REPORT TWO :

SALINITY
AN INDICATIVE ECONOMIC STUDY

BLACKWOOD CATCHMENT ECONOMIC APPRAISAL

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Salinity Rehabilitation – Economic Rationale

Agritech Hydropower

Abstract:

Economic, hydrogeological and waste water disposal factors have discouraged development of drainage systems as a tool in managing excess water in agricultural landscapes. A drainage strategy with disposal to the ocean has been proposed for rehabilitation of salinised land and prevention of further spread of salinity especially in the broad sedimentary valleys of the mixed livestock/crops and cereals agricultural zones. This report presents an economic appreciation of salinity management issues using the Blackwood River catchment where about 245,000 ha of salt affected land is amenable to drainage. The assessment is made of the potential benefits to agricultural production, road and other infrastructure and water supply from alternative salinity management scenarios. The benefit/cost ratio taken over 45 years at 7% discount rate is 0.25 for 50% reduction in excess recharge (as in the State Salinity Strategy), 1.77 for 70% reclamation and 1.63 for 100% reclamation of currently salinised land and elimination of any further spread of salinisation. The ratios are reduced to 0.21, 1.48 and 1.41 (respectively) using a 30 year period. Whilst the farmers are the biggest beneficiaries, the state and federal governments are able to make a significant contribution to the rehabilitation strategy in a zero net cost position.

The study has two conclusions. The recommended resource management initiatives aimed at reducing excess recharge by 50% are economically inadequate for the task. However, the reclamation of current and potential salinised land to full agricultural production is essential to achieve economically viable management of the salinity problem. Consequently, there is need to develop a substantially new management approach combining the use of drainage and disposal of waste water to the ocean to achieve rehabilitation of salinised land with the development of agricultural systems which will achieve a long-term reduction in excess recharge.

Key Words: drainage, salinised land, economic assessment, rehabilitation, agriculture, benefit:cost ratio, Blackwood Catchment

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Jonathan Thomas has over twenty year's experience as a resource and environmental economist in Australia. He was trained as an economist and statistician at Oxford University, where he holds Batchelor and Masters degrees; and later as a management consultant at the Sundridge Park Management Centre. He was Assistant Chief of the CSIRO Division of Water Resources between 1988 and 1997.

Jonathan was an author of *On Rational grounds: Systems Analysis and Catchment Land Use Planning* (Bennett and Thomas, 1982), which considered the problems of salinity in the WA Murray River Catchment, and concluded that vegetative approaches to salinity management were not economic in that catchment. He was also responsible for the economic analysis of national salinity issues in Consultancy Report No 8 to the Water 2000 Study (Peck, Thomas and Williamson, 1983)

As Director of the Resource Economics Unit, Perth, he is a consultant to the National Land and Water Resources Audit on the non-agricultural costs of natural resource degradation, the National Dryland Salinity Program on options for productive use of saline lands, the Western Australian Rural Towns Program on costs of salinity to infrastructure, and the Western Australian Water and Rivers Commission on water futures. He also was engaged in the Mid-term Review of the Natural Heritage Trust, Inland Waterways Theme.

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He was a leading member of the team which conducted the paired catchment studies in the Collie Catchment between 1970 and 1985, and recently contributed to the need for greater emphasis on pumping approaches to salinity abatement in the Western Australian wheat belt. He has been a consultant on salinity management to state governments throughout Australia. He worked with Jonathan Thomas on the National Water 2000 Study Salinity impacts study (Peck, Thomas and Williamson, 1983). He later prepared a major review of salinity trends in the Murray-Darling Basin for the Murray-Darling Basin Commission.

David has contributed to the current interest in drainage approaches for salinity management, through publication of the report *Salinity Crisis Needs Bold Action (*Coyne, Williamson and Giudici, 1999). He also presented papers on the subject of integrated salinity management at the 1999 UWA Winter School and the AGCON 2000 conference.

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Notwithstanding the above, the analyses and interpretations in the report are those of the authors.

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POTENTIAL BENEFITS FROM REHABILITATION OF SALT-AFFECTED LAND BY A DRAINAGE CANAL SCHEME IN THE BLACKWOOD RIVER CATCHMENT, WESTERN AUSTRALIA

by J.F. Thomas and D.R. Williamson

1. BACKGROUND AND OBJECTIVES

1.1 Background to the Report

The Commonwealth has announced the creation of a salinity program with funding of over $1 billion for action in target catchments. The Commonwealth Minister for Conservation has expressed the view that drainage strategies should form a part of overall salinity strategy (The West Australian, March 2nd 2000, p6). The Western Australian State Salinity Strategy (State Salinity Council, 2000) also advocates pumping and drainage where appropriate, but considers that cost makes it prohibitive for reclamation of broad-acre agricultural land.

A Western Australian group coordinated by Agritech Soil Conservation Pty Ltd has undertaken pre-feasibility studies of drainage strategies to combat salinity in the Blackwood River Catchment. Activities of the group so far have included:

- a concept- study by Coyne, Williamson and Guidici (1999)
- engineering evaluation of the concept study by MacMahon Contractors Pty Ltd
- a detailed pre-feasibility, desk-top study for a major programme of groundwater pumping with disposal of the saline discharges via a gravity canal through the Blackwood, Preston and Collie catchments into the sea north of Bunbury (Commercial in Confidence)[1,2]
- the current study into the economic aspects of salinity strategies for the Blackwood catchment.

It is envisaged that these activities will lead to the presentation of a proposal to the State and Commonwealth Governments for funding of a full feasibility study to develop and assess the prospects for improved management and control of salinity in the Blackwood River catchment.

1.2 Objectives

This report presents an economic appreciation of salinity management issues in the Blackwood River Catchment in the south west of Western Australia. The report is based on an assessment of the potential benefits that could be expected to flow from alternative salinity management scenarios.

Too often it is assumed that the benefits will be the same, whatever salinity control strategy is adopted. However, it will be shown that for salinity management in the Blackwood River Catchment there are great differences in the level of benefits obtainable from different strategies.

The study compares and contrasts three scenarios for salinity management:

- Reducing the trend rate of growth in salinity consistent with the State Salinity Strategy
- Arresting the further spread of salinity
- Reclaiming existing salt land and arresting further growth of salinity through a drainage strategy of groundwater pumping and deep open drains with disposal into a canal for conveyance to the ocean.

Costs of the different scenarios are then discussed. It is axiomatic that the larger the potential benefit the greater the amount that it is worthwhile investing in a control strategy.

The study concludes that 1) the currently accepted resource management initiatives aimed at combating the problem have been inadequate for the task, and, 2) on the basis of an assessment of the potential benefits, the study supports proposals to develop a substantially new, more comprehensive approach based on the addition of pumping and drainage to the recharge reduction concepts of the current State Salinity Strategy.

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[1] Sinclair Knight Merz (Dec 1999) *Blackwood Salinity Project: Preliminary Investigation Study* Sinclair Knight Merz Pty Ltd, Perth.

[2] Sinclair Knight Merz (Sept 2000) *Blackwood Hydroelectric and Salinity Pilot Study Report* Sinclair Knight Merz Pty Ltd, Perth.

1.3 The Blackwood River Catchment

1.3.1 Situation and Climate

The Blackwood River Catchment covers an area of 2,260,000 ha (Department of Primary Industries and Energy, 1987) and drains a large part of the Great Southern agricultural district. In terms of area, it is the second-largest river basin in the south west of Western Australia, after the Swan-Avon. In terms of its water flow, of some 2,100 GL near the ocean at Augusta, the Blackwood River is the largest river in the south west of Western Australia. Figure 1 shows the location and outline of the catchment. Local government boundaries are also shown, as these are the principle spatial units for social and economic data used in the study.

The climate is broadly temperate/Mediterranean, with cold, wet winters and warm to hot, dry summers. There is, however, considerable spatial variation of rainfall and temperature within the catchment. Rainfall ranges from around 1,000 mm near Nannup in the intensive agriculture zone in the south west of the catchment, to approximately 500 mm around Kojonup in the mixed livestock-cropping zone of the central catchment; 450 mm in the Katanning district in the medium rainfall wheat-sheep zone; and less than 400 mm in the low rainfall wheat-sheep zone in the most eastern part of the catchment in the Dumbleyung Shire.

1.3.2 History of land use and onset of salinity

A significant portion of the catchment, approximately some 20% of its total area, was alienated for agriculture as early as 1900, with two major nodes of clearing around Boyup Brook and Katanning. By 1930, this had already been extended to almost 80% of the total catchment area. Little of the original woodland vegetation now remains in the eastern catchment. The western part of the catchment is still extensively forested, and intensive agriculture there is located mainly along the lower slopes of the Blackwood valley.

As a result of agricultural development there has been a change in the water balance. The replacement of the natural woodlands, predominantly by a ley-farming system of cereal cropping and mixed livestock production, has reduced the total evapo-transpiration of the vegetation and has increased groundwater recharge. Land and water salinity have resulted from transport

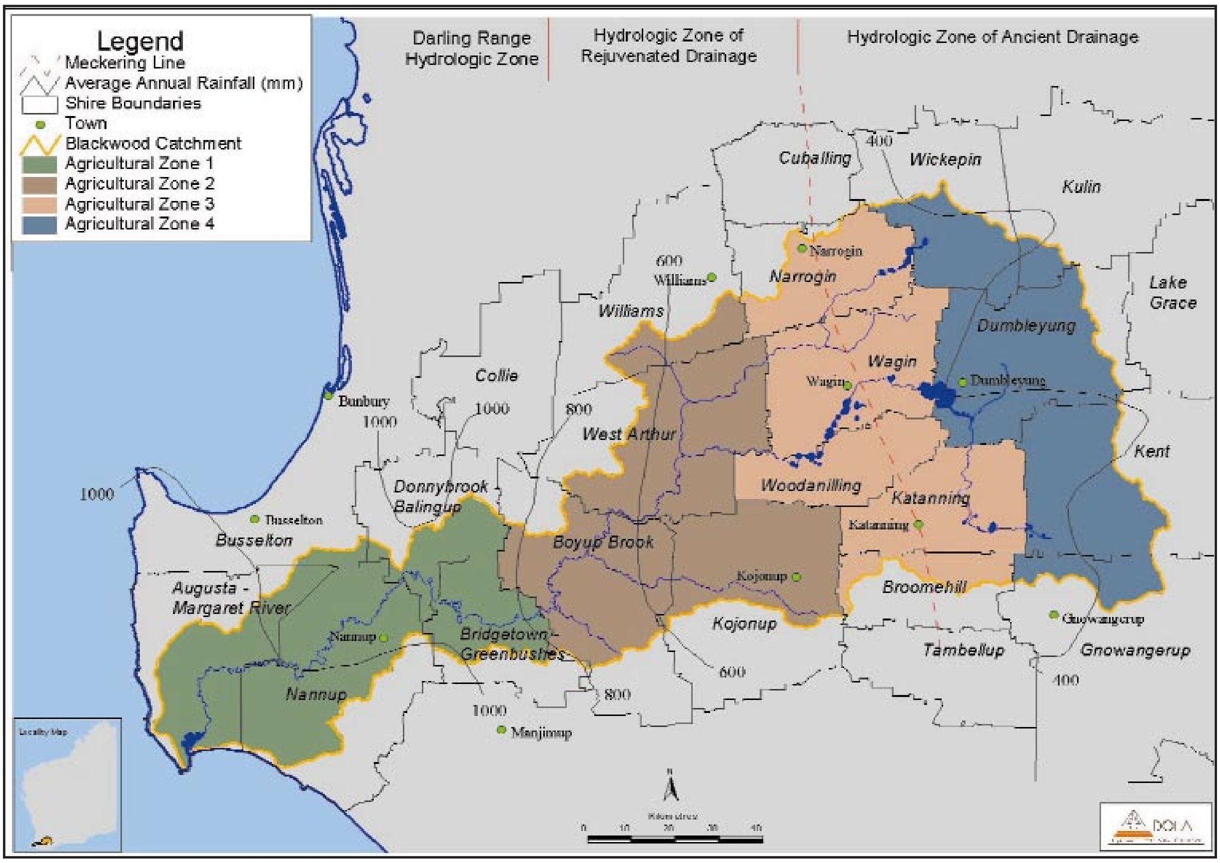

Figure 1: Local government (shire) boundaries, agricultural zones and hydrologic zones in the Blackwood River Catchment

of this excess water to locations, particularly in valleys, where groundwater discharge occurs at the soil surface and into streams. Salts may be concentrated at the soil surface. (Peck et al, 1983).

