These are the ironstone gravelly soils usually found on the highest parts of the landscape, but also as isolated gravelly rises on slopes. Soils 1 and 2 of the Lake Grace Advisory District.</td>
</tr>
<tr>
<td>Red shallow loam</td>
<td>30 to 80 cm of red to brown sandy loam to clay loam over fresh rock. Usually near rocky outcrops. Soil 27 of the Lake Grace Advisory District.</td>
</tr>
<tr>
<td>Rocky outcrops</td>
<td>Dolerite soil Red clay loam over red clay, often calcareous. Usually well structured with deep cracks when dry, and very sticky when wet. Naturally very fertile, but very often quite droughty. Can occur anywhere fresh rock is close to the surface, and usually in long lineaments across the landscape. Groups 39 and 40 in Soil Groups of Western Australia (not described in Soils of the Lake Grace Advisory District).</td>
</tr>
<tr>
<td>Saline discharge soils</td>
<td>All soils that have been salinised. Most prominent in valley positions, but can be found in all parts of the landscape, except sandy gravels.</td>
</tr>
<tr>
<td>Granitic sands</td>
<td>Coarse pale yellow to grey deep sands, usually found skirting rock outcrops, but also as colluvial deposits downslope of outcrops. Often in intimate association with outcrops. 48 and 49 in Soil Groups of Western Australia (not described in Soils of the Lake Grace Advisory District).</td>
</tr>
<tr>
<td>Grey clay/hardsetting sandy loam over grey clay</td>
<td>(See duplex slopes) Often called Sunday soil or Blue-grey clay. Shallow sandy loam over grey clay, or hard, non-cracking grey clay. This association is found near weathered granite (saprolite) outcrops and also near isolated gravel rises surrounded by duplex soils, and drainage depressions. Groups 41 and 37 in Soil Groups of WA. (Not described in Soils of the Lake Grace Advisory District.)</td>
</tr>
<tr>
<td>Mixed soil types</td>
<td>Several soils in close association. Numbers on the map indicate types.</td>
</tr>
</tbody>
</table>
Appendix 5: Explanatory notes for hydrogeological map and groundwater drilling

Rosemary Nott, Hydrologist, Merredin

South East Humps Catchment is 10 km east of Hyden in the Kondinin Shire. It occupies 14,750 ha, bounded to the west by the Greater Humps catchment, to the south by the Eastern Lockhart lake chain and to the east by a small catchment, also draining into the lake system extending west from Lake O’Connor and Lake Carmody.

A hydrogeological map has been produced using available geological, groundwater and topographical data. It was undertaken to obtain an understanding of groundwater and its role in salinity development in the catchment and to assist farmers in developing management strategies. Assessment was based on land units, topographic position and waterlogging hazard. Geological features, including mafic and quartz dykes, fracture zones and lineament directions were mapped on the same sheet from field assessment.

Granitoid basement rocks underlie the area. These are crossed by a large number of fracture zones, some of which have been intruded by mafic rock.

Only a small area of salinity was observed outside the salt lake system. Large areas of waterlogging however have been noted on the lower catchment flats and depressions of the upper catchment following large episodic events. Groundwater levels are between 2 and 5 m on the valley flats and in some cases very salty. This is evidence for concern and reason for large-scale change in catchment management practices.

Methodology

Existing material was reviewed. This review included information from the Water and Rivers Commission databases, geology maps, soil maps and vegetation surveys. Aerial photos and field observations from farm visits were used to map geological features. Hydrogeological data was digitised and stored in series of map layers (recharge units, structures and hazards) at the 1:25,000 scale.

A small drilling program was conducted to install piezometers. Nine sites were drilled with a small auger drill rig. The Catchment Support Officer supervised the drilling. Drill logs were recorded in the field and samples were collected for salinity tests. Water levels and groundwater salinity were measured for each piezometer.

Previous investigations

- Geological information was found in the Hyden Geological Series 1:250,000 Explanatory Notes and accompanying map sheet (Chin 1986).
- Topographical information was obtained from the Hyden (2633-II) and Lake O’Connor (2733-III) 1:50,000 map sheets.
- The WRC Aqua-base contains information from some groundwater drilling.
- Soils information was obtained from farmer soil maps compiled into a catchment soils map by Alex Hollick and Paul Galloway.

Physiography

The catchment is narrow (approximately 10 km at the widest point). The main stream meanders for about 15 km from the top to the bottom of the catchment. The topography ranges from 400 m AHD at the catchment divide in the north to 290 m AHD at the broad outlet to the south. Undulating topography, with slopes up to 10% overlie relict duricrust
peneplain and remnant sandplain in the upper catchment. Granite monoliths with steep sides rise up to 20 m above the peneplain.

