2004

Frankland-Gordon area : catchment appraisal 2003

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Natural Heritage Trust (Australia)

Department of Agriculture
Government of Western Australia

FRANKLAND – GORDON
CATCHMENT APPRAISAL 2003

Compiled by Timothy Overheu

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Helping Communities Helping Australia

Content

SUMMARY

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

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

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

- The Frankland-Gordon study area covers approximately 162,400 hectares in an area to the west of the town of Tambellup, on the South Coast region of Western Australia. It includes the Kojonup, Cranbrook, Tambellup and Broomehill shires.
- Geology comprises colluvial material overlying weathered granites and granite-gneiss.
- The main soils are grey sandy duplex soils, duplex sandy gravels, with pale deep sands and semi-wet soils.
- The soils are susceptible to water repellence, soil acidity, soil compaction and salinity.
- Hydrology is influenced by the high hydraulic gradient and intense landscape dissection associated with the Upper Frankland and Gordon Rivers; the area is affected by confined and perched watertables.
- Current salinity (2000) covers about 5560 ha (3.4 per cent of the area)
- Approximately 17 per cent of the original vegetation remains within the study area.
- The degradation risks are:

Susceptibility to water repellence	74 per cent of the area
Susceptibility to soil acidity	67 per cent of the area
Susceptibility to soil compaction	63 per cent of the area
Susceptibility to wind erosion	46 per cent of the area
Susceptibility to water erosion	28 per cent of the area
Susceptibility to waterlogging	20 per cent of the area

1. INTRODUCTION

The Frankland-Gordon area is located within the central north-west portion of the Great Southern Agricultural region, is approximately 162,400 ha and includes parts of the shires of Kojonup (62,850 ha / 39 per cent), Cranbrook (48,250 ha / 30 per cent), Tambellup (43,680 ha / 27 per cent) and Broomehill (7,600 ha / 4 per cent).

The area covers the sub catchments of Pindellup Creek, Upper Slab Hut, Gordon River, Peter Valley, Lower Slab Hut, Ryans Brook, Uannup Brook, Towerlup North and Towerlup South (Figure 1).

The area has a recognised history of innovative landcare activity.

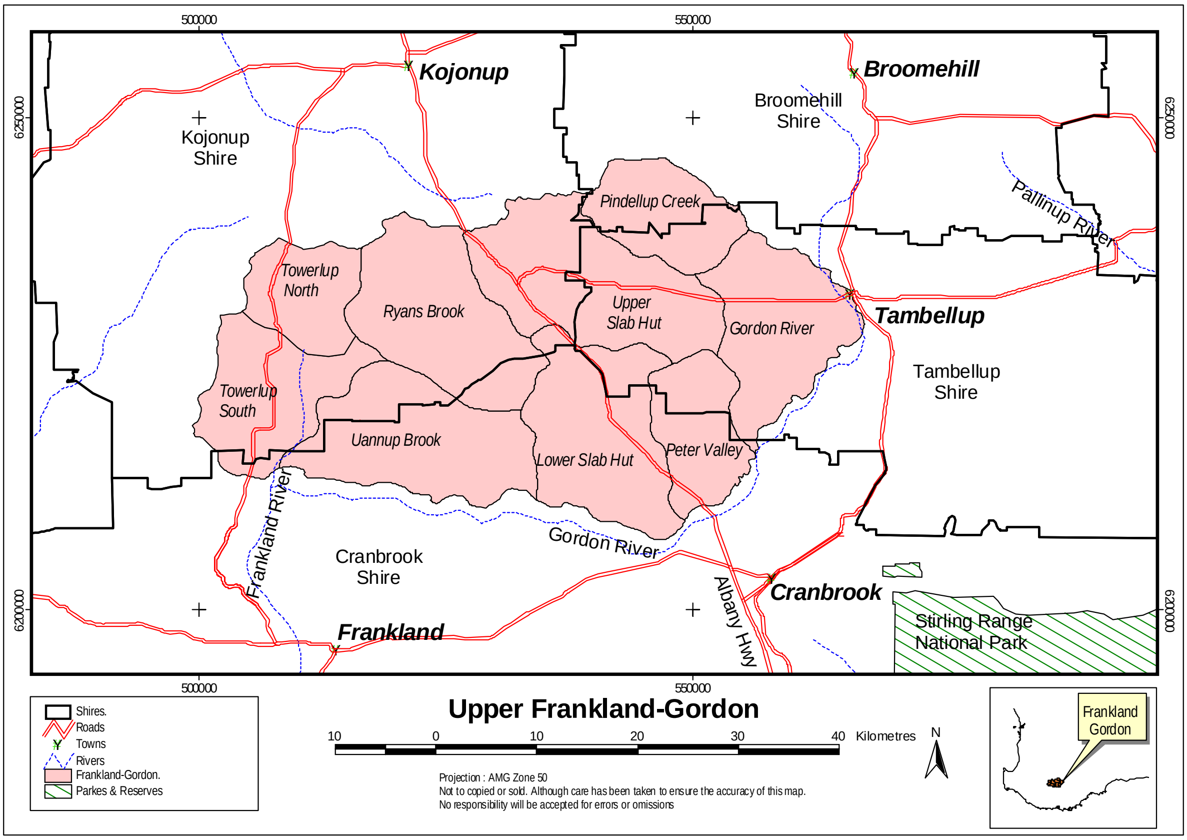


Figure 1. The Frankland-Gordon appraisal area illustrating the sub catchments and shires.

The far eastern portion has subdued topography and sandplain soils, while the central and western portion is characterised by a more dissected landscape, with valleys and undulating to rolling terrain. The area is mostly affected by soil acidity, and has a moderately high risk of salinity and waterlogging.

2. NATURAL RESOURCE BASE

2.1 Climate

John Grant, Albany

The climate is typically Mediterranean with hot dry summers and cool wet winters.

Rainfall

The mean annual rainfall varies from 600 mm in the south-west, to 450 mm in the east (Figure 2). There is a 20 per cent chance of rainfall above 541 mm (wet year) and a 20 per cent chance of rainfall below 446 mm (dry year). Consequently there is an 80 per cent chance of more than 446 mm rainfall. The driest and wettest years since 1957 were 1969 (307 mm) and 1963 (626 mm).

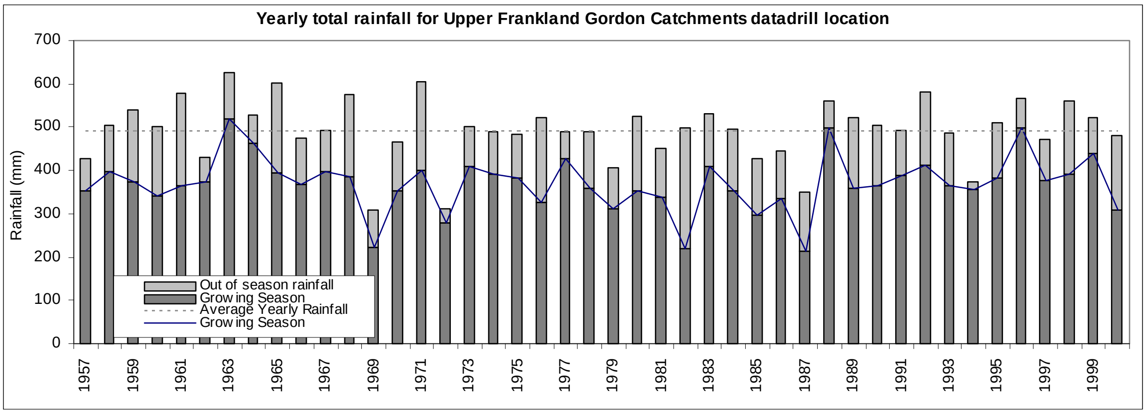
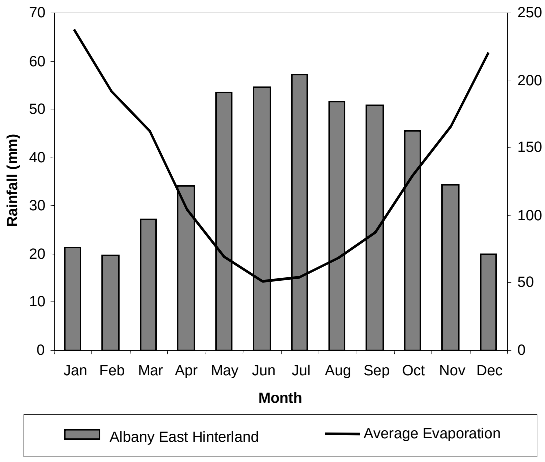


Figure 2. Annual rainfall showing proportion in growing season.

Temperature

The mean maximum temperature in January is 30°C. There are occasional heat waves (mostly in February), during which the maximum temperature exceeds 40°C (Figure 3). The mean daily temperature in July is 9.8°C with average maximums of 17°C. For about 13 days each year the minimum temperature drops below 2.0°C, presenting a high frost risk to crops.



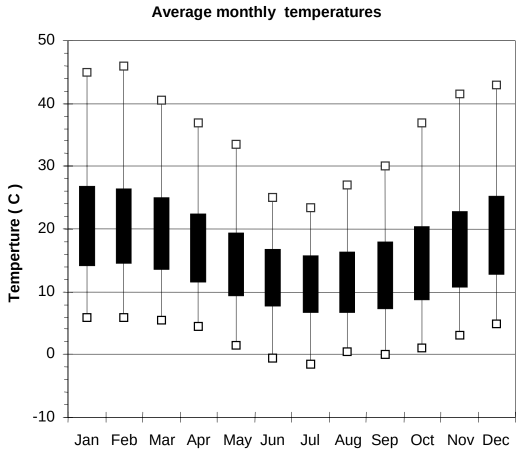
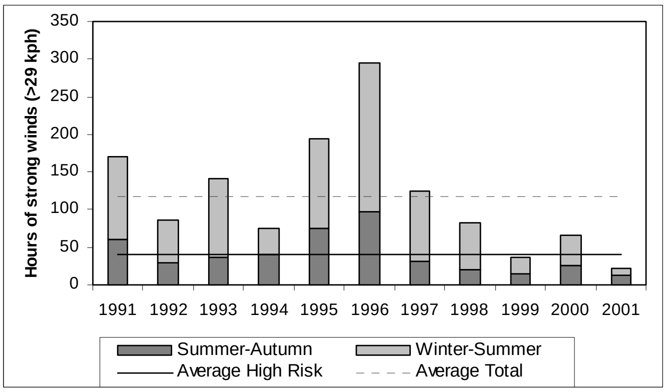


Figure 3 Average monthly rainfall and evaporation (left), and average monthly temperatures for Frankland-Gordon (right). The graph of temperatures shows the highest recorded temperature for the month, the average maximum daily temperature, the average minimum daily temperature and the lowest recorded temperature for the month (since 1957).

Wind

The hours of strong winds (greater than 29 kph) for the 10 years 1991–2001, recorded by the department's climate station situated in Mt Barker (Figure 4 left) have been below average. The predominant direction of strong winds in the region is west-northwest (Figure 4 right).



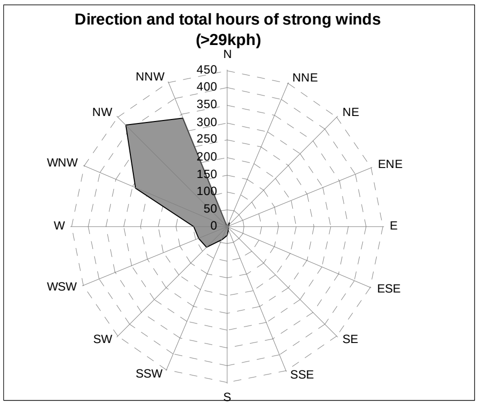


Figure 4. Wind data from recording stations in the region, Department of Agriculture, Western Australia.

