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Stream Salinity Issues In Western Australia And Approaches To Their Management

Report No. WS 14
March 1988

LEGISLATIVE COUNCIL
SELECT COMMITTEE ON SALINITY

STREAM SALINITY ISSUES IN WESTERN AUSTRALIA AND APPROACHES TO THEIR MANAGEMENT

A submission by the
Water Authority of Western Australia

March 1988

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Magnitude of the Stream Salinity Problem

The impact of agricultural development on the levels of stream salinity in the south-west of Western Australia has been dramatic. Less than 50% of the divertible surface water resources remain fresh. Some 35% are so affected that they are no longer potable and a further 17% are of marginal quality and will require active management of their catchments to minimise or reverse further deterioration. Damage costs to the Western Australian community caused by increased stream salinities are at least $35 million per annum.

The salinity levels of virtually all rivers draining agricultural land in areas with rainfall of less than 900 mm per annum are continuing to deteriorate. Much higher salinities than expected have been recorded on some streams where streamflow volumes have been particularly low in recent dry years. Current expectations of the "Greenhouse Effect" suggest that the drying climate will exacerbate current stream salinity problems in the medium term (20-30 years).

Actions to Control Stream Salinity

Western Australian Government action to control both release of crown land and clearing on private land in the south-west was one of the earliest preventative measures in Australia to manage a major non-point source pollution problem. Approximately $35 million has been spent over the last 12 years to prevent agricultural development of approximately 64 000 ha of forest in the salt sensitive regions of the five most important marginal water resource catchments.

Some $10 million has been spent on the purchase and reforestation of farmland. Over three million seedlings have been planted in the eastern portions of the Wellington and Mundaring Reservoir catchments. Over $35 million are expected to be spent over the next few years on developing alternative water resources to replace current town supplies which have excessive salinities.

Administrative controls and related environmental agreements have limited intensive logging and mining operations in the more salt-sensitive portions of State Forest. These measures have been an important part of the regional strategy to protect water resources from increases in stream salinity. Associated research programmes have greatly improved our knowledge of the salinity problem and have assisted in the development of remedial salinity management strategies.

Adequacy of Current Control Measures

Actions to control stream salinity have developed over the last 15 to 20 years and have made important contributions to water resource management and native forest conservation. Nevertheless they are not without their difficulties.

The controls on alienation of crown land and control of clearing in critical water resource catchments have been cost effective means of limiting further larger scale salinity deterioration of strategically important water resources. Unfortunately in many cases these preventitative strategies were introduced too late to be effective by themselves in controlling stream salinity. Current expectations are that the "Greenhouse Effect" will exacerbate the stream salinity problem. In view of this concern a re-evaluation is required of current means of protection of sensitive catchments.

There is also concern that, although compensation has been paid to stop large-scale agricultural development in sensitive catchment areas, there are no means of ensuring the long term viability of remnant forest vegetation on farmland.

The reforestation programme in the Collie River catchment has been an essential element in minimising deterioration of inflow to Wellington Reservoir. The current programme should maintain adequate, if marginal, supply salinities for irrigation but will not be sufficient to return the supply qualities from Wellington Reservoir to potable levels. An expanded programme of catchment rehabilitation will be required. Other catchments are also likely to require active ameliorative management if their water resources are to be returned to potable levels.

Future Directions for Salinity Control

To date catchment management methods have involved legislative controls and government managed projects to maintain or improve stream salinities. A more integrated farm and forestry approach to land management is required. Land management methods need to be developed which involve combinations of the current non-commercial tree plantations of high salt tolerance and high water using capacity, with commercial tree plantations and more water consuming agricultural strategies. Specifically there needs to be a major new thrust to encourage commercial tree planting programmes, upslope from non-commercial plantings in the most critically important water resource catchments.

A far greater effort is also required in agronomic research to develop new perennial grasses, crops and shrubs which will minimise groundwater recharge in agricultural areas of the 600 to 900 mm rainfall zone of the Darling Range.

Specific Future Actions

The following points are seen as high priority for the State Government, its relevant Departments and the Water Authority to pursue over the next 2 to 5 years.

(i) Continue tight control over agricultural development in salt sensitive areas of catchments gazetted under the Country Areas Water Supply Act. Develop a strategy to ensure the long term viability of remnant native vegetation on farm lands.

(ii) In the light of the possible consequences of the "Greenhouse Effect" on stream salinities, review existing river systems with fresh or marginal salinities to re-evaluate whether existing administrative actions to protect their water quality are adequate and recommend future action as appropriate.

(iii) Continue the current programme of reforestation and related research work on Wellington Reservoir catchment to the planned level of 8000 hectares.

(iv) Strongly encourage the development of an integrated approach to commercial tree plantations and lower slope plantations for salinity control. Develop more efficient agronomic practices that are both practical and effective in reducing groundwater recharge. Moreover, encourage the overall integration of agronomic methods and forestry enterprise on farms through extensive farm and catchment planning so that both land productivity is increased and stream salinity decreased. In particular, actively pursue the first major investigation and development of an integrated catchment management plan on the Upper Denmark Catchment.

(v) In light of the above, formulate a new general strategy for catchment management in the Wellington Reservoir Catchment with the aim of restoring the total resource to potable levels in the longer term.

(vi) Evaluate the economic consequences of these new land management approaches and assess the long term economic benefit of protecting water resource quality, with the view of evaluating incentive schemes to increase their application on high priority water resource catchments.

(vii) Support the development of such an integrated approach to land and water management issues with active research and development programmes which concentrate on resolving the stream salinity problem in the 600 to 900 mm rainfall zone of the Darling Range.

(viii) Develop means of implementing Transferable Water Entitlements to encourage more efficient water use in the Collie, Harvey and Waroona irrigation districts and thereby reduce irrigation induced salinity problems.

1. INTRODUCTION

Increases in stream salinity following agricultural development was recognised as a serious problem by water supply and railway engineers in the early part of this century. While concern about salinity has waxed and waned since, the last 20 years have seen a major effort to investigate, understand and quantify the problem. Moreover, the past 15 years has seen the commencement of controls and amelioration measures to protect and improve the salinity of major water resources of the region. Today, the integrated management of land and water resources to protect water quality is one of the most important and most difficult tasks facing the Western Australian community. It is being actively addressed by State Government agencies responsible for land and water matters, and is of major interest to farmer groups, particularly Soil Conservation Advisory Committees, and many voluntary environmental groups.

This submission concentrates on the water resource impacts of salinity and only notes the environmental and land degradation aspects of salinity. The Water Authority recognises the major impact that salinity has had on land productivity and is concerned about the impact of salinity on stream ecology and the surrounding streambank environment. It is believed that these issues will be discussed more fully in other submissions.