There are few remnant lateritic hills around the catchment divide due to extensive erosion of the mid to lower catchment. Aeolian redistribution of sand-sized material has resulted in sandplain formation around some gravel hills. The laterite duricrust, where it occurs, is nodular, grading down to a highly leached kaolin zone and then a narrow band of saprolute over fresh bedrock.

The valley is broad and flat with a slope of 0.5%. It has been extensively eroded adjacent to palaeodrainage channels and infilled by alluvial materials from sheet wash and aeolian lake deposits. Water drains southwards into the regional salt lake chain, but this system is without regular flow. Small lunette dunes exist around a few of the salt lakes, isolating them from the main drainage system.

**Climate**

The climate is Mediterranean with cool moist winters and long, dry summers. Average annual rainfall in the catchment, based on farmer averages, is 304 mm, ranging from 266 mm in the lower catchment to 330 mm in the upper catchment. Growing season rainfall is 241 mm (214 to 276 mm).

**Vegetation**

Vegetation was mapped by Beard (1980). The area is in the Hyden System of the Avon Botanical District. Sandplain ridges were originally scrub heath dominated by acacia, casuarina, grevillea, hakea and leptospermum. *Allocasuarina campestris* (tamma) thickets were sometimes present on ironstone gravel.

Mallee woodland was once widespread in the mid-slopes between the scrub heath and lower slope woodland. These areas included several species of mallee, ranging in height from 4 to 9 m. *Eucalyptus eremophila* is the most common and consistent of the mallee species in the area. An understorey dominated by melaleuca occurred in association with the mallee.

The mid to lower slope woodlands were dominated by *E. salmonophloia* (salmon gum) on alluvial/colluvial soils and *E. salubis* (gimlet) typically on heavy red soil.

The lake bed soils were dominated by *E. longicornis* (morrel), *E. yilgarnensis* (yorrell), *E. kondininensis* (blackbutt) and *E. spathulata* with a shrubby melaleuca and grass understorey in less salty areas, grading to saltbush (*Atriplex hymenotheca*) and greybush (*Cratystylis conocephala*) in more alkaline areas and samphire (*Halosarcia spp.*). Tea-tree scrub was also common on slightly saline lower slopes, but many of these thickets have died due to rising watertables following clearing.

Exposed granite rocks are a significant feature. The shallow soil profiles on the shoulders and in clefts of granite provide habitat for small trees included *Allocasuarina huegeliana* (rock oak) and *Acacia acuminata* (jam wattle), shrubs such as *Calothamnus*, *Melaleuca* spp., *Kunzea pulchella* (granite kunzea) and sedges.

**Geology**

Relevant geological features observed in the field were mapped onto overlays for aerial photographs. 1:250,000 geology maps were consulted for basement geology.

The catchment is underlain by porphyritic granite and ademellite, which is characterised by clean surface rock Chin (1986). A small north-trending intrusion of banded gneiss occurs approximately 12 km east of Hyden on the property of R. Mouritz (Loc. 1460). Irregular shaped intrusions of recrystallised granite, and amphibole derived from mafic rock, accompanies this intrusion. A linear intrusion, designated as quartz-hypersthene-garnet-magnetite granulite by Chin (1986) trends northward from the metamorphic enclave.
Many lineaments were detected on the aerial photographs. Dolerite and gabbro were intruded after the cessation of regional metamorphism and deformation (Chin 1986). The predominant mafic dyke direction is east to east-northeast. The largest of these dykes, part of the regionally significant Binneringie Dyke, cuts through the top of the catchment. A north-west trending faulting pattern was also evident from the photos and possibly influential to current surface and subsurface water flow patterns.

Tertiary duricrust, consisting of nodular and massive laterite, may have once covered a large area. Only remnants of this currently remain along the rim of the catchment. This iron-rich crust is underlain by a mottled clay zone, leached kaolinised zone and saprolytic zone, over bedrock. Where the bedrock is gneiss, the saprolytic zone has high clay content.

Silcrete (silicified sandstone of angular quartz crystals), may occur locally beneath the duricrust but above the kaolinized zone. Silcretes were found in the north-east, about 200 m from the main stream (V. Mouritz - Loc. 2162). It is likely that silcrete underlies a large part of the mid-catchment around the creekline.

Yellow and pale sand deposits were found around remnant duricrust in the upper catchment. It has been derived from quartz sand transported over short distances and eroded duricrust.

Colluvial sediments, formed on slopes from the breakdown of bedrock and moved downslope by water and soil creep, have been found throughout the catchment. Alluvial sediments, of predominantly sand and silt, were found in the upper portions of the drainage valleys. In the valley floors silt and clay sediments from upslope and/or aeolian salt lake sediments overlie alluvium.