During the last 20 years, stream and land salinity in the Blackwood River Catchment have continued to increase. Significant further spread of land salinity is expected within the catchment, with the area ultimately affected likely to be between a fifth and two fifths of the total land area. More effective salinity management for the Blackwood catchment would result in the avoidance of future damage from salinity. Salinity is just one environmentally damaging effect of agricultural development. There has been a virtual total loss of sustainability in natural ecosystems in the Western Australian wheat belt.

1.3.3 Impacts of salinity

The economy and ecology of the Blackwood River catchment are already affected by secondary salinity and the impacts will worsen in future.

- The productivity of agriculture in salt-affected parts of the landscape is severely reduced relative to productivity in the original condition. The valley floors that were once the most productive part of the agricultural landscape are rapidly becoming the least productive part.
- Many towns and roads in the catchment are situated in low-lying areas and are affected by shallow saline groundwater tables, and this involves significant costs to infrastructure.
- Salinisation has rendered the Blackwood River system useless for potable or irrigation water supply purposes, except for some fresh, forested tributaries in the western catchment.
- Salinity has affected the terrestrial and aquatic ecosystems of the catchment, and significant areas of nature conservation are unlikely to survive.

1.3.4 Control efforts

Efforts to combat the spread of salinity have been largely community-based, with technical support from the Agriculture Western Australia and the Department of Conservation and Land Management (CALM). Financial support at the farm level has come through organisations such as the National Landcare Program and the Natural Heritage Trust. The Blackwood Catchment Coordinating Group, now the Blackwood Basin Group, was established, to bring together all affected stakeholders and to develop plans for combating salinity. Approaches that have been tried to date include tree planting, development of deeper-rooted crops such as legumes, planting of salt-tolerant forage crops such as salt-bush, and localised hydrologic engineering in the form of contour banks and some open drains. None of these strategies has been implemented on a scale commensurate with the emerging salinity problem. Also, these strategies have been directed primarily towards a reduction of groundwater recharge, and have not addressed ways of enhancing discharge.

1.4 Outline of the report

The following report describes a preliminary benefit/cost study of alternative salinity management scenarios for the Blackwood River Catchment.

Section 2 describes the methodology of the study. Section 3 gives an overview of population and economic trends in the catchment. This section is not a formal part of the benefit/cost analysis but provides essential social and economic background. Section 4 reviews information collected and assumptions made about the current extent and future development of salinity. This provides the key biophysical assumptions, which underpin the subsequent analysis.

Sections 5 to 7 report the analysis and findings. Section 5 presents estimates of benefits for the agriculture sector and corresponding salinity control costs. This Section necessarily dominates the discussion as the greatest potential economic benefits from salinity management lie within agriculture. Sections 6 and 7 review the potential benefits of selected salinity management scenarios for suppliers and users of infrastructure and water resources. Section 8 is a summary of findings and conclusions.

Finally, Section 9 provides references to material used in preparing the report, and three Appendices deal with (A) definition of spatial units, (B) the spreadsheet model and (C) farm economics data.

2. METHODOLOGY

2.1 Economic analysis

The economic analysis is based on an indicative benefit:cost study of alternatives for salinity management and control. It is assumed that, if nothing new is done to address the problem, past trends in salinity will continue (State Salinity Council, 2000a), and economic and ecological impacts will grow accordingly. In economic parlance these impacts are termed *damage costs*. The benefits of alternative salinity management scenarios are then assessed as the *difference* that the alternative management scenario makes to these impacts.

Improved salinity management would lead to a reduction in damage costs. Reduction of damage costs is therefore taken as the benefit of any control option, and is compared with the preliminary estimates of costs of control. Costs of control include (i) direct outlays on measures such as changed agricultural production systems, engineering works or plantations, and (ii) the opportunity cost of the land required for any control option, or in other words the loss of benefits to producers or consumers that occurs as a result of land use being changed from production to the control measure.

Economic impacts on agriculture are the major consideration, and it is assumed that salinised land has no profitable productive use. The agricultural impacts were estimated using an Excel spreadsheet model based on the likely value added in agriculture as a function of the trend in area salinised. This is described more fully in Appendix B. The control-hydrological response function in each part of the catchment has been based on expert opinion. In deriving assumptions for the trend in salinity, with and without control, reference is made to the predictions given in the WA State Salinity Strategy (State Salinity Council, 2000a). The advice of scientists with many years' experience in WA salinity studies was also obtained.

Economic impacts on infrastructure were estimated based on likely trends in the areas salinised, and damage cost functions for affected items. These include roads, housing, commercial buildings, public services and recreational venues.

The economic value of potential improvements in the quality of water resources in the Blackwood River Catchment was estimated taking account of likely growth in demand for water in the south west of Western Australia as a whole and in the Vasse (Margaret-River), and Blackwood Statistical Divisions, and the cost-effectiveness of utilising a fresher Blackwood River to meet these demands in future.

The economic values of ecological and recreational services yielded by the Blackwood River catchment under the alternative control scenarios have not been estimated. Moreover, the benefits to farmers in the form of carbon credits from extensive tree planting have not been quantified. However, it is judged that these would be considerably less than the opportunity cost of the land needed for such re-vegetation.

2.2 Zonation

For the purposes of this report the catchment has been divided into four zones based on the principle types of agricultural activity, namely (1) Intensive crops/livestock zone, (2) Mixed grains/livestock zone, (3) Medium-rainfall wheat-sheep zone, and (4) Low-rainfall wheat-sheep zone. The zones are shown in Figure 1.

3. ECONOMIC ACTIVITY IN THE BLACKWOOD RIVER CATCHMENT

3.1 Population

The population of the Blackwood River Catchment is estimated at approximately 30,000 (DPIE, 1987). Approximately two thirds of the population resides in the principal towns, which are (moving from south west to east) Augusta, Nannup, Bridgetown, Greenbushes, Boyup Brook, Kojonup, Katanning, Wagin, Narrogin, Woodanilling, and Dumbleyung.

Table 1: Total populations of Shires 1994-99

Shires represented in each study zone	1994	1999	% Change 1994-99
Zone 1			
Augusta Margaret River	7,365	9,564	29.9
Busselton	16,020	21,568	34.6
Donnybrook-Ballingup	4,174	4,489	7.5
Bridgetown	3,993	4,118	3.1
Nannup	1,120	1,229	9.7
Total	32,672	40,968	+25.4
Zone 2			
Boyup Brook	1,754	1,668	-4.9
Kojonup	2,394	2,355	-1.6
West Arthur	999	952	-4.7
Williams	1,062	1,000	-5.8
Total	6,209	5,975	-3.8
Zone 3			
Broomehill	513	553	7.8
Katanning	4,841	4,525	-6.5
Narrogin	5,666	5,565	-1.8
Wagin	1,978	1,962	-0.8
Woodanilling	360	386	7.2
Total	13,358	12,991	-2.7
Zone 4			
Gnowangerup	1883	1,699	-9.8
Kent	828	765	-7.6
Dumbleyung	919	860	-6.4
Wickepin	920	852	-7.4
Kulin	1,068	920	-13.9
Total	5,618	5,096	-9.3
TOTAL	**57,857**	**65,030**	**+12.4**

Note: the table gives total populations of Shires. See Appendix A for information on the proportion of each shire's area that is within the Blackwood River Catchment

Table 1 shows changes in the estimated resident population between 1994 and 1999 for each shire represented in the catchment . Population has been increasing at a relatively slow rate in the southwest of the catchment since 1981, though there appears to have been some acceleration of growth in the 1990s. The central and eastern parts of the catchment have been experiencing population decline at least since 1981. This decline is mainly concentrated in the country towns. While shires on the western fringe of the catchment have been experiencing strong population growth. This is mainly concentrated on the Leeuwin coast, outside the catchment in the Dunsborough, Busselton and Margaret River areas. Towns such as Bridgetown, Nannup and Greenbushes have experienced much slower population growth.

3.2 Employment and Incomes

According to the Census of Population, the average personal weekly income in the Blackwood Statistical Sub-Division (SSD) in 1996 was about 10% lower than the State average. However, the average personal weekly income in the Pallinup and the Upper Great Southern SSDs remained 7% above the State average in 1996. Thus, despite overall population decline, the wheat-sheep zone has remained relatively prosperous. There are, however, significant differences between the towns and the rural parts of the catchment and between social groups.

3.3 Agricultural Production and Income

3.3.1 Overview

The Blackwood River Catchment accounts for a significant share of WA's agricultural production, and contains an estimated 1,447 farms, with a total area of 1.776 million ha (see Appendix A.). Appendix C contains data from the Australian Bureau of Statistics (ABS) and Australian Bureau of Agricultural and Resource Economics (ABARE) on the volumes and values of commodities produced, and estimates of the incomes generated on farms.

The gross value of agricultural production from the 15 shires covering the major part of the Blackwood Catchment was $506 million in 1996-97. The value of major products was $228 million (45%) from grains production, mainly winter cereals wheat, oats, maize and barley; $245 million (48%) from livestock activities mainly wool and meat from sheep and meat from beef cattle and pigs. The remaining $33 million (7%) was from intensive mixed farming in the western part of the catchment, mainly using irrigation or supplementary irrigation for production of fruits, grapes and vegetable crops.

Most commodities produced in the catchment have favourable market outlooks. The grains industry can look forward to continued growth of output and productivity. Also, agriculture is diversifying with a variety of non-wheat grains taking a larger share of the total value of production. Meat markets, both beef and sheep, are likely to re-establish themselves following the recovery of Asian markets. Potentially, there could be large increases in irrigation activity in future in the western parts of the catchment, particularly in the wine grapes and vegetables sectors.

The wool industry has been affected in recent years by poor trading conditions. The poor economic return from wool and meat production has seen some farmers disposing of livestock and relying on cropping systems only. The long-term outlook for wool remains uncertain given international market trends in favour of synthetic textiles and fabrics. However, even in the wool industry, there is great variation in the prices received by producers depending on fibre quality.

3.3.2 Agricultural zones

The agricultural economy of the intensive crops/livestock zone in the higher-rainfall western parts of the catchment contains both dryland and irrigated production. Cereal cropping accounts for a very small percentage of the value of commodities produced. There is a wide spread of irrigation activities with vegetables, fruit, and grapes accounting for most of the irrigated areas. The region around Donnybrook and Bridgetown has traditionally been the centre for orchard fruit production including apples, pears, peaches and plums. Supplementary irrigation is used in orchards.

The mixed grains/livestock zone, which includes shires of Boyup Brook, West Arthur, Williams and Kojonup, specialises predominantly in wool and sheep products. This zone is relatively homogeneous in terms of the type of farming that takes place in its four shires, but it is a transition zone in terms of geology and salinity. Boyup Brook and Williams Shires have much smaller areas of salt-affected land than West Arthur and Kojonup.

The economy of the medium rainfall wheat-sheep zone, which includes Broomehill, Katanning, Wagin, Narrogin and Woodanilling shires, is based on a ley-farming system, in which cropping is conducted in a rotational fashion, alternately with the grazing of pasture or stubble. Cereal grains, mainly wheat, provide the greatest contribution to the value of farm output, but wool and sheep for meat are still important.

Finally, in the low rainfall wheat-sheep zone, which includes the Dumbleyung, Kent, and Wickepin shires, farms are heavily dependent on cereals production, mainly wheat.

3.3.3 Income generated directly by agriculture

ABARE Australian Farm Surveys data for Western Australia, quoted in Appendix C, have been used to provide an indicative estimate of incomes generated in the farming regions of the Blackwood River catchment for the two dominant farming types: (i) wheat and other crops industry and (ii) mixed

Table 2: Estimated Value Added in Agriculture in 1999-2000, by catchment zone

Zone	Estimated area of farmed land ('000 ha)	Estimated Value Added/hectare ($/ha)	Estimated Value Added ($M/year)	% of total Value Added
1. High rainfall, intensive agriculture	161.3	80.00	12.9	10.8
2. Mixed grains and livestock	494.4	60.00	29.7	24.8
3. Medium rainfall wheat and sheep	593.6	70.00	41.6	34.7
4. Low rainfall wheat-sheep	509.6	70.00	35.7	29.8
Total	**1,758.9**		**119.9**	**100.0**

livestock and crops industry. The measure of agricultural income used in this study is "*Value Added*", which is defined as gross margin to the farmer, plus the transfers of income that are made out of farm enterprises, such as interest, rates and taxes. These latter items are actually a distribution of the income obtained from farming to other sections of society.