2. MAGNITUDE OF THE PROBLEM

2.1 Regional Water Resource Impacts

The magnitude of the impact of agricultural development on water resource quality can be gauged by its impact on the total divertible surface water resources of the south-west. The total divertible resource is an estimation of the maximum amount of water which could be diverted from potential dam sites, usually located at the lowest point of development on major river systems.

Prior to agricultural development virtually all the divertible surface water resources were believed to be fresh. Current estimates of the water resources inventory indicate that only 48% remain fresh and 35% have become so saline they are no longer potable. The remaining 17% are of marginal quality and require active catchment management to minimise their further deterioration. Definitions of the salinity levels for fresh, marginal, brackish and saline waters are given in Table 1.

TABLE 1 WATER RESOURCE SALINITY CLASSIFICATIONS

Classification	Salinity Level
Fresh	Less than 500 mg/L Total Soluble Salts (TSS)
Marginal	Greater than 500 mg/L and less than 1000 mg/L TSS
Brackish	Greater than 1000 mg/L and less than 5000 mg/L TSS
Saline	Greater than 5000 mg/L TSS

Note Fresh and marginal waters are generally classified as potable (drinkable). Waters between 1000 mg/L and 1500 mg/L TSS are commonly quite safe to drink although they have a distinct salty taste.

The "Water 2000" report on Salinity Issues, prepared for the Commonwealth Government in 1983, estimated that the annual damage costs due to salinity in Western Australia was $37 million (1982 values). In December 1987 dollar terms the damage cost would be $55.5 million. Of this, about $35 million could be attributed to water salinity problems. More recent assessments in Victoria would suggest that the real costs are much higher, possibly twice as large.

The impact of agricultural development on the quality of large scale water resources has therefore been dramatic.

2.2 Local Water Resource Impacts

The impact on local smaller scale resources has also been substantial and probably underestimated. There is virtually no area, with an annual rainfall less than 900 mm per annum in the south-west, where a creekline dam can supply potable water if agricultural development has occurred within its catchment. Average annual salinities of creeks and rivers draining agricultural areas are invariably brackish or saline. Farm water supplies in this region are usually restricted to very small storages which collect seepage and runoff water from hillsides.

Agricultural development in the 900 to 1100 mm rainfall zone of the Darling Range has also led to significant increases in stream salinity. Average annual salinities can range between fresh and marginal levels depending on the degree of clearing and local characteristics of soil salt storage. Low flows at either the start or end of the season are frequently brackish. This deterioration has restricted the ability to utilise small resources for either potable water or small-scale irrigation of fruit and vegetable crops.

2.3 Salinity Levels, Trends and Predictions

Table 2 summarises the average salinities from the last five years of record for major rivers in the south-west. Also included are the annual average rates of increase in salinity over the last 20 years. The salinities of all major river systems are continuing to increase. Actions have been taken to control further clearing on the most critical existing and potential water supply catchments (Sections 3.2, 3.3 and 3.4). However, because of the slow response of groundwater systems affected by clearing, increases in salinity as a result of previous agricultural development can be expected to continue well into the next century.

The delay times to reach the peak effect vary with annual average rainfall. Delay times of order 10 to 20 years occur in the high rainfall area of the Darling Range, but can increase to well over 100 years in the eastern wheatbelt region of low rainfall. In the eastern portion of catchments of major concern to the Water Authority, groundwater simulation studies suggest that peak streamflow salinities will be within 5% of their peak by the year 2010, some 30-40 years following the last large-scale clearing. Further deterioration will gradually occur until ultimate peak levels are reached by the year 2040.

The time scales for salinities to naturally decrease as salts are gradually leached from the landscape are much longer. The current estimates are of the order of 200 to 500 years for areas of major concern to the Water Authority. Time scales would be considerably longer for the agricultural wheatbelt areas.

TABLE 2 STREAM SALINITY TRENDS OF MAJOR RIVERS

Catchment	NGSN (1)	Period of record	Area cleared (%)	Average salinity over last 5 years of record (mg/l)	Rate of salinity increase since 1965 (mg/l/yr)
Denmark R	603136	1960-86	17	890	26
Kent R	604053	1956-86	40	1870	58
Frankland R	605012	1940-86	35	2192	74
Warren R	607220	1940-86	36	870	15
Perup R	607004	1961-86	19	3410	117
Wilgarup R	607144	1961-86	33	863	14
Blackwood R	609025	1956-86	85	2192	58
Capel R	610129(2)	1959-76	50	423	14
Preston R	611049	1955-75	50	354	11
Thomson R	611111	1957-85	45	534	17
Collie R	612033	1940-86	24	730	24
Murray R	614006	1939-86	75	2792	93
Williams R	614196	1966-86	90	2425	95(3)
Hotham R	614224	1966-86	85	3711	89(3)
Wooroloo Bk	616001	1965-86	50	2092	39
Brockman R	616019	1963-86	65	2040	72
Helena R	616216	1966-85	10	1257	48(3)

Notes
(1) NGSN - National Gauging Station Number
(2) Also includes record from 610219
(3) Salinity trends are all statistically significant except those marked

Figure 1 shows the increase in salinity of inflow to Wellington Reservoir over time. It is typical of many of the major streams in the south west. Also shown are predictions of the effect of previous clearing and of the effect if clearing controls had not been introduced. Figure 2 shows the salinity trends of three other major river systems in the south-west. Table 3 shows the predicted average salinities of the five most important marginal water resources.