**Hydrogeology**

Groundwater data were obtained from the Water and Rivers Commission’s AQUAbase, from 1900 to the present. Five bore logs have been recorded for this catchment, the details of which may be seen in Table A5. None of these bores is currently known to exist. One bore, not contained in the WRC data was found on the road reserve along the Hyden-Lake King Road, just east of the catchment. This bore contains salty water at depth. It is likely that a large percentage of drill holes from the WRC database were not cased because of limited supply and salty water.

Several of the dry holes on the WRC database were drilled to bedrock. The bedrock depth ranges from 3.35 to 32.6 m. No sites were drilled in the palaeodrainage channels.

A number of bores and wells exist were not included in the WRC database. Permanent groundwater has been found in all parts of the catchment, but in most cases it is very salty.

Several dolerite dykes are more resistant to weathering than granite or gneiss and act as barriers (in the solid rock form and in the weathered form) to groundwater flow. Salt seeps are often evident upslope from a dyke because of an increased groundwater gradient. No salinity of this nature is currently evident.

Groundwater conduits have also been identified. These areas allow groundwater flow along fractures and contact zones with bedrock.
Table A5: Historic bore records for catchment

<table>
<thead>
<tr>
<th>Bore ID</th>
<th>Location No.</th>
<th>AMG easting</th>
<th>AMG northing</th>
<th>Drilled</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2733-3-NW-0001</td>
<td>1457</td>
<td>691099</td>
<td>6420323</td>
<td>30-Jun-36</td>
<td>26.52</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Weathered kaolin profile to granite at base, no water.</td>
<td></td>
</tr>
<tr>
<td>2 2733-3-NW-0007</td>
<td>2387</td>
<td>694964</td>
<td>6423346</td>
<td>30-Jun-70</td>
<td>28.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 m of tertiary sand over weathered kaolin profile to granite at base, no water.</td>
<td></td>
</tr>
<tr>
<td>3 2733-3-NW-0008</td>
<td>2387</td>
<td>694159</td>
<td>6422214</td>
<td>30-Jun-70</td>
<td>15.54</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.3 m of tertiary/quaternary sands and clays over weathered kaolin profile to granite at base, no water.</td>
<td></td>
</tr>
<tr>
<td>4 2733-3-SW-0001</td>
<td>821</td>
<td>692967</td>
<td>6406300</td>
<td>30-Jun-28</td>
<td>3.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>In situ sands on a granite base, no water</td>
<td></td>
</tr>
<tr>
<td>5 2733-3-SW-0007</td>
<td>1465</td>
<td>694051</td>
<td>6409329</td>
<td>30-Jun-36</td>
<td>32.61</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lateritic material over weathered kaolin profile, struck water at 23.7 m.</td>
<td></td>
</tr>
</tbody>
</table>

Figure A1: Drill log and sample results

The purpose of drilling was to establish nine bores in the catchment for groundwater monitoring. Nine sites were drilled, but only four were successfully completed and cased. Site 3 (Mouritz laneway) was drilled to 4 m, where it struck a silcrete barrier. The small auger rig was not able to penetrate this layer. No watertable was reached, so the hole was not cased. Sites 4 and 5 were not completed, as the auger was not able to penetrate. SH1 was drilled into lower slope alluvial sediments, deposited during flood events from the stream, and the top of the mottled zone. SH2 comprised layers of grey-brown to brownish black sediments (possibly a combination of alluvial depositions and eolian drifts from nearby salt lakes) over richly mottled clays. SH6 was located in a mid-upper ferrecrete hardpan. Site 7 (along the main creek) was not completed due to a silcrete barrier. Site 8 was drilled to what was termed saprolute by the logger. It is possible that the drill auger reached a bedrock high, or the auger was not capable of penetrating a semi-solid barrier. It was drilled through about 1 m of pale alluvial sand, overlying thinly bedded layers of depositional sand and clay to
mottled zone red to red-brown clays. SH9 was drilled on a valley flat into bands of sedimentary sands and clays. Soil layers were not easily definable at all bore sites as the auger-rig mixed the drill samples as they came up the auger. This problem would have not occurred if a RAB drilling rig had been used.

**Groundwater levels and salinities**

Watertable depths and groundwater salinities were measured from bores SH1, SH2, SH6 and SH9. The results of these measurements are shown in Table 4. SH1 and SH2 have watertable depths to 3.83 and 4.55 m respectively and high salinity. Although there is currently no surface signs of salinity in the immediate vicinity of these bores, the areas are at medium to high risk of salinisation within the next 10-15 years, assuming a rate of groundwater rise of 30 cm/yr. SH6 was also salty, with an electrical conductivity (EC) of 4000 mS/m. The watertable in this area is not an immediate treat to salinisation of surrounding land, but the high EC indicates a high salt store in the upper catchment (remnant lateritic hills to the north and north-west). These salts are potentially being mobilised and carried to the lower parts of the catchment where they are discharged. The EC of SH9 is comparatively low compared to other groundwater measurements. The reason may be that it is being recharged from a relatively small area below the major dyke. The high water level of SH9 is a concern. It is likely that capillary discharge is occurring in the clay soils in this area. Waterlogging of this valley floor site is adding to the problem and needs to be addressed.