Value added per hectare of total farm area (shown for the mixed livestock/cropping industry and the wheat/sheep industry in Tables 22 and 23 in Appendix C) has been higher in the districts that concentrate mainly on production of cereals, (ranging from $59.4/ha to 79.3/ha) than it has for those districts that rely more on livestock (ranging from $55.12/ha to 62.99/ha). These differences were incorporated into the estimated benefits of salt land reclamation in different parts of the catchment.

The above estimates of value added per hectare and the areas farmed provide an estimated value added in agriculture of around $120 million per year in the Blackwood River Catchment (see Table 2). Some 65% of this comes from the two wheat-sheep zones. If the annual value added is converted to a present value using a discount rate of 7% over 30 years, the estimated present value of agriculture in the Blackwood River Catchment is $1,488 million. However, this would not be achieved if salinity continues to further reduce the area available for productive agriculture.

3.4 Forestry

Plantation softwood forestry, hardwood logging and milling are significant in the south west of the catchment. The Blackwood SSD contains a large area of natural hardwood Jarrah and Karri-Marri forest. While most of the forestry activity takes place outside of the Blackwood River Catchment in the Pemberton-Manjimup areas, the economy of the forestry activity needs to be considered. Over 1,000 people are employed in forestry, logging, mills and associated wood products industries, making it the State's prime source of forestry products, with around 60% of the total forestry output. A chip mill near Manjimup produces more than 750,000 tonnes of woodchips per annum for export to Japan. Total value added in the forestry sector is estimated to be around $50 million annually. Many farmers supplement their income by working in the forestry industry.

The future of forestry in the region, under Forest Agreements, has been controversial. Western Australian demand for sawlogs is expected to rise from 1 million cubic metres to between 1.2 and 1.7 million cubic metres by the year 2050. The industry continues to upgrade its value-adding capability. Plantations and tree farming schemes will be used to supplement the yield of sawn and processed timber products from the hardwood forests. The availability of hardwood chip logs is likely to increase. There has been significant investment in re-tooling the timber mills to adapt them to changing production demands, with a smaller throughput of large Karri saw logs. The mills now operating at Pemberton, Deanmill, Manjimup (outside the Blackwood River Catchment), and Greenbushes (inside the Blackwood River Catchment) have state-of-the-art computer-operated systems, with drying and processing facilities. Investment is proceeding in pre-drier technology, high-temperature kilning, and veneer plant.

3.5 Mining and Industry

The principal mining and industrial activities are found in the Greenbushes area (located in Zone 1), where tin, tantalite and spodumene are produced. A lithium carbonate extraction plant has been constructed. More than 50 per cent of the world's spodumene is mined at Greenbushes. Spodumene is a mineral used for feedstock for lithium carbonate and various other lithium chemicals production used in air-conditioning, lubricants and batteries. Tantalum production value increased to $41.9 million in 1997/98. Tin production was $3.6 million in 1997/98.

The mining sector of the eastern parts of the catchment is very small. Manufacturing industry is also small and mainly based on food processing.

3.6 Services

The service sector is a dominant source of employment within the western part of the catchment. This is in part associated with the well-established tourism industry, based on the forests and other attractions of the southwest region. It seems likely that this region will maintain its share of domestic and international tourism to Western Australia.

The service sector in the central and eastern catchment is small relative to the total economy, compared with other regions in WA, and accounts for a low 48% of total employment. The service sector has recently suffered some decline as a result of the rationalisation of services in, for example, banking and financial services, machinery supply and servicing. There is also a tendency for the smaller service centres to decline faster, with service functions becoming more concentrated in the principal country towns.

3.7 Summary

Agricultural activities dominate the economy of the Blackwood River Catchment. Agriculture directly generates a value added of around $120 million annually, excluding significant "multiplier" effects" This may be compared with $50 million of value added in the forest and forest products industry of the Blackwood SSD.

While the economy of the western parts of the catchment is diversified, with mining, forestry, tourism and agricultural activities, the economic future of the catchment as a whole is tied to (i) the performance of dryland agriculture and (ii) to the sustainability of the country towns given the degree of rationalization of service functions that is occurring and which may be expected to continue.

4. LAND AND WATER RESOURCES OF THE BLACKWOOD CATCHMENT

4.1 Land Use

The area of alienated land is estimated to be 1.776 M. ha, which is 79% of the total catchment area of 2.26 M. ha. The proportion of alienated land is highest in the wheat/sheep zones, being around 90%. The mixed crops/livestock zone also has a high proportion (82%) of its total area in farmland. The proportion of alienated land is lowest in the high-rainfall western zone, at 32%.

It has been difficult to establish the component of alienated land that is currently cleared and used for agriculture from the ABS data sets. The ABS data for area of holdings in shires turn out to be a poor estimate of farmland or arable land. The total of area of holdings reported in some shires is greater than the area of the shire, because the data relate to farm enterprises, and geography is defined in terms of the principal location.

The WA Land Monitor Project provides estimates of woody vegetation, which can be subtracted from total shire area to estimate the area of arable land. However, the area of woody vegetation is not presently available for Augusta-Margaret River, Busselton, or Donnybrook-Balingup.

Since the economic data available for estimating the returns to agriculture on a per hectare basis are expressed in terms of the *total* area of agricultural holdings, (i.e. the area alienated including some remnant vegetation on private land), the area of "farmland" used in the spreadsheet analyses is total alienated land.

4.2 Land Condition

4.2.1 Measurement of soil salinity

Soil salinity may be defined as the weight of soluble salts in a unit weight of dry soil. Surface soils are said to be saline when NaCl content exceeds 0.1% for loams or more textured soil, or 0.2% for clay-loams and soils of finer texture. Sub-soils are said to be saline when NaCl content exceeds 0.3% (Peck et al, 1983). However, there are definitional issues in measuring the impacts of salinity on agricultural productivity. While the chemical definitions of soil salinity are precise, they require extensive soil survey to generate representative results for broad-scale natural resources applications.

Between the farmland that has been lost to production completely (i.e. waterlogged land and/or salinised land) and that which remains in good condition (i.e. completely unaffected by salinity), there is a large area of land that is affected by salinity to some degree. In these latter areas there is wide variability in terms of current impacts on pasture and crop productivity. Aerial photographs, for example, typically show some salinised, denuded areas, surrounded by paddocks with scattered areas of sparse vegetation, and often these can be seen to be associated with a developing plume of shallow groundwater. Farmers may continue to utilise paddocks with significantly lower productivity provided they continue to obtain a positive gross margin. Thus, for every hectare of land that is *completely* lost to salinisation and waterlogging, there is usually a further surrounding area where crop and pasture yields have been significantly lowered and will decline further.

4.2.2 WA Land Monitor Project

Measurement of the areas of land that have been affected by secondary salinity relies on field survey, geo-physical mapping techniques and remote sensing technologies that measure surface properties such as temperature or reflectance, the "signatures" of which are derived by the combination of different wave bands, and used as indicators of the area of salinised land. The CSIRO and WA State Agencies have been developing a Land Monitor survey methodology of this kind.

Provisional data on land use and land condition in the Blackwood River Catchment in 1998 are now available for selected periods since 1987, and are summarised in Table 3 (Source: Suzanne Furby , pers comm). These data refer to areas that are "badly salinised", and are described as "saltland", and exclude the surrounding areas where there are undoubtedly significant agricultural impacts. There is no current estimate of the area of saltland using Land Monitor for Augusta-Margaret River, Busselton, or Donnybrook-Balingup, but Ferdowsian et al (1996) give badly affected salt land in 1994 for the Darling Range Zone as 3.8%.

The trend in the area of saltland in the Blackwood River Catchment shows an estimated increase of at least 28,000 ha between 1988 and 1998, and now accounts for some 6% of the total land area. In West Arthur, Williams, Kojonup and Boyup Brook the percentage is 3.5% or less, whereas in Katanning and Wagin the percentages are 9.1% and 8% respectively. (McFarlane and Williamson, 2001).

The percentage of land affected tends to increase from west to east and from north to south.

Table 3: Type of land/vegetation in the dryland agricultural regions of the Blackwood River catchment, in 1998

Type of Land/Vegetation	'000 ha	%
Non-saline arable land	1,680	78
Woody vegetation	331	15
Saltland	130	6
Lakes, water and bare sand	19	1
Total	2,160	100.0

Source: McFarlane and Williamson (2001.)
Note: (i) includes mapped areas within shires of Boyup Brook, West Arthur, Kojonup, Williams, Narrogin, Wagin, Woodanilling, Katanning, Broomehill, Wickepin, Dumbleyung and Kent shires, except for 709 ha which had not been mapped, and (ii) excludes Augusta-Margaret River, Busselton, Bridgetown-Greenbushes and Nannup Shires.

From Table 4 it is seen that the medium rainfall wheat-sheep zone, Zone 3, is particularly badly affected by land salinity, with the major agricultural areas of Katanning, Narrogin, Wagin and Woodanilling having between 7.9% and 9.8% of their total land areas salted by 1994-98. The total value of agricultural production in each shire in 1996-97 is included for comparison.

4.3 Trends in Areas of Salt Affected Land

The data in Ferdowsian et al (1996) and the trend graph in the Western Australian State Salinity Strategy (State Salinity Council, 2000a, p.16) were used to establish the area of salt-affected land and the trends in land salinity for each of the 4 agricultural zones in the Blackwood River catchment. These data refer to land that is either "badly" or "slightly" saline and given the land assessment classification of "saline land". For this report we refer to both these types of land as "salt-affected land". Ferdowsian et al (1996) estimate a much larger area of saline land in the Upper Blackwood Catchment than the State Land Monitor Survey technology.

The trend graph in the Western Australian State Salinity Strategy (State Salinity Council, 2000a, p.16), projects a linear trend of about 0.49% per year over the 2000 to 2050 period, though showing a linear trend of 0.38% per year over the 2000 to 2070 period. (In contrast, the Land Monitor data provides a lower estimated trend of 1% in saline land for shires within the Blackwood Catchment for data in the 7-year period between 1987/91 and 1994/98.) Ferdowsian et al (1996) estimated the area of salt-affected land for the hydrologic Zone of Ancient Drainage and Zone of Rejuvenated Drainage in the Upper Blackwood Catchment from extensive field survey. These data were used to obtain the current (2000) percentage area of salt-affected land.

Table 4: Results of the Land Monitor Survey of Land Salinity 1987-1998

Zone and Shires	Value of agricultural production in 1996-97 ($ million)	Saltland as % of area mapped 1987-91 (%)	% change of salted land 1987-91 to 94-98 (%)	Saltland as % of area mapped 1994-98 (%)
1. *High rainfall intensive agriculture zone:*	n.a.	n.a.	n.a.	n.a.
2. *Mixed grains-livestock zone:*				
Boyup Brook	41.9	0.8	0.2	1.0
West Arthur	40.9	3.5	0.8	4.4
Williams	34.3	1.2	0.3	1.5
Kojonup	59.7	2.4	0.7	3.0
3. *Medium rainfall wheat-sheep zone:*				
Broomehill	25.8	3.0	0.6	3.7
Katanning	31.8	9.1	0.7	9.8
Narrogin	34.7	6.6	1.3	7.9
Wagin	35.4	8.0	1.3	9.3
Woodanilling	19.4	6.7	1.4	8.1
4. *Low rainfall wheat-sheep zone:*				
Kent	69.9	6.2	0.9	7.1
Dumbleyung	48.6	5.4	0.8	6.2
Wickepin	40.0	4.7	0.6	5.3
Gnowangerup	79.0	2.8	1.5	4.3

Sources: McFarlane and Williamson (2001) and Australian Bureau of Statistics Agricultural Census, 1996-97.

The current percentage area of salt-affected land was initially estimated for 2000, extrapolating from the published data for 1994-98 and analysing the trend graph in the Western Australian State Salinity Strategy. The latter indicates a linear trend of about 0.38% per year over the 2000 to 2070 period. However, this rate of increase is not consistent with the recent trends estimated for the Blackwood River catchment in Ferdowsian et al (1996). So the percent of land salted by the year 2000 was increased to better fit the published estimates.

