Water Resources

COLEAMBALLY L&WMP
- REGIONAL OPTIONS

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July 1994

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SUMMARY/CONCLUSIONS

This report deals with the regional options as part of the Coleambally Land and Water Management Plan preparation. It is a collation of the outcome of investigations and background material. The LWMP committee guided the process and helped identifying the most important factors to make best use of available resources. Whilst much of the information in the report has already been used for the economics evaluation process it is likely that it will be referred to again for the integration of on-farm and regional options for the final LWMP.

The objective of the LWMP process is sustainability. The components of the water balance are relevant for evaluation because the relative volumes of each factor help identify which factors should be targeted for more or less effort to remedy a particular process. The groundwater balance in this respect is considered more important than the surface water balance. After compilation it was found a total of about 68 GL/year enters the groundwater system. Of this 55 GL/year is due to rice accessions, rainfall and other crop accessions, whilst 15 GL/year are due to seepage from supply channels. The watertable increase over the last 7 years is estimated to represent 10 GL/year. The volumes will change in the future because groundwater levels increase, causing a decline in some accessions components.

Groundwater levels are expected to increase from the 27,000 ha now to about 60,000 ha by 2013, despite an apparent reversal of the upward trend in the area affected by high watertable in recent years. A significant component of the accessions dissipate by lateral groundwater flow out of the Coleambally area, either through shallow or through deeper aquifers. The leakage is believed to vary from 0.7 x 10 E-5 $[\text{day}]^{-1}$ in the north to 0.3 x 10E-5 $[\text{day}]^{-1}$.

From survey soil salinity data from the MIA and Coleambally it has been possible to determine curves to estimate soil salinity with time for individual watertable categories. This has been applied to a specially constructed model to estimate the soil salinity status for a whole district, or part of a district on basis of the various components of the groundwater balance, which together determine the average watertable height in the high watertable area. It was found that for the No Plan scenario about 24% of the CIA will have salinity above 2 dS/m in 30 years time, including 5% that will have a salinity over 8 dS/m. The predicted soil salinity data may be used to estimate crop salinity loss for various options which influence the waterbalance components, and therefore the average height of the watertable in the district.

The water quality entering the CIA is good, whilst the 9 leaving is not having a significant impact on the receiving systems (Yanco and Billabong Creeks). The intermittent high levels of pesticide residue found is of some concern and should be addressed by on-farm and off-farm management strategies to improve the situation.

Four main options for control of waterlogging and salinity were considered, namely reduction of channel seepage, shallow groundwater pumping, the deep bore options and pumping from sand and gravel pits during high Murray River flows. For each option the methodology, costs and benefits were considered. The latter was expressed as a reduction in the percentage of land affected by soil salinity.

Seepage control options will prevent the accessions of relatively only small volumes, hence the benefits were not found to be very large. The area affected by salinity for example would decline from 24% in 2023 to 20% if channel seepage was reduced by 35% (some 5,000ML).

With groundwater pumping only the option whereby saline groundwater is disposed to drains was considered. The pumping of fresh groundwater and reuse on-farm is considered by NSW Agriculture. On a per volume basis the groundwater pumping option would be more effective than for instance reduction of channel seepage, because the location of groundwater removal would be targeted towards the areas actually affected by salinity. By pumping 6,000 ML/year the area affected by salinity would reduce from 24% to 16, with most of the decrease being in the worst affected parts.

For the deep bore option two future pumping rates were considered, 30 GL/year and 60 GL/year. The lower rate is sufficient to maintain Calivil pressure levels to about 14 metres below the surface, which is just below their current levels. The results from analysis indicate significant reductions in the soil salinity status of the district, from 24% to 15% of the Coleambally land area for the 30 GL option and to 10% for the 60 GL option.

Pumping from sand and gravel pits will only produce small volumes to be disposed of each year, which is unlikely to be significant on a district scale. This also applies for the pumping of groundwater accumulated in depressions.

For the three pumping options considered the cost in terms of Salinity Credits under the MDBC S&D strategy were considered. Since no hydrologic model exists at present the estimates are approximate only. It was found that the shallow groundwater pumping option of saline groundwater above 5,000 uS/cm and disposal to drains would incur a cost of almost 6 EC units. The deep bore option on the other hand will incur a cost of only about 0.2 EC units for the 30 GL option if disposal into the channel system is during the irrigation season only. The pumping of sand and gravel pits and depressions will cost 0.22 EC units in an average year. Pumping from depressions is relatively far more expensive as far as EC units cost is concerned. Effluent from sand and gravel pits in most instances could be reused on-farm.

Part of the DWR investigations program also included the preparation of a "Natural Resource Inventory". Because of uncertainties regarding the usefulness of such an inventory for an irrigation area which has almost fully developed, and the lack of significant remaining stands of trees, this aspect has been changed into a "Listing of Remnant Tree Areas in Coleambally". The total of remnant tree areas over 1 hectare in size is about 366 ha, or 0.46% of Coleambally. The LWMP committee is encouraged to consider this matter further and provide guidance regarding further action. The water balance and soil salinity model indicates that trees in the landscape can provide a worthwhile contribution to groundwater discharges and salinity control if tree areas of 4% and more are considered.

1. INTRODUCTION

In the Coleambally Irrigation Area, of which the location is shown at Figures 1-1 and 1-2, groundwater levels are rising and soil salinity has started to become noticeable in a few locations. Questions regarding threats to long term sustainability of the area have been raised. It was decided to prepare a plan for management of land and water resources. Such a document is also needed as a compliment to conditions for bulk water supply by DWR to the area and the EPA drainage license.

The Land and Water Management Plan committee commenced its task in 1992. A Project brief was prepared in March 1993. The investigations and analysis of On Farm options became the responsibility of NSW Agriculture, whilst DWR State Arm would investigate and analyse the Regional Options.

This report is the collation of the various regional options that have been considered. The attentive reader will notice that apart from the options discussed there are other options which have not been considered in detail. For instance, little work has been done to investigate the option of discharging saline effluent to evaporation areas. Another area not considered in detail is the planting of trees to intercept seepage from the regional channel system The LWMP committee, responsible for the conduct of the planning process, discussed some of these alternatives and provided guidance to the supporting agencies regarding the main options that should be investigated.

The work for the regional options resulted in a variety of reports over a one year period, covering such areas as shallow groundwater pumping, soil salinity assessment and prediction, channel seepage control, district water balances and the deep bore option. These reports (and others) are referred to as appendices, however are only attached as such to the original of this report. Because the investigations were an evolving process not all the data, information and conclusions in each of the appendices are completely consistent with each other. This report for the Regional Options aims to bring the various parts of information from the appendices together into a consistent whole.

Much of the information in this report has already been used for the economics evaluation. However, it is expected that the information will be used again for the integration of on-farm and regional options for the final LWMP, and as a reference during the review process in a few years time. The review no doubt will prompt re-visitation of some of the subject areas.

2. WATER BALANCES

GENERAL

Water balances are an essential part of analysis for Land and Water Management Plans. The volumes of the various factors needs to be known to establish relativities. Technical options to control waterlogging and salinity wherever possible should target the worst accession sources. The economic evaluation requires volumes to establish costs and benefits.

After due consideration of various sources of information, some of which may be found in subsequent sections of this report, the following water balance was adopted for the Coleambally area.

TABLE 1: Coleambally Irrigation Area - Water Balance (GL)

	Irrigation ('80-'90)	Drainage	Ground water	Future Groundwater
Diversions	614			
Rainfall on Channels	3			
Seepage from Supply	-15		15	12
Channel Evaporation	-9			
Escape Losses	-90	90		
Channel Fill/Empty	-11	11		
Coleambally Bore Pump	4		-4	-4
Deliveries	496			
Area Rainfall	320			
Crop ET	-578			
Non Crop Evaporation	-123			
Irrigation Runoff	-30	30		
Rainfall Runoff	-30	30		
Groundwater Recharge	-55		55	45
Rainfall on Drains		3		
Town Drainage		2		
Groundwater seepage		1	-1	-1
Seepage from Drains		-3	3	3
Drain evaporation		-5		
Total Recharge to GRW			68	55
Lateral Dissipation grw			-33	-25
Capillary rise + discharge			-25	-30
Balance	0	159	10	0

The compilation of a water balance for an area involves many factors, many of which are only approximately known. The reliability of the individual numbers needs to be considered. During this process the objectives of preparing the water balance needs to be considered carefully. This will determine which factors should receive most weight.

In Coleambally the purpose of the water balance primarily is its use in assessing the sustainability of irrigation. The critical factor is salinisation. This is caused by groundwater processes. Consequently, the groundwater balance may be more important than the surface water balance. The latter is relevant mainly for assessing losses in the system, or efficiency of water use by plants.

The NSW Agriculture approach was to evaluate crop water use, which is the largest components in the balance, whilst runoff drainage and groundwater factors received a lower initial priority. In this chapter the groundwater components will receive the highest priority, and the crop water use will be more like a "leftover factor". The factors are discussed below.

Surface Water Balance

The Department of Water Resources data (eg A. van der Lely, 1992) show annual diversions of 630 GL, and average deliveries to Coleambally landholders of 470 GL/yr. The difference of 160 GL compares with a total average recorded drainage flow of 146 GL/yr. Table 2 below shows the composition of the drainage flows between DC 500/600, DC 800, and the catchment drain. With a correction for seepage and evaporation from channels of about 20 GL (eg Appendix 8) it would be concluded that all drainage recorded is derived from channel escapes, a conclusion not supported by observations in the field. Farm runoff must account for a fair percentage. In the MIA for instance the water balance work, supported by measurements of farm drainage, suggests that over 50% of total drainage is from farms, either irrigation drainage or rainfall runoff.

Statistical Hydrology of the Department of Water Resources in Sydney has considered the matter and estimated that the diversions are overestimated by 2.5% and the deliveries underestimated by 5%. This gives a corrected 614 GL/yr. for diversions, and 496 GL/yr. for deliveries. With corrections for seepage, evaporation, channel fill/empty, and the pumping of Coleambally Deep Bore water (see below) it then follows that the escape losses would be about 90 GL/yr. This is shown at Table 1.

It was also believed that the drainage flow data, being assessed from flow gauges and Bristol recorders, may have been under estimated by some 10%. This would give a corrected total drainage flow of 160 GL/yr. Considering several minor factors, such as rainfall on drainage channels it was concluded that the irrigation plus rainfall would be about 60 GL/yr. in total. This volume was distributed evenly between rainfall runoff and irrigation runoff, see Table 1. The corrected values compare well with values for the MIA, where the farm runoff proportion is believed to be higher than in Coleambally.