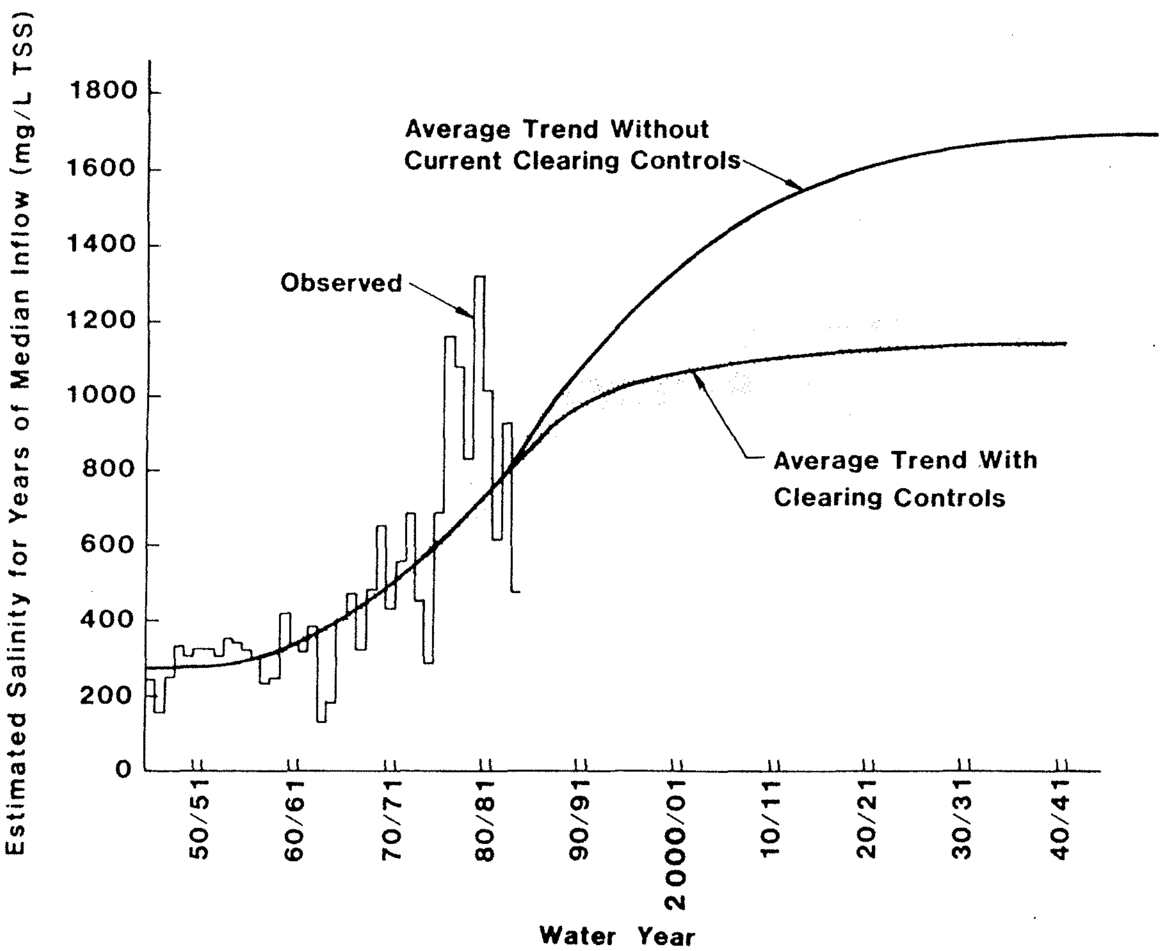


Figure 1 Observed and projected inflow salinities to Wellington Reservoir

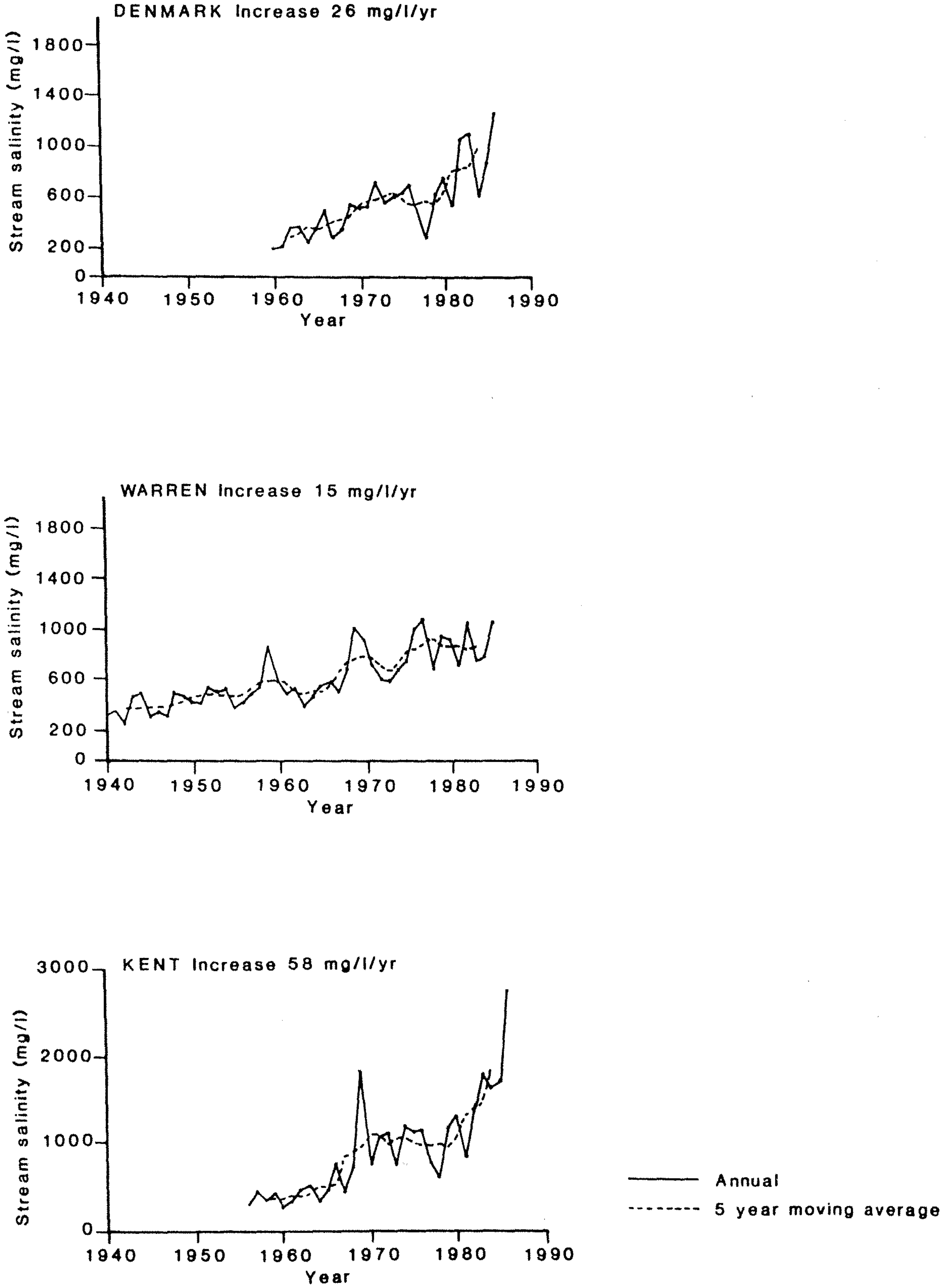


Figure 2 Stream salinity trends on three major river systems in the south-west

TABLE 3 SALINITY PREDICTIONS FOR THE MOST IMPORTANT MARGINAL WATER RESOURCES

River	Catchment area (km^2)	State Forest & Reserves (%)	Private land		Ultimate average salinity resulting from clearing to date* (mg/l)	Estimated Average Salinity if all privately owned land were cleared (mg/l/yr)
			Uncleared (%)	Cleared (%)		
Collie	2830	65	12	23	1150	1700
Helena	1470	95	2.5	2.5	665	1030
Denmark	567	79	5	16	720	790
Warren	4040	54	14	32	1270	1500
Kent	1850	45	15	40	1500	2120

* Estimates for Helena, Warren and Kent Catchments based on studies in 1981. Estimates for Collie and Denmark are based on 1986 studies.

