MIA LAND AND WATER MANAGEMENT PLAN

DEVELOPMENT AND EVALUATION OF PREFERRED PLAN STRATEGY

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FOREWORD

The MIA Land and Water Management Plan Working Group considered that the complex interaction of many issues and options available for determining a preferred plan strategy required optimisation. An "Optimisation Team" consisting of the author (convenor), economists Mr Ian Milward Brown (DLWC) and Mr Graham Marshall (NSW Agriculture), hydrologist Mr Paul Pendlebury (DLWC), Dr S. Prathapar (CSIRO), and research agronomist Mr Geoff Beecher (NSW Agriculture) were nominated and appointed during January 1995. Mr Marshall was later replaced by Ms Catherine Curthoys, then Mr Phil Pagan, and finally, Mr Peter Rooke, all economists with NSW Agriculture.

There is no precedent of optimisation of Land and Water Management Planning options, and the team selected the standard technique of linear programming as its approach. It was then found that such an integrated approach was handicapped by lack of data availability for many options, of which only few had been investigated. The methodology however was continued using best bet information from related reports and experience of the team members.

Extensive consultations with community groups and representatives have occurred during the process the preferred plan strategy. This report reflects the recommendations of the optimisation team based on information collected until the end of 1995. The optimisation team accepts that the recommendations of the final options package of the MIA LWMP may be modified by Working Group discussions and/or the outcome of the additional studies, eg the Northern Hay Plains study.

1. INTRODUCTION

The MIA LWMPlan area extends from Narrandera in the South East to Booligal on the Lachlan River and includes the Yanco and Mirrool Irrigation areas and the Benerembah Irrigation District upstream of Barren Box Swamp, and the Wah Wah Irrigation District, the Lower Mirrool Creek Area, and the Wah Wah Stock and Domestic Supply District downstream of Barren Box Swamp. This report will refer to these areas as “upstream” and “downstream” even though both are situated within the plan area. The downstream areas proper relate to users along the Murrumbidgee and Lachlan Rivers who may be impacted by actions and events within the plan area. Figure 1 shows the boundaries of the plan area.

Because of the multitude of issues related to water supply availability, excess drainage volumes, water quality, needs of the environment and downstream users, insufficient infrastructure to manage drainage and flood events, structural change due to government (de-)regulation and market forces the MIA LWMP is very complex. The LWMP needs to pursue sustainability and satisfy a host of other requirements in both the upstream and downstream areas. The integration process needs to achieve a wide range of objectives and be cost effective.

Investigations have been carried out over at least 5 years and many reports have been produced. A listing of all these reports may be found at Chapter 14. From these investigations a list of about 82 options has been identified for the upstream scenarios, including on-farm and regional. Other options exist for the management of drainage downstream. Each option is likely to contribute in some way to the overall solution to manage the environment, it may be economic in its own right or it may not be economic. Several uneconomic options may need to be incorporated in the plan to address the environmental impacts that exist at present or under the No Plan scenario.

For the MIA Plan Optimisation including many options is to find a balance between the various objectives, or the most preferred package of solutions. Such a package would achieve the following:

1. the package is economic, and possibly maximises economic returns for the district.
2. sustainability and environmental objectives are being achieved
3. double counting of benefits between competing options is avoided as much as possible.
4. high risk solutions are not selected as a priority. These include those for which the cost is high and benefits uncertain, and those for which external conditions may change over the life of implementation.

In addition the preferred package should be robust and outcomes not greatly affected by possible changes in the rate of adoption of key measures compared to the planned implementation, for instance when government assistance is delayed for a couple of years.

The quality of optimisation using these principles depends on the input values into the models. Whilst many investigations have been carried out over the last few years, this is no guarantee that the information is sufficient because many of the investigations were not planned with the optimisation procedures in mind. Consequently it is possible that many factors are still not clearly quantified. Where benefit and cost of economic and environmental assessment are not accurately defined there is more risk that the solutions adopted will not produce the desired outcomes. The uncertainty aspect needs to be taken into account and decisions for options and associated investments should be subjected to risk analysis.

For the MIA Land and Water Management Plan, optimisation and integration has been organised into the following main components :

1. upstream areas including linkages to downstream areas
2. within the downstream areas
3. between upstream and downstream solution packages.

The upstream work has been completed on basis of the information available. The downstream investigations are not yet completed and are awaiting the outcome of the Northern Hay Plains study. The Wah Wah LWMsubPlan has not yet been completed. The optimisation report however deals with all aspects based on the information currently available and careful assessment of the directions into which the downstream solutions are likely to develop or should develop. This assessment is presented in this report. Therefore, even though a number of feasibility studies are still to be carried out, it is believed the integration of the various plan components is now complete and implementation of the upstream part of the MIA Plan may proceed without awaiting the results of outstanding investigations.

This report is a comprehensive account of the deliberations and the work of the Optimisation Team. The team comprised of Mr Geoff Beecher and Mr Peter Rooke of NSW Agriculture, Mr Ian Miward Brown and Mr Paul Pendlebury of DLWC, and the author, who was convenor. The principles of integration have been adhered to as best as possible. The principal outcomes are based on a systematic approach including the use of computer modeling. However, it was found that the final recommendations also required a large element of value judgement. Such value decisions are discussed on basis of practicality, risk and uncertainty factors. The MIA LWMP Working Group will need to deliberate the recommendations and decide whether or not they should be submitted for endorsement by the community.

2. OBJECTIVES FOR MIA PLAN

The MIA LWMP working group early during its activities identified the following key objectives for the plan:

1. to achieve sustainability in the MIA
2. to protect the downstream users and the environment.

When trying to identify options and combine these into a logical framework it is necessary to specify these broad objectives more clearly. In a complex environment such as the MIA this is quite difficult. Many can see the problems, for instance the downstream excess drainage volume issue, or water quality degradation, and may select the solution to one of these problems as the main objective. Others see the degradation in the natural environment and may argue that if that is fixed, then sustainability of the MIA is also achieved. When optimising it is necessary to have a clear focus.

All objectives may be valid. However in optimisation only one main objective function can be selected. For most irrigation areas the best choice would allow an irrigation area to go forward and achieve confidence about the future. The treating of problems is not clearly identified as a positive objective and could be seen as just a band-aid. Land and Water Management Planning is about a vision for the future, not fixing problems or overcoming obstacles.

By nominating a main objective, other objectives that play a role in a LWMP may then be called constraints. For instance, a key objective could be to achieve increased productivity for the irrigation area. This may be achieved if the land resource is in a healthy state, and land salinity is controlled to a sustainable level. This has been nominated as the principal objective for the MIA. However there are other objectives and these are treated as constraints. The main objective is subject to the conditions that there must be no significant external impacts in terms of drainage volumes, water quality, drainage water salinity or groundwater flow. In addition, it is desirable to protect the natural resources in the area against further degradation.

Upstream of Barren Box Swamp

For the part of the MIA upstream of Barren Box Swamp consideration of objectives gave a framework which looks as follows:

Objective:
- Sustainability in terms of Land Salinity to maintain or enhance Productivity.

Constraints:
- Drainage Volumes to external environment to be controlled to acceptable levels.
- Drainage Water Quality leaving area to meet agreed standards
- Drainage Water Salinity to be acceptable for downstream users and uses.
- Groundwater impacts of leakage from the irrigation areas not to be of great concern.
- The Natural Environment of the irrigation areas to be maintained or enhanced compared to its current condition.

Downstream of Barren Box Swamp

The MIA LWMP started with the flooding problems of 1989 and these need to be addressed. The MIA cannot be called a sustainable entity unless there is a sufficient drainage infrastructure downstream of Barren Box Swamp. This becomes the key objective :

- To develop a drainage infrastructure capable of controlling drainage volumes and quality from the MIA.

There are a number of constraints that may prevent the selection of the cheapest and easiest solution :

- There must not be unacceptable water quality or other impacts on the river systems (Murrumbidgee or Lachlan).
- There must not be an unacceptable frequency and durations of flooding of the Lower Mirrool Creek system, in terms of agricultural production cost, wetlands habitat affected, or groundwater accessions.

These constraints may cause that the choice of solutions drift towards the development of additional irrigation to utilise the excess drainage up to the point where the mentioned constraints are met.

The water quality objective for the receiving downstream irrigation areas may be based on current standards, or an enhanced standard. Whatever the choice, this would involve a re-setting of the constraints for the upstream area optimisation and have consequences for the preferred solution package. Similar principles apply to the volume aspects or other objectives.

This approach to the setting of objectives precludes the irrigation option downstream to be a major objective in itself. However there is no problem for the irrigation option to become quite dominant in the optimisation if it shows to be economic and capable of displacing some other options in the overall solution.

General.

The sustainability objective in the MIA, which is henceforth considered central to optimisation of the MIA LWMPlan, could involve different interpretations for sub-component areas, for instance for the gazetted horticultural areas the package of solutions would be different compared to the large area farms. Therefore, instead of looking at the upstream part of the MIA in one block it is useful to consider the main sub-components. These are gazetted horticulture, extended horticulture, vegetable areas and mixed farming. A diagram has been prepared to show the key areas for optimisation and the impacts that each has on the external environment, see Fig. 2.

Downstream of Barren Box Swamp a distinction is made between the irrigation part of Wah Wah, the area of the Lower Mirrool Creek, the Western Wah Wah Area and the (potentially) receiving river systems. These are also shown at Figure 1.

For each upstream component area the optimisation procedure is reduced to :

- finding options that satisfy the sustainability objective function
- where necessary finding additional options to meet the constraints.

The procedure towards solutions for the downstream areas is discussed at section 10.

3. BACKGROUND INFORMATION

3.1. Previous Studies

The MIA has existed since 1912 and a lot of studies have been carried out into problems of sustainabililty since about 1931. McIntosh [27] provides a literature overview of some of the reports. The issues concern watertable control in horticulture since 1956, salinity symptoms in large area farms since about 1960, soil surveys and interpretation.

Drainage problems were experienced in Benerembah since the 1970's and studies were carried out into options [56], the water balance, [58]. An REF was prepared [49], [49], followed by a community supported Strategic Plan [18]. The economics of the scheme was determined [15]. Rahman [37] described the on-farm options of the scheme and these were adopted as a semi-formal LWMP for the area in 1994. The construction of the scheme commenced in 1992. Performance monitoring was considered [10], [18], [37], and is being partially implemented, but without a formal plan. The Stage 4 area to the west of Barbers Road has not been able to proceed due to lack of disposal opportunities, see further section 4.5.3.

The drainage disposal problems downstream of Barren Box Swamp became acute in 1989 and a new series of studies commenced eg. reports on preliminary studies [67], [68]. The NSW government developed an Integrated Drainage policy [68] but the organisation of activities to find solutions for the MIA in 1992 was taken over by a Land and Water Management Plan Committee. Investigations continued into the hydrology of the Mirrool Creek [5], the flood secrurity downstream [3], effluent disposal options [62], watertable control options [65], evaluation of drainage volumes [34]. A district summary was prepared [12], and various options were ranked for economic merit [47]. The current trends scenario was assessed [26].

In conjunction with the MIA plan investigations the impacts on the downstream wetlands environment was studied [40], [41], [43], as well as water quality issues [44], [45]. A Downstream LWMP Steering Committee conducted a major study into the feasibility of the "channel to the river" option [23], [24], but this was not accepted by the downstream Murrumbidgee River community, for a variety of reasons.

The downstream issues are further described at several sections later in this report.

The upstream options studies led to an On Farm options report compiled by NSW Agriculture [30]. This report contains 30 contributions. Several options within this report have been analysed for economics. Several studies on regional options to manage watertable levels [64], seepage from channels [55] and drainage volumes [17],[53] were also completed and analysed for economics. Economics of some regional options was first carried out by ranking [47] and then for specific options [5], [8], [9]. For many options the Coleambally experience is helpful as far as economics is concerned [14], [46].

This report aims at bringing together all the previous and current studies and integrate these. Objectives were described at section 2

3.2. Water Balance for the MIA

To put the analysis of options for the LWMP in some sort of perspective a comprehensive waterbalance was produced for the MIA. The water balance factors include the inflows to large areas and horticulture in the MIA, losses in the system from various sources, evapotranspiration by crops, irrigation and rainfall runoff, the groundwater balances for shallow and deeper aquifers systems including accessions, capillary rise, deep leakage and pumping, drainage balances for the MIA drainage system and Barren Box Swamp. Details are described in the Watertable Control Options report [65]. Figure 3 shows the outcome. All volumes are in Gl/year, and based on averages. The latter may be a drawback to be considered when making decisions based on the values or related models.

Figure 3 shows the linkages between the sub-systems of the water balance and the values in Gl/year. Key numbers are the volume of accessions to groundwater (95 Gl/yr in large area farms), capillary rise (75 Gl/yr), runoff volumes from large area farms (100 Gl/yr) and horticulture (22 Gl/yr), tile drainage (12 Gl/yr) and escape drainage (80 Gl LAF and 30 Gl/yr horticulture). For further detail, see the reference report.