Groundwater Balance

The groundwater balance consists of accessions, discharges and changes in the watertable level conditions of an area. The accessions consist of rice accessions, channel seepage, accessions from other crops, and some minor components, such as seepage from drains. The discharges include, seepage into drains, capillary rise and groundwater flow away from the area considered, and any groundwater pumping. The watertable level changes may be measures from maps and multiplied with the effective porosity.

To achieve a balance the accessions have to match the other two components in the balance. If the totals of individual factors work out too high there is likely to be an error.

The Coleambally Deep Bore pumps about 4 GL/yr. this is fairly accurate. The channel seepage is about 10-15 GL/yr. this estimate is also fairly close, because it is based on actual field measurements. The details of this assessment are given at chapter 6, first part. The seepage from drains is believed to be small, as shown at Table 1. Drains do not follow prior stream courses. There is a considerable amount of clay. The seepage measurements of Appendix 7 and 8 would indicate that seepage rates for drainage channels would be less than 3 mm/day.

The rice accessions are more difficult to assess. There is 22,000 ha of rice in Coleambally, and during the 1970's the percolation was believed to be in the order of 4 ML/ha, or 88,000 ML/yr. total accessions. This has now reduced in the high watertable areas. About 27,000 ha have a watertable within 2 metres and another 23,000 ha has a watertable within 3 metres. If the gradient for downward flow is halved since the 1970's, then the current accession rate is about 44,000 ML/yr.

The accessions from crops other than rice should also be considered. There are irrigation accessions and rainfall induced accessions. Coleambally has a drainage system, therefore the water does not lie around for long before it is being removed. About 100,000 ML/yr. of water is used for the other crops. If 6% of this water (6 GL) results in accessions, and rainfall contributes an equivalent amount over the whole district, then about 12 GL would be involved from this source.

The total of rice accessions and other accessions would be 56 GL. Table 1 shows that a total of 55 GL was adopted for the accessions part of the groundwater balance.

It is assumed that any on-farm channel seepage accessions are included in the on-farm accessions.

The groundwater balance includes lateral groundwater outflow through shallow aquifers, deep leakage to deeper aquifers and the increased storage in the groundwater system.

The latter has diminished a lot since the advent of high watertables during the mid 1980's. Figure 2, of section 3 shows the hydrograph for average watertable conditions in Coleambally. There is an apparent reduction since 1990. However analysis showed that the area with watertable within 2 and 3 metres is still expanding. Measurement of the areas of different watertable categories for 1987 and 1993 indicates that an annual increase of about 0.15 metres has occurred. Assuming an effective porosity of 0.08 (van der Lely, 1987) and 80,000 hectares, this translates to a volume of about 10 GL.

The deep leakage to deeper aquifers depends on the "leakance" and the gradient. The leakance factor in the Riverine Plain typically is 18 mm/yr. for every 10 metres head difference between the shallow and deep aquifer (Punthakey, Prathapar, pers. comm.). In North Coleambally a higher value may be expected, in the South a slightly lower value. Overall the value in Coleambally is probably above average, say 24 mm/10m/yr. The head difference currently is about 14 metres. This means that over 80,000 ha the leakage is assessed at 26,000 ML.

There is also lateral groundwater flow through shallow aquifers out of Coleambally. There is no lateral groundwater inflow. Most of the outflow would be to the west. Assuming the flow is only to the west a 75 km boundary applies, and that the transmissivity of the Shepparton Formation to 40 metres depth is 250 m^2/day, then the outflow would be about 7 GL/yr. This added to the 26 GL for deep leakage gives a total of 33 GL.

The final factor in the groundwater balance is capillary rise and removal of groundwater by vegetation such as trees. It is estimated that in Coleambally about 1000 hectares of trees is remaining or planted. Assuming a transpiration rate of 1000 mm/year a proportion of this would be removed from the groundwater system. After deducting the rainfall of 400 mm/yr. then 6 GL/yr. would be derived by trees from the groundwater system. To this has to be added extraction of groundwater by other perennials. This is estimated to be 4 GL, giving a total of 10 GL by trees and perennials.

The 1000 mm/yr. transpiration value for trees may seem low, but the author believes this to be an upper limit for the existing stands. Many trees are in less than optimal health, or the trees are stressed for considerable periods of the year, eg pine trees on sandhills, or Black Box trees in high watertable areas which are poorly adjusted to high watertable conditions.

Capillary rise is the final discharge factor to be discussed. With watertables within 2 metres an average of 50 mm/yr. is a reasonable estimate, based on values found in the Tatura area and for the Wakool model (eg see Van der Lely, 1988). Over 27,000 ha this represents 13.5 GL.

Table 1 shows a value of 25 GL/yr. for the addition of capillary rise and the removal by trees and perennials, rather than 10+13.5=23.5 GL/yr. The difference is due to the changing of some values to achieve an overall balance between all the factors.

CROP WATER USE

The values for the groundwater balance and the surfacewater balance were entered into Table 1. The rainfall over the District totals about 400 mm/yr. giving 320 GL/yr. over 80,000 ha. This, added to the net irrigation deliveries, and after allowing for drainage and accessions, is used for crop water use and non crop water use. In Table 1 the total for these two components is about 700 GL. Following advice from NSW Agriculture the crop water use is 578 GL, leaving 122 GL for non crop evaporation.

There are many possible questions related to the accuracy of total crop and non-crop water use. The best assessment is for rice and other well watered crops. There is a large variation in pasture water use between farmers. The areas under fallow and other non irrigated areas transpire basically all that is received, except that an allowance needs to be made from time to time for small amounts of groundwater accessions, eg following heavy rainfall.

FUTURE GROUNDWATER BALANCE

Apart from the current groundwater balance, the trends towards the future water balance also need to be predicted. For Coleambally currently there is no accurate methodology that allows these predictions. The groundwater modeling for the area (section 3, third part) has not produced the required results yet. Other Models used for other areas, such as, SHE for Berriquin, have not performed to the extent that they are recommended for wider use.

However, despite these problems, it is known from theory and confirmed by practice that total seepage from channels and rice accessions will decrease with increasing areas with high watertables.

Capillary rise will increase, perhaps double if the high watertable areas double. However as discussed, the current capillary rise estimate includes a component for the removal by trees and deep rooting species and this component could decline if the tree areas continue to decline (No Plan Scenario).

Finally, the lateral groundwater outflow could become a little less if shallow watertables outside Coleambally increase above the current levels, which is expected.

After consideration of such trends, future estimates were determined as shown at Table 1. The groundwater balance between total accessions and total discharge is zero for the future, because watertables have reached their equilibrium.

3. REGIONAL GROUNDWATER CONDITIONS AND TRENDS

Over the last three decades several relevant hydrogeological reports have been published. Pels (1968) discusses the geology of the Coleambally Irrigation Area and Stannard (1968) discusses the geomorphology and physiology. Van der Lely (1987) describes the groundwater hydrology, the interrelationship between shallow and deeper aquifers, and the effect of accessions on the groundwater levels. Woolley and Kalf (1977) describe the deeper groundwater conditions and the hydrogeology of the Calivil Formation. This initial work on the deeper aquifers was later expanded by Evans (1988).

This report assumes this information as being available, and focuses on the aspects that influence the Land and Water Management Plan.

SHALLOW GROUNDWATER

A groundwater report with about 10 maps was produced during January 1994 (Appendix 1). From the databases now available watertable prediction maps have been produced for 1993, 2003, and 2023. The first two of these are shown at Figure 1.

Groundwater levels in Coleambally will continue to rise in the southern part, but not so much to the north. It appears that water levels in the north and central parts have already approached an equilibrium.

The high watertable area has decreased somewhat since 1990, which was the end of a series of very wet winter years, and this is shown at Figure 2. Seasonal variation obviously plays an important part. The trend shown from that graph seems to indicate reason for optimism that the current intensity of irrigation and rice growing practices may be reasonably sustainable, particularly with the continued operation of the existing Coleambally deep bore and several groundwater pumps to the north west of the CIA.