* Figures do not include any allowance for the Greenhouse Effect.

2.4 Salinity Variability and the Effect of Dry Years

Salinities can vary dramatically from day to day, season to season and year to year. As salinities increase over time the rate of increase tends to be larger in the drier years.

Dry years in the late 1970s and the mid 1980s caused some particularly high stream salinities and emphasised the severity of the problem. In two cases, small town water supplies (Balingup and Denmark) were so adversely affected that it necessitated the planning and development of expensive alternative sources. In the Denmark River case the average salinity over the last 5 years has been higher than the predicted long term average for past clearing. Streamflows over this period have been particularly low.

High salinities in Wellington Reservoir (Collie River catchment), partly as a result of the dry years and partly as a consequence of the rapid clearing within the catchment in the 1960s and early 1970s, has also necessitated the development of a major new source for the Great Southern Towns Water Supply Scheme (The Harris Dam Project).

The salinity variations of large river systems such as the Kent, Frankland, Blackwood and Avon, are particularly complex. The salinities are strongly affected by the distribution of rainfall within the catchment each winter and the resultant proportions of salt and water eminating from the cleared and forested portions of the catchment. High salinities generally occur in dry years. There can be cases, however, where there is insufficient streamflow from agricultural areas of the catchment to transport salts down the river system. Lower than expected salinities in such dry years can result.

2.5 The "Greenhouse Effect"

Climatologists have predicted significant global warming as a result of an increasing accumulation of "greenhouse gases" in the atmosphere. The expected changes of climate in the south-west of Western Australia are likely to significantly reduce winter rainfalls.

Climatic change will therefore alter the catchment water balance and cause further changes to the salinity regime of rivers. Changes in saline discharge will respond to these reductions in rainfall much more slowly than will changes in volume of streamflow. Stream salinities are therefore expected to increase more severely for 20-30 years than would occur without climate change. The longer term effect of climatic change on stream salinity is less certain.

If, as expected, stream salinity tends to increase in the medium term the most significant effect would be on water resources now classified as marginal in salinity terms. These rivers are those now subject to current priority in reclamation and control effort. They include the Collie River for which further decline could be critical to a major part of the south-west irrigation district. Any permanent degradation of these marginal rivers will place increased pressure on the remaining resources of the south-west. Under climate change, currently fresh resources could become marginal. Examples could include the Donnelly, Deep and Thompson Brooks.

2.6 Salinity in Irrigation Districts

The Department of Agriculture has estimated that 6200 hectares (17.8%) of the Waroona, Harvey and Collie Irrigation Districts are salt affected. A further 6000 hectares (17.3%) is marginally affected. The problem is caused by high soil salt concentrations in the plant root zone resulting from the close proximity of underlying saline water tables. No evidence is available to indicate that salinity problems in the Collie Irrigation District have been caused by the high salinity of supply from Wellington Reservoir.

Nevertheless salinity problems in the irrigation districts are serious. Continued irrigation of low permeability soils where high underlying saline water tables exist, will exacerbate the current salinity problem.

3. ACTIONS TO CONTROL STREAM SALINITY

3.1 Control of Alienation of Crown Land

The need to control both clearing and release of Crown land on water supply catchments was recognised in the early part of the century on Mundaring catchment. During the 1950s the need to control further alienation of Crown land on Wellington catchment was recognised, when the dam was being raised to provide additional irrigation water demand and to provide the source for the Great Southern Towns Water Supply Scheme. Administrative action to control the release of crown land on the Kent and Denmark river systems proceeded in the early 1960s. In 1977 a State Cabinet decision was made to halt all alienation of Crown land between the Collie River and the Kent Rivers to protect other potential water reserves in the lower south-west.

3.2 Controls on Clearing Native Forest

Through the 1960s there was a growing awareness that control of alienation of Crown land would not be sufficient to maintain satisfactory salinity levels in a number of major water resources. Action would be required to halt clearing on already alienated land. However, it was not until the mid-1970s that legislation to control such clearing was seriously considered. In 1976 amendments to the Country Areas Water Supply Act (1947) were passed by both houses of parliament. The legislation made it an offence to clear or destroy native vegetation without a licence and was applied initially to the catchment of Wellington Dam. In 1978 the legislation was extended to four other critically important water resource catchments. These were Mundaring reservoir catchment, the Warren and Kent water reserves and the Denmark river catchment. While small scale essential clearing is licenced, large-scale agricultural development is not permitted. Farmers affected can claim compensation for their inability to further develop their farm enterprise. Table 4 summarises the expenditures on compensation and the areas protected from further agricultural development on the five catchments concerned. Table 3 indicates the difference in expected ultimate salinities with and without control of private land clearing.

The main thrust of this legislation was prevention of further deterioration of salinity. The catchments were carefully selected to represent those most sensitive to further agricultural expansion. Catchments which were already too saline to be potable were not included under the legislation. These tended to be catchments which drained the main inland wheatbelt of the south-west. Catchments that drained predominantly State forest and were fresh and unlikely to become saline, even if the small amount of private land in their catchments were cleared, were also not included.

TABLE 4 - EXPENDITURE OF SALINITY CONTROL
(Excluding Reforestation)

CATCHMENT	Compensation/ Land Purchase $ million	Research and monitoring $ million	Total $ million	Areas Refused (ha)
Warren	12.8	.12	12.9	25 960
Kent	8.4	.06	8.5	20 250
Denmark	1.2	.10	1.3	2 520
Mundaring	0.9	.08	1.0	2 150
Wellington	9.9	.93	10.8	13 680
TOTAL	32.2	1.29	34.5	64 560

(1) The areas refused reflect areas quoted on farmer applications which were subsequently refused and do not completely reflect the areas for which compensation for injurious affection has been paid.

3.3 Protection of Existing Forested Catchments

Parallelling the control of clearing of private land was a strategy to ensure protection of the existing forest cover. In 1973 more intensive logging operations associated with the growing woodchip industry were excluded from the salt sensitive north-eastern sector of the Woodchip Licence Area. In 1978 the expansion of bauxite mining in the Darling Range enabled renegotiation of agreements between Alcoa and the State to restrict bauxite mining in the intermediate and lower rainfall zones of the Darling Range until research showed that it was safe for such operations to take place without adversely affecting salinity.

3.4 Reforestation (Wellington and Mundaring)

Estimates in the late 1970s indicated that, with clearing restrictions as the only control measure, the salinity of inflow to Wellington Reservoir was expected to rise to an average of 1100 mg/l TSS by the year 2010. This average could then be expected one year in two. In extremely dry years the salinity could reach a peak of approximately 1800 mg/L TSS by about 2010. As this quality is unacceptable for both drinking and irrigation purposes and would limit the future utility of the presently uncommitted yield, partial reforestation of cleared farmland to reverse the salinity trend commenced in 1979 in the drier parts of the catchment. The partial reforestation programme was initially proposed to run for 6 to 10 years, the target 2000 hectares being planted each year. However, due to the limited availability of land and other practical limitations, the replanting rate actually achieved has been between 700 and 800 hectares per year. A total of 5150 hectares (1987 inclusive) have now been planted. Table 5 summarised the expenditures on reforestation.