**Table A6: Bore sampling results**

<table>
<thead>
<tr>
<th>Bore Identification</th>
<th>Depth to water level (m)</th>
<th>Electrical Conductivity (mS/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SH1</td>
<td>3.83</td>
<td>4,330</td>
</tr>
<tr>
<td>SH2</td>
<td>4.55</td>
<td>5,490</td>
</tr>
<tr>
<td>SH6</td>
<td>11.00</td>
<td>4,000</td>
</tr>
<tr>
<td>SH9</td>
<td>1.90</td>
<td>920</td>
</tr>
</tbody>
</table>

**Land salinisation**

Severe salinisation is only evident in the palaeodrainage system. These areas are saturated with saline groundwater to the surface or near the surface. They are salt scalded and have a groundwater salinity range from 12,000 to 55,000 mS/m.

Moderate salinisation is evident in the areas surrounding the severe salinisation in the lower catchment, where dykes have formed groundwater barriers and around saline seeps in the upper catchment. The watertable in these areas is likely to be within 5 m of the surface, varying seasonally. Some tree species have died in the moderately saline areas, leaving only salt tolerant shrubs including salt bushes, samphire and some melaleucas.

Reduced production caused by salinity is occurring in the lower catchment bordering areas of moderate salinisation. The watertable in these areas is likely to be between 3 and 5 m. Surface inundation and waterlogging may be a compounding problem in many areas.

Potentially all the lower catchment below an elevation of 300 m, apart from where there is micro-topographic relief, has a medium to high risk of becoming saline in the near future, given current land management. The major dyke, acting as a groundwater barrier across the main creek, is likely to be a site of increasing groundwater salinity as salts concentrate behind the structure and salinisation as groundwater rises.
Recharge areas

Water infiltrating across the soil surface can become recharge if not used by plants. Recharge may occur through a uniform soil matrix (matrix flow recharge) or cracks, fissures and root channels (preferred pathway recharge). Factors that affect the amount of recharge include: soil texture, amount and intensity of rainfall, seasonal rainfall patterns, vegetation cover and type, soil salinity, tillage method, topographic position and slope, and waterlogging.

1. Soil texture

Some recharge occurs on all soil types. However, the rate of recharge is higher in areas of bare sand or gravel as these soils are very porous and water usually percolates below the root zone faster than the transpiration rate. For example, the rate of water movement through a uniform coarse textured soil (e.g. loose gravel) can be over 2 m/day, while water movement through a heavy clay soil can be less than 0.001 m/day, where there is no preferred pathway recharge (Moore 1998).

2. Amount and Intensity of rainfall

Uniform coarse-textured soils have low water-holding capacity. After the storage capacity of the plant root zone is reached, water continues to move downward. In large rainfall events, large amounts of water recharge below the root zone unless used by plants.

As the intensity of rainfall increases, run-off increases. In a low relief catchment, as rainfall intensity increases, recharge decreases in the upper catchment, but eventually increases in the lower catchment as water accumulates in depressions and low lying areas.

3. Seasonal rainfall patterns

In the eastern and south-eastern wheatbelt rainfall is winter-dominant. In traditional farming systems, crop growth occurs in winter and spring. Very little water is used by plants in summer and autumn. Episodic rainfall events during this period cause recharge.

4. Vegetation cover and type

Recharge is higher under annual crops and pastures compared to native vegetation. The reason for this is shallower rooting depth, short growing cycle and lower leaf area index in annual crops. An interaction exists between vegetation and soil type. If the vegetation type is not adapted to the soil type, recharge will be higher than if it were growing on an appropriate soil type due to poor plant root development.

5. Tillage method

Tillage methods that restrict root elongation may increase recharge due to decreased crop water use. Practices that encourage root growth such as deep ripping and amelioration of soil structure with gypsum or liming on acid soils may increase plant water use. Practices that encourage increased plant leaf area such as correct and timely fertilizer application will increase water use.

6. Topographic position and slope

Topography and slope influence whether water ponds on the surface or runs off. If it runs off, it may recharge further down the catchment, unless intercepted and used by plants.