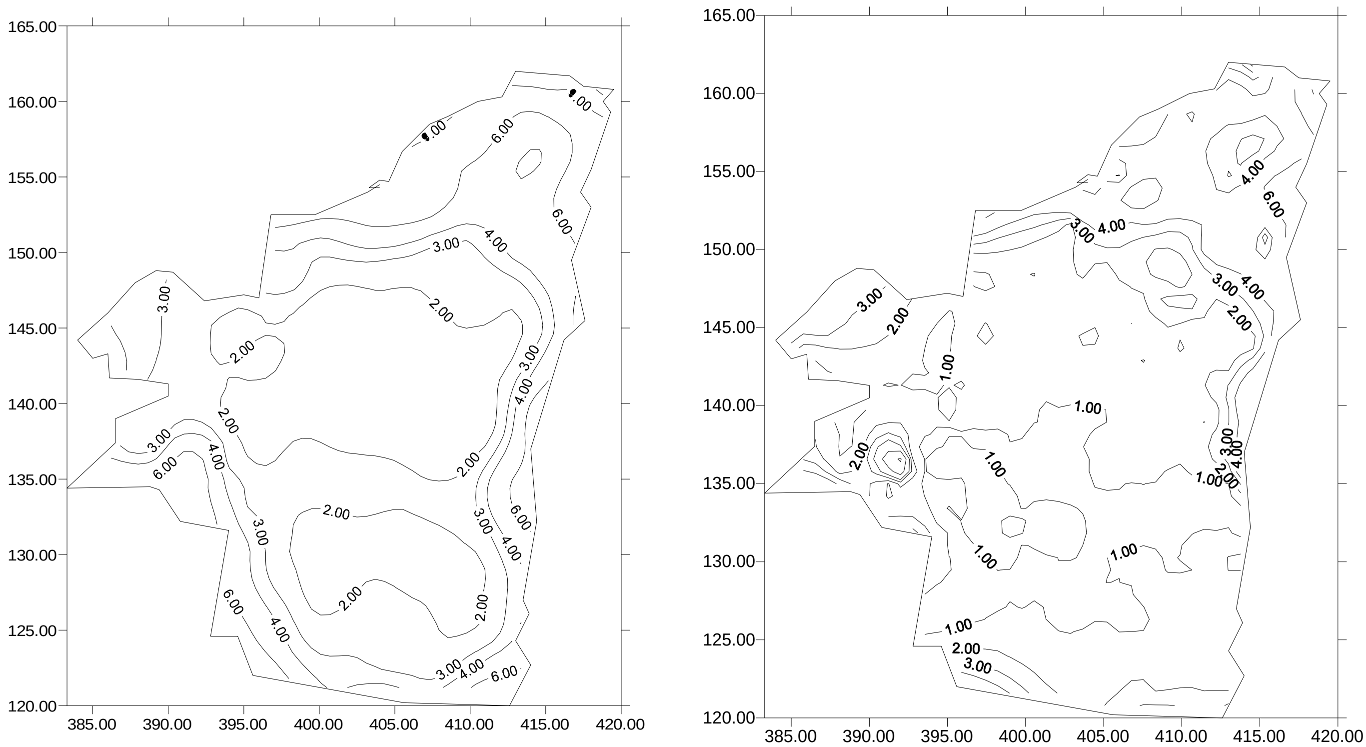
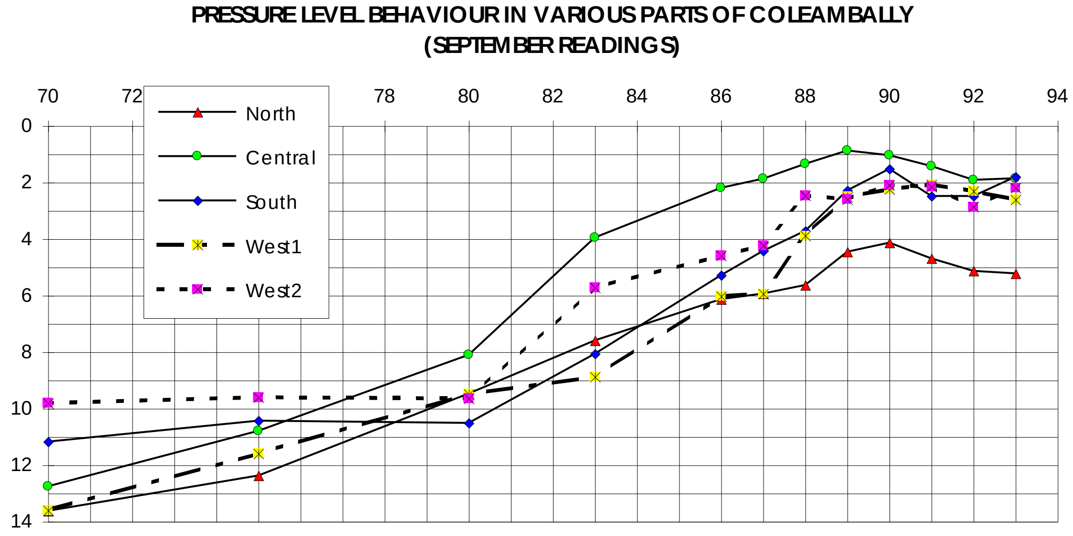


Figure 1: Groundwater levels in Coleambally for 1993 (left) and 2003 (right)

Figure 2. Pressure level behaviour in various parts of the CIA.



The analysis of the watertable distribution, as shown at Table 2 however showed that in 1993 only 27,000 ha had watertables within 2.0 metres from the surface, but that a large area has watertables within 2 and 3 metres from the surface. A large proportion of this is expected to enter the higher watertable category over the next 10 years. This is confirmed by the 2003 map of Figure 1.

Table 2. Pressure level distribution in shallow aquifer, Coleambally Irrigation Area.

Interval	North	Central	South	West	CIA
0-1.0m	0	610	100	0	710
1.0-1.5m	0	5000	3200	100	8300
1.5-2.0	0	12450	12600	1500	26550
2.0-3.0	0	18500	25200	6500	50200
3.0-4.0	750	20600	28900	9600	59850
4.0-10.0	8600	26150	34900	13900	83550

Deep Groundwater

Over the years it became evident that leakage occurs from the shallow aquifer system to the deeper systems. However the quantification of this phenomenon took some time. Van der Lely (1987), using a water balance approach, estimated that about 50 mm/yr. may be involved. In 1988 it was decided to conduct a deep aquifer pumping test to obtain better information of the characteristics of the aquifers and aquitards. A deep bore was installed at the corner of Channel 9 road and Anderson road and a volume of 28 ML/day was pumped for 15 months. Discharge was into Channel 9B. The salinity of the groundwater was about 630 uS/cm. Pressure levels in shallow and deeper aquifers were observed and all data analysed. Lawson (1992) produced the final report. Appendix 2 is the summary document of the experiment.

The experimental pumping test found that there is a watertable drawdown, but it was difficult to identify because seasonal factors in many respects tend to overshadow the pumping effects. In the end the conclusion was that lowering of the pressure level in the deeper aquifer by 10 metres would have a 20-40 cm watertable drawdown effect. The rate of leakage was assessed at 7 mm/day for every 10 metres drawdown.

This rate of leakage result was disappointing and does not match regional groundwater balance estimates. The volumes of leakage, if extended over the whole of Coleambally would be too small a component of the total about 80,000 ML recharge that is annually taking place towards the deep bore pumpers area south west of Darlington Point. Considering some of these regional groundwater balance values it was believed that the Coleambally experimental result could not be representative of the regional picture. Further evaluation was needed.

Regional groundwater modeling by Punthakey, and reviewed by Prathapar (pers comm., 1994) fortunately has been able to provide more realistic estimates. The Riverine Plains model showed that the average "leakance" is 0.5 x 10E-5 $[day]^{-1}$. Expressed as mm leakage per 10m head difference per year, this is about 18 mm/10m/yr. Local variation may be applied to the average. For instance, near North Coleambally the value would be about 0.7 x 10E-5 $[day]^{-1}$, well above average, in South Coleambally it may reduce to below average, say 0.3 x 10E-5 $[day]^{-1}$. In other areas it may be less still, for instance near the northern fringe areas of the MIA.

Groundwater Modeling

A groundwater flow model was developed for the Riverine Plain. This model considered flows in the various aquifer systems, and recharge/discharge phenomena. Whilst it met the objectives of matching regional flow features, it has to date not been possible to simulate the interaction of the Coleambally Irrigation area recharge with the general flow patterns. Consequently, there is no new information that allows closer analysis of the interaction between bore pumpers in the Darlington Point area, leakage from the river system, and leakage from the MIA/CIA.

The modeling process is continuing and it is expected that better information will eventually become available.

A consequence of the lack of modeling results affects the assessment of the impact of a slowly downward moving salt slug underneath Coleambally into the deeper Calivil aquifers. This issue was first described by van der Lely (1987). In his report it is estimated that it would be several decades before the salt slug, now at about the 15-30 metres depth level, would reach the deeper aquifer below 60 metres. Because the salt slug is limited in thickness, and gradually disperses before it reaches this aquifer it is expected that the problem of groundwater contamination by salinity would not be too great.

4. SALINITY ASSESSMENT

Two appendices are attached describing salinity assessment aspects:

Appendix 4: Soil Salinity Trends
Appendix 5. Soil Salinity Assessment Model based on Groundwater Factors.

The effects of salinity and waterlogging manifest themselves as reduced crop yields on the salt affected soils. Models to assess soil salinity are the intermediate steps towards these estimates. The actual estimating of crop losses due to salinity is within the sphere of responsibility of NSW Agriculture.

High watertables also aggravate waterlogging conditions. Transient waterlogging is a temporary perched saturated condition in the topsoil, which affects crop growth. Watertable induced waterlogging is from below. The likelihood of the plant roots being in a saturated condition increases when the watertable comes close to the surface. When the watertable for instance on average is at 2.0 metres, only a small proportion of the land will have a watertable within 0.75 metres, which may be the level at which measurable effects occur. If the average watertable rises to 1.2 metres the proportion of land with watertables within 0.75 metres will be greater, hence the effect will be greater.

Salinity is a function of leaching and capillary rise in the soil, and this is affected by watertable levels. Since with observations in the field it often is difficult to distinguish between the effects of salinity on crops and the effect of watertable induced waterlogging on crops, it is useful for analysis purposes to lump the two together.

Salinity effects may be studied by analysing crop growth as a function of salinity. The main work for this comes from the USA, eg Maas and Hoffman (1978). Information is now also available for Australian conditions for some crops. This has been summarised by Slavich (1992). Basically, as the salinity increases a threshold level is reached above which crop yield reductions occur. The yield reduction is expressed as a proportion of potential yield for each unit increase in salinity. Soil salinity is measured as conductivity (dS/m) in a soil saturation extract.

Soil Salinity Trends

The Land and Water Management Plans are for 30 year time frames. Therefore predictions are necessary of the salinity status of the district for which the plan is prepared. Within the district each farmer may be affected in a different degree, but this is not necessarily considered.

Appendix 4 describes the methods by which the soil salinity predictions have been made, assuming that the current irrigation management practices will continue. The end result from Appendix 4 are curves of predicted salinity versus time of high groundwater levels. For each watertable category a separate curve exists. The curves are based on theoretical considerations, but calibrated against actual soil salinity field surveys in the MIA and CIA.

If the age of high watertable in a part of the district is known, an estimate of soil salinity may be made for a) the current conditions and b) the future conditions.

The prediction is based on the area with high watertables, as well as the duration that the high watertable conditions have existed. With the prediction for a district, where all areas are lumped together, it is difficult to estimate the average age of the high watertable condition. Some parts have existed for several decades already, other parts may have been high for a short time. For instance, in the year 2023 some areas will have a short watertable history in that year and other areas a very long history. This problem is addressed by the Soil Salinity Assessment Model, see next section.

Soil Salinity Assessment Model

Appendix 5 uses the salinity functions of Appendix 4 and overcomes the problems just discussed. For each part of the district with a different watertable history the soil salinity assessment based on the salinity prediction trends is carried out separately. Another feature of the Soil Salinity Assessment Model of Appendix 5 is that it is based on water and groundwater balance data, such as described at section 1 of this report. The various values for the groundwater balance are entered in the model. From this the total accessions are assessed as well as the discharge factors. These two are in equilibrium and produce an average watertable depth for the high watertable part of the district. The high watertable part of the district is an input for the soil salinity assessment model, but is also used to calibrate the groundwater balance factors.

The model uses the assessed average watertable level in the high watertable area to assess soil salinity for the district. This is done by assessing the proportions of the various very high watertable categories 0-70, 70-90, 90-110, 110-130, and 130-150 cm, and then calculate the soil salinity based on the duration the condition in each of these areas has existed. The output is a district table giving soil salinity categories and proportions of land affected. Table 3 reflects the No Plan scenario.