TABLE 5 EXPENDITURE ON REFORESTATION

CATCHMENT	Cleared (1) Land Purchased For Reforestation $ million	Direct Reforestation Costs $ million	Research and Monitoring $ million	Total $ million	Areas Replanted (ha)
Wellington	5.8	3.16	0.54	9.5	5150
Mundaring	0 (2)	0.25	0.08	0.35	500
TOTAL	5.8	3.41	0.62	9.9	5650

(1) As whole properties are purchased with cleared and forested portions precise definition of costs of land associated with reforestation is not possible.

(2) Properties purchased in the 1960s before the introduction of the clearing control legislation.

The reforestation strategy involves planting on the valley bottoms and lower sideslopes, the remaining middle and upper slopes providing viable strips of cleared farmland which would then be exchanged for adjacent lower slope farmland, to further extend the area of reforestation. The separation of the costs specifically for reforestation from those of compensation is difficult. However some $3.4 million has been spent directly on the planting programme and approximately $6 million is considered an approximate estimate of the cost of acquiring the associated cleared farmland. By 1984 sufficient land had been purchased to enable approximately 8,000 hectares to be planted if subsequent land exchange is efficient. The additional planting cost is likely to be a further $2 million, making a reforestation total of about $11-12 million. This reforestation, which will take several years to complete, in the longer term will exert some control on salt discharges from 18500 hectares of the 51,000 hectares of cleared farmland on highly salt susceptible zones of the catchment.

Figure 3 gives the best estimate of the likely effects of this reforestation on the inflow salinity of Wellington Reservoir. The figure provides a range of effectiveness of the reforestation programme. If the reforestation were moderately effective (70%) inflow salinities could be expected to peak at around 1000 mg/l TSS in an average year in the early 1990s. Levels of around 1600 mg/l in a run of dry years, however, could occur. As the effect of the reforestation programme becomes more pronounced, inflow salinities to Wellington reservoir could be expected to stabilise at about 950 mg/l in an average year and around 1500 mg/l in a dry year (around the year 2010).

Some 500 hectares have been planted on the Mundaring catchment by the Department of Conservation and Land Management. These have been planted on existing land repurchased by the Water Authority through the 1960s. Expenditure on this reforestation has been approximately $250,000.

3.5 Engineering Solutions

Studies have shown that saline diversions are very costly. Investigations have taken place of diversion options for the eastern Collie River branches, in the Upper Warren River and for the Upper Kent catchment. All have been very expensive and problems of disposal of the saline effluent are significant and cause a substantial environmental problem. Nevertheless, alternative sources have been necessary to supply current water supply demands because clearing control strategies and reforestation programmes were introduced too late to avoid the necessity for shorter term engineering solutions. Augmentation of the Balingup Town Water Supply was necessary in 1982/83 to improve the towns supply quality. Capital expenditure of about $250,000 was necessary to construct a pipeline from the adjacent town of Greenbushes. A new storage on the Quickup River to supply the town of Denmark is likely to cost $1.3 million. The Harris Dam Project to supply Great Southern Town Water Supply Scheme is likely to cost $35 million. Costs per service for these remedial measures has/will be high ($2000 to $3000 per service).

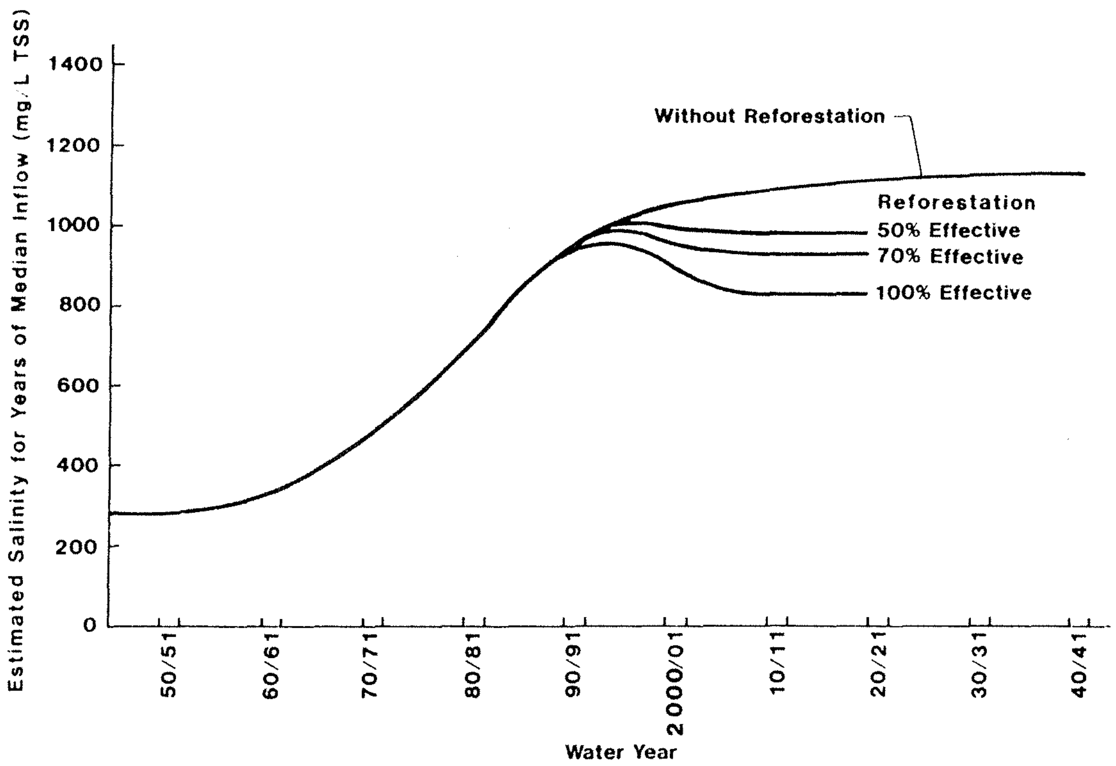


Figure 3 Effect of current reforestation programme on average inflow salinities to Wellington Reservoir

4. ADEQUACY OF EXISTING CONTROL MEASURES

4.1 Clearing Control Legislation

Although often implemented later than desirable, the controls on alienation of Crown land and on control of clearing in critical water resource catchments have been successful in limiting further large-scale salinity deterioration. While total expenditure on compensation associated with clearing controls has been about $35 million over the last 11 years, it remains the least costly proven measure available for controlling stream salinity. Clearing controls have been an essential prerequisite to other actions such as partial reforestation on Wellington Reservoir catchment and hold open the options for partial reforestation and other ameliorative measures in the other catchments.