3.3 Environmental Status

3.3.1. Natural Environment

Jan Grose [16] prepared a report on the natural environment of the MIA which since commencement of irrigation has completely and irreversibly altered. Nevertheless the aim of the MIA plan would be to create an environment in reasonable harmony with the surroundings. This means certain actions regarding tree corridors, prevention of soil salinisation, water quality to the downstream environment, and preservation of remnant tree areas are justified.

3.3.2. Water Quality

The water quality data prepared by Shepheard [44], [45] are complementary to a lot of work by CSIRO (no bibliography prepared) on nutrients and pesticide residues. An LWMP consultancy exists to put all the information together. The status is that there are concerns in all areas, especially salinity and pesticides.

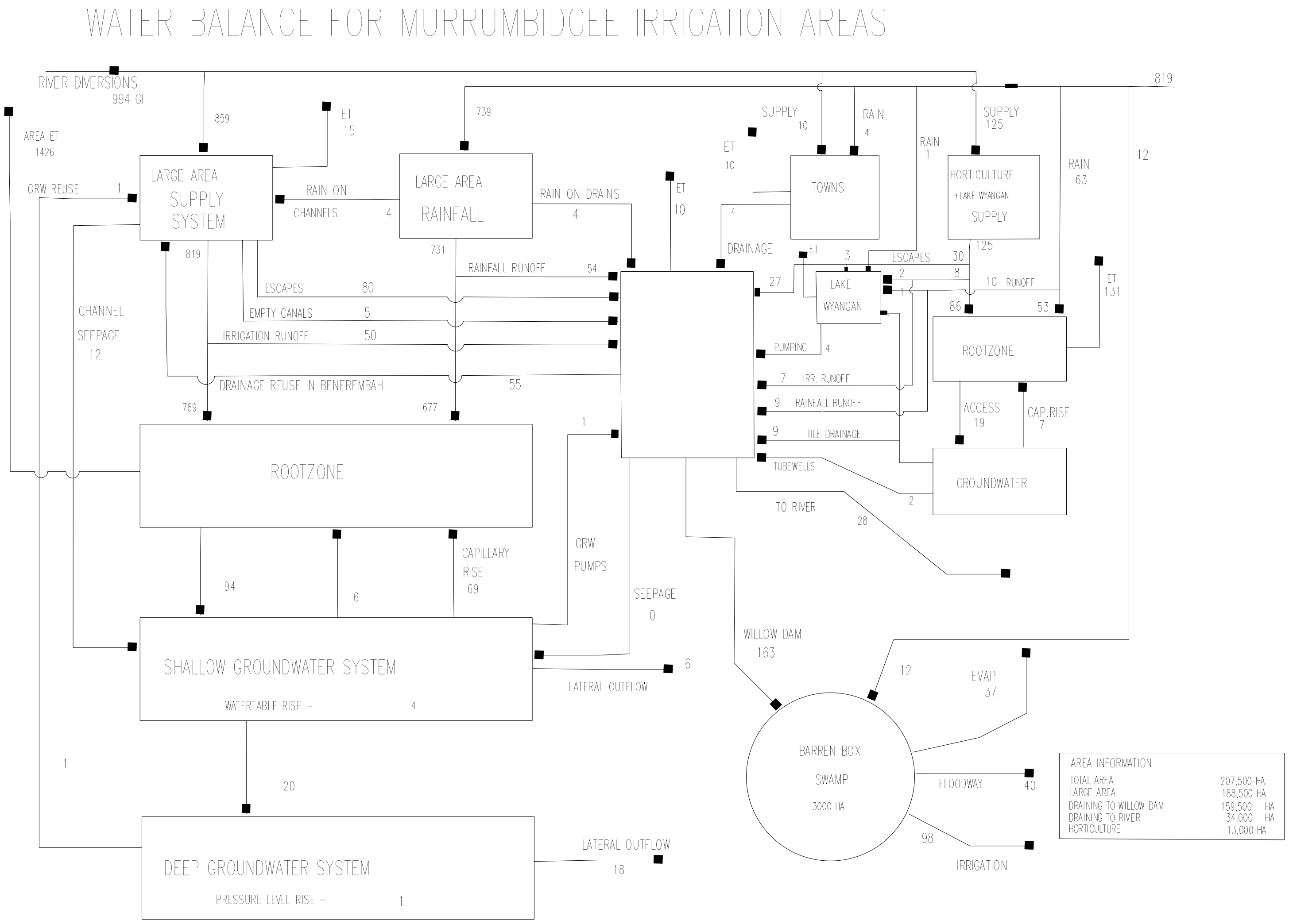

Figure 3.1 : Schematic overview of water balance components in the MIA

Salinity

The salinity of the supply into the MIA averages about 150 uS/cm. Salt loads are derived from many sources, the main ones being horticultural tile drainage and large area runoff. The resulting salinity at Willow Dam varies between 300 and 400 uS/cm in the irrigation season hen flows are in the order of 300-600 ml/day, to 1000-2,500 uS/cm in winter when flows are often less than 100 Ml/day. Van der Lely [58] put together the water and salt balance of the MIA and Benerembah and prepared predictions for the LWMP [64]. It was found that the overall effect of trends from all sources may be fairly neutral, with large area runoff salt load increasing and tile drainage salt loads from existing gazetted horticultural farms decreasing. The Hassall study [20] considered the impacts of additional salt loads to the Wah Wah District. It concluded that there are possible long term impacts on soil salinity in those irrigated parts of Wah Wah not used for rice growing and recommended that the 700 uS/cm maximum limit for the water supply to Wah Wah be reviewed.

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Nutrients

Nutrients in the Murrumbidgee River and the MIA supply are mainly a concern as far as Phosphates are concerned. Average values are about 0.06 mg/L for Ptot (Buchan 1995). In the MIA drainage at Willow Dam the levels are higher, at 0.10-0.15 mg/L. The sources of Phosphorous at Barren Box swamp may be summarised as follows :

Table 3.1 : Phosphate levels in MIA Drainage

Location	Source of Flow	Medium Ptot mg/L	Median Flow Ml/day	Median P load t/a
Willow Dam	Ag Drainage, Main Drain J	0.16	470	28
Main Drain J	Ag Drainage Griffith sewage Griffith Urban	0.21	300	23
Griffith Sewage	Treatment Plant	4.56	6	10
Barren Box Outfall	Flow from Swamp	0.18 0.25 ('90-'93)	250	16
Wah Wah Main	Willow Dam Barren Box swamp	0.19	100-400	8

source : KinHill Study [23]. Averages are for period 1979-93, unless indicated otherwise.

Nitrogen is also present in drainage but is not considered to be equally harmful as far as the effects of algal blooms are concerned.

Turbidity is an other concern, levels from the MIA drainage being significantly higher than the supply. The turbidity (and Ptot) of water from Barren Box swamp in recent years has been very high (40-90 NTU) , possibly due to the effect of carp. Turbidity may also have been the reason for the surprising absence of major algal blooms in the swamp. Blooms however have been reported from Stock and Domestic Dams in the Wah Wah district.

Pesticides

Significant levels of pesticides have been reported in the MIA drainage system. The main issues are the use of Molinate in rice during Spring, and Endosulfan, which can be sourced from both horticulture and large area row crops. Other chemicals found include Atrazine, Malathion, Bromacil, Diuron and Chlorpyrophos.

EPA guidelines are based on the needs of aquatic ecosystems. The "Notification" (to EPA) levels are set about 5 times higher than this and the "Action" levels (do something urgently to stop it) about 10 times higher. Aquatic ecosystem guidelines are relevant as far as the discharges to the Murrumbidgee is concerned, however there is an argument that Mirrool Creek and the reuse supply systems to Wah Wah should not be treated using the same criteria. Nevertheless, Molinate levels above Action levels have been reported for the last three seasons, whilst other chemicals above the guideline levels have also been found. During 1994/95 there were a number of fish kills due to Endosulfan in the MIA.

The monthly values for chemical residues recede during the non irrigation season, when traces only of most chemicals are being found. However, Endosulfan above guideline levels was found in one upstream catchment drain during 1995.

A Riverina Agricultural Chemicals Task Force has been set up and this consultative, interagency committee with industry involvement discusses strategies to reduce the problem.

<u>3.3.3. Groundwater and Salinity</u>

The groundwater and salinity environment has been studied extensively and summarised by van der Lely [65]. This includes the trends with regard to groundwater levels, and soil salinity. Regular surveys are now carried out to determine the latter eg Tijs [51]. About 70% of the MIA has a high watertable and land salinity affects about 18% of the landscape, increasing under the No Plan scenario to 28% in 30 years. Different parts of the MIA are affected differently (Chapter 4).

3.4. Downstream Studies Summary

The downstream environment being affected by the MIA is reported by Shepheard [43] and Roberts [40], [41], but also by the KinHill study [23],[24]. For the evaluation of downstream drainage management options a concordance analysis was carried out [24M]. Groundwater accessions from the Lower Mirrool Creek Floodway are a concern in addition to wetlands degradation, possible impacts on the river, and water quality.

Options to divert excess drainage to either the Lachlan or Murrumbidgee River are reported by KinHill [23]. The study included hydrological, engineering, environmental and economics evaluations [24], however assumed that the drainage conditions from the MIA including quantity and quality would remain the same. From the evaluations based on these assumptions the selection of the best (or least worst) option resulted in a recommendation to construct a 600 Ml/day channel via western Wah Wah to the Murrumbidgee River. This however was not acceptable to the downstream community who had serious reservations regarding water quality effects, and lack of controls on the operating authority. There were also strongly expressed views that this was too much an “engineering” option without treatment of the causes. The Murrumbidgee MCM committee supported the view that the proposal was not acceptable, at least in the short to medium term.

Currently a study is being commenced to use the excess drainage for increased irrigation in western Wah Wah, including opportunities for diversion to large recycling storages and discharge of the remainder to the Lower Mirrool Creek. This is called the Northern Hay Plains study.

Chapters 7 and 10 discuss the nature of the drainage management problem. This report aims at providing a framework which will provide a path towards suitable solutions. Without such a frameork the optimisation process could not be considered complete and the implementation of much of the MIA plan could not commence.

4. ENVIRONMENTAL MANAGEMENT ISSUES

4.1. Mixed farming

Mixed farming on about 150,000 hectares in the MIA and Benerembah comprises rice, annual pastures and wheat, other crops such as Canola, Soybeans and Maize being much less significant. There is hardly any perrenial pastures, but some farmers grow lucerne or hay.

The issues may be put in perspective by a series of conclusions from supporting documents. The issue headings are accessions to the groundwater resulting in land salinity, farm runoff, water quality, salinity in the drainage system, and management of the natural environment.

<u>a) Accessions to Watertables and Salinity</u>

1. About 95 Gl of accessions occur each year of which about 55 Gl is from the about 37,000 ha of rice grown each year [65].

2. Channel seepage is small compared to the proportions in Berriquin and Coleambally, but still contributes 12 Gl/yr from 1,400 hectares of channel [55].

3. Accessions from annual pastures and other crops and fallow contributes about 40 Gl from rainfall and irrigation [30/18].

4. Groundwater levels are within 2 metres from the surface in about 70% of the MIA [64], [65]. This area is expected to expand to over 80% over the next 30 years, however in a sense an equilibrium is already being approached.

5. Land salinity is likely to increase from 18% over 2 dS/m currently to 28% over 30 years [65]. For individual sub-districts however this varies greatly, with the end points in 2025 being about 5% in some southern sub-districts, and up to 40% in the northern districts for the No Plan scenario.

6. The salinity levels of the land affected cover the full range from 2 dS/m to over 8 dS/m. At the lower levels the current cropping systems (rice, pastures, wheat) are not affected much, however some more sensitive species are (eg. white clover, soybeans, vegetables).

7. However, despite the salinity increase, under the No Plan scenario the agricultural losses from salinity may be only relatively small [26].

8. It is important to avoid generalisation. The MIA is not a homogeneous block, but has varying hydrogeology, geomorphology, initial salinity and duration since irrigation development. Watertable conditions and salinity vary between subdistricts [1], [51], with the southern part being less affected than the northern parts [65]. The Wah Wah area, Benerembah Stage 4 area, the Lake Wyangan district and Warburn Swamp area require a special focus of the otherwise similar problems. See sections 4.5, 4.6 and 4.7.

9. Currently there is a full range of management and irrigation practices which together contribute to the No Plan scenario for land salinity and sustainability. Advice is available to help achieve Best Management Practices. However the irrigation systems in the MIA mixed farm areas still rely on flood irrigation and this is unlikely to change significantly in the foreseeable future.

b) Farm Runoff Volumes

1. From the various estimates of large area farm runoff [34], [53], [58], it appears that large area farm runoff totals about 104 Gl/yr, which adds to the about 85 Gl/yr escape drainage from channels in mixed farming areas [65]. Of total farm runoff about 54 Gl/yr relates to rainfall runoff and 50 Gl/yr relates to irrigation runoff.

2. Rice drainage comprises both rainfall and irrigation runoff, of which the former averages 36Gl/yr, however very much dependent on large volumes in some years [34].

3. Improved land management to reduce accessions for better sustainability may involve the increased shedding of farm runoff to drains [Ref 30, eg. pps 4, 5].

c) Water Quality in Drains

1. Water Quality in drains below farms is higher in nutrients than the supply and has occasional high levels of chemicals above notification levels and action levels as determined by EPA.