Table 3: % of salt affected land for Coleambally for No Plan Scenario (*1)

	CIA 1993	CIA 1998	CIA 2003	CIA 2008	CIA 2013	CIA 2018	CIA 2023
2-3 dS/m	0.48	1.63	2.51	3.26	3.91	4.50	5.04
3-4 dS/m	0.37	1.25	1.93	2.49	3.00	3.45	3.86
4-6 dS/m	0.58	1.92	2.96	3.83	4.60	5.29	5.93
6-8 dS/m	0.41	1.47	2.28	2.97	3.57	4.12	4.62
>8 dS/m	0.00	1.16	2.16	3.00	3.74	4.42	5.03
No Action	1.84	7.44	11.84	15.55	18.82	21.78	24.49

(*1). These vales are current values. It may be noted that the NSW Agriculture models for crop loss assessment are based on previous (May 1993) predictions.

Models such as this are necessary to identify the changes in district soil salinity status that may occur as a result of the adoption of a particular option. For agronomic and economic evaluation this information is critical for the changed salinity status represents the benefits of the option.

Until now the benefits for most options were evaluated using a variety of techniques based on theory, "experience" and "rules of thumb". This model may not be any more accurate than several of the techniques adopted, but it is more consistent in its approach. As a result it should be possible to get a more rational basis by which the benefits of various options can be compared.

The outcome for the various options are described in the respective sections.

Crop Salinity Loss Assessment

The Soil Salinity Assessment model may be used to assess the crop salinity losses, in a variety of ways. NSW Agriculture have recently developed new models based on gross margin losses and these are now being adopted for economic evaluation.

The features of the traditional approach, also used for Benerembah were as follows:

- Maas and Hoffman salinity loss factors are used, but modified wherever Australian values are available.
- There is some consideration of watertable induced waterlogging loss (eg for rice).
- It is assumed that that only a proportion of the area with salinity above 8 dS/m is used for farming. This proportion can be modified if necessary.
- It is assumed that all crops will be grown in an even proportion on all land, except for the proportion of saline land nominated to be not used for irrigation farming.
- The salinity loss relates to total crop yield value, not the gross margin reduction after correction of inputs by the landholder.

This type of model has been used to evaluate the Berriquin and Benerembah Drainage project and would (once again) be readily available should this become desirable.

5. WATER QUALITY

Water quality is a measure of the performance of a Land and Water Management Plan. If the water leaving the area does not affect the downstream users or uses (including the environment) then management practices from that angle may be described as good. If management practices are poor, then it is likely that runoff from the land will affect water quality.

The Coleambally Irrigation Area has been subjected to a water quality monitoring program since 1990. Before this some sporadic monitoring conducted generally led to the conclusion that no problems existed. This particularly applied to salinity. The program concentrated on nutrients, salinity, turbidity and pH. Since 1992 pesticide screening monitoring was commenced, and this resulted in a lot of activity during 1993/94 when Molinate and Endosulfan was found in the drainage system.

Data

Data have been collected at supply sites (Coleambally Canal, internal drains (DC400, DC500, DC600, external drains (DC800, Outfall Drain), and the receiving waters (Yanco and Billabong Creeks). The objective was to identify impacts on the latter.

Alastair Buchan (1994) produced a data report allowing the assessment of impacts of Coleambally on the quality of surface waters. Appendix 6 is the summary of that report. Table 5-1 below gives a statistical summary representation of the non pesticide data.

Table 5-1: Benchmarks for Water Quality in supply, internal and external drains and receiving waters of Coleambally Irrigation Area (*1)

	TEMP	pHF	EC25	TURB	PSOL	TPO4	NOx
UNITS	^oC	pH	uS/cm	NTU	mg/L	mg/L	mg/L
SUPPLY							
Mean (*2)	20.0	7.3	140	31.3	0.011	0.066	0.130
SD	5.0	0.19	46	26.2	0.007	0.032	0.142
90%	26	7.5	198	54	0.022	0.098	0.351
MEDIAN	20	7.2	133	27	0.009	0.059	0.066
10%	13	7.0	98	12	0.004	0.041	0.004
N	79	80	88	88	57	88	60
INTERNAL DRAINS							
Mean (*2)	17.9	7.23	598	41.4	0.013	0.096	0.051
SD	5.8	0.23	1681	23.5	0.013	0.035	0.076
90%	25	7.4	353	73.8	0.024	0.146	0.138
MEDIAN	18	7.2	232	35	0.01	0.091	0.015
10%	10	7	145	20	0.005	0.052	0.004
N	65	64	65	65	63	62	62

EXTERNAL DRAIN (DC800)

Mean (*2)	18.2	7.43	186	63.2	0.014	0.098	0.056
SD	5.15	0.42	61.6	30.2	0.010	0.041	0.087
90%	25.0	8.0	265	96	0.029	0.143	0.159
MEDIAN	18.0	7.4	177	45	0.010	0.092	0.019
10%	11.7	7.1	120	28	0.006	0.059	0.005
N	55	65	86	73	37	67	61

EXTERNAL DRAIN (COLEAMBALLY OUTFALL d/s DC500/DC600)

Mean (*2)	18.7	7.39	300	102	0.010	0.10	0.070
SD	5.55	0.35	648	38.5	0.010	0.050	0.138
90%	26.0	7.9	349	102	0.019	0.149	0.162
MEDIAN	18.5	7.4	216	58	0.012	0.096	0.028
10%	11.3	7.0	119	28	0.005	0.047	0.006
N	54	67	87	78	36	68	60

RECEIVING WATERS (YANCO, BILLABONG CREEKS)

Mean (*2)	17.6	7.18	203	50.0	0.016	0.083	0.069
SD	5.3	0.24	74	25.6	0.011	0.030	0.100
90%	24	7.5	301	90	0.029	0.114	0.166
MEDIAN	18	7.2	196	46	0.015	0.085	0.024
10%	10.5	6.99	113	22	0.005	0.047	0.004
N	171	190	82	78	73	72	66

(*1) from reference 2, see below. The data collection period was 1990-1993
(*2) Mean is poor representation of data where they are very skewed

Irrigation water quality was found of uniform and high quality for uses within the CIA. The deep bore water supply is also of good quality.

The drainage water has increased concentrations of nutrients, salt and suspended material. However the declining water quality is not such that it precludes reuse downstream.

Pesticide monitoring showed traces of a number of chemicals on a number (not all) occasions. High levels have been found for two chemicals, being Molinate and Endosulfan. Figures 5-1 and 5-2 show the levels found.

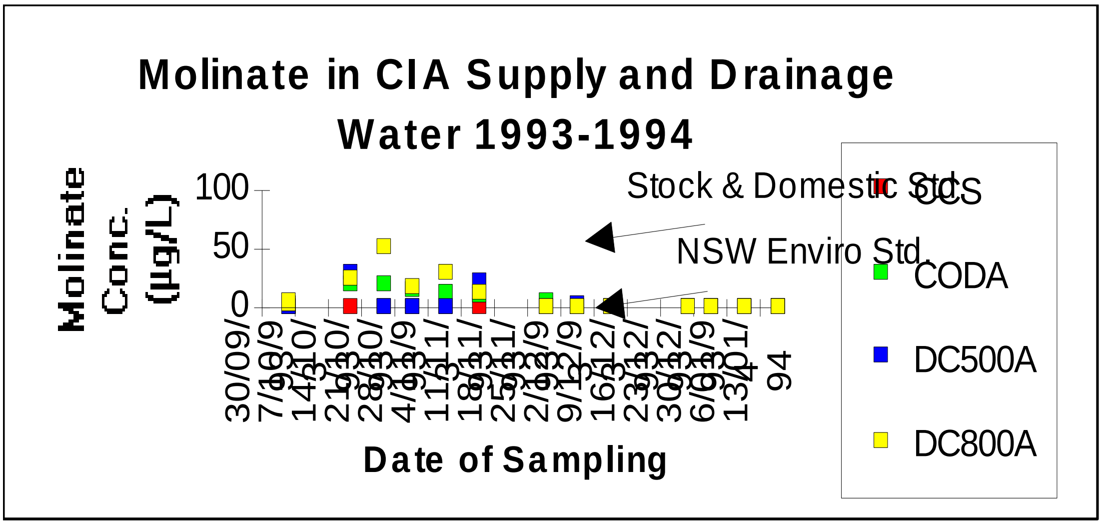


Figure 5-1: Concentration of Molinate found in CIA drains 1993/94.

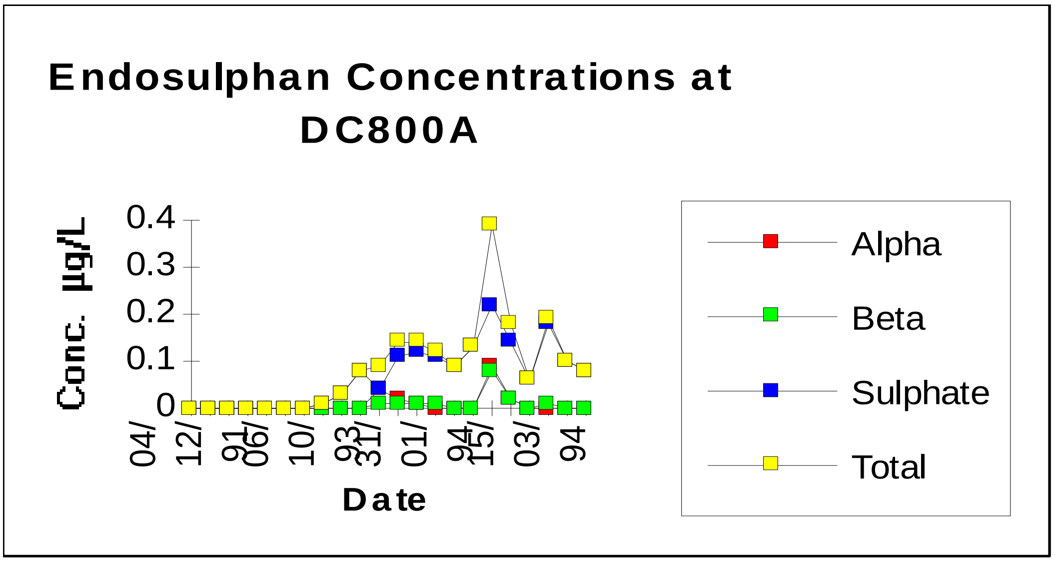


Figure 5-2: Concentration of Endosulfans found in drains 1993/94.