The estimates for the future area of salt-affected land are calculated using the different features of agricultural landscapes and an understanding of the general hydrogeology. Based on the data in Ferdowsian et al (1996), the percentage of salt land at equilibrium (that is, the maximum area lost to salt) would be about 25% for Zone 1 (being largely in the Darling Range Hydrological Zone as classified by Agriculture Western Australia). From a survey of 1.5 million hectares of the Blackwood River catchment, Ferdowsian et al (1996) estimated that the area of saline land could reach 36% at equilibrium in the Rejuvenated Drainage Hydrologic Zone landform. This expectation applies to farmland west of the Meckering Line (shown in Figure 1) in the eastern part of Zone 2 and the western half of Zone 3.

By comparison, for the Ancient Drainage Hydrological Zone landform found east of the Meckering Line in Zones 3 and 4, the saline land was expected to reach only 20% at equilibrium. Ferdowsian et al (1996) also estimated that 90% of the broad alluvial valleys, which are a key feature of the Ancient Drainage Hydrological Zone, will be salt-affected at equilibrium. The percentages of salt-affected land and the trend towards equilibrium used for the four zones in this economic study are given in Table 5. The equilibrium condition is assumed to be reached earlier in the more undulating and steeper terrain in Zone 1 and in the western half of Zone 2, and at a lower percentage of salt-affected land than the state average of 32%. Ferdowsian et al (1996) concluded that, at equilibrium, salt-affected land will reach 40% in the central and eastern wheat-belt. This is basically east of the Meckering Line, and is represented in the Blackwood River catchment by our Zones 3 and 4. Consequently, for this study, Zone 2, which has features of both Zone 1 and Zone 3, is assumed to reach about the State average for salt-affected land at equilibrium, whilst Zones 3 and 4 are assumed to exceed the State average. All these data are used as the best available estimates based on published information, but are obviously open to change if more rigorous methods of analysis were carried out.

Table 5: Assumed trajectory of salt-affected land under the "Do-Nothing-New" scenario

	Zone 1	Zone 2	Zone 3	Zone 4
Current % of salt-affected land	7.7%	10.0%	23.0%	22.0%
Future % of salt-affected land:	***Estimated number of years from now to reach given % of salt-affected land***			
10%	4.0	0	-	-
15%	11.0	7.5	-	-
20%	18.0	7.5	-	-
25%	25.0	30.0	6.0	6.0
30%	-	-	17.0	17.0
35%	-	-	42.0	42.0

5. POTENTIAL BENEFITS OF SALINITY REDUCTION TO AGRICULTURAL ACTIVITIES

5.1 Spreadsheet Model

An Excel spreadsheet model was written to simulate the potential benefits and costs to agriculture of measures to combat land and water salinity. This is described in Appendix B.

5.2 Scenarios for Salinity Control

Indicative estimates are given for future potential benefits and control costs under a number of scenarios for future management in this catchment. Three control scenarios were simulated. The scenarios, which were selected to reflect the principle alternatives, were as follows:

- What impacts on agricultural income might be expected if the targets expressed in the WA Salinity Strategy (State Salinity Council, 2000a) were achieved in this catchment? This option would address the projected 50% recharge reduction through such measures as the planting of perennial vegetation, particularly trees and pasture, on non-saline areas, and the use of halophytic pastures for sheep grazing on currently saline land. For the wheat belt as a whole the Strategy estimates that this would achieve a reduced extent of salt-affected land from about 32% for the "Do-Nothing-New" case to around 20% of the total land area in 2090.
- What would be the expected value of future agricultural income if the area of salt-affected land were to be stabilised at the 2000 level?
- What would be the expected value of future agricultural income if it were possible not only to prevent any further salinisation but also to reclaim all the currently salinised land.

Each of the above control scenarios was compared with the expected present value of agricultural value added if current trends in salinity were to continue until a new equilibrium was reached.

Table 6: Estimated present value of agricultural value added in the Blackwood River Catchment over the next 30 and 45 years at 7% discount rate under the "Do-Nothing-New" salinity control scenario

Salinity Control Scenario	Present Value of 30 Years of Agricultural Value Added at 7% Discount Rate ($ million)	Present Value of 45 Years of Agricultural Value Added at 7% Discount Rate ($ million)
Agricultural Value Added under "Do-Nothing-New" Scenario	1,424.5	1,547.4

5.3 Agricultural income if trends in salinity continue

Table 6 gives our estimate of the present value (PV) of agricultural value added (which equates to incomes directly generated in agriculture) if current salinity trends continue, using a 7% discount rate for two time periods, namely 30 years and 45 years respectively. Because future income streams are discounted heavily over such a long time period there is only an 8.6% difference in the present value of agricultural value added between the two periods considered.

5.4 Implications of the WA Salinity Strategy targets

5.4.1 Benefits

The trend-shifting strategy embodied in the Western Australian Salinity Strategy would be aimed at achieving a 50% reduction in recharge within wheat-belt catchments, and reduce the area of salinised land by about a third - from 32% to 20% in the wheat-belt as a whole in the year 2090. However, the flatness of the landscape in the Upper Blackwood Catchment and its hydrogeology are more severe than the "average" condition in the WA agricultural region and create steeper trends in salinity.

The results of the spreadsheet model, shown in Table 7, suggest that there could be an increase in the PV of agricultural value added in the catchment of between $36.5 million (30 years) and $45.3 million (45 years). Thus the percentage improvement in present value of agriculture is between 2.6% and 2.9%. This relatively small improvement is obtained because it would take many years to achieve the 50% recharge reduction target and the consequent reduction in the proportion of farm area that is salted as compared to the trend scenario.

Table 7: Impact of a 50% reduction in recharge on agricultural value added

Salinity Control Scenario	Present Value of 30 Years of Agricultural Value Added at 7% Discount Rate ($ million)	Present Value of 45 Years of Agricultural Value Added at 7% Discount Rate ($ million)
Agricultural Value Added under Do-Nothing-New Scenario	1,424.5	1,547.4
Agricultural Value Added under 50% Recharge Reduction Scenario	1,461.0	1,592.7
Improvement in Agricultural Value Added	36.5	45.3
Percentage improvement	2.6	2.9

5.4.2 Costs

There have been no published estimates of the costs to farmers and to society as a whole of the 50% recharge reduction strategy. The Preface to the State Salinity Strategy states: *"an enormous effort is needed to reduce the impact of salinity significantly. It will not only require large-scale planting of deep-rooted perennials, changing crop rotations and appropriate engineering works, including pumping and drainage, but will also see most farmers completely changing their land use practices"* (State Salinity Council, 2000a, p.vii). Clearly this change in land use has a cost, which has not yet been identified.

The State Salinity Strategy also states *(our parenthesis)* that: *"The Government of Western Australia currently contributes about $40 million per year to combat salinity. However, the largest investment has come from and will continue to be funded by private landholders"*, and *"a considerable increase in (private) investment is required. The Commonwealth Government has also contributed significantly(and) there is a good case for a post-NHT increase of strategic investment from the Commonwealth Government".* (State Salinity Council, 2000a, p.58)

From these statements it may be concluded that current control costs of salinity management in Western Australia as a whole are of the order of $120 million per year. If this figure is expressed in terms of dollars per hectare of salt-affected land (of which there are currently 1.8 million hectares) we obtain a current control cost of approximately $70/ha of salt-affected land. Applying this factor to the amount of salt-affected land in the Blackwood River Catchment (0.25 million ha) we obtain an order-of-magnitude estimate of current control costs for the catchment of $17.5 million/year. This figure includes outlays to establish new crops, re-vegetation with trees or shrubs, and any engineering-type works, but not the opportunity cost of land used for re-vegetation.

Expressing these estimated annual control costs as a present value, using an annual discount rate of 7%, we obtain a figure of $215 million over 30 years and $238 million over 45 years. This level of cost far exceeds the calculated benefits in terms of improvements in agricultural income, with benefit-cost ratios of 0.17 (30 years) and 0.19 (45 years).

5.5 Prevention of further salting

5.5.1 Benefits

Table 8 shows our estimate of the potential benefits from arresting all further salting of agricultural land. It is estimated that there would be an improvement of only 4.4% to 5.3% in the present value of agriculture, as compared with the "Do-Nothing-New" trend scenario, even if *all* further increases in salinity were prevented. Why is such a small potential benefit estimated when agricultural output and value added in some parts of the catchment would be reduced in the long term by up to 50% if salt trends continue? The relatively small improvement in present value terms is obtained because both the predicted decline in agricultural production and its remediation would take a long time to occur. It follows that present-day investments aimed at shifting the long-term trend must have small budgets or low benefit-cost ratios, or both.

Table 8: Potential agricultural benefits from prevention of any further salting (present value of agricultural value added at 7% discount rate)		
Salinity Control Scenario	Present Value of 30 Years of Agricultural Value Added at 7% Discount Rate ($ million)	Present Value of 45 Years of Agricultural Value Added at 7% Discount Rate ($ million)
Do-Nothing-New (Salt trends continue)	1,424.5	1,547.4
Prevention of any further salting	1,486.5	1,629.8
Improvement in Agricultural Value Added from prevention of further salting	62.1	82.4
Percentage improvement	4.4%	5.3%

5.5.2 Costs

No estimate is available for the costs of arresting the growth in area of salt-affected land. Indeed, it is generally considered to be impossible to achieve this by non-engineering control measures (as concluded by the State Salinity Strategy, 2000a,b,c). However, it is apparent that the agricultural benefits of completely arresting the growth of the salt-affected area remain smaller than the control costs even for the trend-shifting 50% recharge reduction strategy (see previous section).

5.6 Reclamation of Salt-affected Land

The reclamation control scenario for salt affected land is based on the proposals contained in the reports by Agri-Tech Soil Conservation Pty Ltd (Coyne et al, 1999). Two sets of results are presented for this option: one based on full reclamation and the other on partial reclamation.

5.6.1 Benefits of full reclamation

The first set of results is based on reclamation of all salt-affected land that is amenable to drainage. The key assumptions of the analysis are that:

- All currently saline land within the wheat-sheep zones (Zones 3 and 4) would be returned to full agricultural productivity within five years through a regional drainage scheme, and there would be no additional salinity on currently unaffected land in these zones.
- 75% of saline land in the mixed livestock-cropping zone (zone 2) would be amenable to treatment through a regional drainage scheme, and there would be no further salting in this part of the zone; the remaining agricultural land in this zone would continue to experience a rising trend in salinisation
- no currently saline land within the intensive agricultural zone (zone 1) would be addressed by a drainage scheme, and the zone would continue to experience past trends in salinisation
- all reclaimed land would become fully productive at recent levels of value added per hectare

Figure 2 illustrates the assumed trajectories of salt-affected land in each zone under this reclamation scenario. A comparison is made with the trend in salt-affected land for the "Do-Nothing-New" scenario. It is seen that the drainage reclamation scenario makes no impact in Zone 1, where a regional drainage scheme has very limited application to restoring broad-acre agriculture, though potentially relevant to nature conservation. The graph for Zone 2 illustrates the steeper anticipated rise in the area of salt-affected land under the "Do-Nothing-New" scenario as compared with Zones 3 and 4. In Zone 2 the reclamation scenario needs to depend more on reducing recharge and using salt land pastures to manage salt-affected land. The part of Zone 2 not amenable to drainage treatment continues to experience increasing land salinity. The reclamation scenario assumes that the drainage strategy allows salt-affected land in Zones 3 and 4 to be brought back into production within a short period after application, taken to be 5 years (Bourgault et al., 1997).

Table 9 shows estimates of the potential benefit to agriculture from not only preventing further increases in salting, but also reclaiming all existing saline land through the regional drainage strategy. There is an improvement in the present value of agricultural value added of between 23.1% (30 year period) and 24.7% (45 year period) compared with the "Do-Nothing-New" trend scenario. Thus, since prevention of all further salting would imply an improvement in agricultural value added of between

4.4% and 5.3%, it may be inferred that the improvement due to reclamation alone would be between 18.7% and 19.4%.