2. The main chemicals of concern are Molinate, Chlor pyrophos and EndoSulfan, however there have also been traces of other chemicals [30/25], [44].

3. Nutrient levels are not excessively high and the trend actually has changed little over the last 20 years.

4. Turbidity is an issue and relates to a problem with erosion of supply and drainage channels, farm inlets into drains, carp, etc, and requires attention.

d) Salinity in Drains

1. The salinity in farm runoff relates to the salinity of the land shedding the drainage. Current salinity in the runoff ranges from 150 -200 mg/L for irrigation runoff to 200-400 mg/L for rainfall runoff, however higher values may occur from salinised areas [58].

2. The total salt load from farm runoff may increase from some 18,000 tonnes/yr at present to 23,000 tonnes/yr in 2025 for the No Plan scenario [65], [20].

3. Whilst salt loads to drains is an issue, salt discharges help maintain sustainable farming systems in the upstream areas.

4. The present inputs of salt into large area farm lands are larger than the salt loads removed by surface drainage. This is balanced to a large degree by leakage to deeper groundwater systems in the southern parts, but not so in the north. As a result the northern areas have the most difficulty with long term sustainability. Capillary rise and leaching processes produce the net salt movement of salt between the rootzone and the groundwater system.

e) Natural Resource Management

1. The lands of the MIA have been irreversibly altered from the natural habitat. Remaining stands of vegetation are being affected by drainage from farms and groundwater induced waterlogging and salinity. Fauna changes have followed the flora changes [16].

2. A few wetlands areas occur which have value or have potential to be of value if appropriate management can be devised and applied.

3. Many depressions with remnant Black Box vegetation inevitably will be subject to high watertables and salinity and the process of decline in such areas may not be able to be halted economically.

4. The principal function of the MIA is to be an agricultural production zone, however a healthy natural environment adjacent to the MIA and in pockets within the MIA may be seen as a indicator of sound land and water management. Opportunities for improvements may exist.

4.2 Gazetted Horticulture

Gazetted horticultural areas underwent a crisis in sustainability during the 1940's and 1950's when waterlogging and salinity threatened ongoing viability. The problem has been overcome by sub-surface drainage and discharge of effluent to the drainage system. The land is now believed to be sustainable and capable of ongoing high levels of production. However there is a cost to the downstream environment. About 12,000 Ml/yr are discharged by tile drainage pumps containing some 18,000 tonnes of salt with a further 6,000 tonnes being discharged by tubewells serving horticulture in the Yanco area [58].

The issues are:

1. Current salt loads from sub-surface drainage, although declining are still a large proportion of total salt loads in the MIA system [65]

2. Runoff water quality from horticulture is generally low in salt, has raised levels of nutrients and occasionally raised levels of pesticides. Some fish kills have been reported.

3. Runoff volumes from horticulture (and other lands) are a particular problem in the Lake Wyangan area.

4. Escape volumes related to the operation of horticultural supply systems are relatively high. The estimated volumes involved are 30 Gl/yr [65].

4.3 Extended Horticulture

Extension of horticulture into large area farms comprises about 2,000 hectares at present and this is likely to increase to some 4,000 hectares over the next 5 years [20]. With the advent of extended horticulture many issues have already been managed, eg interface problems with adjacent mixed farming, chemical spray drift, environmental review processes. The remaining issues to be considered by the Land and Water Management Plan are mainly those related to the management of saline sub-surface drainage effluent. The issues may be listed as follows :

1. In high watertable areas extended horticulture will require sub-surface drainage eventually.

2. Volumes of effluent from sub-surface drainage will be affected by choice of site and local hydrogeological conditions [63].

3. The effect of high technology irrigation systems on the volumes of accessions and tile drainage volumes as distinct with what can be achieved by Best Management Practices furrow systems.

4. The adequacy of the environmental review report submitted for conversion approval and the ability of reviewing personnel in forecasting problems with groundwater movement near the sites will be important whether problems with high watertables will actually occur.

5. Groundwater flow towards the site can be significant in volume [63], and this has already been discovered at two locations where horticulture has been allowed to be extended.

6. To avoid downstream impacts with salinity in the Wah Wah area, all extended horticultural effluent will have to be kept on-farm [20].

7. Disposal on-farm may be by reuse where the salinity is low, say below 2,000 uS/cm. For intermediate salinities (1,000 - 3,000 uS/cm) disposal to woodlots is considered feasible. For higher salinities disposal would have to be to evaporation areas. In all cases there is a lack of expertise, experience and confidence by the local community. Evaporation areas may not be sustainable unless well designed and constructed, and sufficient in area to store the volumes [63]. Insufficient size has been the main reason why complaints with existing storages have arisen. Leakage from ponds needs to be controlled or intercepted [31], [32]. In some instances plastic lining may be necessary.

8. Some leakage from evaporation areas may be acceptable and even desirable [32].

9. During very wet years the evaporation areas, despite being of design standard size, may get too full and emergency releases may need to be made. This may involve dilution flows to protect the downstream users and the environment [20].

Management of issues such as runoff volumes and water quality are similar to existing gazetted horticulture.

4.4. Vegetable Growing Areas

Vegetable growing on large area farms tends to be concentrated on the Self Mulching soil types which have better physical characteristics than the duplex clay soil types, which occupy the majority of the landscape and more suited for rice growing.

Vegetable growing involves more capital resources, but may produce high returns. The enterprise could be considered to be able to afford sub-surface drainage where it is needed, even if this involves the use of evaporation areas.

The following issues exist from a Land and Water Management perspective:

1. Selfmulching clay soils often exhibit salinity symptoms more rapidly because of the topography of these soils and higher rates of capillary rise.

2. In high watertable areas the application of sub-surface drainage is probably necessary at most locations.

3. The use of mole drainage versus other types of sub-surface drainage

4. If effluent from mole drainage is being recycled a proportion of salts will end up in the drain as surface runoff. Mole drainage produces less salts than conventional sub-surface drainage [32].

5. Evaporation areas design aspects including the finding of suitable sites.

6. Volumes of sub-surface effluent that would be generated, particularly considering furrows are usually too long relative to the flow rates.

7. The degree by which Best Management Practices will be capable to reduce accessions.

Impacts to downstream environments mainly relate to water quality (possible pesticide runoff, and runoff salinity. The latter should be low since the soil used may be assumed to be low in salinity. Where land salinity increases farmers will, after a few years, either consider sub-surface drainage or abandon the land in question for other land.

4.5. Specific Area Issues

Apart from the general MIA LWMP issues there are parts of the region that will require a different focus in terms of land and water management planning. Some of these areas and their issues are described here.

4.5.1 Lake Wyangan

The Lake Wyangan area is unique in that it has different soils, more slope in the land and no drainage outlet. All drainage is collected in the Lake. The volumes of drainage amount to some 6-8,000 Ml/year from a relatively small area. The irrigation practices are not influenced by incentives to reduce drainage. Daylight watering is common. About 2-4,000 Ml/year is being pumped from the lakes at great costs.

Channel seepage from cracked concrete channels is significant. Flood irrigation on permeable saline soils has resulted in significant salting, although the situation has stabilised for some time.   Sub-surface drainage from tile drains is being discharged to local depressions without costs to local landholdders for the environmental impacts sustained.

There are no data but the proportion of escape drainage is believed to be high. There is no performance monitoring of channel escapes.

Water is pumped from Lake Wyangan to DC"U" from the South Lake. During winter since 1994 water is also pumped by a set of new pumps to the Lakeview and then reversed to DC"U". This means that additional salts are being discharged in winter from Lake Wyangan to Barren Box Swamp. The winter impact of this is more significant than the impact during the irrigation season.

There are also farm sub-division and recreational issues to be addressed for the Lake Wyangan area. A "Friends of the Lake" committee exists who is coordinating environmental improvements around the lake. The general water management issues however have not yet been addressed.

In summary, the issues are :

1. The lake environment and recreational use versus the need to operate the lake as an irrigation/drainage storage.

2. Salinity in the lake building up over time, dependent on operation of the Lakeview and South Lakes pumps.

3. Land salinity in the Lake Wyangan area due to the soils, the irrigation practices, and the seepage from a cracked concrete channel system

4. Pumping from Lake Wyangan into DC"U" all year, and into the Lakeview channel during winter, effectively transferring salt loads to Barren Box Swamp.   This is a problem during winter for Barren Box Swamp.

5. Irrigation of horticulture and vegetable areas on more steeply sloping land, causing above average volumes of runoff.

6. Irrigation practives that tend to cause high volumes of runoff and accessions (tile drainage flow).

<u>4.5.2. Warburn Swamp</u>

About 2,000 hectares of mixed farming and horticultural land drains towards Warburn Swamp, which has no outlet. The drainage includes rice runoff, farm runoff, tile drainage, escape flows and pumping from a blue metal quarrie excavated to about 30 metres depth. The salinity in the swamp is about 3,000 uS/cm and it is believed that there is leakage back to the groundwater system which prevents the swamp water salinity going higher. The leakage moves towards to the quarrie pit, however groundwater levels are rising and now threaten to create a land salinisation problem. The wetlands in the swamp, once healthy Black Box, has degraded to mostly Cumbungi over the last twenty years.

There is a probability of conversion of large area farm land to horticulture. The best possible management option for Warburn Swamp seems to preclude its use as a sub-surface drainage disposal area.

The purpose of the swamp as a drainage receival area or a wetland with some significance needs re-definition. Part of the planning process may include a more stringent adoption of appropriate on-farm options and rice management options such as Rice Target Water Use.

The quarrie is deep about 20 metres and is kept dry by pumping about 2.3 Ml/day. The salinity of the effluent currently is about 2,500-3,000 uS/cm, an increase from about 1,100 uS/am about 1980. There are opportunities to reduce pumping by allowing the levels in the unused parts of the quarie to increase. A Development Application (DA) has been submitted to Griffith City Council to obtain approval for continuing operations. The DA license conditions are being reviewed in view of the positive and negative effects of pumping.

The issues are:

1. Wetlands health as affected by drainage volumes and salinity from various sources.

2. Groundwater management issues, including the effects of leakage from Warburn Swamp and pumping from the basalt quarrie.

3. Potential changes in land use to horticulture and sub-surface drainage disposal.

4. Accessions from rice growing may not be as well controlled as they should be.

4.5.3. Benerembah Stage 4 Area

The areas east of Barbers road have been provided with surface drainage over the last four years. A pump station was build to pump volumes from Mirrool Creek equivalent to the average expected drainage volumes from the drained areas, so there is no downstream drainage volume impact from the drained areas. The area to the west of Barbers road (Stage 4 area) however needs to discharge to the Barren Box Outfall Channel, hence such a solution is not feasible. There have been negotiations with Wyvern station to use the drainage volumes for an irrigation enterprise, but these have not been successful. These negotiations included consideration of the building a retention storage and associated works to manage flows.

The current position is that Benerembah Stage 4 area surface drainage construction can not proceed unless a suitable disposal option is found. This is unfortunate since the Benerembah community has acted as one social entity and the affected farmers have already contributed to the drainage scheme and are committed to the implementation of best land and water management practices, which was part of the conditions of commencing the project. The long term viability of the western part of

Benerembah (at November 1995) is at risk without a surface drainage scheme being constructed.

4.6. Barren Box Swamp

Several studies [58], [23] describes Barren Box Swamp behaviour. Pendlebury [24L], [[34]arried out extensive hydrologic modeling. In general the levels have been high due to the demand for irrigation to the west being less than the supply if drainage to the swamp. This problem is excaserbated by the occurrence of wet years. On average it has been found over the last 20 years that release to the floodway and Lower Mirrool Creek is necessary about once every one to two years. The hydrologic model study however considered a longer time frame and assessed that flood releases would occur about 28 times in 70 years. Major flooding may be expected about once every 10-20 years.

The water quality in Barren Box Swamp is referred to at section 3.5.3. The chemical residues of water from the swamp is less than in Mirrool Creek at Willow Dam due to longer retention times. Nutrients and turbidity from the swamp are higher. Salinity tends to be higher due to the evaporation concentration process (adding about 80 S/cm/year) and the winter drainage flows from sub-surface drainage in the MIA. The latter effect is also about 80 uS/cm between 31 May and 1 September, however there is a large variation between years, dependent on winter rainfall.

The water from the swamp needs to be diluted from time to time to achieve the desirable standard of 700 uS/cm. The need to control, and if possible, improve salinity of the outflow is one of the key issues to be addressed for the Land and Water Management Plan.

When the swamp level drops the rate of outflow reduces until it becomes difficult to supply Wah Wah demand. This is then augmented from the MIA system. An air space as large as possible in Barren Box Swamp is desirable to absorb and manage unexpected high rainfall runoff events from the MIA.

Alligator weed has invaded the swamp. Whilst it apears now more or less under control, it has not yet been eradicated. A period of several years of no sightings are needed before the threat of downstream invasion of this noxious plant may be considered past.

Cumbungi used to fully occupy the area of the swamp, however the higher water levels of the last 15 years have all but eliminated this plant, except for small fringe areas. Larger areas with weeds and cumbungi would absorb nutrients entering the swamp and provide habitat for fish and birds. These could occur if water levels were managed lower than those during the 1980’s. Barren Box Swamp is considered to be a wetland of some value. Whilst this value should be preserved or enhanced as best as possible, the main purpose of the swamp is the storage and management of drainage flows in the MIA.