High Endosulfan residue levels were found during late summer. During previous monitoring in 1991 and 1992 no high levels of Endosulfan were found. The chemical is used on soybeans, the area of which expanded rapidly during 1993/94. High Molinate levels occurred during spring 1993. It is a major weedicide for barnyard grass control in rice.

Impacts

The drainage waters leaving the CIA are of similar nutrient, salinity and turbidity concentration than the receiving waters. Henceforth there are no significant impacts for these parameters. There is evidence that the receiving waters themselves have a degraded water quality compared to the river system from which they receive their flow, eg Yanco Creek.

Potential impacts are for any of the inorganic and organic compounds. The nutrient sources in Coleambally are mostly diffuse, and sharp variations between regular sampling occasions would not be expected. Much of the variation would be due to rainfall events and the time fertilisers are applied. Runoff salinity is a function of soil salinity and this changes slowly (see section 4). Turbidity is often caused from channel bank erosion, and scouring of soil near drainage inlets, however some furrow irrigated crops could also produce some sediment runoff.

Pesticides residues are the main point source of pollution and its variation over short periods would be highest. Pesticide runoff levels are affected by rainfall runoff events, and irrigation management. The levels found in drains during the season of application are sufficiently high to raise concern regarding their potential impact on the aquatic environment.

There are several management options which, if adopted, are likely to result in significant and long lasting improvement of water quality in drainage systems and at discharge locations. These options include:

- on-farm recycling systems.
- other improved on-farm irrigation techniques which would result in less drainage.
- requirements and incentives which would increase the drainage water holding periods.
- construction and enhancement of swamp areas along drains and diversion of water through these swamps. Examples are the Retention pondage on DC800, the disused flow regulator on near DC500 and DC600, and Wergambergal swamp.
- Maintenance of as much weed growth in drains as possible, without jeopardising their flow capacity.
- An appropriate monitoring system, with all relevant information supplied to landholders for increased awareness and timely remedial actions.

Benchmarks

The benchmarks for inorganic compounds are based on the results of Table 5-1. When comparing future results against the averages or medians in the benchmark, it will always be necessary to consider the seasonal variation and the percentile ranges into which the found dataset fits. Differences may only be considered significant after appropriate statistical analysis.

With regard to pesticides, the current levels could also be considered benchmarks. However, where levels exceed specific standards as determined by the EPA, the benchmark values may not be acceptable in the long run, and a program to achieve a reduction would be expected. These programs should be incorporated into the on-farm and regional options of the Land and Water Management Plan.

Monitoring System

The water quality monitoring system presently targets the supply, the major outfall drains (DC800, Outfall), and a few internal drains. The monitoring system should meet the following requirements.

- long term data of major parameters
- MDBC EC impact assessment on Murray river.
- Information that will allow rapid actions to be taken when a problem occurs, eg with pesticide residues. The action may be the declaration of "no drainage" periods, more intensive monitoring to pinpoint point sources, or diversions to en-route wetlands of the contaminated flows. This means data are needed within one day after sampling.
- A cost effective procedure

At the present time a contingency plan for monitoring of pesticides is being developed. This development is also being supported by the Pesticide Task Force, which will in due course make recommendations regarding the various issues.

6. REGIONAL CONTROL OPTIONS

Having discussed the regional water balances (section 2), the groundwater trends (section 3), the trends with regard to soil salinity (section 4) and water quality impacts (section 5), it is time to consider the options to control waterlogging and salinity and to ensure minimal environmental impacts, both within and downstream of Coleambally. The options include on-farm options and regional options. Not all options may be viable, but none should be excluded until from the analysis of sufficient data its application is clearly shown to be non-viable.

The LWMP committee considered options and made a decision regarding the options to be analysed for technical and economic feasibility. NSW Agriculture has dealt with the on-farm options. This report considers the regional options, being the deep bore pumping option, shallow groundwater pumping (on-farm and regionally, pumping of sand and gravel pits when an opportunity exists, and reduction of district channel seepage volumes.

A variety of reports have been produced to deal with the regional options. These are attached as Appendices, whilst this section summarises the main aspects.

Option 1: Channel Seepage Reduction

Before any analysis can be carried out it is necessary to determine the volumes of seepage that are lost annually from the channel system. The main system to be considered is the supply system. The discussion of the drainage system is at the end of this section.

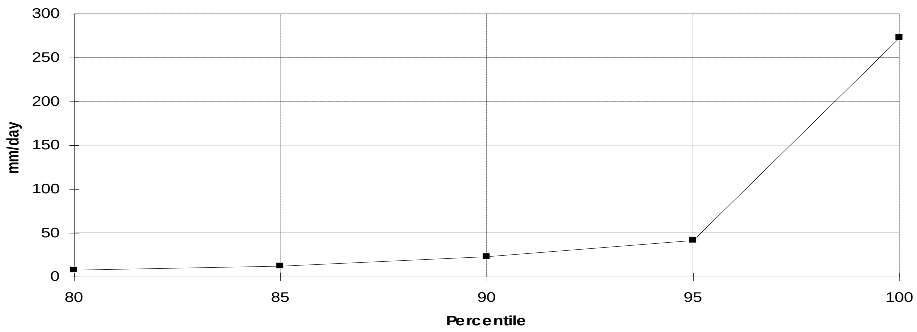
Seepage volumes may be measured by ponding tests, inflow-outflow techniques, seepage meters, or other techniques such as tracers placed on the bottom of the channel (Byrne, 1980). Seepage rates may also be determined indirectly using analytical or numerical groundwater flow models, eg see Wesselink (1963). In Coleambally the seepage meter technique was adopted. During the summer of 1993/94 measurements were taken by University students and Mr Sena Siriwardena. The results are reported at Appendices 7 and 8. Appendix 7 is a data report, whilst Appendix 8 are tables and notes representing the extrapolation of the available measurements across Coleambally.

The length of supply channels in the CIA is about 510 km, plus about 40 km of Main Canal. Previously, seepage losses were identified at about a dozen locations, but volumes were believed to be below 5,000 ML/yr.nnum (eg see van der Lely, "Environmental Status" report, 1992).

The Idaho seepage meter (Byrne, 1980) was used for testing. Overall about 10 % of the channel system was covered by the tests. Measurement points were 400 metres apart. The selection of channels for the tests was probably biased towards the known high seepage locations, it certainly was not random. Most tests were in the deeper watertable area zone.

The median value of all tests was 1 mm/day, and only about 10% of sites showed values over 25 mm/day, and % of sites over 100 mm/day. Figure 5 shows the distribution. The weighted average was about 8 mm/day. Extending the last number to the whole channel system would give about 11,500 ML for the channel system, plus 3,000 ML for the Main Canal, a total of about 14,500 ML (14.5 GL).

Figure 5 : COLEAMBALLY IRRIGATION AREA - FREQUENCY DISTRIBUTION OF FOUND SEEPAGE RATES (Summer 1993/94)



This would be an upper limit, because of the bias in the sample and the reduction in the seepage rate in high watertable areas, which was not accounted for. The actual value lost on basis of current numbers may be closer to 10 GL. However for further analysis a seepage volume of 15 GL has been adopted.

The process involved the identification from the measurements in Appendices 7 and 8 the number of locations with seepage rates over 20, 50, 100 and 200 mm/day, and distribute these according to various watertable category zones. Table 5 shows the outcome.

Table 5: Distribution of seepage sites according to watertable categories.
Large channels

WT	AREA	TOTAL	20-50	50-100	100-200	>200
<2	30,000	6	6	0	0	0
2-5	35,000	8	4	2	1	1
>5	15,000	7	3	2	1	1
		21	13	4	2	2

Medium Channels

WT	AREA	TOTAL	20-50	50-100	100-200	>200
<2	30,000	7	7	0	0	0
2-5	35,000	10	6	2	1	1
>5	15,000	9	5	2	1	1
		26	18	4	2	2

Small Channels

WT	AREA	TOTAL	20-50	50-100	100-200	>200
<2	30,000	13	13	0	0	0
2-5	35,000	16	11	3	2	0
>5	15,000	14	8	3	1	2
		43	32	6	3	2
Total	Sites	90	63	14	7	6

It has been assessed (Stanton, pers. comm) that because of its distribution between high and low rates only about 35-40% of seepage may be in seepage locations where something can be done about it. Table 5 shows that 27 sites have rates above 50 mm/day. The assessed average length of each site is 400 metres (Appendix 8). The volume involved with these sites is about 5,500 ML, which is about 35% of the total assessed seepage loss (Appendix 8).

It is clear from the methodology used and the limited seepage data set that there are uncertainties regarding the reliability of the assessment. Because of these uncertainties any future program to reduce seepage from channels should be guided by an investigations program which identifies the sites that deserve treatment. Nevertheless, the values available now may be used for the best possible economic assessment at this point in time.

Cost of Seepage Control

Options to control seepage considered are clay lining, interceptor tile drainage, bentonite treatment, concreting, and geomembrames. RWC, Tatura has produced a report with assessed cost for typical treatment. This information is shown at Appendix 9. Of all the options available for Coleambally conditions clay lining appears to be the most preferred option, except in very high watertable areas, where interceptor tile drainage may be a good option.

For instance, the costs for clay lining using 60 cm of clay for instance costs about $\$12/m^2$, which is $120/metre of channel if the wetted perimeter is 10 metres The cost of interceptor tile drainage to control seepage is being discussed at Appendix 10. It was found that a tile drainage system on both sides of the channel, which control seepage up to 500 metres away from the pump site, will cost about $23 per metres of channel for installation. Operational costs would be about 1.35/metre/year.

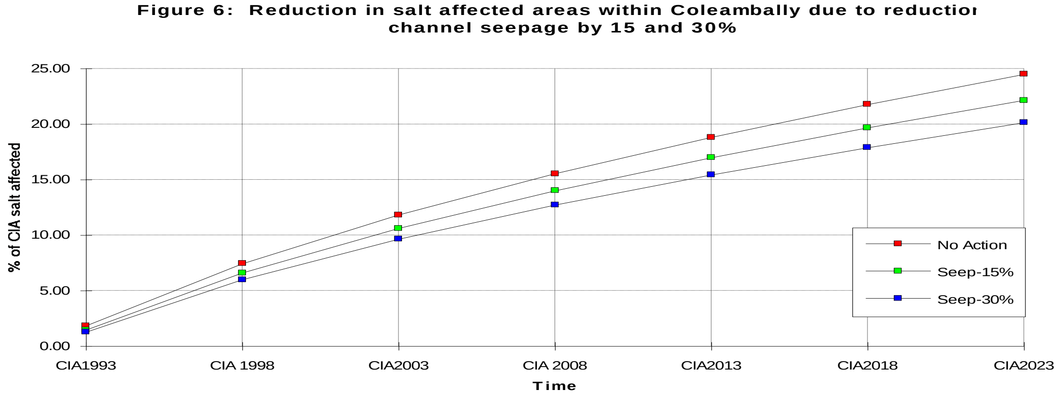
Benefits of Seepage Control

The benefits of treatment considered are value of water lost, agricultural salinity and waterlogging benefits, road benefits. These benefits are being shared with other possible options which may reduce waterlogging and salinity. Therefore channel seepage benefits needs to be considered in context with the other factors, for instance on-farm channel seepage also adds a volume to the groundwater system. In Coleambally rice growing remains the largest source of accessions (section 1).