The clearing controls have restricted agricultural development from approximately 1200 square kilometres in the more reliable rainfall areas of the south-west. Nevertheless this represents only a very small proportion (0.7%) of the 180 000 square kilometres of farmland within private holdings in the agricultural areas of the south Western Australia. Loss of this agricultural production potential has been accepted as a necessary consequence of protecting the five most important water resources of marginal quality.

Administration of the clearing control legislation has not been without its difficulties. Some farmers have undoubtedly claimed compensation for land they had little intention of clearing. More importantly, some areas of forest, usually the smaller clumps of trees in grazing areas, for which compensation has been paid, have not been fenced out and stock excluded. The long term protection and regeneration of these areas is of serious concern. Although it is the responsibility of the land owner to ensure the maintenance of the indigenous bush, policing any gradual decline in forest cover will be difficult. The fencing costs are often high and is a major limitation to protection of remaining bush in farmland.

4.2 Protection of Forest Cover on State Forest and Crown Land

A cornerstone of the regional strategy to salinity management has been the need to protect the existing forest cover on public land. Where there has been any concern that forest or mining operations in State Forest may lead to salinity problems extensive research programmes have been undertaken. Results from these programmes have greatly improved our knowledge of the stream salinity problem. In the case of clearfelling and regeneration of southern forests associated with the Woodchip Industry, results have indicated that, with appropriate management, there is no significant threat to the water quality of regional water resources.

To date Alcoa's bauxite mining operations in the Northern Jarrah Forest have been constrained to the western high rainfall zone of the Darling Range where the salinity risks are low. No increases in stream salinities have been recorded from their current mining and rehabilitation practices.

There is a clear commitment by Alcoa and the State to resolve the question of the salinity risks in the intermediate rainfall zone. Experience to date would suggest the risks of salinity increase are relatively low, although the long term control of the spread of dieback disease and the development of appropriate intermediate rainfall zone rehabilitation strategies require research and evaluation. There is sufficient time to develop these control methods before Alcoa will wish to mine in this zone.

Of more recent concern to the protection of State forest, and potentially much more serious than either woodchipping or bauxite mining, is the impact of major insect damage to the Jarrah Forest. Two insect pests (Leafminer and Gumleaf skeletonizer) currently infest 53% of the jarrah forest. Chronic infection (for at least 20 years) by leafminer in the southern forests has resulted in considerable loss of timber production and a reduction in water transpiration. To date no large-scale deaths similar to those from Jarrah dieback have been directly attributed to insect damage. The leafminer caterpillars can defoliate a stand between June and October-November each year but new spring growth can re-establish a healthy crown within months. Knowledge of the impacts of these changes on the transpiration are unknown.

The consequence for water resources quality could be dramatic if the current broad area of infestation became chronic and caused a permanent reduction in tree transpiration.

Increased effort in the study of insect problems in the Jarrah forest are therefore justified. Continued development of control of dieback disease is also important to ensure preservation of the health of State forest vegetation.

4.3 Reforestation

The partial reforestation programme on Wellington Reservoir is the first Australian attempt to control a distributed non-point source pollution discharge from a large area of privately owned land. As such it has been a large-scale experiment which has proved most instructive and provided much needed experience in the practical application of reforestation techniques, the suitability of different tree species and in the identification of the complexities of the hydrogeological settings requiring rehabilitation. It has also highlighted some of the difficulties of implementing a programme which requires such large-scale restructuring of farming activities.

An active research and monitoring programme in association with the reforestation project has been undertaken. Reductions in groundwater levels have been recorded under many of the monitored plantings (see Figure 4). However, major reclamation of saline seeps and evidence of reduced stream salinities are not yet available. Reduction in groundwater levels have been largest at sites where the areas of planting have been 30% or more of the upslope cleared land. Plantings covering less than 20% of the landscape have shown little reduction in groundwater levels to date.

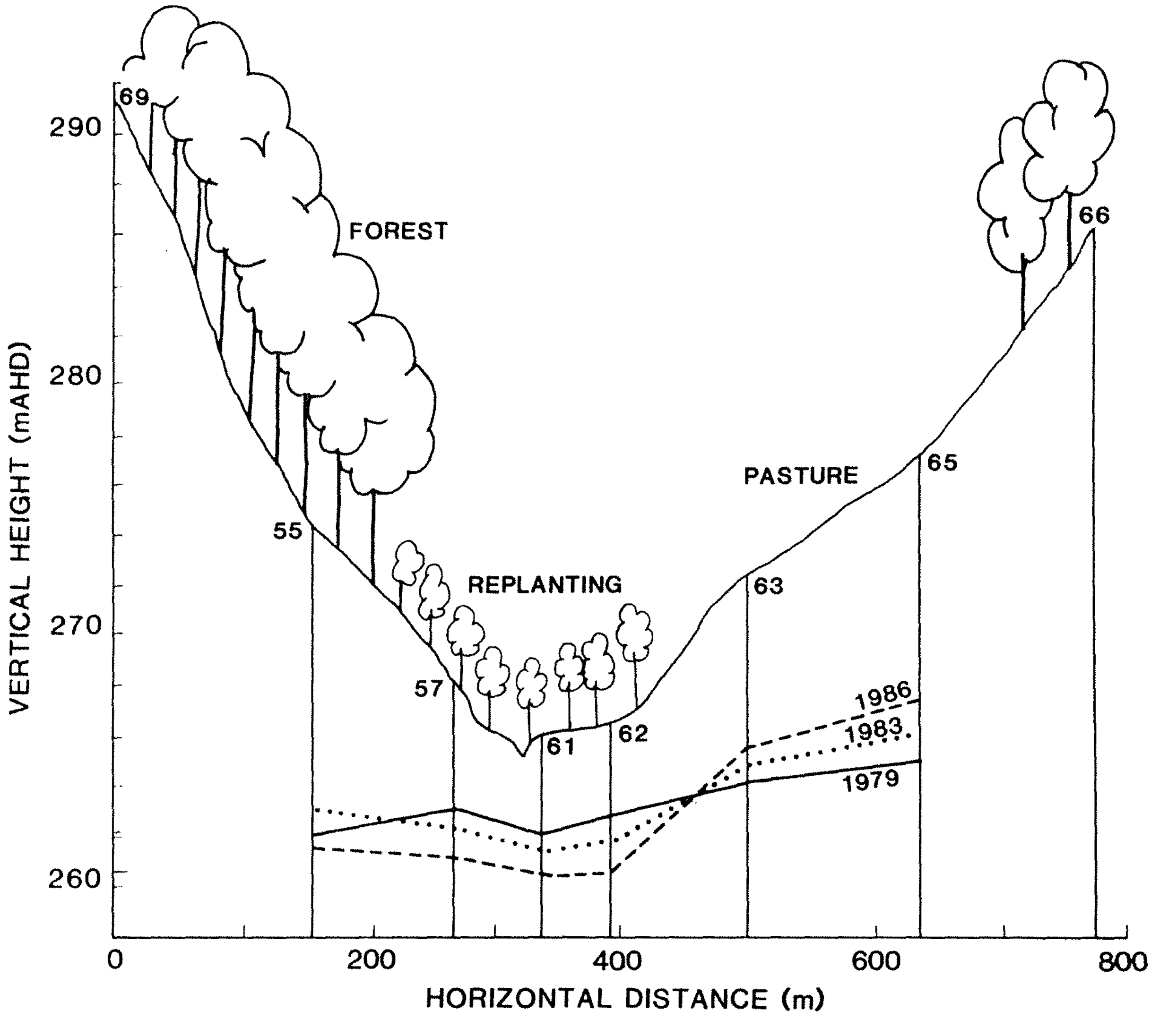
Significant advances have been made in tree species selection. Initial work on improved site establishment techniques to increase survival and growth in waterlogged and saline sites is most encouraging. However, a number of issues remain unresolved. Where broad saline valleys and strong vertical gradients of groundwaters exist within these broad valleys, full control of groundwater discharge is unlikely. In areas where shallow hardpans exist root penetration is virtually impossible and control of salt discharge may be very difficult.