Table 9: Potential agricultural benefits from reclamation of all currently saline land plus prevention of further salting (present value of agricultural value added at 7% discount rate)

Salinity Control Scenario	Present Value of 30 Years of Agricultural Value Added at 7% Discount Rate ($ million)	Present Value of 45 Years of Agricultural Value Added at 7% Discount Rate ($ million)
Do-Nothing-New (Salt trends continue)	1,424.5	1,547.4
Full Reclamation and Prevention	1,753.4	1,929.1
Improvement in Agricultural Value Added	328.9	381.7
Percentage improvement	23.1%	24.7%

In terms of potential benefits, there is a marked superiority of reclamation by drainage over trend shifting through 50% recharge reduction, results from differences in the timing of benefits. Reclamation would return land to full agricultural productivity in a relatively short space of time, whereas the benefits of trend shifting accrue in the long-term future. This results in a very large difference in potential benefits from present-day investments in control.

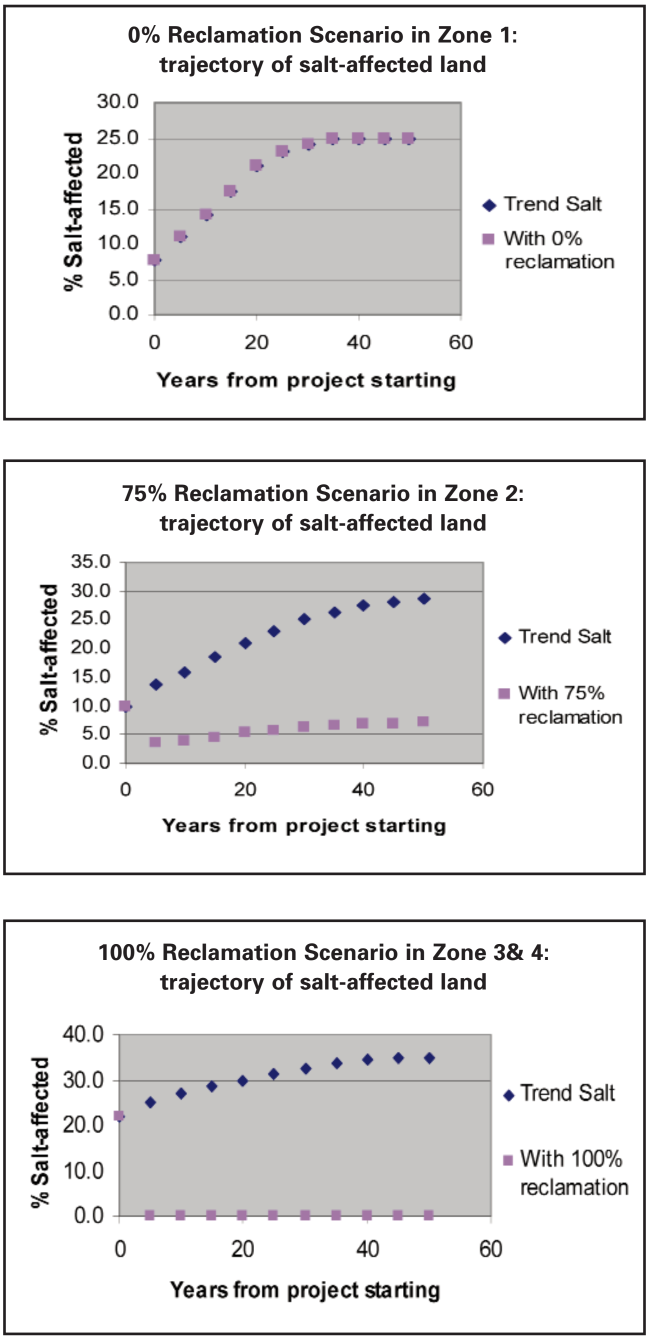

Figure 2: Expected trends in land salinity based on reclamation of all salt-affected land that is amenable to drainage in each of the 4 Zones showing the comparison with the trend in salt for the "Do-Nothing-New" scenario.

5.6.2 Benefits of partial reclamation

The second set of results, shown in Table 10, is based on a more conservative assumption that not all farms would take advantage of the reclamation option. For this scenario the "capture" rate has assumed to be 70%, giving a reclamation scheme of 170,000 ha, rather than the full estimated 245,000 ha of private land that is salt affected. All other assumptions remain the same as for the full reclamation option.

It is seen that under these assumptions the expected improvement in agricultural value added would be from $249.9 million (30 years) to $302.7 million (45 years). Percentage improvement would be 17.5% to 19.6% respectively. Thus, since prevention of all further salting would imply an improvement in agricultural value added of between 4.4% and 5.3% it may be inferred that the improvement due to reclamation alone would be between 13.1% and 14.3%.

Table 10: Potential agricultural benefits from reclamation of 70% of currently saline land plus prevention of further salting (present value of agricultural value added at 7% discount rate)

Control Scenario	Present Value of 30 Years of Agricultural Value Added at 7% Discount Rate ($ million)	Present Value of 45 Years of Agricultural Value Added at 7% Discount Rate ($ million)
Agriculture Value Added under "Do-Nothing-New" Scenario	1,424.5	1,547.4
Prevention of any further salting	1,674.4	1,850.1
Improvement in Agricultural Value Added from prevention of further salting	249.9	302.7
Percentage improvement	17.5%	19.6%

5.6.3 Costs

Agritech Soil Conservation Pty Ltd has supplied a provisional estimate of $151.6 million for the capital costs of a project achieving reclamation of 70% of currently salt-affected land, that is, rehabilitation of 170,00 ha to full agricultural production in the Upper Blackwood catchment. This project would use pumping bores to control saline groundwater discharges, and a canal for conveyance of the saline water to the ocean. The breakdown of these costs is shown in Table 11.

Relatively little work has been done so far on the operational and maintenance costs of the scheme, particularly those on-farm. There are many different ways of delivering water to the collection system, including electric, wind and solar pumps, surface drains and contour drains. These vary in total cost and in the balance between capital and operating costs. Different systems will be needed in different areas, and an important aspect of a proposed feasibility study will be to determine an appropriate selection for different situations. For the purposes of this preliminary benefit/cost study a figure of $30/ha/yr in operating and maintenance costs has been assumed. This includes a contribution from farmers to the maintenance of the main system of collector drains and canals.

Table 11: Cost components for the partial reclamation scenario (all costs are expressed as present values)

Cost Component	**30 yr Period** $ million	%	**45 yr Period** $ million	%
On-farm costs				
Bores, contour and surface drains	51.0	23.7	51.0	23.1
Annual operation and maintenance	63.3	29.5	69.4	31.4
Off-farm costs:				
Canal/collector drain excavation	34.2	15.9	34.2	15.5
Canal lining	52.6	24.5	52.6	23.8
Cuttings	2.3	1.1	2.3	1.0
Land acquisition	0.7	0.3	0.7	0.3
Clearing	3.0	1.4	3.0	1.4
Crossings etc	7.8	3.6	7.8	3.5
Total Costs	**214.9**	**100.0**	**221.0**	**100.0**

Thus it is seen that the benefits from a project involving 70% reclamation of currently salt-affected agricultural land, plus the arresting of any further increase in salt-affected land, would exceed the estimated costs. The ratio of agricultural benefits to project costs at 7% discount is estimated to be between 1.15 (30 years) to 1.35 (45 years).

6. POTENTIAL BENEFITS OF REDUCING THE COST IMPACTS OF SALINITY ON INFRASTRUCTURE AND PUBLIC LAND MANAGEMENT

6.1 Country roads

In recent years there has been increasing awareness of the costs to roads infrastructure from rising saline groundwater tables. A report by ABARE (Oliver et al, 1996) quantified costs in the Murray Valley. Murray-Darling Basin Commission reported on the additional costs of road maintenance and construction in irrigation areas of the Murray-Darling Basin (Hallow et al, 1994). The Australian Road Research Laboratory has provided a report to the WA Main Roads Department on the costs of rising shallow groundwater tables to county roads (McRobert and Foley, 1997).

Table 12 shows the estimated length of roads currently affected by shallow and saline groundwater tables.

Table 12: Estimated length of roads that are affected by shallow saline groundwater tables in the Blackwood River Catchment

	Estimated total length of roads (km)	Possible length of roads affected by shallow groundwater tables (km)
Major inter-regional roads	360	61
Major country roads	700	119
Minor country roads	250	43
Total	**1,310**	**223**

Using an overall average of 17% of land in the catchment east of Bridgetown being salt-affected, the lengths of road affected could amount to some 223 km at present.

The cost of additional road repairs and maintenance due to salinity is obtained by comparing the difference in expected cost with and without the existence of shallow groundwater tables. Major roads have an expected operating lifetime of around 20 years, and the cost of construction is approximately $400,000/km. For the purposes of this study it is assumed that all major roads would be replaced in ten years time. (In practice some will be replaced earlier and others later). Much more frequent repair and maintenance in the form of pavement stabilisation is required for major roads that are affected by shallow groundwater. It is suggested that this cost could amount to around $200,000/km every five years. Impacts on minor country roads have not been considered, but would be relatively small compared to the costs for major roads

The difference in cost streams per kilometre for normal versus affected roads is given below in Table 13. It is seen that the difference in discounted cost between normal and affected roads is approximately $166,000/km over a 20 year period. From Table 12 the length of major roads that could be currently affected is 180 km. Consequently, it is estimated that the net present value of additional road costs due to salinisation is $29.9 million in the Blackwood River catchment.

Any increase in the area of salt land in future under the "Do-Nothing-New" scenario would lead to cost increases. Estimates of increasing trends in salinisation were given in Section 4.3. As the greater part of total road length lies in the central and

Table 13: Estimated costs per kilometre for road replacement, repair and maintenance, with and without shallow groundwater tables and salinisation.

Year Cost is Incurred	Normal road($/km)	Water-affected road $/km)	Normal road Discounted @ 7%	Water-affected Discounted @ 7%
5		200,000		143,000
10	400,000	200,000	203,000	102,000
15		200,000		72,000
20		200,000		52,000
Total	**400,000**	**800,000**	**203,000**	**369,000**

eastern parts of the catchment a figure of 30% of road length being affected in about thirty years' time is likely. This would approximately double the costs then being experienced as compared with the estimated current levels of cost given above. However, this would occur over the thirty-year time period. Consequently, the net present value of the current plus future impacts of salinity under the "Do-Nothing-New" scenario is conservatively estimated at $45 million.

The three salinity control scenarios considered in this report would have different impacts on road repair and maintenance costs. It has not been possible within the scope of this report to accurately quantify the differences, but it is clear that the existence of a reclamation scheme based on pumping and drainage would offer much more rapid reductions in repair and maintenance costs for roads. It is considered realistic to suggest that around 70%, or approximately $31 million, of the road costs due to salinity could be avoided under the reclamation scheme for 170,000 ha,; and 100%, or $45 million, for the full reclamation scenario. The figure for arresting any further spread of salinity would be the "future" component of roads costs, namely $15 million. The 50% recharge reduction strategy would lead to even smaller savings in roads costs, because it would do nothing about the roads currently salt-affected, and would not prevent some further increases in salt-affected land. It seems unlikely that this control scenario could save more than $10 million in roads costs in the Blackwood River Catchment

6.2 Country towns

A recent consultancy study by URS Australia and Resource Economics Unit (REU) has estimated the costs to 6 wheatbelt towns in a project within Agriculture Western Australia's Rural Towns Program (RTP). One of these towns, Katanning, is situated within the Blackwood River catchment, while another, Cranbrook, lies just outside. Other towns within the Blackwood River catchment are located low down in the landscape in similar salt prone locations and are also likely to suffer from the impacts of rising saline groundwater tables. The RTP is currently studying groundwater movement and salinity in a further 23 towns, several of which are within the Blackwood River catchment (eg, Dumbleyung, Nyabing and Wagin).

From the URS Australia-REU study it is clear that the principal costs within the towns are costs to roads and to the residential housing sector. Road costs within the towns are as described for country roads. Housing costs come in the form of damage to stumps from rotting, fretting and cracking mortar, and site waterlogging. There is also a range of other infrastructure and amenity items that may be affected.

The magnitude of costs and their timing varies widely between different wheat-belt towns, depending on a range of factors, including local groundwater depths, household irrigation practices, water management within the townsite, rates of rise of the groundwater and its salinity, the type of infrastructure, townsite topography and town layout.