Section 4 describes the main features of a model which has recently been developed and is capable of assessing relative salinity reduction benefits of various individual options, or a combination of these against a No Action Scenario.

In Coleambally the maximum seepage reduction which may be achieved is 35%. More realistically a seepage reduction of 15% and of 30% should be considered for analysis. The results are expressed as a reduction in the soil salinity status for Coleambally compared to the No Plan scenario (section 4). Appendix 4 discusses the details of the options. Figure 6 below shows the outcome.

The salt affected area reduction is not great. Of course there are other benefits, such as the reduction in water loss from the channel. These are to be considered by the economist.



Option 2: Shallow Groundwater Pumping

The objective of this option is to lower the groundwater levels by groundwater pumping, thereby reducing or reversing the salinisation process and reduce the consequent agricultural yield loss.

Methods

Subsurface drainage has been an effective way of protecting irrigated lands from the effects of soil salinity and watertable induced waterlogging. The methods used include horizontal and vertical drainage systems.

Horizontal drainage, often referred to as tile drainage, collects groundwater from horizontal perforated pipes installed at about 1-5-2.0 metres depth, thereby controlling the watertable level. The installation costs are relatively high (perhaps $1000-2000/ha), restricting its viability to high value crop enterprises. It is unsuited where the soil permeability at the tile drainage depth is very low. This is often the case in the large area farms of the Riverine Plain. Consequently, it is not considered for the Coleambally area.

Vertical drainage consists of the installation of specially designed screens into an aquifer at some depth below the surface and pumping of groundwater using various means. Single bores may be used or several closely spaced bores may be hooked up together to form a single system. Single bores may be pumped using submergible pumps, shaft driven pumps, centrifugal pumps or airline systems. Multiple systems may be pumped using centrifugal pumps or airline systems driven by compressors.

Where multiple bores into very shallow sands are installed using jetting techniques they are often called "spearpoints".

The pumped water is either discharged to waste in the drainage system, if present, or it may be reused in the channel supply. Very saline effluent may be discharged to evaporation areas. The latter is not considered appropriate for the Coleambally Irrigation Area at the present time, since high groundwater salinities are uncommon, the area salinised very small and evaporation areas are considered to be controversial solutions if there is a potential for leakage. Discharge into on-farm or district supply channels is only considered feasible where the salinity of the effluent is below 5,000 uS/cm. For on-farm systems a 3,000 uS/cm criterion may be more appropriate. The end result depends on the shandying achieved and the resultant salinity of the water supply. Values above 500-700 uS/cm may result in crop yield reduction if there is insufficient soil leaching.

The Coleambally LWMP committee has considered the dilution concept and has opted for a lower 300-400 uS/cm target salinity in the receiving channel to allay fears by a proportion of the farming community that crop yields may be affected. This fear may be unfounded, however the effect is a reinforcement of the notion that no groundwater with salinity above 5,000 uS/cm should be discharged to channels.

Currently two "spearpoint systems" are operating in the Coleambally Irrigation area. The pumping rate achieved is about 1 ML/day. Appendix 11 describes the results of these shallow groundwater pumping option investigations in Coleambally. Two spearpoint systems were installed over the 1991-1993 period. The results were evaluated on basis of rates of pumping achieved and the area receiving protection from piezometer analysis. The results were not altogether conclusive. This means the theme needs to be developed using additional information.

Definition Of Option

Examination of groundwater salinity maps, eg those of Appendix 1, has indicated that in about two thirds of the Coleambally Area the groundwater salinity may be too high for mixing into a supply channel. Groundwater pumping systems with possible disposal on-farm are being dealt with by NSW Agriculture in their analysis of on-farm options and economic analysis. This section is concerned with the construction of vertical drainage systems in that part of Coleambally where the groundwater salinity is too high for channel disposal.

The objectives of installing vertical drainage as interpreted in this option are as follows:

- to avoid the agricultural disbenefits of soil salinity and surface waterlogging that result from rising watertables
- to avoid the disbenefits of additional road maintenance that result from rising watertables.

High watertable conditions will eventually occur over much of the landscape. The Department of Water Resources has estimated that 27,000 hectares are affected in 1993, this will rise to 50,000 ha by the year 2003 and 60,000 ha by 2023. The total area of Coleambally is about 80,000 ha. (Section 3).

Effect Of Groundwater Pumping

The height of the watertable once equilibrium occurs is dependent on several factors, grouped together into accession factors and discharge factors. The actual watertable levels fluctuates around this equilibrium dependent on seasonal conditions and the proximity of rice fields in any given year. The equilibrium average watertable is a good indicator of the risk that exists. The critical depth in the MIA and CIA is about 1.3 metres. The accession factors include the proportion of land under rice and the type of soils used for rice growing, rainfall (especially winter rainfall), accessions from crops other than rice, channel seepage, and the presence or absence of a surface drainage system to remove unwanted water. The discharge factors include leakage to deeper aquifers, uptake by deep rooting species or trees, capillary rise to the land surface, seepage into deep drains, depressions and gravel pits, and groundwater pumping.

To understand the effects of groundwater pumping the groundwater behaviour in a district needs to be understood. On a district scale much of the land may not be affected by salinity and some of the land may be affected. The groundwater pumping option is concerned with the latter. If a groundwater bore is constructed at a specific location (probably in the vicinity of salting occurring) then the pumping effort will result in a lowering of the pressure level in the aquifer, and by leakage, a lowering of the watertable. The shape of the watertable reduction is a cone of depression, the largest drawdown being close to the bore, and less and less with distance away from the bore.

The groundwater bore is pumping until an equilibrium is reached whereby the pumped volume is equal to the accessions within the so called area of influence, plus any groundwater inflow into this area of influence. Because of the slope in the landscape (about 0.4 m/km in Coleambally) the cone of depression will tend to be shaped as an ellipse, with the location of the pumping bore in the more upstream of the two centres. This is important when designing locations of bores in relation to the occurrence of saline areas.

Within the area of influence a combination of non-saline land and salt affected land occurs. The net accessions of both type of lands will need to be removed by the bore. Accessions from non saline lands enter the groundwater system and over time find their way to the discharge areas which are becoming saline. These accessions may be intercepted by deep rooting species, or trees, and a proportion may result in deep leakage. If this happens the pressure towards the discharge areas may be less, and less land is affected by salt. An assessment of the benefits of these processes in terms of reduced areas with salinity may be made with the model described by van der Lely (Appendix 4).

In the absence of other discharge factors the discharge areas would grow and an equilibrium between accessions and capillary rise in the discharge areas would occur. This applies to the Tragowal Plains area. Groundwater pumping bores if installed would replace the capillary rise process and the saline area becomes less.

Design Pumping Rates

The volume to be removed by groundwater pumping therefore is a matter on finding the appropriate balance between accessions and discharge factors. On a district scale the volume to be removed could be determined from the groundwater balance, if all factors are accurately known.

These approaches to derive the design pumping rates are fraught with difficulties, because it tends to ignore many of the interactions between watertable depth and accessions from various crops, between watertable depth and uptake by trees or deep rooting crops, between watertable depth and channel seepage, etc. This is a variable and not always linear factor across the landscape.

All other factors being equal, the minimum volume of groundwater that needs to be removed relates to the minimum leaching concept. A certain amount of leaching is necessary to maintain a suitable rootzone salinity, else salts in the irrigation water will accumulate over time. In Coleambally this amount is about 0.1 ML/ha. (van der Lely, pers. comm.). Another approach is to look at groundwater flow between rice areas and non rice areas over the period of one season. Under average aquifer conditions this volume has been assessed at 0.35 ML/ha/yr (van der Lely, 1981). The SWAGSIM models of CSIRO calculate similar volumes. This flow may be equated with the theoretical salinity hazard but it is unlikely that all of this flow needs to be intercepted to achieve sustainability.

The CSIRO has estimated from the SWAGSIM groundwater model in the Hanwood area that pumping at an equivalent rate of 0.2-0.25 ML/ha/year over the whole area, with pumps in targeted locations of the landscape would ensure that salinisation rates in most of the landscape are minimised. Salinisation of some low lying depressions however may need to be accepted.

Where deep leakage is a significant factor the lower end of the 0.2-0.25 ML/ha range is an appropriate starting criterion. This applies for Coleambally. This initial economic assessment is based on pumping rates of 0.2 ML/ha being sufficient to achieve sustainability.

A typical bore in Coleambally would discharge 1 ML/day, or 300 ML/year, after allowance for maintenance and breakdowns. Such a bore therefore would provide protection for about 1500 hectares. Some of the land within this 1200 hectares is salinised, most is not.

In a 60,000 hectares high watertable area the groundwater pumping effort would need to be about 12,000 ML. This may be achieved from about 40 bores. One thirds of these would be in fresh aquifers and supply channel disposal. For this option this leaves two thirds of the area to be protected by groundwater pumping and disposal to drainage channels. About 26 bores are estimated to be needed to achieve protection for 40,000 hectares.

Since the high watertable area is developing over time it is not necessary to install all bores immediately. The construction may be phased in over a 15 year period.

A final complication is that not all the Coleambally area is underlain by aquifer systems suitable for pumping. It is estimated from bore logs this applies to one third of the area. This means that it is not possible to protect 40,000 hectares, but only about 26,500 hectares of high watertable, high groundwater salinity land in this option. This is achieved by the construction of 18 vertical groundwater pumping bores, each pumping 300 ML/year. The annual volume pumped would be 5,400 ML (say 6,000 ML).