4.7. Wah Wah District

The Wah Wah District receives drainage from the MIA. The southern part receives water via Barren Box Swamp whilst the north receives water directly from the Wah Wah Main, which diverts from Mirrool Creek. The area has a large range of soil types, not all of which are suitable for rice. Pasture watering is a major activity. Rice growing has resulted in high accessions in many locations. There is no surface drainage and water is to be kept on farm. Drainage to depressions on-farm and into Wah Wah Creek has been common practice and both these type of areas have become degraded as a result. This issue is to be addressed by the Wah Wah LWMP.

An environmental status report was prepared by Tiwari [52]. Water quality data are reported by Shepheard [45]. The salt loads and volumes of drainage to Barren Box Swamp are investigated by van der Lely [58] and Pendlebury [34]. Groundwater levels are rising at up to 50 cm/year and soil salinity is affecting a small proportion of the soils [51]. The intensity of irrigation may be a significant factor in the extent of the drainage problems that occur.

Other water quality issues may also be of importance but generally most concern relates to salinity. The extension of horticulture to large area farms in the MIA potentially could bring about extra salt loads. Following a community process an environmental review was carried out [20] which recommended that no discharge of extra salts be allowed. This study also reports a possible concern with soil salts increases in non rice irrigated areas of Wah Wah. The significance of that issue is yet to be followed up by research, however the local Wah Wah LWMP group has expressed that one of its main objectives is to eventually receive 400 EC water through the supply system. Until such improvement can be achieved the maximum target salinity of 700 EC units for Wah Wah supply will continue to be implemented.

Recently Keefer (1995) prepared a draft report for on farm options in the Wah Wah district (not yet released). The regional options are to be investigated, including surface drainage management, seepage from channels, water availability (includes irrigation hydraulic loading) and groundwater and salinity management, which includes a review of rice land suitability, hydrogeological assessment and irrigation techniques such as bed farming.

The practice to escape water from the Wah Wah supply system to some extent can not be avoided, but could be improved if remote sensing of flows at critical points was adopted and operational management improved.

The viability of the Wah Wah District depends on the volumes and the water quality it receives from the MIA. With regard to volumes the Wah Wah landholders have water allocations, but some have become very reliant on off-allocation flows being available from the full(ish) swamp. Concern has been expressed that water volumes would diminish if the MIA drainage reduction was successful, or if other irrigation groups came to the fore and claimed their share of the off-allocation flows.

The LWMP for Wah Wah is scheduled to be completed during 1996, following which it will be integrated in the MIA plan. The Wah Wah Plan will not affect the MIA plan unless the local group negotiates a change in the water quality target, and this will depend, amongst other factors, on economic considerations. The Wah Wah Plan does depend on the successful implementation of the MIA plan.

4.8. Lower Mirrool Creek and Western Wah Wah

The Lower Mirrool Creek consists of a partially constructed floodway to about Narrabri swamp west of the Carrathool Stock Route and a series of large depressions draining to the Lachlan River. The vegetation and impacts of the area has been described by Roberts and Wylkes [40], [41]. During 400 Ml/day releases from Barren Box Swamp over 5,000 hectares eventually become flooded, and this may lead to significant groundwater accessions. The effect of groundwater accessions causes the salinity of discharged water in a downstream direction to not increase as rapid as expected, however this feature is also aided by preferential flood flow through the deeper parts of the creek system.

Some landholders in the upper part of the Lower Mirrool Creek have taken advantage from the water going through their holding, however downstream there has been a lesser ability to do so. Overall losses on an annualised basis have been estimated to be a net $300K by Stanton [46] to a gross value of $470K by Mactier [24K].

The management of major floods has been considered by DLWC [3]. This resulted in proposals to upgrade culverts and bridges and some levees.

The Western Wah Wah area is served by two Stock and Domestic channel systems with a capacity of about 50 Ml/day each. An interest has been expressed to obtain an irigation capability. This would have been possible if the KinHill [23] recommendations were adopted, however this is not the case. At present the irrigation option is being considered as part of the Northern Hay Plains study.

The potential to use agroforestry to absorb moderately saline winter flows and other excess available drainage has been subjected to a feasibiltiy study. The concern is that salinity may build up in the soil and make the plantings unviable over a too short time frame (say 30-40 years). The investigations by Tiwari et al [54] showed that these concerns are largely unfounded provided some care is excercised with choice of site and the salinity of the irrigation water does not exceed about 2,000 uS/cm.

The main problem with irrigation in western Wah Wah seems to be the cost of channel construction relative to the total area which may benefit. Crop returns are unlikely to be sufficient to pay for the infrastructure. The KinHill study [24K] points to such a conclusion.

4.9. Regional Management Issues

4.9.1. Operational Management

Whilst the organisational framework for Land and Water Management Plan implementation still has to be worked out Murrumbidgee Irrigation is responsible for significant parts of the overall regional management of environmental issues. Core issues which may affect salinity sustainability and the environment include :

1. Channel seepage. The survey by Tiwari [55] shows seepage from the system is generally low but requires attention at a number of locations.

2. Water quality. Once contaminated water enters the drainage system it needs to be managed. There is presently no re-routing potential of contaminated slugs, except for using Barren Box swamp and dilution.

3. Salinity of the Mirrool Creek during winter adds to Barren Box swamp salinity. The swamp salinity also increases due to evaporation during summer.

4. About 80% of the drainage in the MIA is being reused in the Benerembah and Wah Wah Districts. However, volumes of drainage in wetter years are disproportionate to the demand of irrigation water in the Wah Wah District. The solution involves more than just reducing drainage from the MIA.

5. Escape flows from the channel system in average years are high compared to diversions and compared to districts without drainage. This applies especially to those parts of the horticultural areas where daylight only watering is being practised.

6. The management and policing of salt loads in the drainage system from tubewell drainage, tile drainage, and other sources (eg Lake Wyangan).

7. The frequent diversion of excess drainage and escape flows downstream of Barren Box Swamp to the Lower Mirrool Creek wetlands has caused irreversible changes of the local habitats and significant accessions to the groundwater system when up to and over 5,000 hectares are flooded. These changes are in addition to changes that have already occurred due to land management practices including grazing pressure.

8. The MIA was developed under conditions of lesser irrigation intensity than at present. The irrigation intensity and total volumes diverted increased but the infrastructure required for managing the extra drainage was never upgraded to a sufficient standard. The lack of drainage infrastructure downstream is resulting in impacts on downstream landholders and the environment.

4.9.2. Current Institutional Incentives Framework

Much of the problems with management of land and water management issues relate to behaviour by individuals, including landholders and town dwellers. The application of best management practices in many ways depends on institutional measures that are being adopted. The designing of an appropriate system of incentives is difficult and quite controversial since there are many interest groups, and nobody wants to be disadvantaged, or deprived of an advantage they have at present. The list below represents the current set of incentives.

- Water Act: There are clauses in the Water Act that prevent the misuse or abuse of water on land causing degradation. The supply of water may be refused if there is a breach. The powers are quite strong but rarely implemented, except through policies such as the rice growing policy or occurrences of illegal discharges.

- Clean Waters Act : Administered by the EPA, the prospect of a Drainage License is a strong incentive for Murrumbidgee Irrigation to apply pressure on landholders to improve on-farm drainage practices.

- Rice Policy. Developed by the Rice Environmental Policy Advisory Group and implemented by DLWC on behalf of the rice industry this policy contains criteria and rules by which the suitability of rice growing or the impact on groundwater systems is being implemented. A discussion paper was prepared by van der Lely [66]. The power to support implementation resides with the Water Act. A system of sanctions and fines rather than water supply restrictions as a first resort, has been introduced in consultation with the rice industry to enforce the agreed to policy. As districts are gaining a higher degree of autonomy the powers to implement policy is being transferred to the irrigation authority (in a LWMP framework).

- Environmental Planning and Assessment Act : This applies to all significant development, however the main issue being managed using this instrument is the conversion of large area farms to horticulture. The conditions derived from the process may include prohibition to discharge saline drainage.

- Pesticides Act. Regulates the use of pesticides in accordance with set guidelines.

- Local standards. For instance a commitment exists to keep the salinity of the Wah Wah supply to below 700 uS/cm. The supply of the Lakeview channel is kept at about 500 uS/cm or better.

The above list may not be comprehensive. Water pricing, drainage charges or salt load charges have not been used in the past to change behaviour with regard to the discharge of contaminants or salt loads, or accessions to the groundwater system.

There may be misconceptions regarding rights to pollute. For instance horticultural growers have expressed the view that a right to discharge salts in tile drainage exists whilst this can only be implied from an agreement issued by the previous Department of Water Resource to discharge effluent, with conditions regarding management of volumes and water quality attached. Any agreement of this nature is potentially subject to re-issue after a period under the Water Administration Act or Clean Waters Act, with changed conditions.

5. NO PLAN SCENARIO

5.1. Environmental Factors

The various environmental factors are described at sections 3 and 4. The No Plan scenario assessments for the MIA are briefly described below. The No Plan scenarios for Wah Wah are still to be developed.

<u>Groundwater Levels</u>

The areas with high groundwater levels is likely to increase further, but not drastically so. The areas with watertables within 2 metres may increase from about 70% to about 80% of the MIA and Benerembah. Within these areas the water levels are at about 1.35 metres from the surface now, and these are expected to not vary much under the No Plan scenario.

The deeper groundwater pressure levels show a gradient to the south and west. Any changes in deep bore pumping could see a change in the pressure level and henceforth a change in the deep leakage. At present the indications are that groundwater pumping will not diminish, and perhaps may increase somewhat. This means that the existing leakage rate from shallow to deeper aquifers, which provides some protection to the southern parts of the MIA, is unlikely to become less favourable.

Land Salinity.

In horticultural farms salinity is not considered an issues since sub-surface drainage exists. In vegetable areas and extended horticulture there is potential for increasing land salinity but this would be overcome by adoption of subsurface drainage and on-farm disposal of effluent. The assessment of the No Plan scenario therefore is not highly relevant. The main concern exists with the mixed farming areas of the MIA and Wah Wah.

The assessments for nine individual sub-districts of the MIA have been carried out and are reported by van der Lely [65]. Some of this information is provided at section 6.1. The conclusions are that there are increasing trends which should be addressed. The groundwater balance for the MIA is linked to the No Plan salinity assessment and this provides a mechanism of analysing the positive effect of any options.

Water Quality

From the land salinity assessments it was possible to estimate the future runoff salt loads from mixed farming enterprises. This is going up. Other salt loads will mostly remain the same whereas tile drainage salt loads may decrease [20]. The overall impact is that the situation would remain about the same. Possible increases in salinity could be due to a lesser dilution being available from escapes or other low salinity sources relative to any changes in the more saline sources.

With regard to pesticides it is impossible to identify a trend from the limited information available. Whether or not the current actions in response to proposed EPA licensing of drainage should be regarded as No Plan, or With Plan is debatable.

With regard to nutrients, there is no strong indication that Phosphate levels have increased over the 15 years that monitoring has now been carried out. Without a Plan it is still likely that the Griffith City Council will improve the load from the sewage works, hence an overall improving trend for nutrients is likely for the No Plan scenario. On the other hand it is uncertain how the concentrations in the discharge from Barren Box swamp will change over time. These have gone up over the last few years due to release of previously trapped nutrients from the benthic layer at the bottom of the swamp, possibly stirred up by carp.

The trend in turbidity in drains is partially an effect of farm runoff and partially an effect of channel erosion, particularly near inlets. The situation with regard to the latter is not satisfactory, however is not likely to worsen in the foreseeable future.

Drainage Volumes

Drainage volumes from all sources have been high in the past. However there are indications that even under a No Plan scenario there will be a reduction in irrigation drainage. On the other hand there could be an increase in rainfall drainage due to better management on-farm to reduce accessions, for instance landforming is likely to cover the whole of the MIA within the next about 15 years.

The value of water is increasing as restrictions imposed by the MDBC and environmental flow requirements become effective over the next few years. This will be an incentive to save water. The transfer of saved water is likely to be acceptable. Murrumbidgee Irrigation is likely to invest in measures that will save water and achieve better control downstream.

The advent of the handover of tile drainage pumps to horticultural farmers would have reduced flows from that source compared to the 1970's and 1980's. A significant improvement in irrigation techniques and practices is likely to occur even without a plan. High technology irrigation is not considered economic but will be adopted by some farmers, and this will make a small difference. Recently the use of cheap subsurface sloted plastic corrugated pipe has received attention. This method appears to have much potential for saving accessions and irrigation runoff.

5.2. Economics.

The economics of the No Plan scenario has been considered for mixed farming enterprises of the MIA and Benerembah by Marshall and McGrath [26]. The aspects considered are for the effects of land salinity and waterlogging. Effects on roads and power poles were also considered.