2.2 Geology

Ruhi Ferdowsian, Albany

Geological and hydrological history

The area lies within the southern margin of the Yilgarn Craton, and is covered almost entirely by the geological unit referred to by Cope (1975) as the Ravensthorpe Ramp. The Ravensthorpe Ramp's northern boundaries are approximately 350 m above sea level, while the Gordon River forms its southern boundary and is the lowest part of the study area (210 m above sea level).

The Ravensthorpe Ramp comprises benches, separated by ridges that run in an east-west direction. The main drainage lines in these benches had eastern to western flow directions and were surrounded by large areas of ancillary swampy flats. The Lower Gordon, Upper Kent and Upper Denmark Rivers and their associated swampy flats are remnants of the east to west flowing drainage lines.

Basement rocks

Basement rocks in the study area, are Archaean in age (>2500 million years old). These rocks are generally igneous and metamorphic. The area also has numerous dolerite dykes that have a south-east to north-west direction.

Numerous shear zones and faults occur in the Archaean rocks. These features have dictated the position of the creeks and affect surface and groundwater flows in the Frankland-Gordon area.

Regolith

In hilly areas, the regolith is shallow to moderately shallow (<20 m) and is mostly composed of in situ weathered material over basement rocks. This weathered profile contains a considerable quantity of salt (up to 2,000 t/ha) and consists of sandy clay that changes to gritty sandy clay. A thin layer of coarser material usually exists just above bedrock, through which most of the groundwater flows.

Regolith in the south and east is moderately deep (10 to 30 m). In most of this area, the basement rocks or the in-situ weathered profiles are covered by sediments of Tertiary age (Pallinup Siltstone), which is overlain by Quaternary alluvium.

The hydrology of lower areas is strongly influenced by the broad and often stagnant flats that are found mostly around the main drainage channels and rivers. The regolith in these flats consists mainly of a heavy clay profile that hinders the movement of groundwater due to low hydraulic conductivity.

2.3 Soil-landscape Information

Angela Stuart-Street, Katanning

The area lies largely within the Avon soil-landscape province, and occurs mainly as part of the Southern Zone of Rejuvenated Drainage. On the western boundary, a small area of the area falls within the Warren Denmark Southland Zone. A small area on the eastern boundary falls within the Stirling soil-landscape province, as part of the Stirling Range Zone.

2.3.1 Soil-landscape units

Seven soil landscape systems have been identified within the appraisal area (Stuart-Street, 2004). The Farrar (48 per cent) and Carrolup (36 per cent) are the main soil-landscape systems. The Farrar system, occurs mainly in the western and central regions, consists of undulating terrain with rock outcrops and narrow drainage lines. The Carrolup system appears as a more subdued landscape of gently undulating rises and low hills with narrow alluvial plains to the immediate east of the Farrar system.

The broad alluvial plain at the southern and eastern boundaries is described by the Gordon Flats soil-landscape system. These are extensive floodplains of the Gordon River and its tributaries and cover about 9 per cent of the study area. The remaining soil-landscape systems include the gravelly undulating terrain of the Frankland Hills system, the granitic rises of the Jaffa system, the salt lakes and alluvial plains of the internally drained North Stirling system, and gravelly rises of the Jingalup system. These remaining systems make up just 8 per cent of the area. See Appendix 1.1 for the soil-landscape map of the Frankland-Gordon appraisal area and Appendix 3 for the associated AGMAPS CD-ROM.

2.3.2 Soil groups

The main soil groups (Schoknecht 2002) are grey deep sandy duplex soils, duplex sandy gravels, shallow duplex and deep sandy gravels (Table 1).

Table 1. Soil groups

Soil group	Area (ha)	% Area
Grey deep sandy duplex	54,790	34
Duplex sandy gravel	19,580	12
Grey shallow sandy duplex	14,030	9
Deep sandy gravel	7,400	5
Saline wet soil (varying textures)	6,270	4
Brown deep sand	6,140	4
Red shallow loamy duplex	5,800	4
Bare rock	5,030	3
Loamy gravel	4,740	3

2.3.3 Land management units

The land management unit areas presented in Table 2 are derived from occurrences of WA soil groups across the zone (see Section 2.3.2). The remaining information is taken from farm planning workshops and focus catchment work undertaken by the Department of Agriculture and Frankland-Gordon farmers within the Frankland-Gordon study area from 1990 to 2000.

Table 2. Land management units

Land management unit	Approx. area (ha)	Landscape position	Associated vegetation	Main soils and landscape position
Moderately drained sandy duplex	60,600	Crests, upper and lower slopes	Wandoo (white gum); marri (red gum); York gum	Well drained sand or sandy loam over clay at 10-60 cm; seasonally perched watertables common
Gravel ridges and slopes	35,600	Hillcrests and upper slopes,	Jarrah; marri (red gum); wandoo (white gum)	Ironstone gravel >60% overlying clay or hard ironstone at varying depths; usually >30 cm and often >60 cm
Red/ red-brown soils	16,300	Upper to lower slopes (often associated with dolerite dykes)	Jam; wandoo (white gum); Flooded gum; marri (red gum)	Reddish brown sandy loams over clay or grading to clay at 10-20 cm (red loams); red or reddish brown clay loam over red clay at <10 cm or grading to red clay at depth (red clay)
Poorly drained sandy duplex	15,900	Lower slopes, drainage lines and broad valley floors	Flooded gum; flat topped yate; York gum	Sand or sandy loam over clay at 10-60 cm; clay may be blue/grey in colour or very mottled, very wet in winter months
Salt-affected land	6.300	Valley floors, drainage lines and saline seeps on hillslopes	Salt tolerant vegetation - samphire; barley grass	Various soil types
Grey/greyish brown soils	6,200	Lower slopes or valley floors	Flat topped yate, flooded gum	Hard setting grey clay loam and clay including cracking clays and crabhole clays
Pale deep sands	6,100	Crests and slopes	Christmas tree	Pale grey or white sands deeper than 80 cm
Rock outcrops	5,000	Outcrops of granite, dolerite, quartz and hard ironstone	Wandoo (white gum); York gum	Includes outcrops of granite; dolerite quartz and hard ironstone
Yellow & brown deep sands	3,900	Valley floors, often as low dunes and on slopes	Banksia; Christmas tree; paper barks; sheoak	Yellow or brown sands deeper than 80 cm
Mallet Hills	3,450	Breakaways or upper slopes and ridges	Blue and brown mallet	Pink or reddish water repellent soils, maybe gravelly, often acidic
Wet Soil	2,900	Swamps, lakes, non-saline hillside seeps	Flooded gum; flat topped yate; York gum, swamp sheoak	Various soils which are waterlogged from 30 to 80 cm or less for a major part of the year
Salt Lakes	30	Salt lakes	Swamp sheoak, Melaleuca thickets	Variable soils & seasonally waterlogged salt lakes.

A stylised cross section diagram showing the typical positions within the landscape that each land management unit will be situated can be observed in Appendix 2.

2.4 Hydrolgeology

Ruhi Ferdowsian, Albany

2.4.1 Groundwater & aquifers

In the Upper Slab Hut sub catchment a salt storage of 2038 t/ha was measured where the regolith was 30 m deep (Ferdowsian and Ryder 1999). In this profile salt concentration exceeded 15 Kg/ m3 in the sandy clay but was as low as 2 Kg/m3 in the coarse clayey sand beneath that. In the same catchment, 50% of the profiles have less than 500 t/ha salt storage. These relatively low salt storages are because of the thin regolith and high hydraulic gradients in dissected areas of Frankland-Gordon catchment that help leach the salt out of the landscape.

2.4.2 Groundwater & aquifers

Aquifers in hilly areas

Aquifers in the hilly areas have local scale flow systems. This means that the top and bottom of the flow systems are no more than a few kilometres apart. In local flow systems, the hydraulic head surfaces (in most cases it is the same as groundwater levels) conform to local topography, and recharge areas are close to and up-slope of the discharge sites. In these areas every hillside has a local scale aquifer and their boundaries coincide with, or are close to, the ridge tops.

Depth to bedrock in these dissected areas is mostly less than 20 m, so aquifers are generally thin and shallow. Most of the profile would be low yielding because of the clay type in the regolith (i.e. often, kaolinitic white clays). However, a thin layer of coarser material (saprock) usually exists just above bedrock, which often acts as a conduit for groundwater.

It is likely that prior to land clearing there would have been no aquifer or saturated zone on the upper slope areas. After clearing, recharge increased and the saprock could not contain the excess groundwater flow. Consequently the levels of groundwater rose and the clayey soils above the saprock became saturated. Saturation of the clayey layers (high salt storage) caused groundwater salinity to increase.

Problems with salinity and rising groundwater in local scale flow systems are likely to be due to local recharge within the boundaries of the local scale flow systems. Therefore, management practices outside the influence of these areas will have little or no effect on the extent of their salinity. However, the management of land with a local aquifer will affect others downstream. Salinity in these areas is in three forms: (i) creek lines, (ii) valley floors and (iii) occasional hillside seeps.

Well-defined and narrow creek lines will become salt-affected because they become discharge sites as well as the carriers of saline baseflow.

Hillside seeps occur in the lower parts of dissected landforms where basement rock highs or dolerite dykes obstruct the saline groundwater and bring it close to the soil surface.

Data to 2004 indicates that there is a seasonally fluctuating watertable that is very close to the surface in low-lying areas and where there is particularly shallow bedrock obstructing flow on the hillsides.

Bores in the hilly areas of the Frankland-Gordon appraisal area have salinity levels ranging from 200 mS/m (probably in a shallow perched system), to 3000 mS/m, which is very saline (half of seawater salinity). The salt content is due to:

- Salt accumulation in the soil profile (predominantly from rainfall) over thousands of years.

- Clearing of remnant vegetation and excessive recharge under cropping and annual pastures has caused the rising water levels to mobilise the salt.

Brackish groundwater (between 300 and 700 mS/m) may be found in the upper hillsides in some of the dissected areas such as the Upper Slab Hut and the Ryans Brook sub catchments.

Aquifers in the stagnant flats

The aquifers under the stagnant flats are very large (10 to 30 km) and extend to neighboring areas. They are intermediate or regional scale flow systems with numerous saline depressions intercepting and forming windows to the groundwater. The hydraulic gradient is very low and consequently the groundwater is stagnant.

Prior to clearing, there was a permanent and hyper-saline aquifer with its levels within 2 to 4 m from the soil surface. After clearing the levels have come even closer to the land surface and in most valley floors and flats are within capillary range. Evaporation in dry periods will cause groundwater to rise to the soil surface through capillary forces.

The depressions on the stagnant flats have become discharge sites due to rising groundwater levels. As groundwater discharges into the depressions and evaporates, these areas become bare depressions in summer and stagnant sumps in winter. This function maintains groundwater flow towards the soil surface. The eastern portion of the area has broad open depressions that become poorly defined watercourses in wet periods. Low gradients and the existence of closed depressions cause ponding of surface run-off for extended periods, hindering pasture growth.

Depth to bedrock in the stagnant flats could be greater than 40 m, so the aquifer is assumed to be reasonably thick. Most of the deep regolith profile would be high yielding because of coarser material (i.e. usually Werillup formation).

Lack of lateral groundwater flow in this stagnant regional aquifer makes salinity and rising groundwater significant on-site issues. Because of the low hydraulic gradient, the management practices on each farm can influence the extent of salinity on that property. Salinity in these areas is in the form of salt scalds and depressions on the flats. As groundwater levels rise, the number and the extent of the salt-affected areas will increase. The combination of salinity and excessive waterlogging will affect considerable areas and eventually much of flat and low-lying areas of the paddocks will become unworkable and have low productivity.