It is also apparent that the cost of controlling rising groundwater tables varies greatly between towns, depending on local conditions and the salinity of the groundwater. In some towns the groundwater may be stratified with a freshwater lens at the water table. In this case there may be a net benefit from groundwater pumping, as the product water is fresh and can be used as a source of supply to substitute for expensive water imported from the Great Southern Towns Water Supply Scheme (GSTWSS).

Further, and importantly, it is not immediately obvious how a general reduction in groundwater tables as a result of changed agricultural land use would benefit particular towns in the Blackwood River Catchment. A general conclusion of the URS Australia-REU study is that poor urban water balance management, including inadequate surface water drainage and importation of scheme water, was often the cause of the towns' problems. So a general reduction of groundwater table beneath agricultural areas in the wider catchment might only alleviate the problem in the towns when there is a regional reduction in hydraulic pressures in aquifers associated with the town salinity problem.

However, it can be said that the availability of a regional canal system for disposal of pumped groundwater could considerably reduce the costs of town salinity control, by providing an alternative to the construction of evaporation basins. Indicative estimates suggest that salinity control costs for Katanning could amount to around $8 million, discounted at 7%. Other towns have not yet been studied in enough depth for an accurate estimate to be developed. However, it is reasonable to assume that up to $30 million could be required for all the towns within the catchment that will require control measures within the next 20 years. Expenditure on evaporation basins could amount to a third of this figure, or $10 million. This expenditure could be avoided under a reclamation scheme based on pumping and canal construction, as this would provide the necessary disposal route. It seems unlikely that the other control scenarios considered in this report would have much effect in reducing salinity costs in rural towns.

6.3 Public Lands

All salinity management scenarios considered in this report would benefit State Government departments such as CALM, Water and Rivers Commission and Agriculture Western Australia, that undertake expenditure for the management of public lands, including lakes and rivers. Such expenditure is often undertaken to protect environmental values.

It has not been possible to determine the total expenditure involved, but this could be considerable. The effectiveness of measures is also an issue, particularly where the protection of terrestrial and aquatic ecosystems is dependent on broader-scale land management initiatives.

Public (Crown) lands represent around 10% of the landscape in Zones 2, 3 and 4 of the Blackwood River Catchment. As a very approximate figure it would be reasonable to assume that in these zones the benefits to public land management agencies are 10% of the benefits to agriculture from the alternative salinity management scenarios. This equates to a present value of about $25 million over 30 years.

7. BENEFITS OF IMPROVED WATER QUALITY

7.1 Water Resources Quantity

Mean annual runoff of the Blackwood catchment, estimated as basin outflow, was 1,060 GL in 1983-84 (Department of Primary Industries and Energy, 1987). This makes the Blackwood by far the largest river in terms of flow in the south west of Western Australia, when compared with the Murray River (720 GL) and the Avon River (280 GL). The major divertible resource is 428 GL. Annual rainfall has been below average since the early 1980's, so mean annual runoff is now lower. Groundwater, which is of variable quality, is largely contained in sedimentary aquifers.

Table 14 summarises the water resource situation in the catchment as it was in 1982-83 (DPIE 1987). The water resource of the Blackwood River Catchment remains largely undeveloped, with usage of just 1.04% of the major divertible resource in 1983-84. This increased substantially between the years 1983-84 and 1999-00. By the latter year licensed usage within the Blackwood SSD was some 29.8 GL, or 7% of the major divertible resource. However, current usage in 1999-00 represents approximately one third of the divertible fresh resource.

Table 14: Water resources of the Blackwood River Catchment, 1983-84 (in GL)

	Surface Water		Ground Water	
Mean Annual Runoff (in GL)	1060			
Divertible Resource Quality:	*GL*	*%*	*GL*	*%*
Fresh	90	21	50	38
Marginal	18	4	45	34
Brackish	320	75	23	17
Saline	0	0	15	11
Total Major Divertible Resource	428	100	133	100

7.2 Water Resource Quality

The salinity of a water sample is measured as (i) Total Dissolved Solids (TDS in mg/L), (ii) Sodium Chloride NaCl (mg/L) or (iii) EC Units (micro-Siemens per metre mS/m). Common qualitative descriptors for water salinity, used by the WA water agencies, are (i) "fresh" (TDS < 500 mg/L), (ii) "marginal" (TDS between 500 and 1,500 mg/L) (iii) "brackish" (TDS between 1,500 and 5,000 mg/L) and (iv) "saline" (TDS >5,000). Brackish or saline water is considered unsuitable for human consumption. Metropolitan and southwest town water supplies are all fresh, though some WA Midlands towns such as Mount Magnet, Cue and Meekatharra receive water of marginal quality. Brackish water may be used for irrigation of some crops and pastures provided that a salt leaching fraction is maintained, but this is not ideal and some yield loss is likely. Stock may tolerate a salinity of up to 7,000 mg/L TDS.

The water resource of the Blackwood River Catchment is extensively affected by salinity. While the major divertible resource is 428 GL, some 320 GL of this, or 75%, was brackish in 1983-84, and has trended towards the saline category since. Therefore, only 90 GL of fresh water remained harvestable, mainly from tributaries in the western catchment. Water quality has continued to deteriorate since the early 1980s (McFarlane and Williamson, 2001) The stream salinity at Darradup (GS609025) has shown an annual increase of 58 mg/L TDS since the 1950's when the river flow was potable water at about 500 mg/L (McFarlane and Williamson, 2001).

The State instrumentalities that are responsible for water supply and water resources management have come to regard the Blackwood River itself as being of little further interest as a future water resource, given its current and worsening salinity. Expressed in economic terms the agencies believe that the river has zero value as a water resource. However, the catchments of the smaller Kent and Denmark Rivers have been designated as "recovery catchments", where it is hoped it will be possible to return the rivers to fresh condition for water supply purposes. Within the feasibility study for the Drainage/Canal proposal there will be an analysis of the potential water quality benefit from the reduction of salt discharging into the Blackwood River.

7.3 Current Water Use

Total water use figures are available at the Statistical Sub-Division (SSD) level.

By far the dominant form of water use occurs in the Blackwood SSD for irrigated agriculture, which is estimated to account for over 85% of the total, mainly for production of fruit, grapes and vegetables. Due to the generally poor quality of local surface and groundwaters, shires in both the Upper Great Southern and Pallinup SSDs are supplied with water for domestic and stock purposes from the Harris Dam near Collie, which is distributed through the Great Southern Towns Water Supply Scheme (GSTWSS). Before the Harris Dam was constructed the GSTWSS took water from the Wellington Dam, but due to salinisation of the Collie River the Harris Dam was built as a substitute resource.

Water use in the Pallinup SSD is relatively low, and is mainly for stock and household use. Two thirds of the water used in the Upper Great Southern SSD is for stock, and most of the remainder is for domestic supply. Mining, manufacturing and services take small volumes.

7.4 Future Water Demands and Sources of Supply

Recent work on future demand for water in the south west of WA (Water and Rivers Commission, 2000) has indicated that there could be a substantial additional demand for water for irrigation, mining, industry and urban use. On the coastal plain, from Perth south to Bunbury, the growth in demand for water could easily exceed the available resource.

One large uncertainty in forecasting demand for water in this region is how well the irrigated dairy industry will be able to compete with eastern states producers under the newly de-regulated trading system for whole milk. The conventional wisdom is that the dairy industry will contract and will be a net supplier of tradeable water rights in future. However, if this turns out not to be the case, or if the growth of other irrigation industries outstrips any decline in dairy industry water use, then rapidly-growing irrigation sectors such as the fresh fruit, vegetables and wine grape industries may find it difficult to expand in the Perth-Bunbury corridor. If so, demand is very likely to be displaced to the Augusta-Margaret

River/Blackwood regions and accelerate the growth in water demand that is already taking place there.

The water demand scenarios for Blackwood SSD are dominated by significant continued growth of the region's irrigation industries, with some extra demands appearing in other sectors. Total water use could range between 48 GL and 53 GL by the year 2020-21, with irrigated agriculture increasing by approximately 60% to 80%.

The existing manufacturing industry sector is small and mainly serves the local population and mining and agricultural industries. However, there was a $1.9 billion proposal in the early 1990s to establish a pulp and paper industry within the southwest region. The proposal did not proceed, but a similar project seems likely to re-emerge within the next twenty years and this could add considerably to industrial water demand if located within this region. There could also be some growth in services as real incomes grow, though in terms of water use this is projected to be a relatively small increment on a small base.

To summarise, on the basis of projected demands for water for the irrigation sector, it is reasonable to suggest a demand for an additional 100,000 ML/year in the Blackwood and Vasse SSDs, with an average value to the irrigators of around $300/ML ($0.3/m^3). This would give a market value of $30 million per year for the additional water requirements.

7.5 Benefits of an increased freshwater resource

While the groundwater resource endowment of the Blackwood River Catchment is considerable, it is questionable whether the groundwater resource is suitably located or is a cost-effective source of supply for future irrigation demands in the Vasse and Blackwood SSDs. Improvement of the water quality of the Blackwood River to a level that could be used for irrigation would provide a relatively low-cost water supply for expansion of irrigation industries in the south west.

The availability of a large new freshwater resource in the southwest would be a considerable benefit. Towns within the catchment might draw water from the Blackwood and the redevelopment of existing dryland farms for irrigation along the lower Blackwood Valley, which is currently constrained by water quality, would become feasible. This change in fresh water supply availability could release water from the Harris Dam for use by industry and urban areas further to the north. It requires further work to adequately quantify this benefit. For the purposes of this indicative benefit/cost study it is assumed that a fresher Blackwood River could supply 30% of additional irrigation demands for the Blackwood and Vasse SSDs (i.e. 30% of a total of 100,000 ML/year), and the cost-advantage of a marginal-quality Blackwood River for irrigation use would be around $100/ML ($0.1/m^3). Allowing for a phased up-take, beginning 10 years after the canal-drainage project took place the cost-advantage yields a present value of $13.1million over 30 years, and $16.4 million over 45 years at a discount rate of 7%.

8. SUMMARY AND CONCLUSIONS

8.1 Benefit and cost summary

Tables 15 and 16 summarise the estimated benefits and costs for 30 year and 45 year periods, respectively, for all sectors, for each scenario. It is seen that both reclamation scenarios show positive benefit/cost ratios, of approximately 1.4 to 1.5 over 30 years and 1.6 to 1.8 for a 45-year period. It is notable that in both of the reclamation scenarios the benefits to agriculture alone exceed the control costs. Benefits to road costs, town infrastructure and water supply simply increase the benefit/cost ratio. By contrast, it is extremely difficult to demonstrate an adequate level of benefits for the trend-shifting scenario of the State Salinity Strategy, even based on a 50% reduction in recharge.

Table 15: *Summary of benefit and cost estimates ($ million) for three salinity management scenarios for the Blackwood River Catchment taken over 30 years at 7% discount rate.*

Benefits and Costs	50% Recharge Reduction	No further spread of salt-affected land	100% reclamation plus prevention of further spread	70% reclamation plus prevention of further spread
Present Value of Benefits:				
Increased Agricultural Value Added	36.5	62.1	328.9	249.9
Avoided road costs	10.0	15.0	29.9	20.9
Avoided town and infrastructure costs	nil	nil	10.0	10.0
Reduced costs of land and water management	3.6	6.2	32.5	24.7
Water supply cost savings	nil	nil	13.1	13.1
Total Benefits	**50.1**	**83.3**	**414.4**	**318.6**
Present Value of Costs:				
Operating and maintenance costs	n.a.	n.a.	93.0	63.3
Capital	238.0	n.a.	200.0	151.6
Opportunity cost of land	Excluded	Excluded	Included	Included
Total Costs	**238.0**	**n.a.**	**293.0**	**214.9**
Benefit/Cost Ratio	**0.21**	**n.a.**	**1.41**	**1.48**

Table 16: *Summary of benefit and cost estimates ($ million) for three salinity management scenarios for the Blackwood River Catchment taken over 45 years at 7% discount rate.*

Benefits and Costs	50% Recharge Reduction	No further spread of salt-affected land	100% reclamation and prevention of further spread	70% reclamation and prevention of further spread
Present Value of Benefits:				
Increased Agricultural Value Added	45.3	82.4	381.7	302.7
Avoided road costs	10.0	15.0	5.0	31.0
Avoided town infrastructure costs	nil	nil	10.0	10.0
Water supply benefits	nil	nil	16.4	16.4
Reduced costs of land and water management	4.5	8.2	37.7	30.0
Total Benefits	**59.8**	**105.6**	**490.8**	**390.1**
Present Value of Costs:				
Operating & Maintenance			102.0	69.4
Capital costs	238.0	n.a	200.0	151.6
Opportunity cost of land	Excluded	Excluded	Included	Included
Total Costs	**238.0**	**n.a**	**302.0**	**221.0**
Benefit/Cost Ratio	**0.25**	**n.a**	**1.63**	**1.77**

8.2 Distributional Issues and Cost Sharing

Table 17 shows one way in which the benefits and costs of the partial rehabilitation scheme could be distributed between stakeholders. This table assumes that:

- dryland farmers obtain two-thirds of the benefit of increased agricultural value added as post-tax income
- the Commonwealth obtains 33% of the improvement in agricultural value added through taxes
- dryland farmers pay the ongoing operating and maintenance costs of the project, both on-farm and off-farm
- future irrigation farmers will obtain two-thirds of the benefit of reduced water supply costs in the form of reduced future irrigation water prices
- the Western Australian Government or instrumentalities obtain 100% of the benefits of reduced costs for infrastructure and land management, and one third of the water supply cost savings
- the Western Australian Government contributes its full benefit as a capital contribution to the project
- the Commonwealth makes up the difference between total project costs and the contributions made by the State Government

It is seen that farmers would be the biggest gainers from this distribution of benefits and costs, while the Western Australian Government would be in a zero net cost position and the Commonwealth would be a small loser, to the tune of $14.4 million.