The results are that whereas salinity is expected to increase from 17% affected to 28% affected, the effect on agricultural production will only be very limited. Basically in the MIA the loss in gross margin will increase from $0.6 to $0.9 million per year over the 30 year period, but in Benerembah there will be a drop in the loss from $1.1 to $0.7 million after an initial increase during the early part of the 30 year period. The result is surprising and is explained by the ongoing increase in the adoption of landforming and improved Land and Water Management Practices over this area.

The anticipated losses in production are only a very small part (ab 3%) of the annual agricultural production of the MIA, suggesting that the problem is not as great as suggested from the land salinity estimations. However there are still unanswered questions regarding the methodology used for the evaluation, and the need to preserve the land resource in such a state that the flexibility to switch to crops other than rice, pastures and wheat has not diminished.

The MDBC DESM model to assess losses in production from the MIA has not been used and would have resulted in greater losses. Nevertheless the indications are that it will be difficult to justify expensive rehabilitation or other measures to reduce the effect of accessions to groundwater.

6. UPSTREAM SALINITY SUSTAINABILITY TARGETS

The achievement of sustainability in terms of land salinity may have different implications for different types of agricultural systems. Whereas groundwater accessions and the reduction thereof will be the primary focus, the available management options are different. This also affects the targets, what it is that is being aimed for and how much of it can be achieved. This section discusses these aspects for the main land categories in the MIA.

6.1. Mixed farming

The watertable control options report by van der Lely [65] describes the salinity patterns for the No Plan scenario and the methods by which it can be assessed how reductions in accessions influence the outcome. The MIA mixed farms allow a total of 95 Gl/year of accessions, of which about 55 Gl/year comes from rice. A reduction in accessions is required to reduce the predicted salinity trend, which is at 18% at present, increasing to about 28% in 30 years.

The model was used to assess the required reduction. Figure 6.1 shows the results. A reduction of 10, 20 and 25 Gl/year reduction in accessions would produce a salinity outcome in 30 years time of 24.5, 21.5 and 20.0%.

Figure 6.1. No Plan salinity trends in MIA together with trends for different levels of reductions in accessions

It needs to be decided what the target for the Land and Water Management Plan should be. The community groups consulted, eg the IREC Drainage Committee, have not determined a clear target, however there seems to be consensus that there should be an effort to achieve sustainability at reasonable cost. This means that the 20% target should be aimed for, at least initially in the optimisation process. That target would ensure that the situation will not get worse than at present. The present situation, whilst not perfect, allows for ample potential to maintain productivity and even expand into more intensive entrprises in many parts of the MIA. The northern areas will be the most limited in terms of their capacity to diversify.

No targets have been set for individual sub-districts. This contrasts with the Coleambally LWMP where it was determined that no sub-district should have a salinity exceeding 15% of the landscape in the long term. However, during the optimisation process and selection of options the relative effectiveness of individual options in various parts of the MIA should be considered. See Sections 7 and 8.

Since 55 Gl/year out of 95 Gl/year is from rice it may be difficult to achieve a 25 Gl/year reduction in accessions from non-rice crops without resorting to sub-surface drainage schemes. It is possible that reductions in rice areas should also be considered. Sub-surface drainage schemes allow for compensation where the management of accessions is not being successful. In the end there needs to be a balance between different options, costs and productivity impacts in the short and long term. In that context it is possible that the 20% target is over-ambitious for the current system of land use. The options for management are further discussed at Section 8.

6.2 Gazetted Horticulture

In Gazetted Horticultural farms no specific target for land salinity is necessary since all the land is already protected by sub-surface drainage or natural drainage. Perhaps another 5% of the area involved may still be sub-surface drained.

All targets for gazetted horticulture are related to constraints, for instance there should be a reduction in salt loads from gazetted horticulture and this may be achieved by reductions in tile drainage flows. This in turn may be best achieved by improved irrigation practices to reduce accessions (Neeson and McAlpine [30/31], [30/32], [30/33]), or management of tile drainage flows (Muirhead [30/37], Neeson [30/38]. Section 7.6 identifies a desired reduction target of 3,000 Ml/year, or 25% of the volumes that have occurred over the last 15 years. Hassall Associates [20] suggests that the salt load from horticulture should be lowered to 1.0 t/ha, which is a similar target.

There are targets for gazetted horticulture, but they are not driven by the sustainability objective of horticultural land. nevertheless they are very important for the overall MIA plan, see sections 7 and 9.

6.3 Extended Horticulture

Extended horticulture in large area farms will be sustainable in deeper watertable areas. In these areas the targets are related to minimising accessions. Since the areas are being converted from previously mixed farming including rice, it is likely that the extended horticultural areas allow less accessions to the groundwater than the previous landuse, particularly if Best Management irrigation practices are being adopted. No specific sustainability targets are needed for these areas if the committments made during the conversion process are being implemented.

In high watertable areas the sustainability will depend on the balance between accessions, groundwater flow into the area in question from surrounding rice and capillary rise. On balance it must be expected that sub-surface drainage is needed to protect the land. However, current policy dictates that effluent be kept on farm or is disposed of locally without discharge to drains. Under such circumstances and with proper design of all systems within the framework of a whole farm plan there should be no downstream impact except through surface drainage.

Whereas in mixed farming the target concerns a proportion of the landscape that may become salinised and this proportion is being accepted as part of the overall solution, in extended horticulture such a target is not appropriate. All the land used will have to be sufficiently low in salinity, and this is being achieved by pumping whatever groundwater as may be required. The target is say <5% salinity affected.

To achieve a near zero target salinity in the high watertable areas the sub-surface drainage volume to be pumped is the same as the combined volumes of groundwater inflow from rice and the accessions (eg van der Lely [63]). Best Irrigation Management Practices may reduce the volume of accessions and thereby the volume to be disposed to evaporation ponds. If the volume of groundwater flow from surrounding farms is too great there may still be an unsustainable situation, and that possibly can only be changed by further changes in landuse (on the farm in question, or the adjacent farm, or both). Such problems of course should have been identified before the approval to convert was given.

In conclusion, the target salinity is zero, but the target volumes to be pumped where sub-surface drainage is needed varies from farm to farm.

6.4. Vegetable Growing Areas

The vegetable growing areas also may be located in higher or deeper watertable situations. The same principles apply as for extended horticulture. The type of targets are the same. The method of implementation however will be different. Because of the shallow root systems of vegetables and lesser risk to plantings mole drainage appears the most suitable alternative to manage unavoidable accessions. Unfortunately, there is a chance that mole drainage will contribute to runoff salt loads, dependent on the manner in which the surface drainage and recycling systems are managed.

6.5. Wah Wah Irrigation District

The assessment of soil salinity in the Wah Wah District would be based on the work by Tijs [51] and the Hassall consultancy [20]. A status report including a description of all issues was prepared by Tiwari [52], and recently the On-Farm options report was completed by Keefer (NSW Agriculture, Yanco). For the evaluation of the Wah Wah Plan however the No Plan scenario model for land salinity in the Wah Wah District is yet to be developed. This model would be followed by the options evaluation.

7. TARGETS FOR INTEGRATING UPSTREAM AND DOWNSTREAM SOLUTIONS

7.1. Introduction

The integration of upstream and downstream solutions involves the three impacts identified, namely drainage volumes, water quality and salinity. Another factor to be considered is economics. For instance, the cost of upstream solutions for a certain volume of drainage reduction may be less than the cost of a downstream engineering solution. If there is scope for a range of drainage reductions, then the final choice should be leaning towards the cheaper overall solution. This includes consideration of environmental benefits and costs.

In this context distinction needs to be made between economic benefits and costs from a State perspective and financial benefits and costs, which are likely to be the focus of the local management authority. There may be a substantial difference. These considerations will be referred to more fully at sections 12 and 13.

The integration between upstream and downstream of Barren Box Swamp involves the weighing up against each other of the following :

1. potential reductions in total drainage volumes in the MIA against what is the desirable reduction in drainage volumes downstream in view of water availability to Wah Wah and the timing and frequency of flows.

2. improvement in water quality from upstream against what is the EPA guidelines for reuse and the environment downstream, for as far affected.

3. improvement in salinity of the drainage from upstream against what is an acceptable standard for reuse and the environment downstream.

These three factors in fact are constraints for the main objective, which is the sustainability of the component parts of the region (Section 2).

Whilst the general criteria objectives can be defined this way it is subsequently necessary to devise a model in which all the available options can be compared and adjusted until a suitable mix is achieved. Such a model is used and discussed at Section 9. A key element of the model is the use of targets for various management components, eg reduction in accessions, reduction in drainage volumes, remaining required use frequency of the Lower Mirrool Creek Floodway. This section discusses the general regional targets, whilst section 6 discusses the targets for soil salinity sustainability

The optimum results for some factors may be found by running the model many times and comparing the results for a range of scenarios. To start the procedure however a set of criteria, or targets, have to be developed. The development of these criteria is based on information presented or referred to at sections 3 and 4. This Chapter explains this process.

The optimised result in fact may end up being a compromise between the various objectives and constraints. Whilst compromised solutions are suitable at least for the short to medium term it is useful to state what the context of an ideal solution would be. For the MIA LWMplan downstream areas this would involve the following :

- Absence of excess drainage volumes causing impacts on the environment.
- Water quality in drainage that meets EPA guidelines.
- Salinity levels which meet the stated desired level by the downstream community. This is a 400 EC salinity standard in the Wah Wah supply or better.

The latter aim may or may not be possible to achieve. The current commitment by Murrumbidgee Irrigation is that 700 EC water salinity will be maintained. The much lower standard is based on recommendations of the Hassall study [20], which is yet to be confirmed by further study. Whether or not the desired level of salinity can be achieved is a topic for the evaluation process of the MIA LWMP. The minimum standard is the 700 EC value, the achievement of the 400 EC value is a matter of technical feasibility, and economic costs and benefits between upstream and downstream options.

7.2. BBSWAMP Model Results

The BBSWAMP model uses MIA supply and drainage system data and assesses the resultant downstream volumes and salinity. By using 65 years of rainfall and evaporation data for the current irrigation management practices and pre-determined operating rules for Barren Box Swamp Management it was possible to calculate the frequency of likely discharges to the Lower Mirrool Creek, the reliability of the Wah Wah supply to irrigators, the volumes in the swamp and the required number of occasions and volumes that special diversions would be needed from the river to augment drainage from the MIA to the level of demand.

The results from this model have been extensively used for the KINHILL study [23], [24].

The model also can calculate the impact of reductions in drainage from the on the above factors and the consequences for salinity at Willow Dam. This was reported by Pendlebury [34], [24L] for large reductions (25%, 50%, 75% and 100%) of the main components, which was above the realistic targets. Further calculations have been made for 5% to 25% reductions by DLWC Statistical Hydrology and these are shown at Table 7.1.

The mean annual inflows to Willow Dam shown include any additional river diversions that may have been made to counter possible shortfalls. Such occasions however do not coincide with high rainfall conditions or conditions whereby the swamp is full.

The total drainage from the MIA as assessed by NSW Agriculture and van der Lely [65] amounts to some 245 Gl/year. A 25% reduction represents some 60 Gl/year. Table 7.1 shows this translates to only a 39 Gl/yr reduction at Willow Dam because Benerembah tends to receive a fairly constant volume (not proportion) of all drainage and drainage to the river from the Yanco area also has to be substracted.

It is shown that over a 70 year period the floodway would be used only 28 times, or 40% of years, which seems to be contrary to the experience of the last 15 years. The volumes on each occasion reduce as the MIA drainage is being reduced, but there is no further reduction below 18/70 (25% of years) in the number of occasions that the floodway is used once the drainage reduction is above 10%. This is a strong indication that there are only limited additional environmental benefits to be gained if the drainage is reduced by more than 10% in an average year. Of course it would be desirable to reduce drainage by a larger percentage in wetter years.

Table 7.1: Effect of drainage reductions in the MIA on downstream volumes and flooding frequency (*1)

Flow Component	**Base case**	**Less 5%**	**Less 10%**	**Less 15%**	**Less 20%**	**Less 25%**
Mean monthly inflows to Willow Dam (Gl)	13.51	13.05	12.68	12.41	12.15	11.86
Mean annual inflows to Willow Dam (Gl).	162.1	156.6	152.2	148.9	145.8	142.3
Mean annual river diversions (Gl)	1098	1087	1078	1064	1056	1049
Mean annual additional river diversions (Gl)	7.55	9.35	11.33	13.60	15.72	26.75
Reduction in flow at Willow Dam (*2) (Gl)	0	7.3	13.7	19.2	24.5	39.0
Mean annual supply to Wah Wah (Gl)	114.7	114.3	113.3	112.3	111.1	109.6
Mean Annual shortages at Wah Wah (Gl)	3.55	3.98	4.92	6.04	7.16	8.64
Mean annual Wah Wah Reliability	97.0	96.7	95.9	95.0	94.1	92.9
Mean annual floodway flow volumes (Gl)	21.2	17.3	14.9	14.2	13.5	12.5
Number of floodway releases in 70 year period	28	23	18	18	18	17

(*1) Drainage being the combined on-farm drainage, escape drainage and tile drainage flows.

(*2) Reductions if the additional diversions are being omitted from the equation.