7. Waterlogging

Recharge is higher on waterlogged soils due to poor plant growth and thus reduced evapotranspiration. Ponded water on fine-textured valley-floor soils infiltrates slowly and
contributes to recharge. In duplex soils, preferred pathway drainage may also contribute to recharge.

8. Soil salinity

Recharge may be greater on saline soils due to reduced plant growth. This effect is increased if the site is also waterlogged.

Discharge areas

Discharge predominantly occurs on valley flats where salt accumulates in salt lakes, paleochannels and along creeklines. On upper slopes, discharge also occurs at hillside seeps (area of skeletal topsoil downslope from deep topsoil) or upslope from dolerite dykes and bedrock highs.

The main mechanism for discharge is capillary rise. When groundwater gets within 1 to 2 m of the surface, discharge occurs by evaporation. The depth to which capillary rise starts depends on soil texture. In a sandy soil, the critical depth for capillary rise may be as high as 0.5 m, while in a clay soil the critical depth may be 2 m due to a greater volume of capillary pore space in fine textured soils.

Hillslope discharge may also occur as a result of the watertable intercepting the surface, or near surface (in which case capillary rise contributes to seepage).

Recharge map

A recharge map was produced for the catchment. The recharge potential units and the corresponding soil landscape units may be seen in Table 4. Some very small areas may have been generalised due to limited farm visits and the mapping scale.

One of the purposes for the hydrogeological map and catchment drilling was to aid in design and implementation of catchment strategies for salinity control. Remedial action for salt-affected land needs to consider the recharge contribution of all areas of the catchment. In the past, the focus of salinity management has been on problem areas, with little emphasis placed on the causes. Following are some recommendations for various recharge areas of the catchment.

Granite rock outcrops

A significant amount of water runs off exposed and shallow granite rock. In the Catchment examples of exposed rock may be found on Locations 1329, 1458, 1459, 1460, 1461, 1462, 1464, 1465, 2379 and 24295. Water enters the groundwater system downslope of the rocks through porous granite sands (saprolyte). In some situations it may be possible to harvest water from the rocks and store in dams, or pump relatively fresh water from this part of the saprolyte aquifer. Alternatively, revegetating areas around outcrops can reduce recharge, provided the soil profile is not too shallow for the species planted. Selectively planted trees and shrubs will use stored moisture over summer and minimize recharge from episodic events. Species with useful timber may be considered, e.g. sheoak (*Allocasuarina huegeliana*), sandalwood (*Santalum spicatum*) and jam (*Acacia acuminata*) suggested by Baxter (1996). Wildflowers may also be a viable enterprise with the current tourist attractions in Hyden.

Breakaways

Breakaways occupy only a small area, however these areas (on Smith’s – Loc. 1457, Walton 2379, R. Mouritz 1460 and V Mouritz 1462) contribute large amounts of recharge though broken laterite. Bare areas should be fenced to avoid stock trampling and revegetated as they contribute little to agriculture. Species that are adapted to growing in broken rock are most suitable e.g. white gum (*Eucalyptus wandoo*). Problems with poor water-holding
capacity of these soils may be avoided in part by forming absorption banks for the areas below the breakaways. Some revegetation downslope of breakaways may be difficult if erosion has occurred exposing acid subsoil.

**Sands/sandy gravels**

Deep sands occupy a significant area. Sandplain is a uniform coarse textured soil that allows an even downward movement of water (matrix recharge) and thus salt leaching. Commonly, a sheet of fresh groundwater will sit over saline groundwater. This water is available for deep-rooted plants, but it has been noted (Baxter 1986) that trees may exhaust this supply within a few years of planting, resulting in stunting and death. Acid-tolerant plants also need to be considered where the sandplain is acidic.

**Hillslopes**

Hillside duplexes are one of the largest soil units. Water percolates through the A-horizon and perches on top of the B-horizon. Preferred pathway recharge may occur through root channels and cracks in the clayey B-horizon. If the A-horizon is fully saturated and a gradient exists, water will run off by saturated overland flow. Where there is minimal gradient waterlogging occurs, creating an environment for preferred pathway recharge.

Trees planted on hillside duplex soils will eventually put down roots into clayey subsoil, but if a shallow saline groundwater table exists their lives will be short. The most beneficial place to plant trees in hillside duplexes is on contours, below earth works so as to make maximum use of surface water and minimise effects on farming practices. Watertable depth should be assessed before large-scale tree planting. If groundwater is at 5 m or higher and the trees are not salt-tolerant, they may have a lifespan less than 10 years.

**Hillside seeps**

Hillside seeps occur where saline water is discharged on the side of a hill where the regolith becomes thin in the case of a granite bedrock high or where a dolerite dyke forms a barrier to groundwater flow. Water either trickles downslope or waterlogs around the seep, creating a site of preferred pathway recharge.