Aquifers in broad flats

Broad flats exist in the transitional zone between the dissected areas and the stagnant flats. Aquifers in the broad flats have intermediate scale flow systems. The aquifers in these areas extend greater than 10 km and discharge sites may be affected by recharge along the hillsides up to 3 km away. Depth to bedrock in these areas could be between 20 m and 40 m. The regolith may be partly alluvial and partly Tertiary in origin and has a high clay content, although a thin layer of coarser material might exist just above bedrock. Lenses of coarse material may also be imbedded in the alluvial depositions.

Salinity in these areas is in the form of saline patches in flats and broad valley floors, which have become permanent discharge areas. The flats have become target areas for deep drain construction in recent years. Performance of these drains is dependent on the presence or absence of coarse material within the drain profile.

Prior to clearing there would have been an aquifer or saturated zone in these broad flat areas. Groundwater levels were below the root zone of the natural vegetation. After clearing and as levels rose, the remaining natural vegetation started to die and the floors are gradually changing to bare, salt-affected ground.

Bores in the broad flat areas of the catchment have high salinities (>2000 mS/m). The high groundwater salinity as well as excessive waterlogging has become increasingly detrimental to the health of these flats and a hindrance to land use.

2.4.2 Waterways and wetlands

State of the waterways in the Upper Frankland-Gordon catchment

Department of Environment, Albany

The Upper Frankland, the Upper Gordon and other waterways in the Frankland-Gordon area show signs of degradation due to stock access, salinity, waterlogging and weed invasion. Catchment changes including rising groundwater levels, increasing salinity and nutrient levels draining from the appraisal area are impacting on the health of the waterways in the sub catchments, the river and the Nornalup Inlet. There are weeds proliferating along the upper Gordon River and the river receives increasing volumes of water coming off cleared catchments, resulting in unstable banks, erosion and sedimentation of pools.

A survey of the Gordon River (above the Frankland River) recorded foreshore vegetation condition, habitat values, pool locations and condition, channel stability and sedimentation. The river was graded into four categories; pristine, intact vegetation to slightly disturbed, degraded vegetation and erosion prone, and eroding ditch or weed infested drain (Figure 5).

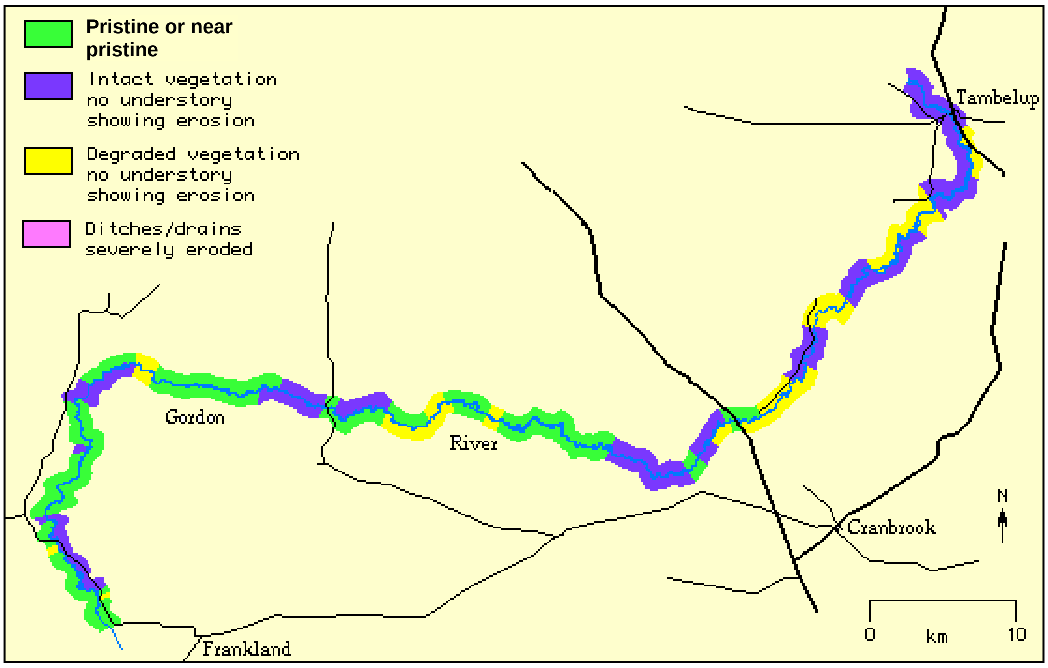


Figure 5. Quality categories for the surveyed portion of the Gordon River.

2.5 Native vegetation

Geoff Woodall, Albany

The vegetation communities are diverse and species composition usually reflects soil type and landscape position. The area was included in Beard's vegetation survey (1979), which mapped the pre clearing vegetation at a regional scale, primarily using physiognomy. About half of the study area lies within the Darling Botanical District (50 per cent Jingalup and 5 per cent Beaufort vegetation systems) and the rest in the Avon Botanical District (Tambellup vegetation system). The Jingalup vegetation system is characterised by forested jarrah and marri hill tops with woodlands of marri and wandoo without jarrah on the slopes. The Tambellup System consists of woodland of wandoo (*E. wandoo*) and yate (*E. occidentalis*), with, small outliers of jarrah (*E. marginata*) on the ironstone-capped hills and to a lesser extent on the sandy pockets along the valley floor where it occurs with river gum (*E. rudis*).

Most (83 per cent) of the original vegetation has been cleared for agriculture and that which remains is highly fragmented (c.f. Appendix 1.2) and often degraded.

2.6 Land use and agricultural production

Kelly Hill, Cranbrook

Farming systems are predominantly annual crops in rotation with annual pastures, with an average annual ratio of 60:40 (crops: pasture). Since the late 1990's, perennial pastures (lucerne, tall wheat grass), saltland pastures (saltbush) and some warm season crops (sorghum, feed millet) have become more prominent in the area and are being incorporated into the rotations. Even though the rainfall varies, grain, sheep and wool make up the majority of the farm income. Some landholders, particularly in the higher rainfall zone, have established sawlogs (*Eucalyptus* species for furniture production), pines, blue gums and sandalwood.

The main crops are wheat, barley, canola and oats, with lupins and minor field peas (and some triticale although not common). The typical rotation is a four to six year cropping phase, followed by a two to four year pasture phase (e.g. canola: wheat: barley: lupins: wheat: pasture: pasture). In some cases there is rotation of one-year crop followed by one year of pasture, for the purpose of weed control. In most cases wheat or barley is sown following a canola crop, for yield advantages. The conventional ley farming with annual pasture and cereal has been largely replaced.

Table 3. Yield range of common crops in an average year

Wheat	**Barley**	**Canola**	**Lupins**	**Oats**
2-4 t/ha	2-4 t/ha	1-2 t/ha	0.5-1.5 t/ha	2-4 t/ha

There has been a strong move towards minimum tillage and no tillage cropping in the past five years to reduce soil erosion, improve soil structure and to ameliorate acidic soils. Most landholders have an annual plan for applying lime and potash in response to soil deficiencies.

There is a current trend of increasing sheep numbers for fine wool production and prime lambs, after many landholders had to de-stock during recent dry years. Many landholders have done some form of pasture manipulation to maximise their clover production. Few landholders have a particular grazing strategy (some still set stock), however those who do use cell grazing or a mixture of both.

Land managers believe the main problems are soil acidity, non-wetting soils, waterlogging (in prone areas), salinity, water erosion and, for some, herbicide weed resistance and worm resistance.

Interest has increased in perennial pasture production, with considerable areas being sown to lucerne and tall wheat grass, generally on a small ‘trial’ basis. It is becoming accepted that lucerne can be an important contribution to grazing strategies and cropping systems with the added benefits of reducing recharge, increased soil nitrogen and the ability to manage the problem of herbicide resistance. There is also a growing interest in perennial grasses, particularly natives and medicinal perennials. In recent years, some landholders have established summer crops (sorghum, feed millet) but with limited success because of the dry summers.

Other systems

Intensive and alternative farming systems being explored on a small scale include:

- raised beds in waterlogged areas
- aquaculture - marron, yabbies, saltwater trout and perch.
- flower production
- organic farming methods

- agroforestry, including blue gums, oil mallees, tea trees, sandalwood, acacia species, pines and other Eucalypt species
- perennial horticulture in the form of viticulture, berries and olives
- other livestock including chickens, pigs, alpacas, emus, deer and apiculture.

Future aims

Future aims of the landholders in the area include:

- improving pastures to increase production (particularly increasing the area sown to perennials)
- increasing the diversity of their farms, planning for drought, decreasing the use of chemicals
- increasing soil health
- a few people are looking to decrease their cropping programs and increase their sheep numbers
- improved land use sequencing (research and development priority).

Farm performance

Lucy Anderton, Albany

BankWest benchmarks show that farms in the Great Southern Agricultural region are, (in comparison to other BankWest analysed regions), the smallest in Western Australia (Table 4) and carry the highest debt per effective hectare. However the value of assets and equity levels is high, reflecting the high value of land. Debt to income ratios is 13 per cent higher for the Great Southern compared to the State average. For every dollar of debt, 95 cents of gross farm income is generated compared to 84 cents for Western Australia. Therefore on average, farms in the Great Southern Agricultural region can generate more income per hectare.

There is substantial variation in farm performance between the top 25 per cent and the low 25 per cent (Table 5). These data are only from a small sample of BankWest clients, but give some indication of the variation between farms. Also note that the Frankland-Gordon appraisal area only covers about 40 per cent of the Kojonup shire.

Table 4. BankWest benchmarks 1997 to 2000/2001

Capital Analysis	**Great Southern** **4-year Average 1997 to 2000**	**Western Australia** **4-year Average 1997 to 2000**	**Kojonup shire** **4-year Average 1997 to 2000**
Effective Area (Ha)	1,645	2,653	1,304
Assets ($/Eff Ha)	1,514	1,089	1,707
Debt ($/Eff Ha)	215	162	245
Long Term Debt ($/Eff Ha)	151	104	213
Equity (%)	86	84	85
Long-term debt to Income (%)	60	48	
Return to Capital	0.8	0.1	2.8
Machinery Value ($/Eff Ha)	211	193	144
Operating Analysis			
Farm Income ($/Eff Ha)	226	193	223
Operating Costs ($/Eff Ha)	155	136	142
Operating Cost/Farm Income (%)	70	74	65
Grain % of Farm Income	45	68	25
Sheep and Wool % of Farm Income	38	20	61
Crop Production			
Crop % of Effective Area (%)	47	60	25
Machinery Value ($/crop ha)	414	360	706
Sheep Production			
Total Sheep Income ($/Winter grazed Ha)	159	116	166
Sheep Costs ($/Winter Grazed ha)	105	N/A	82
Wool Price ($/Kg)	3.59	3.38	2.9
Average Sheep Sale Price ($/Hd)	23	24	22

Table 5. Retained profit for Kojonup shire 1997 to 2000 (BankWest benchmarks, 2001).

Retained Profit/ha	**1997/98**	**1998/99**	**1999/00**	**2000/01**
Top 25%	$67.00	$59.00	$69.00	$63.00
Other 75%	-$9.00	$10.00	$11.00	$37.00
Low 25%	-$38.00	-$30.00	-$28.00	$28.00

2.7 Infrastructure

Tim Overheu, Albany

Major infrastructure includes the town of Tambellup (with a zoned area of approximately 507 ha within the appraisal area). The impact of salinity on the zoned area is shown in Table 6. Other infrastructure includes the townsite of Tunney, several road bridges that cross the Upper Gordon River and associated tributaries as well as a 37.5 km section of the Albany Highway.