Table 7.1 also shows that the reliability of the Wah Wah supply is not affected greatly by drainage reductions up to 20%, at which level it would still be better than the MIA supply reliability (92%). However, if the drainage reduction exceeds 20-25% the required additional supply to Wah Wah from the river increases sharply and more strain would be placed on the MIA channel system to supply the shortfalls in drainage to the Wah Wah district. This requires consideration.

Note: Reliability in this context is defined in terms of water availability to the area of crops, not in terms of water allocation (Paul Pendlebury model).

7.3 Downstream Impacts of Excess Drainage

Another method of looking at the downstream volumes impacts is by considering Figure 7.1. It shows from left to right the range of Willow Dam flows and the Wah Wah demand from the driest year to the wettest year of the spectrum. The values have been entered based on the Pendlebury results [34] and interpretation by the author.

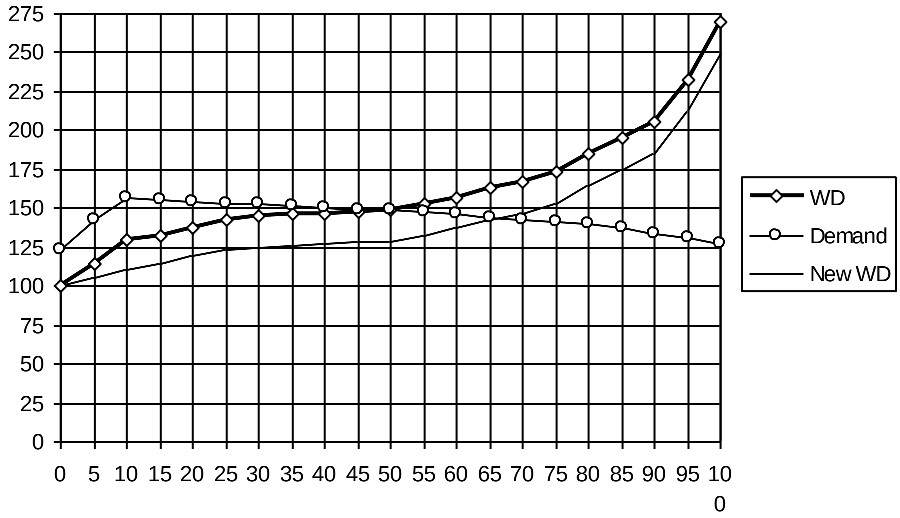

Figure 7.1 : Distribution of Willow Dam Flows and Wah Wah Demand for the full range of dry to wet years. A hypthetical reduction of 20 Gl/year in Mirrool Creek drainage flows is also shown. The vertical scale shows Gl/year and the horizontal scale the frequency of occurrence from 0-100%.

The third line drawn represents a potential reduction in drainage from the MIA, which would reduce Willow Dam flows.

The difference between the two lines on the dry end of the spectrum is the shortfal in supply to Wah Wah which is met in three possible ways

1. drawing out of volumes stored in Barren Box swamp
2. special diversions from the river via the MIA system, or,
3. allowing escapes to run a bit higher in an over-ordering situation.

The difference on the right hand of the spectrum represents the excess drainage that may be stored in Barren Box Swamp for a following dry season. If there is too much drainage the floodway will have to be used. The graph suggests drainage in excess of supply happens about once every two years. This more or less conforms with Table 7.1, which is based on 70 years of rainfall records. However, recent experience would indicate that drainage in excess of demand is quite frequent, because the floodway is being used at least 40% of years. The frequency of floodway use so high suggests one of two things, firstly not very much of the excess drainage is saved and used for following dry years, and secondly the two lines of Figure 7.1 may be subject to some error. For instance it is probable that the Willow Dam flow and Wah Wah demand lines, although probably correct in shape, may not be positioned exactly at the correct height. Perhaps the Willow Dam flow line should be shifted upwards by some 5-10 Gl/year.

If drainage was reduced by 20%, irrespective whether there is a dry year or a wet year, then the differences would change quite dramatically. The number of years with a "shortfal" would increase and the number of years with excess decreases. However this excercise demonstrates that to get a further reduction in the number of years with an excess, the drainage would have to be reduced by much more. In fact, it is probable that there will always be at least 25% of years that there will be excess drainage.

The graphical interpretation suggests it is not useful to reduce drainage by more than 20% else the number of occasions of a shortfal will increase too much and the supply to Wah Wah will have to be artificially augmented too often. Of course, it is always better to be able to “control” the supply to Wah Wah rather than being dependent on erratic and out of season drainage flows.

The balance also depends on the operational volume of Barren Box Swamp. The present operational rules use the range between a storage volume of 40 Gl and 65 Gl, or 25 Gl. Below 40 Gl there are emerging concerns that the potential rate of withdrawal from the swamp may become less than demand, at 65 Gl there are concerns that the swamp gets too full. The operational volume can be increased significantly by additional options, of which a pump station is considered prominent. This would give greater flexibility in transferring drainage saved in wet times to dry times, assuming that drainage volumes from the MIA are reduced also.

The volumes to the floodway causing the environmental impacts are reported at Section 7.2. Figure 7.1 does not give answers regarding the change in frequency of floodway use.

The areas under the curves differences suggests that a reduction of 10-20% should be aimed for. Section 7.2 suggests a value closer to 10% may be sufficient. A 10-15% reduction value was adopted as an initial target for the optimisation model. This represents a total volume of 24-36 Gl/year from the MIA

7.4. Potential to Reduce Drainage Upstream

The three main sources of drainage in the MIA to be considered are:

1. farm runoff
2. escape volumes
3. tile and tubewell drainage

In addition drainage to downstream areas would be reduced if there was a larger degree of reuse. This will be examined also.

The water balance for the MIA considers average volumes [65]. The farm drainage was split up based on results of Pendlebury [34], Tiwari [53] and van der Lely [58] as follows:

Table 7.2: Volumes of Farm runoff in the MIA

Source	Rainfall Runoff	Irrigation Runoff
Horticulture	10	10
Large Area Farms	54	50

Best Management Practices may achieve reductions in irrigation runoff but recycling systems are necessary if the rainfall component is to be reduced as well. Water quality considerations could see the adoption of storages if there are sufficient incentives.

Possibly, as an upper limit, a reduction in irrigation runoff in excess of 25% may be achievable if Best Management Practices were adopted by a greater proportion of farmers. This would represent 15 Gl/year. With large scale adoption of recycling systems the potential saving would be much larger. For instance, NSW Agricultural economics reports suggest that recycling systems with 12 mm storage dams may save 131 Ml/year [14] for an average farm in an average year. If all 600 large area farms adopted this option the potential saving would be 78,000 Ml/year from this source alone. The question is of course whether the 78 Gl/year matches with the total 104 Gl/year in table 7.2. Different techniques were used to find the value in each case. Nevertheless it is clear that the potential savings are quite large, certainly exceeding 50,000 Ml/year from large area runoff.

In terms of escape volumes, the total volumes lost in an average year are about 110 Gl, of which 30 Gl/yr being related to channels serving horticultural areas [Ref 65]. The Levels of Service report by Hallows associates [17] suggests that savings due to a longer water ordering period is not advisable, but that better forecasting of demand, and improved performance monitoring of the larger escape sites could reduce drainage by significant amounts. It was not stated by how much. The author believes that based on the Coleambally experience, where it is proposed to save 30 Gl/yr out of a current loss of 90 Gl/yr, it is not unreasonable to put an upper limit of 25% on the possible savings that can be made. This would be about 27 Gl/year. Such a saving would require a special effort/invstment in a LWMP context. It is likely however that some of this saving would also occur under a No Plan scenario, since water is becoming more scarce and valuable, providing an incentive for the irrigation authority.

With regard to tile drainage, the current volumes are about 10-12,000 Ml/year (including the Yanco area). The volumes represent about 1 Ml/ha of horticulture and include rainfall and irrigation accessions, more or less in an even proportion. The latter volumes can be reduced by better irrigation techniques or management of pumps (see Muirhead et al [30/37], [30/38]). Rainfall accessions can be reduced by improving runoff. Although arguably this does make no difference in total drainage it is usually better to have surface runoff rather than sub-surface drainage, because of salt loads, the downside being that surface drainage presumably contains more potential chemical contaminants than sub-surface drainage. If all possible options were adopted by most farmers an overall saving of about 25%, or 3,000 ML, would not be unrealistic.

In terms of pumping from drains for reuse in the MIA, this already occurs at Benerembah where up to 14,000 Ml/year can be extracted by pumps [43]. Upstream of Willow Dam there would be several sites where a similar option should be feasible. The option has been investigated for the Yanco area [5] and there is potential. No investigations have been carried out for the Mirrool area. Costing is not available, hence a feasibility study still has to be carried out. It is also possible for farmers to reuse drainage and a drainage reuse policy actually exists (see Rubenis [42]). Without having done a survey it is likely that at least 40 farms are situated adjacent to drains where the flow is sufficient for a viable pump set up linked to on-farm recirculation. If each extracts 150 Ml/year this reduces MIA drainage by 6000 Ml.

The reuse by pumping option managed by Murrumbidgee Irrigation is particularly attractive since the pumps may be managed for use only during periods of drainage excess, or about one third to on half of the time. Even during wet years there are periods that this option can be maximised. Four pump sites at 2,000 Ml each would represent 8,000 Ml/yr

In conclusion, the total potential savings have maxima of :

- on farm drainage : 15- 50 Gl/yr
- escape drainage : 27 Gl/yr
- Tile drainage : 3 Gl/yr
- Reuse : 14 Gl/yr (some of this only once every two years)

From this the total potential reduction (upper limit) is in the order of 45-94 Gl/year.

Since the total reduction required is only in the order of 24-36 Gl/yr (section 7.3) there will need to be some optimisation to determine which options to reduce drainage should be preferred. In that process several aspects need to be considered:

- the cost aspect of reducing drainage for each of the above sources of drainage. Ideally this means comparing economics between the options.
- the possible water quality constraints, namely reduction of fresh water sources will affect concentrations of contaminants downstream.
- the effectiveness of individual options in reducing drainage during the periods that it matters most, which are the wetter periods.

For the final economics analysis the cost of reducing drainage up to the limits identified will need to be compared against the reduction in downstream costs between the No Plan scenario and the optimal package of downstream solutions.

The water quality constraints are discussed next, whilst the other aspects are considered at Sections 8.

Another important principle not to be overlooked is that if drainage reductions overshoot the target, particularly with respect of the more contaminated components of drainage, then it is always possible to deliberately divert fresh water from the river into the system to satisfy demand downstream. Overall this would achieve a more satisfactory outcome with respect to a) operational control, and b) water quality. The only constraint for this principle is the ability of the supply system to supply to Wah Wah via the drainage system. If there is more reuse on-farm there should be an under usage of capacity in the supply, however with some possible bottlenecks at the downstream end of the supply system.

7.5. Water Quality and Salinity Constraints

There are several aspects to water quality and salinity targets, and these are considered separately.

1. Effect of Water Quality on Drainage Reduction Targets

The salinity in drainage at Willow Dam is affected by all sources, each including a volume and a salt load. By changing the volume of one or more of the components in a drainage reduction strategy inevitably the mix changes and the salinity changes. The concentration of other water quality contaminants will also change. The constraint for the MIA LWMP is that whatever mix of solutions is adopted, the salinity must not get worse.

The highest concentrations of salinity are from the groundwater sources. Escape drainage is the best quality. To achieve the salinity constraint therefore the tile drainage volumes should be reduced by at least an equal proportion to the reduction of the other main sources. This is the first criterion.

There have been suggestions that reductions in tile drainage volumes would increase its concentration. After all, the outputs of salt into a farm must eventually balance the inputs through irrigation water. The proposition is not being supported here. The tile drainage salt loads from most farms is still substantially above the inputs through irrigation water, usually by a factor of two. A continued decline therefore is likely.

In terms of other water quality factors, these are mostly derived from farm runoff, both large area and horticulture, and perhaps some tile drainage. To avoid increasing concentrations in the drainage system it is prudent to reduce the on-farm drainage flows by at least the same proportion as the reduction in for instance escape drainage. This is the second criterion.

EPA guidelines are applied to key sites in the drainage system where considerable dilution usually has taken place. However, in theory the drainage derived from each individual contributing farm has to meet the guidelines and farmers can't rely on dilution by someone else as a solution to pollution. Dilution is really only a regional tool to be used in emergency situation and not for the run of the mill drainage unless all of it is being reused.

If the MIA was treated as one entity then only the external drainage outlets should be considered. In that context the MIA achieves an 80% reuse value and water discharged via the floodway runs through 100 km of grassed waterways before it reaches the Lachlan River (excluding the Yanco catchments draining to the Murrumbidgee). However, the concerns extend to within the MIA system as well, the only way by which reuse within the system can be encouraged and achieved is by getting all drainage sources from every farm to achieve reasonable minimum standards.

Because of the nature of the second criterion the mix between the target reductions may be balanced in slightly different ways, as long as the total is in the range 24-36 Gl/year. Section 7.6 provides the final split up of drainage volume reduction targets.