Experience with land purchase, land exchange and negotiation with farmers on land boundaries has resulted in lower than desirable areas of plantings, particularly on properties not initially purchased and subdivided by the Water Authority. That is, farmers adjacent to properties previously purchased by the Authority are often reluctant to sell much more than the worst salt affected portions of their farms in exchange for adjacent upslope farmland owned by the Authority.

The current reforestation programme involves major capital outlays to purchase complete farms for subsequent subdivision and exchange. Alternatives that minimise the purchase of land while still ensuring deep rooted vegetation is established, possibly through subsidy, would be a financial attraction.

The initial target rates for reforestation (2000 ha per year) were set with the hope that a rapid planting programme would avoid the need to develop costly alternative sources for the Great Southern Towns Water Supply System (GSTWS). A combination of the practical limitations and difficulties in achieving the desired planting rates (see section 3.4), combined with below average streamflow input to Wellington Reservoir has meant that supply salinities have been unacceptable in recent years. Development of the Harris Dam Project therefore became necessary.

While the Harris Dam Project has been designed to solve the problem of the GSTWS, the current reforestation programme has been an essential element in minimising further salinity deterioration of the total water resource from Wellington Reservoir catchment and should form an integrated part of catchment management strategies in the future (section 5.3).



– approx 2m reduction

Figure 4 Reductions in Groundwater Levels beneath Valley Plantings - Bingham River Valley

However, considering the above difficulties with the reforestation programme a period of review is warranted before the programme is expanded past the current planned 8,000 hectares of plantings (see section 5.4). The Water Authority is currently undertaking such a review.

5. FUTURE DIRECTIONS FOR SALINITY CONTROL

5.1 Introduction

Although introduced later than was desirable, actions to control stream salinity problems in the last 10 to 15 years have been appropriate and relatively cost-effective. Nevertheless two recent decisions of the State Cabinet has emphasised the need to develop additional cost-effective ameliorative catchment management measures to improve both land productivity and reduce stream salinity.

Firstly, the Minister for Water Resources in his response to the Minister for the Environment on appeals associated with the EPA report on the Harris Dam Project ERMP stated that: "The Water Authority of Western Australia is committed to the long term objective of returning the Collie River to a salinity level such that the quality of water supplied from Wellington Reservoir is suitable for domestic water supplies".

Secondly, State Cabinet supported the development of an Integrated Catchment Management Plan for the Upper Denmark catchment, the aim of which was to improve land productivity while also reducing stream salinity.

A significant commitment has therefore been made to actively pursue further rehabilitation strategies to return these two critically important water resources to potable levels.

The continued deterioration of other rivers and streams is of serious concern. Competition for the remaining fresh water resources will intensify as water demands for both public and private use, and to satisfy environmental constraints, also increase. The likely consequences of the "Greenhouse Effect" will heighten this competition. From a water resource management perspective then, continued efforts in prevention of further salinity deterioration are essential.

The environmental impacts of stream salinization should not be underestimated. The conservation and restoration of extensive areas of farmlands and river systems, in addition to those in the Wellington Reservoir and Denmark River catchments, should be encouraged as part of the State's conservation strategy.

5.2 Ongoing Protection of Forest Cover and Control of Agricultural Development

It is imperative that remaining forest cover, particularly in the salt-sensitive zones of catchments currently gazetted under the Country Areas Water Supply Act, be protected in perpetuity. This will involve the continued strict application of the current tight guidelines under which licences to clear native vegetation are granted. An assessment of the problems, methods and costs of ensuring the regeneration of remnant forest on farmland should be undertaken and the development of a strategy to ensure the application of such regenerative techniques in all areas should be developed. Emphasis should also be given to encouraging individual land owners to take responsibility for regeneration of remnant forest vegetation and protection of streamlines from further degradation.

Options could include :

(i) schemes to encourage fencing all streamlines and gullies and to include the extension of current local Soil Conservation Districts Committee schemes for fencing streamlines to include protection of remnant vegetation.

(ii) subsidies or community service schemes to assist individual farmers to fence remnant vegetation on specific catchment areas of high priority particularly bush on which compensation has been paid.

(iii) The establishment of a goal for maintaining at least 15% of native forest on a farm property (as recommended by the Land Resources Policy Council in 1986) as a component of the State Conservation Strategy and develop incentive schemes and farmer peer group pressure to encourage farms to achieve this goal on their property.

A review of the potential effect of current insect damage to the Jarrah Forest and its implications for water resource protection should be undertaken. Pending the results of such an investigation a much increased research effort to investigate and to control insect problems in the Jarrah Forest may be warranted.

In the light of the possible consequences of the "Greenhouse Effect" a re-evaluation is warranted of the expected salinity levels of river systems which currently have fresh or marginal salinities but which have significant proportions of private uncleared land. This review should examine whether existing administrative actions are adequate to protect their water quality and recommend future action as appropriate.

5.3 Ongoing Reforestation on Wellington Catchment

The recent commitment to return water supplied from Wellington Reservoir to potable levels will necessitate an active ongoing programme of catchment management.

Future developments in catchment mangement are likely to involve a combination of means of minimising groundwater recharge from upslope locations with means of minimising groundwater discharge using lower slope plantings of salt tolerant, high transpiring vegetation (see Section 5.4). That is there is always likely to remain an element of non-commercial specialist species plantings to control groundwater discharge in the lower portions of the landscape.