Table 6. Current impact from salinity on towns

Town	Total zoned area	Area of impact (2000)	% of zoned area
Tambellup	507 ha	44.5 ha	8.8

The area has over 200 km of gazetted roads, the majority of which are unsealed roads or tracks. Salinity affects 37.5 km of the Albany Highway and 24 km of local sealed or gravel roads.

2.8 Demographics

Demographics relevant to the area are in Table 7.

Table 7. Demographics of the Frankland-Gordon area (ABS, 1996 & 2001)

Demographics	Kojonup		Broomehill		Tambellup		Cranbrook	
Total Population								
1996	2,214		470		701		1,121	
2001	2,145		451		673		1,049	
% change	-3.1%		-4.0%		-4.0%		-6.4%	
Employment (1996)								
Farmers & Farm Managers	411 people		123 people		163 people		261 people	
As a % of the Shire's population	19%		26%		23%		23%	
Age of Farmers (1996)	No. of people	%	No. of people	%	No. of people	%	No. of people	%
15-24 yrs old	11	3	7	6	4	2	9	3
25-34 yrs old	77	19	25	20	34	21	53	20
35-44 yrs old	119	29	36	29	42	26	67	26
45-54 yrs old	108	26	31	25	31	19	69	27
55-64 yrs old	63	15	14	11	36	22	35	13
65 and over	33	8	10	9	16	10	28	11
Education of Farmers (1996)								
Degree	29		6		3		12	

Demographics	Kojonup	Broomehill	Tambellup	Cranbrook
Diploma	34	15	7	19
Vocational	19	7	6	23
Not Applicable	328	90	146	204
Computer Use (2001)				
At home	38%	41%	37%	33%
Internet use	28%	31%	29%	23%

The following is a summary of the information provided in Table 7 in combination with data from the National Land and Water Resources Audit (NLWRA, 2002).

Age

The median age of farmers is 43 (in the statistical period from 1996-2001) and increasing. It is also noted that there has been a significant decrease in population of the ages between 15 and 25.

Farm financial characteristics

The median farm family income is $35,000.

Off-farm income for the area ranged from $8,000 to $16,000 per farm.

Average farm debt for the 3 years 1996-1999 ranged from $225,000 to $300,000.

Farm structure/ family characteristics

Average farm size is less than 2,000 hectares.

Less than half of the families have dependent children.

In 1996, almost half of farmers in the area had a documented farm plan or property management plan.

Land valuation

The trend in land values are shown in Figure 6. Downturns are related to a number of events including high debt levels and interest rates, and fluctuating wool values.

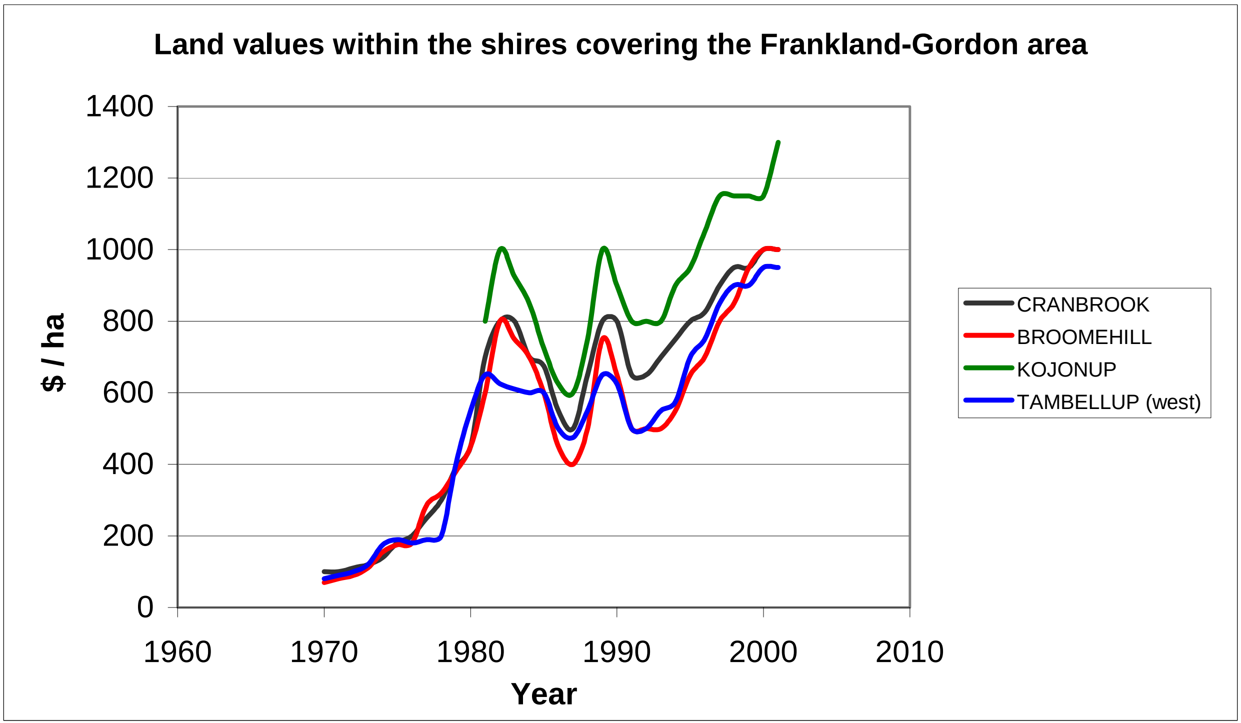


Figure 6. Land valuations (Gusto 2001; WA valuer generals' office)

Further information can be found in:

- Australian Bureau of Statistics (ABS) - http://www.abs.gov.au
- National Land and Water Resources Audit (NLWRA 2001) – http://www.nlwra.gov.au

3. Catchment condition and future risk

3.1 Climate change

Tim Overheu, Albany

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

Some projections for the southern region of Western Australia (Foster 2002 and Ferdowsian 2002) are:

- land surface temperatures will increase by about 2 to 5 degrees by 2030
- seasonal rainfall will decrease by at least 10-30% for winter-spring by 2030
- occurrence of sporadic summer storms will increase.

These changes would have the following impacts:

- cropping area may increase, however more variable summer rainfall could also increase the risk of wet harvests
- waterlogging could be reduced, but yields could also be reduced
- a need for improved surface catchments to improve water use efficiency
- reduced recharge and lower risk of salinity
- biodiversity change with species loss or migration.

3.2 Soil degradation risks

Salinity has visually disturbing consequences and, therefore, attracts more attention than the ’invisible’ forms of land degradation such as soil acidity, water repellence and soil acidification. These less obvious forms affect far larger areas than salt in this region (Table 8 and 9).

Table 8. Summary of degradation hazards

Water repellence 120,160 ha (74%) at risk	Pale deep sand, yellow and brown deep sand and poorly drained sandy duplex land management units are susceptible to water repellence.
Soil acidity 108,795 ha (67%) at moderate to high risk	This land quality is only a general indicator because management, productivity and crop rotation all affect the rate of subsurface acidification, which refers to acidification below the depth of normal cultivation (10-20 cm). Risk factors are sandy, highly leached soils with low organic carbon content that have little resistance (or buffering capacity) to pH change. Soil groups most at risk are the sandy duplex soils and pale deep sands.
Soil compaction 102,300 ha (63%) at moderate to high risk	Soils with a wide range of particle size, low organic matter and no secondary structure are particularly at risk Risk factors are sandy duplex units and yellow and brown deep sands.
Wind erosion 74,695 ha (46%) at moderate to high risk	Wind erosion is largely a function of wind speed and duration, soil erodibility, ground cover, aspect, soil moisture and nutrient availability. Strong winds are common in the area, causing erosion, particularly in dry years. Most susceptible are the sandy duplex soils and pale deep sands and yellow and brown sands, particularly on exposed crests and upper slopes.
Water erosion 45,465 ha (28%) at moderate to extreme risk	Water erosion involves complex processes of run-off and soil detachment and is influenced by rainfall erosivity, soil erodibility, slope angle, management practises and the amount and type of groundcover.
Waterlogging 32,475 ha (20%) moderate to very high at risk	Risk factors include soils with poor permeability subsoils that develop perched watertables during the winter growing season. Another risk factor is the sensitivity of many crops to waterlogging. Waterlogging events during the growing season can cause a large loss of production. Soils most at risk are poorly drained sandy duplex and grey / greyish brown loams and clays (particularly on lower slopes), wet soils and salt affected lands.

Table 9. Assessment of land degradation hazards[1] for land management units in the Frankland-Gordon area

Land management unit	Approx area (ha)	Salinity risk	Waterlogging /inundation risk	Susceptibility to water erosion	Susceptibility to wind erosion	Susceptibility to subsurface (10-20 cm) acidification	Susceptibility to water repellence	Susceptibility to topsoil structure decline	Susceptibility to subsurface compaction (10-30 cm)
Moderately drained sandy duplex	60,600	Low risk*	Low	Moderate	Moderate to High **	High	Moderate	Low	Moderate
Gravelly ridges and slopes	35,600	No risk	Nil	Moderate	Low	Moderate	Moderate	Low	Low
Red/ red-brown soils	16,300	Low risk*	Low	Moderate	Low	Low	Low	Moderate	Low
Poorly drained sandy duplex	15,900	High	Mod to High for lower slopes	Mod to low on valley flats	Low	High	Moderate	Low	Moderate
Salt-affected land	6,300	Presently saline	Very high	High	Low	Variable ***	Low	Not rated	Not rated
Grey/greyish brown loams and clays	6,200	Low risk	Mod to high on valley flats	Moderate (on slopes)	Generally low	Low	Low	Moderate to High	Low to Moderate
Pale deep sand	6,100	No risk	Nil	Moderate	High	High	High	Low	Low to Moderate
Rock outcrops	5,000	Variable	Nil	Low	Low	Low	Low	Low	Not rated
Yellow and brown deep sands	3,900	Moderate	Very Low	Moderate	Moderate to High**	Moderate to High	High	Low	Low to Moderate
Mallet hills	3,450	No risk****	Nil	High	Low	Presently acid	High	High	Low
Wet soils	3,000	High	Not rated	Low	Low to moderate	Moderate to High	Not rated	Low	Low
Salt lakes	30	Presently Saline	Not rated	Low	Low	Not rated	Not rated	Not rated	Not rated

* Low risk, salinity likely to develop as hillside seeps on the units where shallow bedrock forces saline groundwater close to the surface

** Highly susceptible to wind erosion on crests and upper slopes

*** Soil pH on saline soils is highly variable but they may not be economic to lime

**** Many Mallet Hills have acid clay subsoils that are often saline.

1 Risk assessments based on guidelines in Van Gool, Tille and Moore, 2000.

3.3 Hydrological Risk

3.3.1 Groundwater

Ruhi Ferdowsian, Albany

Potential salinity risk

The number of monitoring bores in the Frankland-Gordon catchment area is limited and the monitoring of the few bores that do exist has been sporadic. However, a strong network of bores with long-term monitoring data exists in adjacent catchments (e.g. Peter Valley). It is assumed that groundwater level changes observed in the adjacent catchments will also occur in the study area.

From limited bore data for the Frankland-Gordon catchment, aquifers in hillside slopes generally show a rising trend. The average rising trend is 0.14 m/year. Figure 7 illustrates a typical hydrograph for the area and shows 0.13 m/year rise in groundwater levels.