If the area recharging a hillside seep is fairly small, discharge may be controlled with vegetation management. Only salt tolerant trees and pastures should be planted immediately upslope from the discharge site. Further upslope, where depth to saline groundwater is lower and the water less salty, trees may be planted to control recharge. It should be noted however, that up to 80% of the recharge area might need to be planted to prevent discharge flow. Alternatively, if the seepage area is of significant value and a safe disposal site can be located, drainage may be the only option. If the site is of low value, fencing and leaving it may be the most economical solution.

**Sandplain seeps**

Sandplain seepage may occur where the blanket of sand tapers out and there is only a thin layer of sand over impermeable clay. The first step in management is determining the salinity of the seepage water. If the water is fresh the obvious option is to collect the water for stock water supply or irrigation. Sandplain seeps are most likely to be fresh as salts have been leached from these profiles over a long period of time and a perched watertable exists on top of an impermeable clay or creted base. Alternatively, a fresh water mound (from recharge through the sandplain) may be sitting above salty groundwater. In this case the seep will remain fresh through the early summer and then become salty as fresh seepage water is used up.

Salty sandplain seeps, or fresh seeps where the water supply is not required, can be controlled by increasing water use above the seep. Growing deep-rooted perennial pastures may also use enough water to dry the seep.
Valley flats
Valley floors contribute significant amounts of recharge to the catchment although a large area of the valley floor is also discharging water. Recharge is by preferred pathways when the valley floor is waterlogged. Large recharge events occur in the valley floor during episodic flood events when large quantities of water is ponded for long periods of time (Baxter 1986).

The first management strategies should be engineering solutions to reduce waterlogging. Engineering and revegetation solutions employed in the mid and upper catchment will contribute towards reduced flooding and waterlogging on the valley floor. Vegetation solutions for valley floors should incorporate perennial plants to use more of the water falling on the flats and dry the surface soil. Some consideration should be given to the depth of saline watertable and lifespan of the perennial species, given a predicted rate of groundwater rise of 25 cm/yr.

Creeks and drainage depressions
Major drainage lines contain thick bands of depositional sand. Normal winter rainfall and light summer rainfall events infiltrate quickly through these sands and recharge the groundwater table. Large episodic events cause run-off. Fast moving water travels down creeks from the upper catchment to flood the lower flats, causing preferred pathway recharge. Prior to clearing, less run-off would have reached the lower flats, and that which did would have infiltrated by tree root channels to be used during dry periods of the year.

Creeklines are ideal locations for revegetation because they have little agricultural use, are natural water-gaining areas for good plant survival and may be used as plant and animal corridors. The major consideration in revegetation is the depth to saline groundwater.

Minor drainage depressions feeding into creeklines, can be contoured towards creeks or dams and then revegetated behind banks if applicable.

Remnant bush
The amount of recharge contributed by remnant bush depends on its quality. Recharge under ungrazed native bush is minimal. However, in grazed native bush the understorey disappears and recharge increases as a result of decreased leaf area index. Mature trees may also die as opportunities for seedling regeneration are diminished. Isolated patches in paddocks may also die as a result of unviable population size, chemicals and fertilisers.

Conclusion
Hydrological equilibrium has not been reached. The reality is that groundwater will continue to rise in all parts of the catchment, causing widespread salinity on the flats and further outbreaks on the slopes, unless action is taken throughout the catchment. Higher water use farming systems need to be adopted to reduce the extent and severity of salinity. Research from George et al. (1999) suggests that only extensive revegetation, over as much as 70-80% of the catchment, will significantly reduce a regional watertable. Their recommendation is that trees planted in recharge areas will have the best long-term effect. Discharge area plantings may have a positive effect on a local watertable, but provide little long-term benefit in reducing groundwater at a catchment scale. However, there may be reasons other than controlling groundwater tables at a discharge site, such as aesthetics, increasing crop or pasture productivity, windbreaks or erosion prevention. Few trees can adequately transpire salty water (>1000 mS/m). In order to maximise the impact of revegetation, trees should be located on relatively fresh aquifers, or where there is significant profile depth for the tree to survive above the salty watertable. Another finding from George et al. (1999) is that tree plantings will have maximum control of a perched (sandplain seep) or local groundwater
system or systems with thin aquifers. A small block of trees planted on one property may not change the valley floor watertable of the catchment.

The long-term situation for agricultural production is daunting. Unless significant changes are made to farming systems, many producers will not be in business in 50 years, or in some cases even in 10 years time. If current social structures in rural communities are to be maintained then some radical changes need to be made to farming systems.