<u>2. Pesticide Contamination</u>

Water quality targets relating to pesticides and nutrients are not easily quantifiable. The targets really are the guidelines set by EPA based on analysis of downstream uses and needs (irrigation and stock and domestic) and agreed to by the community. This process is on-going. Nevertheless a problem is identified which needs to be addressed. As far as nutrients are concerned the main effort presently is put into the reduction of nutrient from the Griffith sewage works, which will effectively target 30% of the load for a reduction (based on Shepheard [44], [45]). This leaves the pesticide issue for optimisation and selection of remedial type options.

It is at present not possible to quantify by how much the pesticide contamination problem can be improved by any particular option. For that reason, for the purpose of the optimisation report it has been decided to qualify the problem as a 100% problem, and then assign values to various options in terms of the proportion of the problem that could be overcome if the option was adopted by all potential participants. The optimisation improvement target may initially be set at 60% and then varied until the more economic options have been used up. In other words, the target comes out of the optimisation process rather than preceeds it. Uneconomic options could be introduced later if this proves necessary.

The process is separated for horticulture and mixed farming. Each of these components has to achieve a 60% improvement compared to the current situation.

Different options have different effects. Radical expensive options such as the requirement to construct recycling and storage have drawbacks and are not necessarily 100% effective either (more about this at sections 8 and 9.5). However, if there is a likelyhood that recycling is adopted as a common practice then this is likely to save large volumes of farm drainage. This would in turn have the consequence that the required savings of other low salinity sources of drainage (such as escapes) are less.

3. Salinity Targets

With regard to salinity a similar approach is used however the targets may be expressed as an EC (at Willow Dam) improvement, rather than a percentage. Each EC unit at Willow Dam represents about 150 tonnes of salt if it is considered that about 60,000 tonnes are present in about 160,000 Ml of annual drainage. On a regional scale it was found that the No Plan scenario does not involve higher salt loads in the future [65], but there will be a reduction in the tile drainage salt load and a corresponding increase in the large area runoff salt load. The shift each way represents about 5,000 tonnes or 30 EC units (nominally).

In terms of targets Hassall Associates [15] recommends that the reduction in horticultural salt loads should be achieved more quickly than the No Plan scenario trend over 30 years. It was concluded that a reduction to 1.0 tonne of salt per hectare (from about 1.8 t/ha)) should be feasible by better management practices. This would be achieved by a 40% reduction in volumes pumped into drains. The author however believes that such a target would be too optimistic with Best Management Practices only and could only be achieved if there were special incentives, such as a charge on discharged salt loads.

Improvements made in this respect will be reduced if there was less dilution in the drainage system from sources such as channel escape drainage or farm runoff.

With regard to large area farms, the trend is towards larger salt loads in runoff. The challenge is to arrest this trend by better management. If the No Plan scenario land salinity increase is reduced the salinity benefits would be proportional. In the end the target salinity improvement for mixed farming may still be negative, but the final increase may well be less than the positive gains made in the horticultural areas.

4. Management of Salinity in the Wah Wah Supply

The northern part of Wah Wah receives low salinity supplies, but the southern part depends on the salinity of Barren Box Swamp, which is increased by three factors:

- evaporation from 3,200 hectares
- winter drainage flows from the MIA through Mirrool Creek
- Pumping from Lake Wyangan in the off season.

The last of these factors has increased since the implementation of the Lakeview Pumping scheme, which permitted additional pumping from Lake Wyangan during the off- season when the irrigation channels are not used.

The evaporation factor and the winter drainage factor each contribute about an equal amount to increasing salinity in the Barren Box swamp. The net evaporation is about 25,000 Ml/yr out of an inflow into the swamp of 125,000 Ml/year. The combined outflows are close to 100,000 Ml/year [58]. This means that 20% is evaporated and salinity increased by about 80 mg/l, the average being about 400 mg/l. The winter drainage to Willow Dam is about 22,000 Ml on average, containing about 10,000 tonnes. The water and salt balance study for the MIA and Benerembah [58] shows that the swamp salinity from the end of May to late August increases by an average of about 80 mg/l, which is the same as the evaporation effect.

To improve the salinity of the supply to the southern part of the Wah Wah ID it would be necessary to consider options and compare these for costs and benefits. At present the target salinity in the Outfall Drain is set at 700 uS/cm, or 420 mg/l (420 ppm). It is believed this target is not causing agricultural production disbenefits at the present time. The current target is being achieved, albeit with the occasional need for a dilution flow. Most of the time the salinity is less, eg during 1994/95 it was between 500 and 600 uS/cm. However, the Hassall Assoc. study on environmental impacts of further salt discharges from the MIA [20] has identified that perhaps the target should be lowered to about 450 EC to guarantee sustainability of irrigation land use in the Wah Wah District. Before a decision is made in this respect further investigations are necessary. If it is found that a lowering of the target is needed, then the implementation of salinity reduction options becomes a much greater urgency.

The options for reducing the salinity in the Outfall Drain are discussed at Chapter 10 with this context in mind.

7.6. Summary of Targets for Optimisation.

From a downstream point of view there appears to be little gain environmentally if the drainage was reduced by more than about 15% or about 36 Gl/year from the MIA, which would be equivalent to a reduction in flow at Willow Dam of about 19 Gl/year (Table 7.1) and a reduction in the use of the floodway from 40% of years to about 25% of years. This assessment however is based on averages of flow and salinity. Since it is desirable to achieve a better than average impact in wet years it appears useful to implement solutions that have the capacity to reduce drainage by a larger volume in wet years.

In terms of water quality the downstream target used is that no serious chemical contamination or nutrient loading in excess of accepted guidelines should occur, whilst the salinity in the Barren Box Outfall Channel should not exceed 700 uS/cm. The cost and benefits of lowering the 700 EC value should be assessed.

Reuse by pumping of drainage in the MIA will help in taking the top of the drainage flow and this option would be particularly helpful in wetter years. The target drainage reduction in an average year, based on section 7.3, would then be about 24 Gl/year. Considering the two critera a following mix of <u>initial</u> targets could be realistic.

1. Tile drainage reduction	:	3 Gl/year
2. Farm runoff reduction	:	11 Gl/year
3. Escape drainage reduction	:	11 Gl/year
Total		25 Gl/year

The distribution between these targets are not rigid and may be altered if necessary by the modeling process, see section 9. For instance, if it is found that drainage reductions do not involve high costs or even involve a net benefit, then the savings may be increased to 40-50 Gl/year, corresponding to about 20% of total drainage.

The downstream and upstream balance for drainage reduction targets were discussed at Sections 7.3 and 7.4. A major criterion is that the tile drainage reduction as a proportion of historical values should always be higher than the combined other reductions. If that criterion is being achieved it does not really matter what the sources of other drainage reduction are. The model could be asked to identify the most economic combination of options consistent with the constraint.

The balance between farm drainage redutions and escape drainage reductions may be adjusted according to other criteria, such as the need to improve on pesticide contamination. Such modifications should be part of the sensitivity analysis of the MIA project, incorporating the need also to provide some extra capacity to reduce drainage when it is most needed.

8 UPSTREAM OPTIONS FOR LAND AND WATER MANAGEMENT

8.1. Identification of Options

As far as the upstream LWMP are concerned, the various working groups have identified options and many have been evaluated either quantitatively or qualitatively. The On-Farm Options report edited by Morgan et al [30] is a bibliography of means and methods by which accessions or runoff may be reduced, or water quality improved. A variety of regional options was evaluated e.g. levels of service including escape loss reduction [17], impact of extended horticulture [20], evaporation disposal [31], [32], seepage from channels [53], rice policy guidelines [66], watertable control options [65], Benerembah surface drainage [18]. A previous study by Stanton [47] had already excluded options such as deep well injection and the pipeline to the sea.

All options that appear to exist were listed by the optimisation team and categorised according to the type of land it may have an environmental benefit for (horticulture (H), extended horticulture (E), Mixed farming (M) and vegetable growing (V)). A total of 83 options were listed. These were split according to whether they were considered be Best Management Practices or not. Tables 8.1 and 8.2 show the options.

Table 8.1. Best Management Practices Options used for optimisation, categorised according to land use type (*1)

Type	BEST MANAGEMENT PRACTICE	ID
E	Improved Soil Structure Management	E01
E	BMP's for Reducing Accessions	E02
E	On Farm Seepage Control	E10
E	BMP Fertiliser application management	E11
E	BMP On Farm Pesticide application	E12
H	Improved Soil Management	H01
H	BMP Hort Furrow to reduce accessions	H03
H	BMP Hort Furrow to reduce runoff	H04
H	Controlling Tile Drainage Flow Rates	H08

H	Biological control of pests	H11
H	BMP Fertiliser application	H12
H	BMP On Farm pesticide application	H13
M	Convert LAF farms to Extended Horticulture	M00
M	Protection of Remnant Vegetation	M02
M	Keeping cover crops on salinised land	M05
M	BMP's for Reducing Accessions	M07
M	On Farm seepage control	M14
M	BMP Fertiliser application management	M16
M	BMP On Farm Pesticide application	M17
M	Rice Bay BMP's to reduce runoff	M18
M	BMP Aerial Pesticide Applications	M32
V	Improved Soil Structure Management	V01
V	BMP's for Reducing Accessions	V02
V	On Farm Seepage Control	V10
V	BMP Fertiliser application management	V11
V	BMP On Farm Pesticide application	V12

(*1) E=Extended Horticulture, H=Gazetted Horticulture, M=Mixed farming, V=Vegetables

Table 8.2 : Miscellaneous Options used for Optimisation of MIA LWMP, categorised according to Land Use Type (*1)

Type	OPTIMISATION OPTIONS	ID
E	Intercepting Supply Channel Seepage + Return	E03
E	Mole Drainage + Recirculation	E04
E	SS Drainage + Disposal by Shandy + Reuse	E05
E	SS Drainage + Disposal to Trees/Saltbush	E06
E	SSD + Evap	E07
E	SSD + Evap + Drainage Disposal & Dilution Flows wet years	E08
E	High Tech. Hort Irrigation Systems	E09
E	Transfer Salt to Community evaporation areas	E13
E	District Channel Seepage Control	E14
H	Automisation Irrigation (includes High Tech)	H02
H	Recycling Tile Drainage on Farm	H05
H	Mole Drainage Horticulture	H06
H	Tile/Tubewell Drainage	H07
H	High Tech Hort Irrigation Systems	H09
H	Reducing Hillslope seepage	H10
H	Runoff Recycling 12 mm runoff storage	H14
H	Runoff Recycling No Storage	H15
H	Better forecasting water demand	H16
H	Two or Four day water ordering to reduce losses	H18
H	Performance Monitoring to reduce escape loss	H19
H	Community Evap Areas Hort TD	H20
H	District Channel Seepage Control	H21
H	Integrated Renewal of Systems	H21
M	Farm Pumping District Drains	M01
M	Conversions to Perennial Pastures etc	M03
M	Irrigated Woodlets in MIA	M04
M	On Farm Seepage control by Perm. Past.	M06
M	Rice Target Water Use implementation	M08
M	Intercepting Supply Channel Seepage + Return	M09
M	Mole Drainage MIA Large Area Farms + Recycle	M10
M	SSD + Evap	M11
M	SSD + Disposal to trees + saltbush	M12
M	SSD + Shandy + reuse	M13
M	Rice Puddling	M15
M	Drainage Recycling 10 Ml storage	M19
M	Drainage Recycling 12 mm runoff storage	M20
M	Drainage Recycling No Storage	M21
M	Four day water ordering to reduce escapes	M22
M	Better Forecasting water demand	M23
M	District Pumping District drains	M24
M	Performance Monitoring to reduce escapes	M25
M	Plant Corridors of Trees	M26
M	Rice Hydraulic Loading area reduction	M27
M	Community Tile Drainage schemes	M28
M	Community Tubewell schemes +Evap	M29
M	Deep Bore Pumping + Irrigation Use	M30
M	District Channel Seepage Control	M31
V	Intercepting Supply Channel Seepage + Return	V03
V	Mole Drainage + Recirculation	V04

V	SS Drainage + Disposal by Shandy + Reuse	V05
V	SS Drainage + Disposal to Trees/Saltbush	V06
V	SSD + Evap	V07
V	SSD + Evap + Drainage Disposal & Dilution Flows wet years	V08
V	High Tech. Irrigation Systems	V09
V	District Channel Seepage Control	V13
V	Transfer Salt to Community evaporation areas	V14
V	Recycling + 12 mm storage	V15

(*1) E=Extended Horticulture, H=Gazetted Horticulture, M=Mixed farming, V=Vegetables

A brief description of each option listed above may be found at Appendix 1.

The next step in the process is to identify current and future expected adoptions rates, find economic cost and benefit values, and environmental benefits and costs for all the objectives and constraints discussed in previous sections. However, prior to this some further discussion of the role of Best Management Practices is useful.

8.2. Best Management Practices

The term "Best Management Practices" (BMP) seems to be derived from business management jargon where companies like to demonstrate to the outside world that they adopt the best and most efficient management techniques. With regard to farming the term is confusing in that usually there is a range of practices that produce improved results, but this may be aimed at increased production rather than environmental objectives. The practice that provides the best result is difficult to identify from a range of alternatives, and may depend on the soil type, the crops, the irrigation layout, seasons, the operator, etc. An investment in a BMP may not give the desired result unless the operator is also investing the time and care. Alternative terms such as "Good Management Practices", Best Known Practice or Best Bet Management Practices" have been used to overcome the implied idea that there is only one practice that is best.