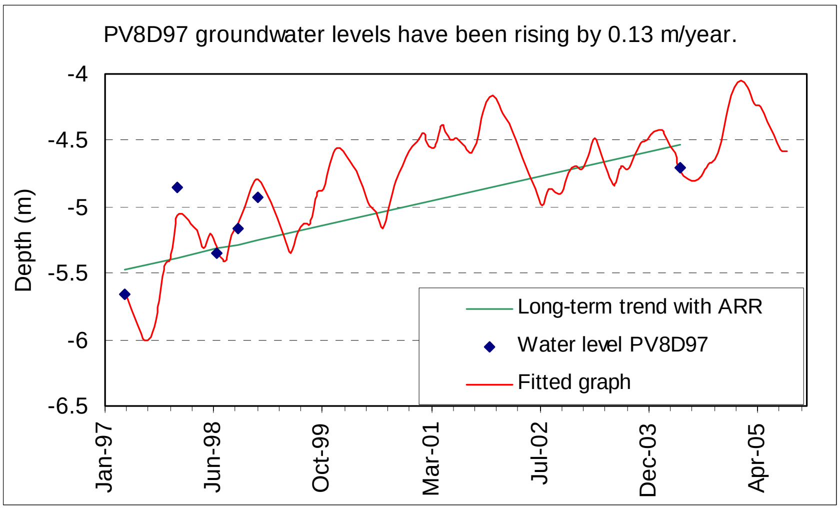


Figure 7: A typical hydrograph in the area showing steady rise in groundwater levels.

Flowtube analysis (a groundwater flow path model presenting possible long-term trends in groundwater levels) was used to simulate groundwater level changes in the area.

Surface topography was taken from 2m contours of the area generated by the Department of Land Administration (2000). Initial groundwater levels for the model were taken from bores in Upper Slab Hut and Ryans Brook sub catchments. A representative drilling log for one of the bores in the Upper Slab Hut sub catchment can be observed in Appendix 4.

Scenarios

Possible groundwater changes are illustrated for three landscape types (Figures 8, 9 and 10).

All scenarios show that groundwater levels under the hillside will continue to rise unless changes are made in managing recharge and surface water. Based on these scenarios some parts of the landscape may develop shallow (less than 1.5 m) groundwater and be at risk of salinity.

Figure 8 shows the influence of a basement rock high and how it forces up groundwater levels in the initial years, causing hillside seeps.

Figure 9 illustrates changes in groundwater levels, where the basement rock is deep.

Figure 10 shows what may happen if a 1.5 m deep drain is constructed in the valley floor of the same landscape. The deep drain is likely to lower groundwater levels slightly and its effects may be observed as far as 50 m away from the drain. Concurrently, the other parts of the landscape are facing groundwater level rises. The effectiveness of the drain in this scenario is because of the high hydraulic gradient and conductivity assumptions inserted in the Flowtube estimation. The 50 m distance may not be achieved, where hydraulic gradient and conductivity are very low.

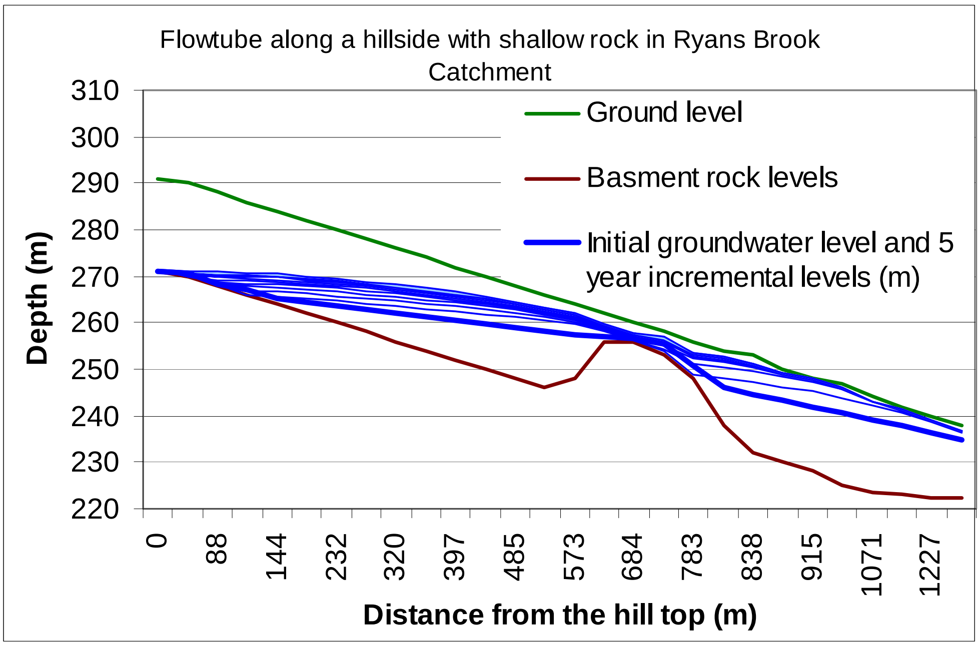


Figure 8. Expected groundwater rises over 50 years in a flow path typical of the Ryans Brook area. The shallow basement rock in this landscape elevates groundwater levels.

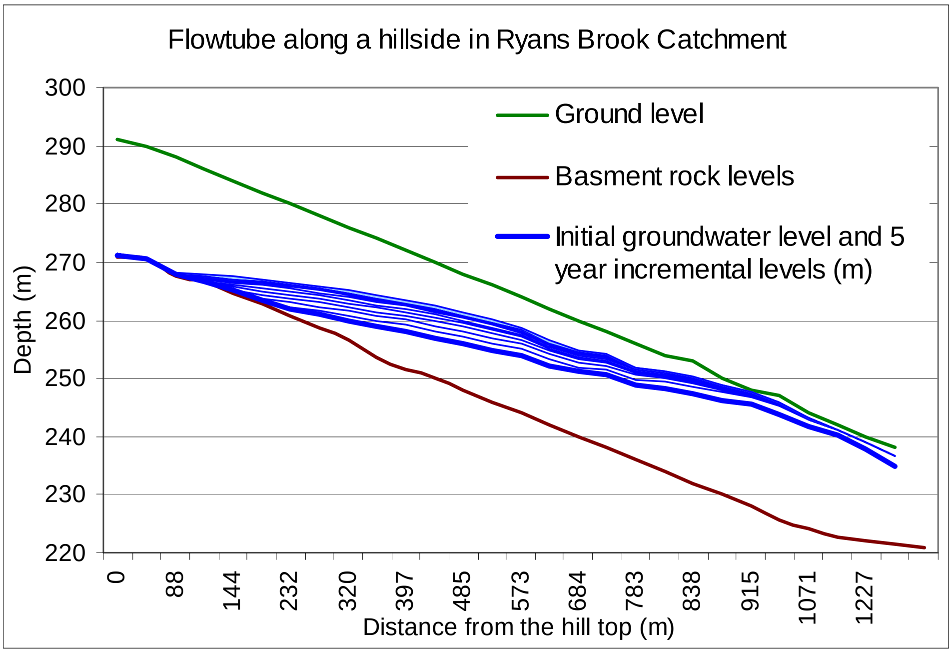


Figure 9. Possible groundwater rises over 50 years in a flow path typical of the Ryans Brook area. It is assumed that this cross-section does not have basement rock highs.

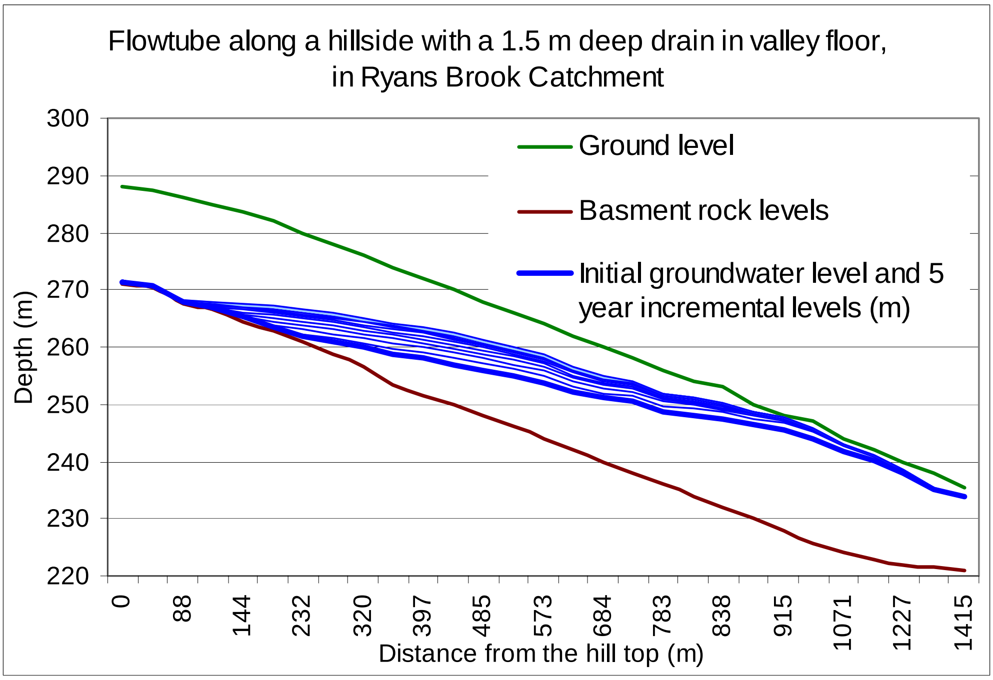


Figure 10. Possible groundwater rises over 50 years in a flow path typical of the Ryans Brook area. In this scenario construction of a 1.5 m deep drain has slightly lowered groundwater levels near the deep drain.

Areas at risk of salinity

In the scenarios modelled above, the flow path suggests that equilibrium is reached in 50 years (when extra recharge is matched by increased discharge to streams and evaporation). Potential salinity could be approximately where groundwater is less than 1.5 m from the soil surface and where capillary forces could bring groundwater to the soil surface. When the groundwater reaches equilibrium, the valley floor, footslopes and some parts of the lower slopes may also become salt-affected. The extent of increase in salinity is dependant on the recharge control measures strategically placed in the catchment.

3.3.2 Surface water

There are four gauging stations located within and adjacent to area, on the Frankland Gordon River, three of which are still in operation. Comprehensive information associated with these gauging stations can be accessed from the Department of Environment's Information Centre or via an online search in the following websites:

- http://www.wrc.wa.gov.au/waterinf/wrdata/FLOW/602008/602008.htm
- http://www.wrc.wa.gov.au/waterinf/wrdata/FLOW/605013/605013.htm
- http://www.wrc.wa.gov.au/waterinf/wrdata/FLOW/614060/ssm.htm
- http://www.wrc.wa.gov.au/waterinf/wrdata/FLOW/6071125/ssm.htm

3.4 Vegetation condition and risk

Geoff Woodall, Albany

Vegetation at risk of salinity and waterlogging

Altered hydrology and salinity is one of the greatest threats to remnant vegetation and its constituent plants, animals, microbes and ecological processes.

In 1990 about three per cent of the catchment's remnant vegetation was affected by salinity and by 2000, salinity affected a further three per cent. It is estimated that an additional eight per cent has the potential to become affected (14 per cent total). At most immediate risk are those areas that occur in the lowest landscape positions, which, in the study area are the medium woodlands of yate and wandoo and the low paperbark woodlands (Melaleuca species). Several plant species of high conservation priority occur in the area that Beard (1979) mapped as being woodlands of yate and wandoo. These systems are not only at risk from saline discharge but also from the increased salinity of overland flows and altered hydro period. (Cramer and Hobbs 2002).

Some woodlands of yate and wandoo that have been salt affected have been replaced by thickets of *Melaleuca cuticularis*. An example of this is just north of the Tambellup town site where, *M. cuticularis* is now the dominant species, but prior to altered hydro period/ salinity it was a minor species.