**Recommendations**

It is vital that a groundwater monitoring system be established for the catchment group to know how quickly groundwater is rising, and to test the effectiveness of applied management strategies. I recommend firstly that bore sites 3, 4, 5, 6, 7 and 9 are re-drilled. Site 7 should be drilled to obtain the depth to bedrock, while the other sites should be drilled to watertable level. I also recommend that site 8 be replaced with another site to water level further up the creek from site 6. A rotary air blast drill rig should be hired because of the presence of silcretes, which can only be broken with compressive forces. Further bore sites should be drilled at sites where management is changing, to determine its effect on groundwater.

- Bores should be monitored at least four times a year to obtain maximum information on seasonal trends. Information on bore monitoring may be found in the Appendix.
- Drainage lines need to be revegetated and fenced.
- Sandplain seep control is already being carried out in some parts of the catchment. Small seepages which farmers do not intend to control with revegetation should be fenced to prevent further damage from stock trampling.
- Banks should include vegetation lines to use more water on the slopes
- High water use plants need to be used in all recharge areas. This may include pastures for livestock grazing or productive tree crops.

**References**


Appendix 6: Surface water

Mahtab Ali, Farm Water Planning Officer, Lake Grace

South East Humps is a small catchment with only five farmers. Of the total 14,913 ha, 10,955 ha is cleared (73%). About 91% of the cleared area is under crop and only 9% is pasture. Average annual rainfall varies from 300 to 347 mm. Most farmers have agisted or sold sheep and moved toward intensive cropping due to the low wool price. Table A7 shows the farm, cleared and cropped areas along with major soil types and main landform.

Table A7: Farm, cleared and cropped area, major soil types and landform

<table>
<thead>
<tr>
<th>No</th>
<th>Trading Name</th>
<th>Farm area (ha)</th>
<th>Cleared area (ha)</th>
<th>Cropped (ha)</th>
<th>Major soil type</th>
<th>Main landform</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>VR &amp; DJ Mourtiz</td>
<td>3,294</td>
<td>3,000 (91%)</td>
<td>2,200</td>
<td>SC and SG</td>
<td>UP</td>
</tr>
<tr>
<td>2</td>
<td>IG &amp; MJ Walton</td>
<td>2,915</td>
<td>2,227 (76%)</td>
<td>2,227</td>
<td>SC and SG</td>
<td>UP and LP</td>
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<tr>
<td>3</td>
<td>Smith &amp; Sons</td>
<td>2,146</td>
<td>1,620 (75%)</td>
<td>3,300</td>
<td>SC and SG</td>
<td>UP</td>
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<td>R &amp; C Payne &amp; Co.</td>
<td>5,668</td>
<td>3,238 (57%)</td>
<td>1,620</td>
<td>SC, SG, L, C, DC</td>
<td>UP and GUP</td>
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<tr>
<td>5</td>
<td>JH &amp; CM Forrest</td>
<td>890</td>
<td>870 (98%)</td>
<td>640</td>
<td>SG and G</td>
<td>GUP</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>14,913</td>
<td>10,955 (73%)</td>
<td>9,987</td>
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</table>

Major soil types

- SC  Sand over clay
- SG  Sand over ironstone gravel over clay
- L   Red loam or loamy-surfaced soils
- C   Heavy soils clay to the surface
- G   Gravely conglomerate
- DS  Deep sand (80 cm plus of sand)
- LP  Level plain (slopes less than 1%)
- GUP Gently undulating plain (slopes 1-3%)
- UP  Undulating plain (slopes 3-10%)

1. VR & DJ Mouritz

Vern Mouritz is seriously concerned about the increasing waterlogging problems on his farm. He is also concerned about the reliability of the water in his dams and wants to build several small and one big gully wall dam. During the visit he showed me many sites which were waterlogged and he explained his future program to deal with them. In addition to this he also showed me a couple of sites for building dams and roaded catchments. The details of each site are given below:

Site 1

This site was waterlogged and Vern wants to develop a sandplain seep (soak). After looking at the soil type and the landscape I told him this might not be a good site for this purpose. The reasons were: a) the sand was not as coarse as it should have been; b) the soil had considerable amount of clay and silt which might not allow water to escape out of the soil; c) the location in the landscape was not good with regard to having good recharge from the catchment above it.
I suggested that we could check the ability of the soil to release water by digging a small pit. Vern dug to about 1 m and we found that no water was seeping into the pit and concluded that the water would not be seeping in even if we dug 2 m deep. After observing this Vern didn’t pursue his idea of a soak. I recommend that we drill this site to at least 5 m to see if there is any deeper layer with good moisture and hydraulic conductivity.

Site 2
This was another waterlogged site and Vern again expressed his intention to have a soak by developing the sandplain seep. The sand was coarser and the amount of clay and silt was less compared to site 1. The recharge area was more than site 1, therefore I suggested that before developing this site he should do some drilling to check its prospect for releasing enough water without going to be salty in future.