Benefits

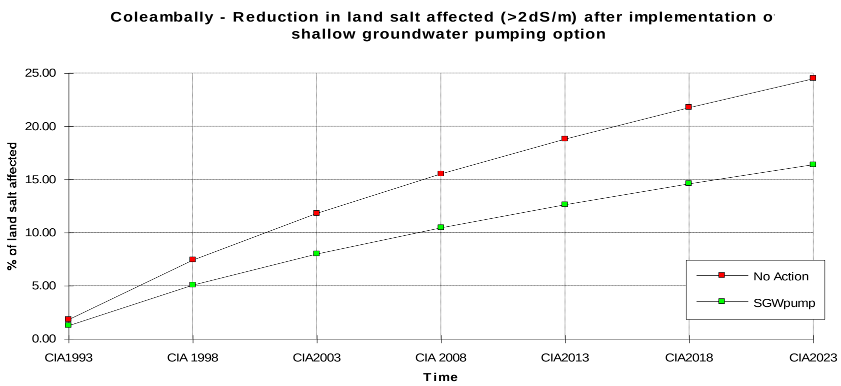
The soil salinity assessment model of section 4 was used to assess the improvement in soil salinity status of the district if 6,000 ML/yr. was pumped and discharged to the drainage system. Table 6 shows the result.

The area affected by salinity decreases from 24% to about 16%. The model outcome may appear to not achieve the desired outcome. After all the design of the shallow groundwater control option aims at providing sufficient protection Two points need to be made:

- This option only caters for the part of Coleambally where saline groundwater is being pumped. Shallow groundwater pumping with disposal to the supply channel system is not considered here. It would create an additional beneficial effect. Also, the groundwater pumping is limited to that part of Coleambally where aquifer transmissivity is sufficiently high.

- Most of the reduction in salinity is being achieved in the more saline soil salinity categories (see tables in Appendix 5). Groundwater pumping will be targeted for these areas. Most of the remaining salinity area will be in the 2-4 dS/m categories. The yield of the main crop in Coleambally, which is rice, is not seriously affected at this level.

Figure 6: Reduction in area affected by salinity if the shallow groundwater pumping option is implemented.



If larger volumes than 6,000 ML of pumping were considered, then the benefits of this option would be higher to show more complete protection.

Option 3: Deep Bore Option

The experimental work supporting this option is described by Lawson (1992). Appendix 11 contains a summary of this report and describes a few options to achieve the objective. The objective is to lower shallow watertables by pumping deep groundwater and maintaining the maximum possible leakage from the shallow to the deeper aquifer.

Section 3 describes the groundwater conditions and the leakance that exists between shallow and deeper aquifers. This allows assessment of the leakage that can be achieved by pumping either 30 GL/year or 60 GL/year from the deeper Calivil aquifer Formation. Table 5 was compiled to allow consideration of the Coleambally Deep Bore option.

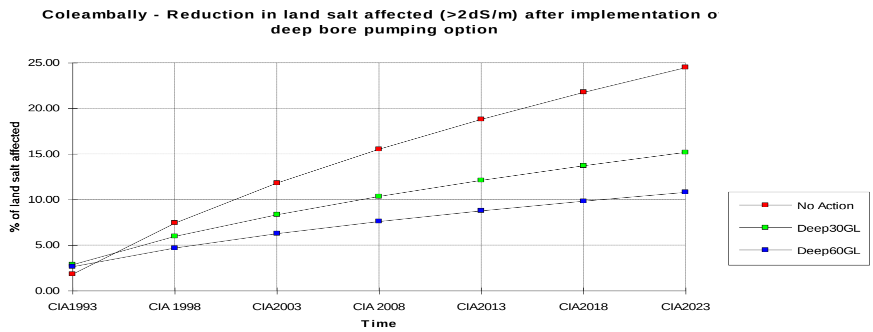
Table 5: Evaluation of deep leakage in parts of Coleambally

Factor	North	South	Comment
Area	40,000	40,000	Total 80,000 l
High WT area	15,000	15,000	Total 30,000 ha
Future high wt	20,000	30,000	50,000 ha by 2003
No Action future level Calivil	10m	5m	7.5 m average
Option 1: PUMP 30 GL/yr.			
Expected Calivil pressure level	15 m	15 m	This is about ave. current regional levels
Leakance	0.7 x 10 E-5	0.3 x 10E-5	day [-1] dimension
Pressure drop achieved	5m	10m	
Leakage achieved	12.7 mm	11.0 mm	mm/year
Factor	**North**	**South**	**Comment**
Specific yield in surface clay soils	3%	3%	
Watertable drop expected	42 cm	37 cm	average 40 cm
Option 2: PUMP 60 GL/yr.			
New Calivil pressure	17 metres	18 metres	Drawing down to below 15 m is difficult
drawdown	8m	13m	
wt drop expected	66 cm	47 cm	

Table 5 makes assumptions regarding the pressure level in the Calivil Formation that would occur for the No Plan scenario. The pumping test of 1990-1992 provided information regarding the likely drawdowns that would be achieved if 30 GL resp. 60 GL was pumped. The new pumping levels shown are compared to the No Plan scenario, and effectively the benefits are calculated from the leakage assessment and the effective porosity of the clay soils near the land surface.

Appendix 3 contains preliminary estimates of costs for an effective deep bore drainage scheme. The benefits once again may be expressed in terms of a reduced soil salinity status in the CIA, as described in section 4 and Appendix 5. Figure 8 gives the summary outcome.

Figure 8. Reduced soil salinity status of Coleambally as a result of implementation of the deep bore option.



It is shown that significant reduction would be achieved by the deep bore option.

Option 4: Pumping From Sand and Gravel Pits and Depressions

Analysis of flows in the Murray River at Euston shows that about once every two years a flow above 20,000 GL/day occurs during the months August, September and October. These high flows are also possible during other months, but at a lesser frequency. If high flow periods are targeted for discharge of saline effluent, then a lower MDBC Salinity and Drainage strategy EC cost would be incurred. The latter aspect is discussed at section 7. It was decided to investigate the option further.

Appendix 12 is a report on the volumes of water and the corresponding salt loads that would be discharged to drains, not only for this option, but also for the other pumping options (2 and 3). The information regarding sand and gravel pits and depressions is taken from the tables in Appendix 12, but corrected for expected changes in effluent salinity once option is being implemented. For instance the salinity of one depression currently is 70,000 uS/cm, but the nearby groundwater salinity is only 15,000 uS/cm. The effluent salinity will reduce to the lower value, multiplied with an evaporation correction multiplier, once the stored salts are removed. The final values are summarised as follows:

Table 6: Expected future volumes and salt loads in depressions, and sand and gravel pits.

Source	No of Locations	Volume (ML)	Salt Load (tns)
Sand and Gravel Pits	15	200	640
Depressions	11	233	3000
Total	26	430	3640

These volumes are representative of future salinity conditions, not the current scenario, which involves far less volumes and salt loads.

Costs and Benefits

Costs relate to pumping of these sources of groundwater, whilst the benefits may be analysed using the method of section 4 (Appendix 5).

"INSERT THIS INFORMATION HERE"

7. MDBC EC CREDIT NEEDS

Appendix 13 gives background to the MDBC S&D Strategy, correspondence from Mr A. Close of the MDBC regarding methods of assessment and details of the options discussed, this section summarises findings.

The following options discussed in this report involve the discharge of salts to the Murray River.

2. Shallow groundwater pumping and discharge to drains

3. Deep groundwater pumping option and reuse via channel system
    3.1. Pumping in irrigation season only
    3.2. Pumping all year

4. Pumping from sand and gravel pits or depressions filled with groundwater

Option 1, reduction of channel seepage, involves a reduction in the volume of channel seepage. Depending on whether this volume is then used for increased irrigation or for dilution in downstream in the Murray River it may attract salinity credits. This aspect is to be considered in a later stage of the LWMP process.

Other options, such as pumping of fresh shallow groundwater with discharge to (on-farm) supply channels also are to be considered separately.

Options 2, 3 and 4 are assessed for future (year 2023) conditions of waterlogging and salinity, after watertables have risen to higher levels and salinity conditions have worsened. Pumping rates assumed are the maximum likely scenarios. For these options need for discharge would increase gradually, and the pumping schemes constructed over a 10 or more year period.

Table 7 below shows the calculated impacts for the selected scenarios. Impacts are assessed as increase in EC units for the month considered. These values may be added up to get annual totals.

Option 4 relates to discharge during high river flows (>20,000 ML/day at Euston). These flows are likely 50% of the years during August, September and October, but less during other months (see Appendix 13). Options 2 and 3 would involve discharge without consideration of the Murray River flow at the time.

The assessment of EC requirements will be based on hydrological models. These are not yet available. What is available in the interim are some rules by which a reasonable interim assessment can be made. These are used in this report.

The main consideration for evaluation are the volumes of effluent and the salt load involved in each option. Basically, the salt load in the effluent causes a requirement for EC units. The information supplied by A. Close (Appendix 13) allows the assessment of that aspect. The volume of effluent however also needs to be considered. The volume may cause the gaining of an EC credit. Where the salinity of the effluent is high (say 5 times or more) compared to the salinity of the receiving water the volume correction would be very small and may be ignored. This applies for options 2 and 4. Where the salinity of the effluent is small a correction for effluent volume should be applied. This applies for the deep bore option.

At the time of writing of this report the assessment of the volume correction has not yet been achieved. This can only happen after a flow model has been developed. At present the assessment of EC credit requirement for the deep bore option may be overstated to some extent.

The shallow groundwater option involves the discharge of some 6,000 ML of effluent each year (after about year 10 of the plan period). The salt load in this effluent at 4,000 mg/L would be 24,000 tonnes. Pumping would be assumed to occur during any month of the year.

Deep bore option 3.1 involves the pumping of 30 GL or 60 GL per year into the supply system. Over 9 months this is 3.33 GL, resp 6.67 GL/months. At 600 uS/cm this represents 1200 respectively 2400 tonnes/month. It is estimated that about 12% of this escapes at the bottom end of the channel system (Sena. Siriwardena, pers.comm.). Therefore the salt load reaching the drains is 144 resp. 288 tonnes/month. The total volume reaching the drain is 3,600 resp 7,200 ML per year.

The volume involved is quite significant and could attract a significant EC credit to partially offset the EC cost of the option. This can not be estimated at present since no guidelines are available, however one way of making a correction is by reducing the salt load in the drainage by the salt load that already exists in an equivalent volume of the receiving waters. With the deep bore salinity being 600 uS/cm and the average salinity in the receiving waters being 200 uS/cm this represents a one third reduction. This means that 96 tonnes/month and 192 tonnes/month are the values that may be used as "best guesses" in the assessment.