Other risks to the remaining native vegetation include grazing, weed invasion, altered nutrient and soil input, altered fire regimes, pests and diseases, and feral animals.

Some privately owned remnant vegetation is still used for grazing and this will severely jeopardise the long-term survival of remnants (ie. passive clearing). Although overt clearing of native vegetation has essentially ceased, passive clearing continues. Fencing has excluded livestock from some remnants, but further vegetation loss will occur in areas that are not fenced off.

3.5 Agricultural production

Over recent years there has been an increase in return from cropping and horticulture and a decline in sheep and wool production. Agriculture continues to be an expanding industry in the region and its production includes; wheat, barley, beef, sheep, wool, canola, timber, oats, legumes, timber plantations, vineyards, olive groves, minor horticulture and aquaculture (GSDC 2001).

3.5.1 Agricultural production and groundwater management

Arjen Ryder, Albany

Estimating recharge through the AgET model

AgET is a model that provides an estimate of recharge based on soil, rainfall and plant species (Table 10). The output of the model (Table 11) was based on a typical 1300 ha farm from the Frankland-Gordon area.

Table 10. Proportion of farming system landuse used in the model (i.e. comparison of an annual based system against a perennial based system).

Landuse	Annual system (ha)	Perennial system (ha)
Annual pasture	679 (53%)	432 (33%)
Crop	556 (42%)	556 (42%)
Perennials	0	247 (20%)
Remnant bush	65 (5%)	65 (5%)
Total	1300	1300

Impact of increasing the area sown to perennials

Table 11, shows that across a typical farm recharge can be greatly reduced in a perennial based farming system in comparison to the annual system. The integration of perennials into the farming system can include plants such as lucerne, kikuyu, tagasaste or perennial grasses.

Table 11. Results showing estimated recharge obtained from the AgET model. *Calculations were done for annual and perennial farming systems using three different annual rainfall amounts.*

Rainfall (mm)	**Recharge with 42% crop (mm)**	**Recharge with 65% crop (mm)**	**Recharge with 20% of the farm under perennials (mm) and 42% crop**
446 (dry year)	55	50	40
510 (average rainfall)	70	65	50
541 (wet year)	80	75	60

Impact of increasing the area sown to cereals

Increasing the area under crop results in small recharge reductions and in the long term may not provide enough reduction to have any major impact on reducing salinity.

However, a point worth noting is that where strategic perennial plantings are concentrated on high recharge areas (e.g. deep sandy gravels) then recharge would be slighter lower than the figures shown in Table 11. For example, lucerne roots have been found growing down to 3.5 m and dried the soil profile by approximately 200 mm compared with annual pasture. Therefore growing lucerne will reduce recharge and decrease the potential extent of land at risk of becoming saline.

3.6 Infrastructure

Timothy Overheu, Albany

The road transport network includes local gravel roads, sealed bituminised main roads and a section of the Albany Highway. Approximately 116 km of the road network occurs in low-lying areas, making those roads susceptible to waterlogging and possible salinity – if the water tables continue rising.

Other major infrastructure includes the western portion of the town of Tambellup. The potential impact of rising water tables and salt creep on town buildings is well documented in a report by Whitfield (2001) “Groundwater study of the Tambellup townsite” as part of the Rural Towns program.

4. Management options and impacts

4.1 Land management

Timothy Overheu, Albany

Comprehensive information on representative soils for the Frankland-Gordon area (with matching agricultural land management options) is presented in an AGMAPS Land Manager CD-ROM for the area (Overheu 2003). Table 12 below presents a summary of land management options suitable for the area to manage the common natural resource management risks (previously discussed in section 3.2).

Table 12. Options for managing common natural resource risks

Natural resource risk	Management options
Water repellence	• Options include claying (100t/ha), furrow sowing and wetting agents. • The effectiveness of claying depends on using the right type of clay, and the economic benefit depends on finding a suitable source close by. • Regular passes to incorporate the clay may cause soil compaction.
Sub surface acidity	• Dry lime, added at 1 t/ha by surface spreading or, preferably, placed into acid layer at about 10-20cm will improve soil pH and displace aluminium. • Liming will improve crop and pasture production and assist in the establishment of lucerne.
Soil compaction	• Minimum tillage and/or direct drilling on the heavier soils. • Where the topsoil is sodic (i.e. exchangeable sodium percentage is greater than 14 per cent), topdressing with gypsum together with practices to increase the organic carbon content of the soil, such as stubble retention, can improve plant growth. • Green manuring with legumes (pastures or crops such as lentils or peas) may improve organic matter content and soil structure. • Long fallowing in a crop rotation and stubble burning should be avoided.
Wind erosion	• It is critical to maintain ground cover at adequate levels. On soils at risk, practice stubble retention or aim to maintain >50% ground cover. • Minimum tillage and stubble retention, or revegetation with trees (various suitable species available) for shelterbelts or alley farming together with management of summer grazing on risk soils (including de-stocking during dry seasonal conditions).
Waterlogging	• Options are either agronomic (including strategic application of fertiliser to assist crops through waterlogging) or engineering solutions such as surface water management and raised bed cropping. • Agronomic options, such as phase cropping with lucerne will help use excess moisture in the soil profile and reduce recharge. In saline conditions, fence these areas off (where practical), and establish tall wheat grass and other salt tolerant perennial grasses.

Natural resource risk	Management options
	• Engineering options: Grade banks are effective in controlling water erosion and waterlogging where interception of clay is possible.

4.2 Water management

4.2.1 Surface water management

Austin Rogerson, Albany

Surface water engineering options
Where the slope and soil characteristics of the land encourage water to shed off the land (shedding landscape - Farmer, Stanton and Coles, 2002), surface water earthworks can reduce the velocity and volume of the peak flow, avoiding serious soil erosion. Where there is little slope in the land, water flows from a shedding landscape and accumulates in a receiving area causing waterlogging, flooding and adding to groundwater recharge.

Soil landscape and slope analysis

The surface water landscape in the study area is generally water shedding (i.e. approximately 83 per cent has slopes that exceed one per cent).

The landscape for the eastern portion, although characterised by subdued topography and sandplain soils, will still shed water. Slopes in this landscape area are generally less than 5 per cent.

The landscape for the central and western portions is more dissected, dominated by valleys and undulating to rolling terrain where landscape slopes generally exceed 5 per cent. Surface water engineering can minimise soil erosion in these areas.

Tertiary sediments washed into valleys and river channels have created valley floors with low gradients with resultant floodplains, swampy flats and areas of poor drainage adjacent to the Gordon River valley. Prolonged and frequent inundation and increasing salinity has caused widespread vegetation decline in these areas. Examples of these poorly drained areas are Towerlup, Uannup, Slab Hut and Peter Valley. These areas represent about 16 per cent of the appraisal area and have land slopes generally below 1 per cent and consequently are regarded as receiving landscapes.

Despite some deeper sandy soil profiles, the valley floor landscapes can benefit from engineering options such as ‘W’-drains and shallow relief drains that improve water movement and reduce waterlogging.

This section provides only a general guide to the potential for surface water earthworks over six major soil-landscapes within the area. For more accurate and quantified information, site-specific surveys are essential.

Table 13. Approximate area (ha) of agricultural land suitable for surface water earthworks.

Soil-landscape	Slope Class				Total
	0-1%	1-5%	5 -10%	>10%	
Crests, ridges and upper slopes. South Kojunup (Uannup,Cowenup &Towerlup catchments) Common soil type; Grey deep sandy duplexes, duplex sandy and outcrops.	2,380	30,150	15,460	590	**48,580**
Upper slopes adjacent to the Gordon River. Common soil type; Grey sandy duplexes, mainly deep with minor duplex sandy gravels and brown deep sands	3,560	32,770	4,750	30	**41,110**
Mid to lower slopes and foot slopes. South Kojunup (Uannup,Cowenup &Towerlup catchments) Common soil type; Grey deep sandy duplexes, duplex sandy and outcrops.	2,700	20,180	14,610	670	**38,160**
Broad valley floor with low dunes, swampy depressions and low gravelly rises along the Gordon River. Common soils; Grey deep sandy duplex with semi-wet soil, pale deep sand, duplex sandy gravel, saline wet soil and grey shallow sandy duplex	11,200	4,530	520	10	**16,260**
Upper (deep sandy) soils, slopes adjacent to the Gordon River. Common soil type; Grey sandy duplexes, mainly deep with minor duplex sandy gravels and brown deep sands	770	4,620	2,540	100	**8,030**
Narrow valley floors and drainage channels of Uannup, Slab Hut, Peters Valley and drain lines around Tambellup	4,780	2,970	80	Nil	**7,830**
Total (ha)	**25,390**	**95,220**	**37,960**	**1,400**	**159,970**

Surface water engineering for Shedding landscapes

The shedding landscapes in this area, comprising upland hillslopes with slopes exceeding 1 per cent, are dominant with a shedding-to-receival landscape ratio of 6:1.

After heavy rain, surface run-off can cause severe erosion.

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

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

The grey sandy duplex soils are suitable for grade and interceptor banks to harvest good quality water. Dams can, in addition to storing water, provide some 'buffering' or retention of surface water flow if grade-banks are linked into them such as within a 'Keyline System' (Yeoman 1954). Grassed waterways have not been used in this area.

Surface water engineering for receiving and limited self-draining landscapes

Receiving areas have lower relief than the adjacent shedding slopes, and water may not drain as rapidly, causing waterlogging and flooding.

Natural drainage lines in these areas are typically flat, shallow, and parabolic shaped and act as detention areas (such as shallow swamps). Sandplain areas also occur in the wider valley sections or sections with lower gradients. Increased run-off following clearing has resulted in channel broadening and sedimentation deposition. This in turn leads to multiple braded channels, inundation and poorly defined drainage.

Also, within the receiving landscapes, waterlogging can be alleviated by shallow relief drainage, to remove excess surface water and barriers to surface water movement. Shallow relief drainage, constructed by cutting channels into the soil surface, allows surface water to enter and drain at a nominated grade at a safe water velocity, preventing soil erosion.

Shallow relief drainage is the most effective surface water engineering option for reducing waterlogging and inundation.

Land managers in these flat floodplain or sandplain areas should consider using Differential Global Positioning System data (DGPS) to accurately map paddock contours and develop strategic surface water drainage plans that include permanent waterways (non cropping drainage lines) and shallow relief drains that could be cropped over.

The areas where drainage is most likely to be economic are the flood plains and sand plain areas of the Towerlup, Uannup, Slab Hut and Peter sub catchments. The catchment areas under 1 per cent grade may benefit from shallow relief drains to alleviate waterlogging. Even where these sand plain areas have deep sandy and highly permeable profiles, if they are saturated and subject to ponding, drainage can greatly improve crop yields through reduced waterlogging.

The areas or locations suitable for shallow relief drains and raised beds cannot be determined using Table 14. However, it is estimated that about 27,000 hectares (or around 16 per cent) of the landscape slopes are less than one per cent and could be suitable for shallow relief drainage.