Site 3
This was a patch with waterlogging. He said that it only has a moderate affect on crop yield and disappears in dry years. I suggested that he have a critical look at it for a couple of years and if it becomes worse then contour banks can be made above this site to stop water to flow towards the site.

Site 4
This was where Vern was interested to build a big gully wall dam with 50,000 cubic metres capacity. I examined the site and found that it might be good if it passes all the engineering tests, e.g. depth and strength of the soil, clay content of the soil, good bond between wall and dam body, consideration of hydraulic pressure exerted by different forces i.e. wind and earth quake. I discussed all the engineering aspect. In addition to this run-off calculation should be made to check the possibility of the dam being filled in future. Leakage through the dam should also be given serious consideration.

Site 5
This was where a new dam had been built. Vern was planning to put a roaded catchment on it. He got some advice on the location of the roaded catchment.

Site 6
Vern was planning to dig a traditional dam (4000 m^3) with a roaded catchment. He got advice about the suitability of this site for this purpose. In addition to this, advice was also given on building graded banks to harvest water from the catchment above the dam. The location of the graded bank was suggested in such a way that it will save the other site below this catchment from being waterlogged. The appropriate roaded catchment size for having 200 cows for this dam according to the DAMCAT-II would be 4 ha.

2. IG & MJ Walton
Of the 2,915 ha, 2,227 ha. were cleared and were under crop on this farm. The water storage in the dams is not an issue because there is no livestock. There were few patches with waterlogging and most of them were not having any impact on the crop yield. The farmer was concerned about one waterlogged site, which was going to become worse. This site was near the salt lakes. I found that this site has a good drainable soil, i.e. its hydraulic conductivity looked to be enough to have a drain and to get rid of excess water from the waterlogged site into the nearby salt lake. I suggested to the farmer to consider the idea of having a drain after getting the hydraulic conductivity test. The possible route of the drain was also suggested to the farmer.

3. Smith & Sons
Many sites at this farm were having problems related to the surface water management.
Site 1
This had water erosion problem. The washing of soil was severe and in my opinion it was due to two reasons: a) light soil b) high water velocity due to the slope of land above. The other reason might be the lack of maintenance. It was suggested that they maintain the existing creek at this point and try to reduce the peak flood by holding water in level banks or by having contour or graded banks with dams above this point (if possible).

Site 2
This was one of the few other sites where the farmer was planning to put a dam. The suitability of the site was discussed and it was offered to the farmer that he might get some help from me to know the appropriate size of the roaded catchment and dam according to his future requirements.

Site 3
Here the farmer was looking to develop a sandplain seep. All aspects of a successful soak were discussed. This site might have a good soak if it passes preliminary tests.

Site 4
This was also having erosion problems. I suggested some contour banks in the upper catchment to reduce the run-off velocity. The possible location of banks was also discussed.

Site 5
This had a wide waterway which was causing waterlogging on adjacent land. I suggested having a w-drain. The possible location was also discussed. A few sites with minor problems of waterlogging and erosion were visited and some possible solutions were discussed.


According to the farmer the salinity problem has decreased in the last 60 years. He demonstrated a few sites where he had salinity and now it has disappeared or is decreasing.

This farm has one salty dam. Other dams are near the salt lakes but according to the farmer all have good quality water. The farmer showed a site where he wants to put a dam. The catchment above this dam would be 80 ha. After having a look I agreed that this might be a good site for this purpose. I suggested to get some drilling done to get an idea about the sealing capability of the soil and watertable depth before going ahead.

5. JH & CM Forrest

This is a small farm of 890 ha at the top of the catchment. Of this, 640 ha are under crop. The farmer has no sheep. He has 3,500 pigs and four dams to water them. He has 20 ha of roaded catchment and all dams are in a series so that the overflow of the first dam goes into the second and so on.

He was concerned about one dam, which has a moderate leakage (2-8 mm/day). After having a look on the excavated soil of the banks and basement I concluded that either there is not enough clay to seal the dam and/or the clay is dispersive. The water was very muddy and might be due to the dispersion of the clay into the water. I suggested the farmer apply 2-3 tonnes of gypsum and observe any change. If it improves a little then he can apply a second dose after a couple of months. The other option might be chemical treatment or clay lining. In case of chemical treatment we have to take soil and water samples and get them tested to know the chemical properties and their response to Sodium Tripolyphosphate (STPP). After these tests the appropriate dose of STPP may be applied.

(Tim Lloyd, a farmer near Pingaring, also has one leaky dam and he has gone through the soil and water-testing phase. In future he might apply STPP and we may be able to benefit from his experience.)