Similar principles apply for option 3.2, however the salt loads per month are less because the 30 GL resp. 60 GL pumping rates are spread over twelve months, not nine. The drainage volume in the winter time is much larger because there is no irrigation reuse, giving a much larger salt load and EC impact overall.

With option 4 the volumes of all the potential pits and depressions that may be pumped is about 430 ML (Section 6, Table 6). The salt load is estimated to be 3640 tonnes. This discharge would typically occur over a period of about 2 months on each occasion because the option is unlikely to be available in October, the last month that high river flows are likely on a 1 in 2 year frequency.

The water could be pumped back into farm supplies if the salinity is less than 2000 mg/L. This should be encouraged and would reduce downstream effects.

Outcome Of Assessment

Table 7 shows a summary of the outcome of a strategy whereby the salt loads are kept down to a minimum. This is achieved by assuming 33% reuse of any drainage water discharged into the drainage system during the irrigation season. The reuse is along Yanco Creek, the Outfall Channel and along Euroley Creek.

Table 7: Assessed minimum requirements for EC credits for several options in the Coleambally area.

No	Option	EC Credit Used No Reuse	EC Credit Used d/s Reuse	Cost $K d/s Reuse
2	Shallow Saline Groundwater pumping	7.88	5.91	560.3
3.1	Deep Bore (30 GL)	0.29	0.19	17.9
3.2	Deep Bore (30 GL)	0.77	0.65	69.6
4	Pumping pits and depressions during high Murray Flows (*1)	0.44	0.44	22.8

(*1) : reuse during high Murray flows is likely to be negligible

With regard to the reuse factor d/s of Coleambally, this is unlikely to apply for option 4 during the period that discharges are targeted, namely August to October. On the other hand, options 4 is likely to be used only once every two years on average, and this would half the EC requirement shown, to bring the assessment back to an annual average.

Option 2 will require about 6 EC units and this will be a severe constraint for economic viability. Option 3 on the other hand does not involve much EC cost, especially if pumping is restricted to the irrigation season only.

The costs above are MDBC costs, which are quite different from the cost which NSW incurs to obtain an extra EC unit credit. The costs to NSW are based on the marginal cost to obtain an additional unit, not the average for all units. In fact, the MDBC values represent an economic cost, whilst the NSW values represent a financial cost. It is coincidental that both are nearly the same at the present time.

The DWR, who administers the Salinity and Drainage Strategy in NSW, intends to compare the EC unit requirements of all Land and Water Management Plans being prepared and in the process compare cost versus benefits derived. The final allocation of EC units will depend on where the most benefits per unit is derived. The number of units available in total is limited (about 12).

8. LISTING OF REMNANT TREE AREAS IN COLEAMBALLY

The text below was prepared by Mr Phil Green after examination of data collected by Mr Sena Siriwardena.

Introduction

While it is necessary for their economic viability that farmers optimise the area of their land which is under production, there are many benefits to be gained from retaining some native vegetation (which is usually in the form of trees).

Trees act as windbreaks; sheltering stock from cold winds, helping to prevent crops from drying out, and helping to prevent soil from drying up and blowing away. Trees provide shade for stock in hot weather. Trees can assist in keeping watertables down. Trees can be useful around the farm as a source of timber for fenceposts, firewood, etc. Trees also add to the scenic value of the area, and provide habitat for native animals, particularly birds and bats.

The purpose of this report is to describe the remnant vegetation of the CIA in terms of its; type, location, extent, health and other aspects which may be useful. This should provide a basis for decision making on such matters as the need for planting new areas or changing the management of the existing areas so that they are sustainable.

For the purpose of this study the term remnant vegetation refers to stands of trees. It is realised that there are some areas dominated by other native species such as Boree wattle (*Acacia pendula*). However, these shrubby species, while they no doubt have some environmental value, are relatively short-lived and therefore not considered to be as important for the sustainability of the area as the trees.

Methods

Aerial photographs (1991-92) were used to identify all areas of remnant vegetation greater than 1 hectare in area. The extent of each of these areas was estimated. The are as identified are shown on Figure 1.

Each site was visited (during 1993), the dominant tree species were identified and a qualitative assessment of the health of the trees was made. Other observations were also made, including; height of trees, the amount of tree regeneration that was occurring, evidence of grazing intensity or other landuse, soil type and presence of salt on the ground.

Information on the depth to the water table was obtained from the nearest piezometer. (Unfortunately, these were sometimes a few kilometres from the site, so may not be particularly relevant to the site.)

Results

The results of the survey are summarised in Table 1.

Twenty Eight remnant vegetation areas were identified in the CIA (This does not include Boona State Forest). These ranged in size from 1 to 48 Ha.

Table 8: Listing of remnant tree areas in Coleambally.

Ref No	Dom. Sp.	Height (m)	Health	Regen.	L'use	Disturbance
2	C.Pine	12	Good	Some	Many birds	None
3	C.Pine	12	Good	Some	Many birds	Some dead trees
4	B.Box	12	Good	Some	Many birds	Some dead trees
5	B.Box	12	Good	Some	Many birds	Some dead trees
6	B.Box	12	Good	Little	No birds	Some grazing
7	B.Box	12	Poor	Much	Many birds	Heavy grazing
8	B.Box	12	Poor	Much	Many birds	Old cars/junk
9	B.Box	15	Poor	Much	Some birds	No grazing
10	B.Box	20	Poor	Some	Some birds	Some grazing
11	B.Box	10	Good	Some	Some birds	Metal rubbish
12	B.Box	15	Poor	Some	Some birds & beehives	None
13	R.R.Gum	18	Good	Much		Some grazing
14	B.Box	12	Good	Much	Many birds	Heavy grazing
15	B.Box	12	Poor	Some	Some birds	Heavy grazing
16	C.Pine	15	Good	None		Heavy grazing
17	C.Pine	15	Good	None		Heavy grazing
18	B.Box	15	Good	Some	Some birds	Some grazing
19	B.Box	12	Poor	None		Some junk
20	C.Pine/ B.Box	12	Good/ Poor	Little	No birds	
21	B.Box	15-20	Good	None	No birds	No grazing
22	B.Box	15	Poor	None	No birds	No grazing
23	B.Box	15	50% dead	None	Many birds	
24	B.Box	15	Poor	None	Some birds	Some grazing
25	B.Box	15	Good	None	Some birds	Frequent flooding
26	B.Box	15	Good	None		Farm house
27	B.Box	12	Good	Much	Many birds	Some grazing
28	C.Pine	12	Good	Some		

The total area of remnant vegetation was 366 Ha.

Of the 28 areas identified, 6.5 of them were dominated by White Cypress Pine (*Callitris glaucophylla*) and 20.5 of them were dominated by Black Box (*Eucalyptus largiflorens*). One area of 2 Ha was dominated by River Red Gum (*Eucalyptus camaldulensis*).

The trees in all of the Cypress Pine areas were generally healthy. All the pine areas had some regeneration occurring, with the exception of areas 16 and 17. These two areas also appeared to be relatively heavily grazed.

The pine areas were all characterised by sandy-loam soil. The depth to watertable in or near the pine areas ranged from 1.7 to 7 metres. No signs of salinity were evident on the ground in the pine areas.

Of the 20.5 Black Box areas, the trees in 14 areas were generally of a healthy appearance, while in 7.5 areas they appeared unhealthy. Regeneration was variable across both the healthy and unhealthy areas, ranging from none to much.

The Box areas were generally on clay-clay loam soils, except for areas 12 and 25 which were on clay-loam, 27 which was on sandy-clay loam and 26 which was on a sandy-loam. The depth to watertable ranged from 1.1 to 8.5 metres. Patches of salt were observed on 3 areas; 15, 21 and 24. Cumbungi was observed on 2 of the Box areas; 14 and 20.

Discussion

The total area of the CIA is 79,100 Ha. The total remnant vegetation area of 366 Ha therefore represents only 0.46% of the area of the CIA.

Boona State Forest should also be included when considering the total tree cover in the CIA. This State Forest has an area of 1900 Ha, but only 60% of this is treed. Its area of remnant vegetation is therefore 1140 Ha.

The total area of remnant vegetation in the CIA is therefore 1506 Ha, which represents 1.9% of its area. This is significantly less than the 5-10% of the area of a farm which Bird (1984) suggests can be devoted solely to trees with no impairment of agricultural productivity.

Although all of the pine areas are apparently in good health, areas 16 and 17 do not show evidence of regeneration. A lack of regeneration is a cause for concern as it means that there will be no young trees to replace the existing ones when they eventually die. The observations suggest that heavy grazing pressure may be the cause of this lack of regeneration. To ensure the sustainability of these two sites, a reduction in grazing intensity appears to be warranted.

The trees in a third (8 out of 21) of the Black Box areas appear to be unhealthy. This represents 37% of the total Black Box area of the CIA. Though many of the areas which have unhealthy trees do have regeneration occurring, the decline in tree health is still a cause of concern. If the areas are no longer suitable for the mature trees, the young trees are unlikely to reach maturity and the trees will eventually die out.

From the data, there are no apparent correlations between Black Box health and depth to watertable. (This could be due to the fact that the piezometers from which the watertable data was obtained were not located right in the tree areas.)

There are three likely causes for the poor health of some of these Black Box areas:

(i) Black Box trees will decline, and eventually die if their roots become waterlogged. It is known that watertables around the area have risen. It is therefore likely that the groundwater has risen to a level where the roots of these trees have become waterlogged (to some degree).

Those areas where patches of salt were observed on the ground (15, 21 & 25) are likely to be suffering from elevated watertables.

(ii) Black Box depressions are sometimes used as irrigation drainage and water storage areas. This can result them being them being inundated either permanently or for a long period each year. This will result in a decline in the trees due to waterlogging.

Prolonged inundation is likely to be the case with areas 14 and 20, where the growth of cumbungi was evident.

(iii) Black Box trees are adapted to being inundated every few years. They will lose vigour if they are deprived of this watering -as can occur if the local hydrology is altered. This is unlikely to be the case in the CIA, but is worthy of consideration if the decline in health cannot be related to an elevated watertable or prolonged inundation.

The appropriate management to prevent the decline of the Black Box will depend on the cause of this decline. Where the decline is due to elevated watertables, replanting with waterlogging / salt tolerant species may need to be considered.

Conclusion

The area of remnant trees in the CIA is relativley small, and there is cause for concern regarding the sustainability of much of it. The LWMP committee should consider the information in context with other issues related to the natural environment in Coleambally.

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