After defining the problem and carrying out land assessment, the type and design of earthwork to be constructed is selected. Design criterion for earthworks commonly used in Western Australia is presented in Table 14. Earthworks alone, however, cannot halt rising watertables and they must be used in conjunction with other conservation farming strategies. More information can be found in the following website:
www.agric.wa.gov.au/environment/land/drainwise/options/index.htm

Table 14. Design criterion for common surface water earthworks used in Western Australia

Earthwork design	Land slope (%)	* Soil type	Grade (%)	Landscape position
Grade bank	Up to 10	Shallow duplex / Loam	0.2 to 0.5	Upper & mid-slope
Seepage interception bank	Up to 10	Shallow duplex / Deep duplex / Sand		Lower & mid-slope
Broad-based banks	2-6	Shallow duplex / Loam	0.15-0.3	Upper, mid & lower-slope
Shallow relief drains	Up to 0.2	Clay / Shallow duplex	Up to 0.2	Valley floor
Levee waterways	Up to 10	Clay / Sand / Deep duplex / Shallow duplex	Up to 10	Valley floors and hillslope
Raised bed	0.1-2		0.1 to 2	
Evaporation ponds	Site-specific		0	
Dams	Up to 10	Clay / Shallow duplex / Deep duplex / Loam	Up to 10	Not in valley watercourse
Roaded catchment	Up to 6%	Clay / Shallow duplex	Up to 6%	Good clay required close to surface

Earthworks require careful planning because inappropriate and poor designs can cause soil degradation. Suitably qualified people need to be consulted regarding legal aspects, design and construction. The following points must to be addressed.

- **Land assessment;** information on soil condition, woody vegetation (and perennial) cover, catchment area, annual average rainfall and slope is used to calculate maximum flows, safe grades and safe velocity. Where appropriate, farming systems and farm practices are also considered. http://www.agric.wa.gov.au/progserv/natural/assess/index.htm
- **The annual recurrence interval (ARI);** is the frequency an earthwork is designed to fill or safely fail. Important earthworks, such as dams, waterways and absorption banks are designed for at least a 20-year ARI. The minimum design of most drains and banks is a 10-year ARI (Bligh 1989).
- **Legal aspects;** there are legal aspects that must be considered before earthworks are constructed. Diversion of flows, increasing flow velocities or increasing quantity of flow, could cause damage to neighbouring properties for which the drainage proponent may be responsible (Keen 1998). Catchment planning and discussing planned earthworks with potentially affected neighbours is recommended.

Conservation earthworks

Comprehensive descriptive information about various conservation earthworks and their placement in the landscape, is available on-line through the Department of Agriculture's Internet website (c.f. Table 15 and Figure 11). Similar information can be sourced through several other Department of Agriculture technical publications.

- Further information about all of the structures presented in Table 4.2.2 can be found through the following web page. **www.agric.wa.gov.au/environment/land/drainwise/options/engineering**

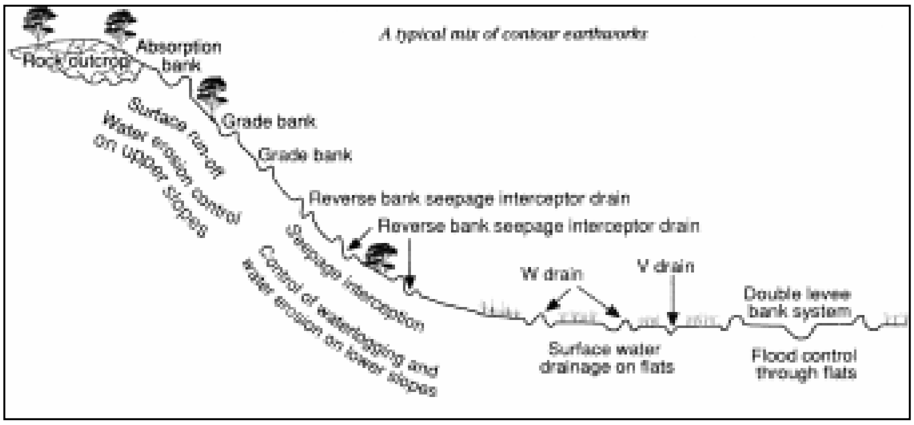


Figure 11. Schematic representation of some typical surface earthworks (after, Negus unpub & Lefroy n.d.)

Table 15. Web links to follow on design, description and placement of conservation earthworks.

Valley floors and lower-slopes	
Shallow relief drains	www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Sh_relief.htm
Levee and leveed waterways	www.agric.wa.gov.au/environment/land/drainwise/options/engineering/levees.htm
Raised beds	http://www.agric.wa.gov.au/environment/publications/rmtechreports/tr229/index.htm
Lower to mid-slopes	
Seepage interceptor drain	www.agric.wa.gov.au/environment/land/drainwise/options/engineering/seepge.htm
Mid to upper-slopes	
Diversion and broad-based banks	www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Div_bbks.htm
Grade banks	www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Gr_bnk.htm

Table 16. Other earthworks

Dams
www.agric.wa.gov.au/environment/land/drainwise/options/engineering/dams.htm
No dam site should be selected without drilling for soil suitability.
Roaded catchments
www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Rdd_cmnt.htm
Evaporation basins and ponds
http://www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Evap_Bsns.htm
Evaporation basin design is based on the criterion that no leakage occurs to any groundwater that has an existing beneficial use or a potential beneficial use, nor should there be any overflow to environmentally sensitive areas.

4.2.3 Groundwater management

There are only a few options for managing groundwater before it contributes to waterlogging and salinity. The effectiveness of these options is limited due to the local and intermediate groundwater flow systems that typically have low permeability and gradients and therefore have a low ability to move groundwater. Table 17 offers some options that may be suitable in the Frankland-Gordon area.

Table 17. Groundwater management options

Open deep drains
Deep drains are used to lower the watertable close to the surface, reducing waterlogging of the topsoil while allowing rainfall to leach salt from the upper profile. Construction of deep drains is a relatively expensive option. Open drains remove land from production and their effectiveness is variable according to soil type. Careful planning and site assessment is required to ensure deep drains are effective. Deep drain construction cost are estimated between $3000-$6000 kilometre (based on 2mtr depth) Farmers must notify the Commissioner of Soil Conservation of their intention to construct deep drains at least 90 days before undertaking the earthworks.
http://www.agric.wa.gov.au/environment/land/drainwise/options/engineering/deep_drains.htm

Groundwater pumping
Pumping is most often used to protect sites in recovery catchments (nature conservation), rural towns and other areas where high value assets are at imminent risk. Groundwater pumping is most effective in permeable aquifer systems. These include deep sandy profiles, thick saprock over basement rocks with coarse material and in some geological faults and shear zones. The Commissioner of Soil Conservation must be notified at least 90 days before undertaking groundwater pumping with associated earthworks.
Farmnote 20/2001 Agriculture Western Australia.
http://www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Gwtr_pump.htm
Relief wells (artesian bores)
A relief well is a 'free flowing' groundwater bore driven by artesian pressure. A typical relief well with a drilling diameter of 100 mm, installed using 50 mm diameter casing, to a depth of 20 to 30 m, is estimated to cost $2000.00 When planning to install relief wells, a notice of intent (NOI) is required to be submitted to the Office of the Commissioner for Soil and Land Conservation at least 90 days prior to installation.
Farmnote 42/2001 Department of Agriculture Western Australia.
http://www.agric.wa.gov.au/environment/land/drainwise/options/engineering/Rlf_wells.htm
Legislation: Notice of intent to drain or pump
Regulations established under the Soil and Land Conservation Act require that, 'When an owner or occupier of land proposes to drain or pump water from under the land surface because of salinity of the land or water and to discharge that water onto other land, into other water or into a watercourse, the owner or occupier shall, at least 90 days before the draining or pumping commences, notify the Commissioner in writing inn the manner set forth in Form 2 Schedule 2' Landholders need to understand that they have a duty of care to ensure their management actions do not lead to land degradation. A penalty will apply to the owner or occupier who fails to notify the commissioner.
http://www.agric.wa.gov.au/environment/land/drainwise/legal/index.htm

(Cf. engineering, agronomic and soil amelioration options, Section 4.1).

4.3 Productive use and rehabilitation of saline land

Ronald Master, Albany

The relatively high rainfall in the area (570 mm annual average) combined with sporadic summer rain provides several options for the productive use of saline land.

Severe waterlogging in many cases exacerbates the effect of the salinity. Where this occurs, earthworks should be considered in an effort to remove surface water. On some of the broad flats, raised beds are also an option that could allow cropping or the establishment of perennial pastures. Siphon assisted relief wells have also shown some promise in the more dissected portions of the landscape and could be considered in conjunction with saltland agronomy options.

There are several pasture species that could be considered for the severely waterlogged and mildly saline valley floors areas:

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

Additional rehabilitation techniques on mildly saline waterlogged valley floor sites could involve rows of salt tolerant oil mallees, *Acacia Saligna*, with interows planted to balansa and persian clovers. All revegetation must be on mounds, preferably using a niche mounder.

In mildly to moderately saline areas (i.e. solid to patchy barley grass areas) single rows of saltbush with tall wheat grass, puccinellia and balansa clover sown in between should be considered. Saltbush should be direct seeded using a niche seeder. The saltbush should be established first and allowed to grow for at least 12 months before perennial pastures are established. Some saltbush species are not tolerant of waterlogging (eg *Atriplex nummularia*). Suitable species must be chosen which will grow in saline waterlogged conditions (e.g. *Atriplex amnicola* or River Saltbush).

In areas less prone to waterlogging, with good surface drainage and a low to moderate level of salinity, perennials such as Rhodes grass could be considered. For mildly to moderately affected sites, with full to patchy barley grass cover, a mixture of tall wheat grass and puccinellia would be suitable with balansa clover included if the salinity is less than 0.8mS/m (1:5). An additional strategy would be to sow the sites with a shotgun mix of balansa clover, tall wheat grass and puccinellia. This would ensure that a broad range of saline environments could be covered in the one application.

Many hillside seeps cover relatively small areas and it is often more appropriate to plant the sites with high water use perennials. Saltbush species and salt tolerant natives could be established into mounds with the site, then fenced off and left to regenerate.

The options for severely salt-affected sites are limited. Sites that are dominated by samphire or are bare should be avoided when considering saltland agronomy options. The best course of action is to fence the site off and allow samphire to re-establish. Where possible highly salt tolerant species like *Melaleuca thyoides, Casuarina obesa*, saltbush and other salt tolerant native species could be established to stabilise these sites and possibly provide faunal habitats.

4.4 Economics of some options for land management

Table 18. Selected enterprises for land management

Option	Costs / disadvantages	Benefits / advantages	Cash flow implications	Main profit drivers
Engineering water management	Shallow relief drains cost around $350 to $550 per km (depending on site-specific circumstances including soil types, contractors used, machinery used and size of drains) (Grade bank cost is $550 per km dependent on site-specific issues such as soil type, machinery used, size of banks and contractors used. Maintenance of banks is required every five years ($150/km).	Shallow relief drains are channels constructed to remove water from areas that may be affected by waterlogging, inundation or flooding, (Drainswise, 2002). Grade bank benefits include reduction in waterlogging between 50 and 100 metres down slope	Cost recovery period will depend a lot on cost of implementation.	Area of land recovered from lost production. Area grown. Crop yield boost in following seasons. Livestock condition.
Perennial pastures, such as lucerne	Establishment costs are usually similar to cost of planting a crop. Ongoing costs are similar to annual pasture. Removal can require several sprays and careful management. Dead plants can create problems for seeding following crops. Soil profile will be very dry after a perennial pasture phase. Crop yields may suffer if growing season rainfall is low. Potential for animal health problems on lush green feed, but risk can be managed.	Reduced recharge. Supply of quality feed during autumn feed trough. Disease break for following crops. Nitrogen fixation by legumes (e.g. lucerne).	Usually negative cash flow in year one, but cover cropping can help recoup costs. Positive cash flow from year two onwards. Anticipate full cost recovery after two to seven years.	Livestock and wool prices. Flock structure. Success of establishment (failed establishment is expensive). Quality and quantity of out of season feed. Availability and cost of other feeds. Yield and protein boost in following crops. Area grown (average value declines as more area is sown).
Balansa clover	Should cost less than a crop to establish. Careful grazing management is required.	Can be grown in areas where traditional pastures perform poorly. Waterlogging allows growing season to be extended.	A well-managed balansa pasture can be very profitable.	Quality of dry feed in summer. Livestock and wool prices. Flock structure. Area grown.