Consequently the current planting programme should continue until the planned 8000 hectares of lower slope plantings are achieved.

5.4 The Development of an Integrated Approach to Stream Salinity Rehabilitation

Difficulties with the current reforestation programme have emphasised that an integrated approach to farm and catchment planning, that seeks to maximise land productivity while also reducing stream salinity, is essential if large river systems are to be cost-effectively rehabilitated. This will involve a major effort in agronomic research and management, the establishment of a major new commercial forestry enterprise in the inland portions of important water resource catchments and in the continuation of current reforestation research programmes.

5.4.1 Commercial Tree Plantations

A major means of improving the cost-effectiveness of rehabilitation strategies is to increase the commercial viability of the tree planting programmes without jeopardising the aims of controlling saline groundwater discharge. If a major new forest industry based on commercial plantations on farmland can be established then many of the current uncertainties of the reforestation programme would be resolved.

In particular the encouragement of commercial tree plantings in rainfall zones below 900 mm per annum is most important. Growth rates of commercial plantations Tasmanian Blue Gum (E. globulus) in the 600 to 700 mm rainfall range of the Collie catchment have been most encouraging. Based on short rotations of 7 to 10 years the economic returns appear promising. Means of integrating such plantings with existing agricultural enterprises and with non-commercial plantings along creek lines to control groundwater discharge to streams is a high priority for investigation and research. The prospect of high proportions of the farm landscape being planted to a tree crop holds out the potential for a reduction in the areas of non-commercial salt tolerant tree plantings.

5.4.2 Agronomic Approaches

Under current agricultural practices there is an excess of water which passes the root zone of annual crops and pastures and contributes (recharges) to the saline groundwater system. Methods of salinity control using deep rooted trees, either to control groundwater discharge along streamlines or to control groundwater recharge (through broad acre commercial plantations) have been discussed above. Only a small effort has been undertaken to develop improved agronomic means of controlling groundwater recharge.

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In the 600 to 900 mm per annum rainfall region of most concern to the Water Authority, it is unlikely that shallow-rooted crops and pastures, even with a major research effort, will be able to completely stop groundwater recharge. Nevertheless a much greater effort is required to research and develop agricultural plants with higher water using characteristics than existing annual pastures. While some initial studies have commenced a much larger and more radical approach is necessary.

A whole range of trees and shrubs suitable as a fodder source on farms should be actively researched. This includes the investigation of the value of acacias, of edible nut trees, as well as continued study of tree lucerne (Tagasaste) and other nutrient rich species. Aspects of their establishment, management and water using characteristics require investigation.

Much more research work is required to develop more conventional agricultural crops and pastures which have much greater rooting depths, and which can survive the harsh soils and dry summer conditions characteristic of many of the south-west areas. It will involve a greater effort in crop breeding to find new varieties of crops of proven water using ability, such as lucerne, which can grow and survive in the Western Australian environment.

5.4.3 Continued Research and Management of Lower Slope Plantations

As noted previously, continued planting of salt tolerant vegetation in harsh saline and water-logged sites in lower landscape positions will remain on essential feature stream salinity control strategies.

Continuation of current research and monitoring, particularly site establishment research and studies of ongoing management problems of such plantations, will be critical to the overall success of catchment management strategies to control stream salinities.

5.4.4 The Integration of Farm Planning and Catchment Restoration

The subdivision of land associated with the Wellington Reservoir Reforestation Programme took into consideration practical aspects of farm management such as access to water supplies, sheds and other services. The integration of commercial tree planting and new agronomic methods for the remaining agricultural land will necessitate a much higher level of integration of farm and catchment restoration planning. Such an approach is being initiated in the Upper Denmark Catchment through a joint project of the Department of Agriculture, the Department of Conservation and Land Management, the Water Authority and the local Soil Conservation Advisory Committee.

5.5 Economic Considerations

The development of commercial tree plantations on farmland has the potential to both increase and decrease stream salinities. Recent studies have shown that dense plantations of pines can significantly reduce stream salt loads but they also reduce streamflow volumes substantially. When located in regions of high salt discharge they can significantly improve the salinities of regional water resources. If, however, they are planted in rainfall zones above 900 mm annual rainfall, they are more likely to increase the salinity of regional water resources through reducing the dilution effect of streamflow from the high rainfall portions of these catchments.

Means of directing commercial tree plantations into areas which have the most long term benefit to salinity control may be required.

The economics of establishing commercial tree plantations in areas with annual rainfall less than 900 mm are not as high as in wetter areas. The competition from existing farming enterprises, such as wool grazing, is high. Nevertheless the difference in economic returns between commercial tree planting and farming should be less than the current costs involved in land purchase, subdivision and non-commercial reforestation. Closer economic investigation of these differences is planned as part of current studies of integrated catchment management in the Denmark River catchment. The Water Authority intends to assess the economic benefit of preserving the Denmark River water resource.

Such studies would provide the necessary economic background for Government to consider subsidies to encourage private enterprise to grow commercial plantations in the most important water resource catchments.

As noted above there is a need for a more adventurous approach to developing new agronomic strategies for controlling groundwater recharge. Both long term breeding programmes and extensive field trials are likely to be required. Means of encouraging the private sector to be involved in such long term research, possibly through taxation concessions, should be considered.

5.6 Irrigation Salinity Problems

Currently, water allocation in the irrigation districts is based on a rated area of land. While there is some flexibility in allocations, specifically between properties in the same farming arrangement and in seasons with sub basic allocations, the rated hectare allocation system is very restricting to efficient water use. It has contributed to the continuation of traditional practices such as flood irrigation and over watering which, in turn, has exacerbated salinity problems.

The ability to sell and/or transfer water entitlements (Transferable Water Entitlement or TWEs) is being actively pursued by the Water Authority as an important means of promoting more efficient water use in the irrigation districts. It will allow farmers to selectively convert to dry land farming in the worst salt affected area, and should result in a lowering of water tables. It should result in an overall improved productivity from the irrigation areas by shifting water use to the more efficient managers and the more productive soils and will enable the rationalisation of the Water Authority distribution system.

Care will need to be taken, however, to ensure that any concentration of water usage per unit area is associated with excellent water control to avoid over watering and an exacerbation of salinity problems.

6. CONCLUDING REMARKS

The seriousness of the stream salinity problem has generated a major research and investigation effort over the last 10 to 15 years. While much has been learned over this period much remains to be done particularly in the area of restorative land management strategies. There is considerable promise that new forestry enterprises can be integrated with developing agronomic options to control stream salinities. Such plans are only currently being formulated and it will be many years before restoration of a major water resource to potable salinity levels will be achieved. A commitment to a long term multi-disciplinary programme of land management research will be required if satisfactory rehabilitation of currently marginal water resources are to be achieved.

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