Clearly, with variations in the assumptions and adjustments to the data estimates, there could be a different distribution of benefits and costs. Since there is an overall net benefit of a considerable size it would be possible to redistribute cost contributions so that all stakeholders might gain. The main mechanism for this would be to extract some further cost contribution from the farmers. This could be done differentially over time so that those who joined the project early would pay the least in overall cost contributions. The farming community would be the prime net beneficiary under the distributional arrangements detailed in the table.

Table 17: Net beneficiaries from the partial (70%) rehabilitation scenario, considered over 30 years ($ million)

Benefits and Costs	Total Value of Benefit/Cost	Benefits Received & Costs Paid by: Farmers	State	Commonwealth
Present Value of Benefits:				
Increased Agricultural Value Added	249.9	166.6	nil	83.3
Avoided road costs	20.9	nil	15.9	5.0
Avoided town infrastructure costs	10.0	nil	10.0	nil
Reduced water supply costs	13.1	8.7	4.4	nil
Reduced costs of land and water management	24.7	nil	18.7	6.0
Total Benefits	**318.6**	**175.3**	**49.0**	**94.3**
Total Costs	**221.0**	**63.3**	**49.0**	**108.7**
Net benefit	**97.6**	**112.0**	**nil**	**-14.4**

8.3 Conclusions

This report has incorporated the best available information at the time of writing for estimating the benefits and costs of alternative scenarios for salinity management in the Blackwood River catchment.

It is concluded from the preliminary benefit-cost assessment presented in this report that further refinement of all aspects of the strategy of groundwater pumping, drainage and canal disposal to the ocean - organisational, technical, social, environmental and economic - is well warranted. Based on the net cost alone over 30 years the strategy should be supported as a matter of priority by the Commonwealth and Western Australian Governments.

The rehabilitation scenario based on the drainage/canal strategy is not proposed to entirely replace other approaches for salinity management in the Blackwood River Catchment, if only because, in part, the drainage project would not apply to the all the salinised land in the catchment. There is still a need to reduce the source of water causing the redistribution of salt within the catchment. It is also possible that farmers would combine investment in drainage for salt-affected land with other responses to salinity, including changed crop rotations, saltland pastures, partial re-vegetation for protective purposes and redesigning agricultural landscapes for greater water use and improved sustainability.

Critical factors for economic viability are:

- the proportion of salt-affected land that can be rehabilitated within the drainage scheme. Every increase above 170,000 ha will yield increased net benefits.
- the resolution of engineering issues affecting costs of constructing a canal and system of collector drains;
- the achievement of acceptable levels of operating and maintenance costs at the farm level;
- scheduling of on-farm and off-farm investment streams, and deferment of large capital items until they are absolutely essential; and
- the rapidity with which reclaimed land will be returned to its full productive potential (see Bourgault et al, 1997 for estimation of about 5 years under natural rainfall).

Further economic research is required on a number of aspects, in particular:

- a full, formal sensitivity analysis needs to be undertaken;
- more work should be done on the options available to farmers and land resource managers for effectively combining drainage and other salinity control measures;
- a more detailed evaluation is needed of the benefits flowing to the infrastructure, land management and water supply sectors;
- an economic evaluation is needed of the added benefits and costs of a hydro-electric development utilising the flow in the proposed canal as water passes down the Darling Range escarpment;
- an economic evaluation is needed of the potential to use drained saline water for the mining industry;
- a detailed economic and financial analysis for all stakeholders based on the full feasibility study should be undertaken and used in determining cost-sharing arrangements; and
- the possibility of developing innovative organisational forms for implementation and cost recovery for the project as a whole should be investigated.

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APPENDIX A: STUDY SPATIAL UNITS

The Blackwood River Catchment contains the whole or parts of 20 ABS Statistical Local Areas (SLAs). These SLAs, which are defined in terms of local government boundaries, are listed in Table 18, together with the estimated area of agricultural holdings. The recorded area of agricultural holdings sometimes exceeds the total shire area, because land held by a farmer in another shire may be recorded against the main location of the farm enterprise. Agricultural holdings included both cleared and uncleared areas on alienated land.

Table 18: Area of Local Government Areas (SLAs) lying wholly or partly within the Blackwood River Catchment, and estimated areas of agricultural holdings ('000 ha)

	Total Shire Area	Proportion in Blackwood Catchment	Estimated Area in Blackwood Catchment	Area of Agricultural Holdings in Shire	Est. Area of Agricultural Holdings in Catchment	Estimated Number of Farms in Catchment
Zone 1: High Rainfall Intensive						
Augusta-Margaret R.	224.2	0.56	125.2	120	67	70
Busselton	145.4	0.07	10.3	90	6	30
Donnybrook-Ballingup	156.0	0.38	58.6	80	30	40
Bridgetown	133.9	0.65	87.0	50	33	111
Nannup	293.4	0.73	214.5	35	25	50
Total Zone 1	***952.9***		***495.7***	***375***	***161***	***302***
Zone 2: Mixed cropping/livestock						
Boyup Brook	282.8	0.67	189.5	190	127	170
Kojonup	293.1	0.58	169.6	301	174	156
West Arthur	283.3	0.75	212.9	212	159	138
Williams	230.5	0.18	42.1	185	34	23
Total Zone 2	***1,089.7***		***614.1***	***887***	***494***	***487***
Zone 3: Medium Rainfall wheat/sheep						
Broomehill	117.2	0.40	46.4	112	44	31
Katanning	151.8	1.00	151.8	152	152	107
Narrogin	163.1	0.76	124.5	143	109	95
Wagin	194.7	1.00	194.7	186	186	134
Woodanilling	112.9	1.00	112.9	102	102	67
Total Zone 3	***739.7***		***630.3***	***695***	***594***	***434***
Zone 4: Low Rainfall wheat/sheep						
Gnowangerup	426.7	0.10	43.3	384	39	18
Kent	563.1	0.27	154.4	640	175	46
Dumbleyung	253.9	0.84	214.0	245	206	103
Wickepin	204.0	0.44	89.1	203	89	52
Kulin		0.04	19.1	434	18	7
Total Zone 4	***1447.7***		***519.9***	***1636***	***516***	***225***
TOTAL	**4,230.0**		**2,260.0**	**3,863**	**1,776**	**1,447**

The 20 SLAs include some land that lies outside of the hydrological catchment. In this report the hydrological catchment itself is referred to as the "Blackwood River Catchment". Data for the SLAs are referred to as "the 20 (or in some places 15) SLAs of the Blackwood Catchment".

The 20 SLAs are included in 4 ABS Statistical Sub-Divisions (SSDs), which are broader areas than the SLAs, and which contain some SLAs that lie entirely outside of the Blackwood River Catchment. These SSDs are named Vasse, Blackwood, Upper Great Southern and Lower Great Southern. Data on these SSDs have been used to illustrate some points within this report.

Table 18 also shows the grouping of the 20 SLAs into the four sub-catchment zones used in the analysis of agricultural value added.

APPENDIX B: AGRICULTURAL MODEL

B1. Mathematical Formulation

An Excel spreadsheet model was written to simulate the potential benefits and costs to agriculture of measures to combat land and water salinity. This model compares the likely changes to agricultural value added and salinity control costs under different scenarios for management of salinity. In formal terms the model computes:

$$Z = [S(V_{zts} * C_{zs} - V_{ztN})/(1+r)^{t}] - [(K_{ts} + K_{tN})/(1+r)^{t}]$$

Where:

V_{zts} = estimated agricultural value added for zone z in year t under control scenario **s**

V_{ztN} = estimated agricultural value added for zone z in year t under the "Do-Nothing-New" control scenario

C_{zs} = capture factor for scenario **s** in zone **z;** equal to the proportion of land that is amenable to treatment under the control scenario times the proportion of farmers who are to become involved in the scheme within the treatable area

K_{ts} = estimated control costs (both capital and operating, on-farm and off-farm) in year t under control scenario **s**

K_{tN} = estimated control costs (both capital and operating, on-farm and off-farm) in year t under the "Do-Nothing-New" control scenario

r = discount rate

t = number of years from the time the project starts

Value added for any zone in a given year may be defined as:

$$V = R - C_{V} - C_{F} + T - S$$

Where:

R = farm receipts

C_V = variable operating costs

C_F = fixed operating costs

T = income transfers (e.g. interest, rates, taxes paid)

S = subsidies received (e.g. fuel subsidies)

We have taken the view that over the long term, and for significant changes in the levels of farm output, both variable and "fixed" operating costs should be included in the calculation of value added per hectare because in the long term all costs are variable. This is not a major point, however, as can be seen from inspection of Tables 21 and 22 in Appendix C where most of the farm costs are actually variable. Thus, we have assumed that both fixed and variable costs will be incurred on any reclaimed land and that savings of both fixed and variable cost will be made if land becomes salt-affected.

The operational costs attributable to groundwater pumping or on-farm drainage in the rehabilitation scenario are included in the term K_{ts}

The financial costs of investment in farm machinery and farm improvements, mainly interest and debt repayments, are excluded as they are serviced out of farm income, or other financial resources of farm owners. To the extent that a larger total area of farmland may result from any salinity control scenario, this may require additional levels of general agricultural capital replacement over time, as compared with the "Do-Nothing-New" scenario, which generates a smaller total farmed area. These additional costs have not been included in the calculations of agricultural benefits from the salinity control scenarios.

B2. Data

In order to make estimates of benefits it was necessary to develop estimates of agricultural returns and costs for different farm types within the catchment. To do this, Australian Bureau of Statistics (ABS) data on the value of agricultural production in each shire were combined with ABARE data on typical costs for different kinds of farming, to arrive at an estimate of value added per hectare generated directly from farming (see Appendix C). The products of the Blackwood River catchment are generally saleable at world prices on international markets. Therefore, an increase in the volume produced will have no discernible effect on prices received. Thus, total farm receipts, **R**, are simply production volume times expected price.

It is assumed that all land that remains in productive condition will continue to have the same returns and costs per hectare as the current land use. It is also assumed that each hectare of agricultural land that is either successfully protected from salinisation or is reclaimed, ***will have the same proportional pattern of land use, and returns and costs per hectare, as currently exists on agricultural land in the particular SLA***. For example, if one third of the area of agricultural holdings in an SLA is typically used for cereal cropping, then it is assumed that a third of any reclaimed or protected land will be used in that way. By implication, it is assumed that reclaimed or protected land will be fully productive.