Option	**Costs / disadvantages**	**Benefits / advantages**	**Cash flow implications**	**Main profit drivers**
Tree crops (including sandalwood)	Often costs over $1,000 /ha to establish, plus ongoing maintenance. Livestock must be excluded for at least the establishment phase, often longer. Future prices and yields are uncertain. Recharge benefits restricted mainly to land on which trees are planted.	Stabilises soil. Reduced recharge.	Depends strongly on how well the plants are utilised. Well-managed stands can be profitable.	Success of establishment. Availability and cost. Area grown.
Tagasaste	Establishment cost typically in the order of $100-150 /ha. Require ongoing management to prevent plants getting to big. New fences might be needed. Mustering can be a problem.	Stabilises soil. Reduced recharge. Provides year round feed.	Depends strongly on how well the plants are utilised. Well-managed stands can be profitable.	Feed must be utilised in order to realise benefits. Livestock prices. Success of establishment. Availability and cost of other feeds. Area grown.
Saltbush pasture system (e.g. saltbush, puccinellia, tall wheat grass, etc)	Establishment costs vary enormously, typically ranging from $75 /ha to over $200 /ha. A good supply of fresh water must be provided for stock. New fences might be needed. Mustering can be a problem. Generally not suitable for lambing ewes and young sheep.	Reduced recharge. Reduced water erosion. Saltbush dries soil profile enough to allow salts to be flushed from topsoil. Other pasture plants can then establish (e.g. balansa clover, grasses). These other pasture species form a large part of the grazing value. Can last for many years if managed well.	Some grazing available in the first year. Cost recovery period will depend a lot on cost of establishment. Have been demonstrated to be profitable, especially when a good understorey of highly nutritious pasture is established.	Livestock and wool prices. Success of establishment (failed establishment is expensive). Quality and quantity of out of season feed. Availability and cost of other feeds. Area grown.

5. CONCLUSION

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

- Water repellence affects approximately 74 per cent of the area
- Surface acidification affects approximately 67 per cent of the area
- Surface and subsurface soil compaction affects approximately 63 per cent of the area.
- Salinity (surface), although only currently affecting about 5,500 ha (3.4%) of the study area, is believed to be somewhat under-estimated.

Land managers are already working towards addressing many of the natural resource issues within the Frankland-Gordon area:

- There has been a major shift to no-till or minimum-till, which will help mitigate erosion and subsoil structure decline risks and reduce density of earthworks required.
- Liming to ameliorate soil acidity is widespread, although application rates are still less than what they should be to lift soil pH to satisfactory levels.
- Earthworks are being implemented where possible to mitigate waterlogging and erosion.
- Perennials (mainly lucerne) are being established to increase production while reducing waterlogging, recharge and salinity. Phase cropping with lucerne will help reduce the impact of resistant weeds and help utilise stored soil moisture.

Based on the coarse data presented in this report:

The eastern portion of the appraisal area will continue to decline in population, with an increase in farm amalgamation and a decrease in population.

The existing bore network is limited. For accurate trend analysis, more observation / monitoring bores need to be established in the catchment, particularly in sub catchment areas such as Ryans Brook and Towerlup.

Salinity will reduce land available for agriculture. There will be an increased use of systems for the productive and profitable use of saline land, such as salt tolerant trees and perennial pastures.

The major areas at risk from salinity are the low-lying landscape areas and geologically controlled features such as dykes, bedrock highs, confined watertables and hillside seeps.

The medium to high rainfall areas will provide opportunities for high value crops. Timber plantations will decrease because of the impact associated with climate change. Issues associated with land development after timber plantations will need to be investigated thoroughly. Landuse sequencing is a priority for research and development.

Soil acidification will have the potential to be a major degradation problem if untreated. Research needs to be undertaken to investigate options to reduce acidifying practices together with research into finding alternative sources of lime, if the use of native lime is unsustainable.

Nonetheless, given the economic trends, the future of agriculture within the Frankland-Gordon area would appear to be strong. There are many options and opportunities (with sound planning) for future sustainable agricultural development in the area.

While land degradation issues are prominent across the region, they are not insurmountable. However, research needs to be undertaken to improve the effectiveness and profitability of amelioration options.

There are still many areas of high biological value in the study area, particularly along the Upper Gordon River and it's tributaries. These areas are at a greater risk of salinisation and are likely to exhibit symptoms earlier than some of the surrounding agricultural landscapes. It is possible to reduce the impact on remnant vegetation and the wider landscape provided that measures are taken to improve water-use efficiency across the landscape by such means as recharge reduction, matching land use to land capability, improved cropping and pasture yields.

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7. Further information and contacts

<table>
<tr><th>Topic</th><th>Organisation</th><th>Local contact</th><th>Website address</th></tr>
<tr><td>Climate</td><td>Bureau of Meteorology</td><td></td><td>www.bom.gov.au/climate</td></tr>
<tr><td>Farming Systems and Group Development</td><td rowspan="5">Department of Agriculture, Albany District Office
Tel: (08) 9892-8444
Fax: (08) 9841-2707

Department of Agriculture, Katanning District Office
Tel: (08) 981-3333</td><td>Farming Systems Development Officer</td><td>www.agric.wa.gov.au</td></tr>
<tr><td>Soils & Land Use</td><td>Soil Resource Officer</td><td>www.agric.wa.gov.au/progserv/natural/assess/
www.agric.wa.gov.au/progserv/natural/assess/lra_soil_mapping.htm</td></tr>
<tr><td>Surface water management</td><td>Land Conservation Officer</td><td>www.agric.wa.gov.au/drains</td></tr>
<tr><td>Productive uses for saline land</td><td>Farming Systems Development Officer</td><td></td></tr>
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- salinity mapping
- national audit</td><td>Hydrologist</td><td></td></tr>
<tr><td colspan="2">Land Monitor</td><td>www.landmonitor.wa.gov.au</td></tr>
<tr><td colspan="2">National Land and Water Resource Audit</td><td>www.nlwra.gov.au</td></tr>
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<tr><td>Native vegetation</td><td>Department of Conservation and Land Management, Albany Regional Office
Tel: (08) 98 424500</td><td></td><td>www.calm.wa.gov.au</td></tr>
</table>

8. APPENDICIES

APPENDIX 1. Maps

Three maps are presented with the report.

A1.1. Soil-landscape map for the Frankland-Gordon area
The mapping was compiled by field sampling, aerial photograph interpretation (at 1:50,000) and use of Landsat TM and Digital Elevation Models (at 1:100,000) to refine line work. Field sampling was undertaken with broad observation density. Further soil-landscape unit definition can be found in Appendix 2.

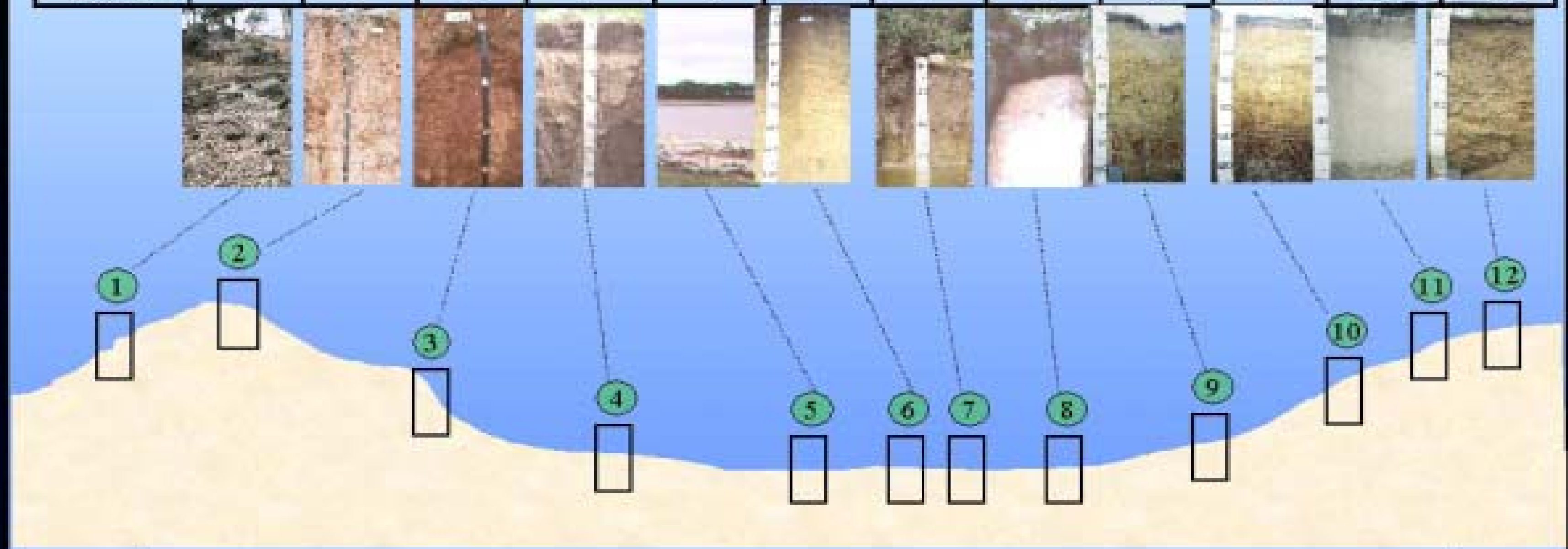
A1.2. Land Monitor: Current salinity.

This map shows areas of salinity for two time periods (1990 to 1992 and 1996 to 1997) illustrating recent increases in salinity.

A1.3. Land Monitor: Hydrological hazard map.

This map illustrates areas where valley floor salinity and waterlogging may develop if the watertables continue rising.

APPENDIX 2. Approximate landscape positions for common land management units



LAND MANAGEMENT UNIT	Rock outcrops	Mallet Hills	Red/Red-brown Soils	Grey/greyish brown loams and clays	Salt Lakes	Yellow and brown deep sand	Salt affected land	Wet Soils	Poorly drained duplex soils	Moderately drained duplex soils	Pale deep sand	Gravelly ridges and slopes
LANDSCAPE POSITION	Outcrops of ironstone, granite and dolerite on ridges and slopes	Breakaways and some isolated hillocks	Slopes and ridges, often associated with dolerite dykes	Lower slopes and broad valley floors	Seasonally water-logged salt lakes	Valley floors and lower slopes	Valley floors, drainage lines and seepage areas on slopes	Swamps, lakes, non-saline hillside seeps	Lower slopes and larger drainage lines	Mid to upper slopes	Mid to lower slopes	Mid to upper slopes and hill crests
Profile No	1	2	3	4	5	6	7	8	9	10	11	12

Figure A2.1. Schematic cross section of land management units in the Frankland-Gordon area

APPENDIX 3. AGMAPS Land Manager CD-ROM

An AGMAPS Land Manager CD ROM is also available for the Frankland-Gordon appraisal area. This CD provides:

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

The CD is available from the Department of Agriculture, Western Australia.

APPENDIX 4. Example bore drill log

Drilling Log Upper Slab Hut 1997

USH10/97

Easting: 541200 **Northing:** 6230194 **Date drilled:** 28/5/97
Slotted depth (m): -34 to -36 **Salt Storage (TSS t/ha):** 1280
Groundwater salinity (mS/m): 1235
Water level below ground (m): -9.35
Landform Pattern: Low hills (30 to 90 m relief)
Interpreted Geology: 0-36 m *in situ* weathered granitic material (rich in kaolin).