B3. Spreadsheet

An Excel spreadsheet implements the mathematical model outlined above. The key variables, values of which must be entered by the user, are:

- the current percentage of total area of agricultural holdings which is salt-affected in each zone
- value added per hectare of total agricultural holdings at the current salinity level in each zone
- the number of years into the future at which given proportions of salt-affected land (ranging from zero to 0.4) are to be expected in each zone under (i) the "Do-Nothing-New" scenario and (ii) the particular control scenario being evaluated: this is termed the "salinity trajectory" for the particular zone
- the number of years over which benefits and costs are to be counted
- the chosen discount rate
- whether or not salt-affected land is to be reclaimed
- the "capture rate" for the reclamation scheme, defined as the product of (i) the proportion of each zone addressed by the reclamation scheme, and (i) the proportion of farms in the reclamation area which will participate
- establishment and operating costs of the control scenario: the costs of a control scenario are specified in terms of capital costs, including engineering costs or costs for establishing e.g. new tree-planting or saltbush pastures. In the case of a scenario that involves the commitment of land to unproductive vegetation an estimate of the opportunity cost of lost production may also be entered as a cost of the particular control scenario. Operating costs of on-farm groundwater pumping and drainage have also been included here.

The user simulates the effects of different salinity control scenarios by changing the number of years into the future at which a given percentage of total farmed area is expected to become saline, or to be reclaimed, in each zone. The model then calculates the discounted agricultural value added and control costs, using the predicted area of productive land (equal to total area of farm holdings minus the proportion that is salt-affected at each future point in time).

APPENDIX C: AGRICULTURAL PRODUCTION DATA FOR THE BLACKWOOD CATCHMENT

Table 19: Resource utilisation on farms in 15 SLAs of the Blackwood Catchment, 1996-97.

	Number of Farms	Areas (ha) or Stock numbers
Total area of holding (ha)	1,992	2,528,633
Crops and pastures for hay - total area (ha)	1,027	33,189
Wheat for grain - area (ha)	868	319,474
Oats for grain - area (ha)	1,368	122,918
Barley for grain - area (ha)	1,064	145,967
Triticale for grain - area (ha)	23	1,050
Total area (ha) of all Cereals for grain	**1,581**	**589,542**
Legumes for grain - total area (ha)	603	67,635
Canola - Area (ha)	294	27,119
Vegetables for human consumption - Area (ha)	19	454
Citrus fruit - Total tree number	8	3,651
Pome fruit - Total tree number	29	26,458
Nuts: total tree number	11	4,540
Grapes - Total area (ha)	25	81
Breeding ewes, 1 year and over (at 31 March)	1,636	3,347,367
Lambs and hoggets under one year (at 31 March)	1,590	1,688,289
Sheep number, excluding lambs (at 31 March)	1,733	5,277,443
Total number of sheep and lambs (at 31 March)	**1,743**	**6,965,732**
All other sheep number (excluding breeding ewes)	1,682	1,930,076
Dairy cattle (excludes house cows) at 31 March	15	2,699
Meat cattle at 31 March - total number	644	106,110
Pigs, total number	126	64,074
Layers, hens and pullets - number at 31 March	8	7,895
Meat chickens, total number held at 31 March	3	5,850

Source: based on data from Australian Bureau of Statistics Agricultural Census, 1996-97; the data relate to whole shires, including parts outside of the Blackwood River Catchment.

Shires included:

Zone 1:
Bridgetown-Greenbushes
Nannup

Zone 2:
Boyup Brook
Kojonup
West Arthur
Williams

Zone 3:
Broomehill
Katanning
Narrogin T
Narrogin S
Wagin

Zone 4:
Kent
Woodanilling
Dumbleyung
Wickepin

Table 20: Gross Value of agricultural production in 15 SLAs of the Blackwood River Catchment in 1996-97.

Commodity of Farm Production	Value of Production ($ million)	(%)
Total pastures cut for hay	2.4	0.48
Wheat for grain	132.7	26.21
Oats for grain	30.8	6.08
Barley for grain	50.3	9.93
Triticale for grain	0.3	0.05
Cereals for grain total	**214.0**	**42.27**
Legumes for grain	14.6	2.88
Pome fruit	1.0	0.20
Stone fruit	0.4	0.08
Total orchard fruit including nuts	**1.4**	**0.29**
Grapes	0.1	0.03
Wool	142.8	28.20
Milk	3.2	0.63
Sheep and lambs slaughtered	54.3	10.73
Cattle and calves slaughtered	22.6	4.46
Pigs slaughtered	17.3	3.42
Summary totals:		
Total fruit	1.6	0.32
Total crops (excluding pastures & grasses)	258.6	51.07
Total livestock slaughterings	94.7	18.70
Total livestock products	150.0	29.63
Total value of agriculture	**506.3**	**100.00**

Source: based on data from Australian Bureau of Statistics Agricultural Census, 1996-97; the data relate to whole shires, including parts outside of the Blackwood River Catchment.

Shires included:

Zone 1:

Bridgetown-Greenbushes

Nannup

Zone 2:

Boyup Brook

Kojonup

West Arthur

Williams

Zone 3:

Broomehill

Katanning

Narrogin T

Narrogin S

Wagin

Zone 4:

Kent

Woodanilling

Dumbleyung

Wickepin

Table 21: Commodity composition of farm output in the Blackwood River catchment in 1995-96, by principle types of farming ($/ha of total farm area).

Commodity of Farm Output	Intensive Crops -Livestock Zone (i)	Mixed Grains -Livestock Zone (ii)	Medium Rainfall Wheat-Sheep Zone (iii)	Low Rainfall Wheat-Sheep Zone (iv)
Total pastures cut for hay	16.16	1.16	0.03	0.02
Wheat for grain	0.51	4.93	61.60	99.27
Oats for grain	2.31	16.21	17.48	4.69
Barley for grain	1.97	18.64	22.26	20.98
Triticale for grain	0.03	0.18	0.04	0.07
Total Cereals for grain	**4.89**	**39.97**	**101.38**	**125.01**
Legumes for grain	0.35	3.01	7.02	8.14
Citrus fruit Total	0.10	0.01	0.00	0.00
Pome fruit total	10.53	0.13	0.00	0.00
Total Stone fruit	4.59	0.01	0.01	0.00
Total orchard fruit including nuts	15.51	0.14	0.01	0.00
Grapes	0.18	0.15	0.00	0.00
Wool	**29.66**	**88.31**	**53.82**	**28.45**
Milk	33.48	0.34	0.00	0.00
Sheep and lambs slaughtered	16.97	32.25	20.71	11.50
Cattle and calves slaughtered	123.69	11.23	2.00	0.89
Pigs slaughtered	2.20	6.17	12.04	3.77
Summary totals $/ha:				
Total value of fruit	15.84	0.30	0.01	0.00
Crops (excluding pastures & grasses)	55.85	57.17	121.25	138.03
Livestock slaughterings	143.93	49.75	35.04	16.22
Total livestock products	63.83	90.97	55.36	29.42
Total Receipts - $/ha	**279.88**	**199.29**	**211.89**	**183.97**

Source: calculations based on ABS Agricultural Census data, 1996-97

Shires included:

1. Bridgetown-Greenbushes and Nannup Shires
2. Boyup Brook, West Arthur, Williams and Kojonup Shires
3. Broomehill, Katanning, Narrogin, Wagin and Woodanilling shires
4. Dumbleyung, Kent and Wickepin Shires

Note: Summary totals may exceed detailed commodity values, due to excluded items in ABS records

Table 22: Average receipts and costs in the Wheat & Other Crops Industry, Western Australia, 1994-95 to 1998-99: ($/ha of total farm area)

	1994-95	1995-96	1997-98	1998-99
Cash Receipts ($/ha)				
Sales:				
Sheep	6.21	7.02	8.11	7.75
Beef cattle	0.71	0.80	0.64	0.05
Other livestock	0.69	0.46	1.31	0.89
Wool	15.21	10.97	14.78	8.74
Wheat	108.93	128.26	130.69	129.23
Barley	5.56	13.64	17.06	9.90
Grain legumes	17.35	18.58	21.62	18.64
Other crops	0.94	3.54	7.69	17.88
Off-farm share-farming	0.23	0.31	1.02	2.23
Off-farm contracts	1.09	0.74	4.06	3.91
Other cash receipts	5.24	6.20	7.45	6.15
Total Cash Receipts - $ per hectare	**162.15**	**190.51**	**213.46**	**205.38**
Cash Costs ($/ha)				
Livestock purchases:				
Sheep	1.84	1.99	2.27	3.20
Cattle	0.17	0.47	0.19	0.00
Hired labour	3.39	3.42	3.60	6.44
Shearing & crutching	2.60	3.03	3.18	3.09
Fertiliser	21.09	23.23	29.10	30.06
Fodder	0.26	0.27	0.51	0.20
Crop/pasture chemicals	15.77	14.92	22.96	24.43
Fuel, oil, grease	8.37	8.09	9.40	10.15
Repairs & maintenance	11.71	11.22	14.43	14.19
Other materials	3.22	3.21	4.24	4.45
Contracts	1.67	2.09	2.87	2.98
Rates	2.03	1.99	2.27	2.30
Other services	36.01	41.66	45.34	51.39
Interest	7.66	8.10	8.01	7.91
Rent	1.27	2.38	0.48	1.77
Payments to share-farmers	0.00	0.66	0.00	0.00
Other cash costs	0.05	0.15	0.05	0.17
Total Cash Costs - $ per hectare	**117.11**	**126.86**	**148.89**	**162.74**
Receipts minus Costs plus Transfers ($/ha)				
Cash Operating Surplus	45.04	63.65	64.58	42.64
Plus Transfers	14.36	16.00	14.35	18.43
Agriculture Value Added $/ha	**59.40**	**79.53**	**78.93**	**61.07**

Source: calculations based on data from ABARE Farm Surveys, Western Australia

Transfers = Hired labour + rates + interest paid + rent.

Value added/ha of total agricultural holdings assumed in spreadsheet calculations = $70/ha for Zones 3 and 4 at the current percentage of land which is salt-affected in those zones.

Table 23: Average receipts and costs in the Mixed Livestock/Crops industry, Western Australia, 1994-95 to 1998-99: averages $/ha of total farm area

	1994-95	1995-96	1997-98	1998-99
Cash Receipts ($/ha):				
Sales:				
Sheep	18.28	26.51	21.84	19.72
Beef cattle	5.31	6.84	2.16	3.05
Other livestock	9.59	0.27	1.35	0.16
Wool	53.54	46.79	45.77	27.92
Wheat	46.41	47.91	63.09	83.35
Barley	14.53	18.90	24.17	9.97
Grain legumes	4.35	3.86	7.60	8.02
Other crops	12.63	10.11	12.81	24.80
Off-farm share-farming	0.30	0.62	0.24	1.19
Off-farm contracts	2.24	5.31	5.80	2.17
Other cash receipts	4.05	8.12	7.28	6.45
Total Cash Receipts - $ per hectare	**171.23**	**175.24**	**192.10**	**186.81**
Cash Costs ($/ha):				
Livestock purchases:				
Sheep	5.60	4.65	3.17	3.02
Cattle	0.15	1.36	0.10	1.22
Hired labour	3.14	3.54	5.01	4.77
Shearing & crutching	8.38	10.60	9.44	6.84
Fertiliser	17.44	19.82	23.40	28.55
Fodder	2.50	2.51	2.15	0.46
Crop/pasture chemicals	7.74	7.05	14.46	16.33
Fuel, oil, grease	7.51	8.14	8.93	9.13
Repairs & maintenance	12.18	14.62	13.64	12.52
Other materials	6.75	7.43	7.72	6.64
Contracts	2.85	2.74	4.43	4.14
Rates	2.49	3.33	3.25	2.88
Other services	33.85	37.01	41.40	40.46
Interest	10.31	9.60	11.46	12.15
Rent	1.16	0.35	2.16	1.10
Payments to share-farmers	0.08	0.00	0.14	0.77
Other cash costs	7.81	0.05	0.15	1.60
Total Cash Costs - $ per hectare	**129.95**	**132.82**	**150.99**	**152.59**
Receipts minus Costs plus Transfers ($/ha)				
Cash Operating Surplus per hectare	41.28	42.42	41.12	34.22
Plus Transfers	17.10	16.82	21.87	20.90
Agriculture Value Added $/ha	**58.38**	**59.24**	**62.99**	**55.12**

Source: calculations based on data from ABARE Farm Surveys, Western Australia

Transfers = Hired labour + rates + interest paid + rent.

Value added per ha assumed in spreadsheet calculations = $60/ha for Zone 2 at the current percentage of land which is salt affected in this zone.