In the context of Land and Water Management the object of Best Management Practices is to reduce the impact of a perceived problem, such as too much accession to the groundwater, pesticide runoff, discharge of saline water to drains. There are many actions that could be classified as BMP's and it is not practical for this report to list them all. Table 8.3 categorises various actions into seven topics. When considering any of these seven categories as a BMP this report assumes that all the associated possible actions including those listed at Table 8.3 are considered and implemented where relevant.

Table 8.3 : Categorisation of Best Management Practices

	BEST BET MANAGEMENT PRACTICES (*1)						
		LAF	**GAZ_H**	**VEG**	**EXT_H**	**STURT**	**ECON**
1	**SOIL STRUCTURE MANAGEMENT**						
	Cover crops Bare Soil	v	v	v	v		
	Cover Crops Saline Soil	v		v			
	Permanent Sod Interrow		v		v	v	v
	Reduced Tillage	v	v	v	v		v
	Limited Tractor Movements	v		v			
	Liming where soil pH is down	v					
	Gypsum for Sodic Soils	v	v	v	v		v
	Bed Farming	v		v			

		LAF	GAZ_H	VEG	EXT_H	STURT	ECON
2	**FERTILISER MANAGEMENT**						
	Dosage	v	v	v	v		
	Timing	v	v	v	v		
	Method of Application	v	v	v	v		
	Incorporation	v		v			
3	**PESTICIDE MANAGEMENT**						
	Deciding What to Use	v	v	v	v		
	Deciding When to Use	v	v	v	v		
	Weather	v	v	v	v		
	Timing	v	v	v	v		
	Method of Application	v	v	v	v		
	Dosage Rates	v	v	v	v		
	Droplet Size	v	v	v	v		
	Prevention of Runoff for a Period	v		v			
	Aerial Application BMPs	v		v			
	Drum Disposal	v	v	v	v		
4	**REDUCING ACCESSIONS**						
	Whole Farm PLan	v		v	v	v	
	Landforming	v	v	v	v		
	Improved Surface Drainage	v	v	v	v		
	Use More Deep Rooted Species	v				v	v
	Crop Selection	v					
	High Tech Irrigation		v		v	v	v
	Rate of Flow	v	v	v	v		
	Irrigation Scheduling	v	v	v	v		
	Sealing On Farm Leaking Channels	v	v	v	v		
	Lucerne/PP on Channel Banks	v	v	v	v	v	v
	Strategic Use of Trees	v		v			
5	**REDUCING RUNOFF**						
	Irrigation Scheduling	v	v	v	v		
	Timing of Shut Down Supply	v	v	v	v		
	Recirculation where feasible	v		v	v		
	Automisation / Sensors	v	v	v	v		
	Rice Bank Height	v					
	Bottom Bay Management	v					
	Recession Curve Use		v	v	v		
	Tree Lots Bottom end of farm	v		v	v		
	Cover Crops	v	v		v		
6	**REDUCING TILE DRAINAGE**						
	Correct Irrigation Techniques		v		v		
	Good Surface Drainage System		v		v		
	Switching Pump Off if No Rain		v		v		
	Set Float Switch Higher		v		v		
7	**PROTECT REMNANT VEGETATION**						
	Stop Draining to Depressions	v		v			
	Tree Planting	v		v			
	Reduce Accesssions	v		v			
	Avoidance Chemical Spray Drift	v		v			

(*1) "Sturt" refers to those BMP's considered when identifying adoption rates, "Econ" refers to those options for which economic analysis has been carried out

It is shown that for the MIA LWMP only a few practices were considered when surveys were carried out to identify adoption rates for the NO Plan and With Plan scenarios (STURT column), and also that only a few practices have been considered as part of economic analysis.

8.3. Adoption Rates for Optimisation

Adoption rates are a very contentious issue in the MIA. It represents the proportion of farms that have adopted a particular practice or technology or may adopt this in the future. Of course, many farmers may only partially have adopted the practice or technology which complicates matters. An adjustment needs to be made for this. The following types of adoption rates may be distinquished and are graphically displayed at Figure 8.1:

1. Current level of option of a practice or technology (AR 1)
2. No Plan level of adoption at the end of the 30 year period considered (AR 2)
3. Potential level of adoption, representing the maximum proportion of farmers that could participate (AR 3)
4. Maximum increase in level of adoption, the difference between the potential and the current level of adoption (AR 4). In other terms : AR4 = AR3 - AR1
5. With Plan level of adoption, this is the extra number of farms adopting with a plan being implemented (AR 5)
6. With Plan increase in adoption rate above the No Plan scenario rate (AR 6). Hence: AR6 = AR5 - AR2

Another adoption rate was used for the MIA LWMP (and other plans) modeling of salinity conditions for the next 30 years. These models are based on current salinity conditions which are a function of all the land and water management practices and changes therein of the last 30-50 years. This past trend is assumed to continue over the forecast period of the next 30 years. See AR7 in Figure 8.1. It is not the same as the No Plan scenario, which is a forecast based on current trends only.

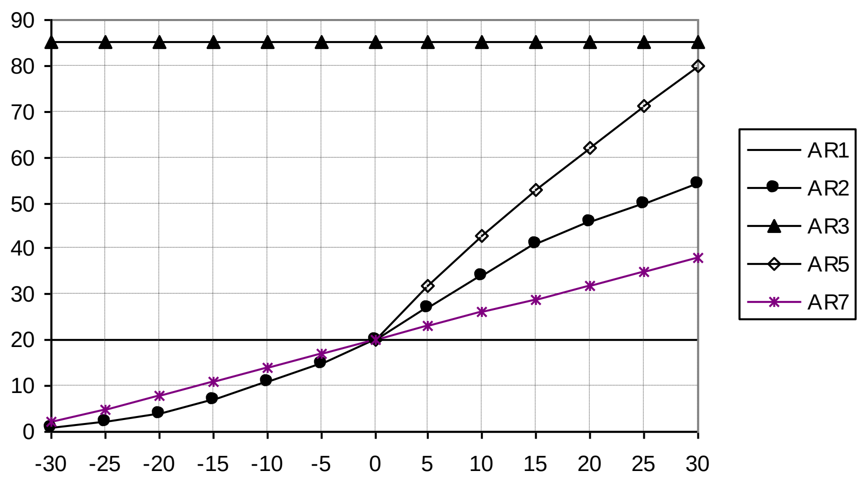

Figure 8.1 Different types of Adoption Rates

For the purpose of optimisation it is necessary to assess environmental benefits and costs compared with the current situation. Certain targets need to be achieved. In most instances it does not matter whether these targets are achieved with or without the plan. All improvement in adoption will help towards the targets. However, for the purpose of economics evaluation of the preferred strategy the difference between the No Plan scenario and the With Plan scenario is the most relevant (AR6). This gives a conflict in the assessment procedures.

Adoption rate AR 5 is what is being aimed for and this is a proportion of AR 4, which represents the situation that all farmers who have not yet adopted the practice start adopting it. The minimum value of AR5 is just in excess of the minimum required to meet the environmental constraints. AR 5 minus AR 2 will give AR 6 for the final economic analysis.

NSW Agriculture has undertaken a study to determine current (AR 1) and future adoption rates with and without incentives being available. STURT University has written the report [25]. Unfortunately, only a narrow range of options were considered during the survey. Some of these are identified at Table 8.3. For other options the adoption rates can only be estimated from the trends that seem to be coming out of this survey (and the Hassal study [19]).

For the optimisation model discussed at section 9 the No Plan scenario adoption rates were determined for all options. As far as the so-called “With Plan” scenario is concerned, such values were determined for the Best Management Practices options only. For the other options the model was allowed to use a larger range of farms. For this AR4 (=AR3-AR1) was used as a guide, but in most instances scaled down by a fraction. This procedure provided the “market” of “potential customers” who may adopt the practice. This upper value gave the model the required flexibility to discriminate between options to determine how the targets for the MIA plan can be best achieved.

The options were considered on their economic merit, and in this context some are deemed to be economic, and others are not. Some economic options may not be financially attractive to landholders. In the end the model determined how many farms (or units of option) in the MIA should adopt the practice. After determination from the modeling excercise what options are needed the next step is to work out how this can be achieved in practice, in other words what incentives are needed to achieve the desired outcome.

The Land and Water Management Plan Working Group, aided by the UNE consultancy on institutional arrangements has the task of identifying what type of incentives would be needed to achieve AR5 compared to AR2. This study preceeds this consideration. For options where an incentive is needed the relative level of incentive or support would be dependent on the economics of the option, the financial attractiveness and the degree by which an environmental objective is being achieved.

Appendix 2, Table 1 gives a schedule of the adoption rates used for the BMP and other options listed at Tables 8.1. and 8.2. The adoption rates are shown as percentage of farms that may adopt a practice as well as the number of farms in the landuse category. The latter values were entered into the optimisation model, to calculate the number of farmers which need to adopt the option to meet the objective or constraint.

8.3 Economic Costs and Benefits

Of all the 83 options listed economic data are available for only a few, as shown in the schedule of Table 8.2 :

Table 8.2. MIA options for which economic analysis has been carried out

Landuse	Option	Ref.	Option	Ref.	Option	Ref.
M	M03	(*1)	M04	(*1)	M06	(*1)
M	M08	(*1)	M10	[26]	M15	[18]
M	M19-21	(*1)	M28	[5]	M29	[5]
M	M30	[40]	M31	[40] (*1)		
H						
E	E04	[26]	E14	[40],(*1)		
V	V04	[26]	V14	[40](*1)	V15	[10]

(*1) : Report not yet available

For many of these Stanton [47] provided preliminary analysis, now superceded. For a few other substantial options, eg M09, M25, M11 (without evaporation areas), and M30 the results of the Coleambally LWMP can be used (Stanton et al [46]. However the conclusion is that of 83 options identified economic analysis is available for less than 25%.

There are reasons for the lack of analysis. For instance it is not practical to do analysis for Best Management Practice type options, which may involve little cost except more care and a changed attitude by the farmer. There are about 20 of these. BMP's often involve many different things all lumped together for this purpose. For instance reducing accessions may involve whole farm planning, landforming, better drainage, irrigation scheduling, altered design of irrigation runs and flows. Some of these aspects (eg landforming) may have been investigated by economists, others not.

Other options have an institutional feature, eg four day water ordering or changing rice hydraulic loading. Some other options for the MIA LWMP were dismissed for economic analysis because they are not believed to result in significant adoption, eg planting saltbush, or layout changes between rice and wheat rotations.

As far as optimisation is concerned, to proceed it is necessary to substitute values where they are not available from economists. This was done as best as possible between the author and Mr G. Beecher of NSW Agriculture.

Proper economics evaluation involves Net Present Value assessment of costs and benefits over the life of the plan, or 30 years. This was not considered practicable because of the nature of many options. To get some values into the model which will allow comparison between options for economic factors the following procedure was followed :

- identify capital costs involved
- determine approximate life of capital equipment
- convert to an annual repayment at 7% interest
- identify operational costs
- add up for average annual costs per farm/unit.
- identify annual benefit for each farm/unit adopting the option.

Appendix 2, Table 2 shows the outcome of this data. The costs and benefits per year for individual units in the model (usually a farm) were transferred into the optimisation model .

In the model the optimisation aims at picking the most economic options. This was achieved by multiplying costs and benefits of individual units with the adoption rate determined by the model. This allowed calculation of net benefits, which may be maximised by the model. A surrogate BCR was of the package was also calculated and used to optimise economic returns.

Further discussion of the economics evaluation of the final recommendations is at section 12.

8.4. Environmental Benefits and Costs

The targets of Section 7 can be achieved if there are sufficient farms/sites which adopt a specific option and if each of these farms/sites produce sufficient environmental benefit for the combination of option considered. To achieve this, values need to be determined for the environmental benefit achieved by the adoption of an option on an individual unit/farm.

The problems encountered when trying to do this are similar as for the economics assessment. Only for some of the options values exist based on scientific assessment. They include landforming, converting annual pastures to perennial pastures, the target rice water consumption, recirculation with and without storage, rice puddling, planting trees, growing lucerne. Some data are also available for some sub-surface drainage options, eg tile drainage, mole drainage, deep bore pumping, channel seepage control, shallow groundwater pumping to evaporation areas by tile drainage ot tubewell drainage, interceptors along drains.

For many other options a technical report is available but there is no quantification of the volume of accessions, runoff or escape drainage saved, or the water quality improvement that is achieved. The optimisation team had to find substitute numbers. This was done by the author aided by Mr Geoff Beecher of NSW Agriculture.

The values determined after repetitive checking are listed at Appendix 2, Table 3. The values shown are for drainage water salinity, water quality and savings of runoff, escape drainage, tile drainage and accessions to the groundwater system. A brief discussion follows below.

<u>1. Water Quality and Salinity</u>

Salt load reductions will produce a lowering of salinity in drainage. The values are mostly estimates. When considering the impact of an individual option it was considered that 1 EC unit at Willow Dam represents about 150 tonnes.

Note : This estimate actually is a little high, based on Reference [58] during the irrigation season the value is probably closer to 144 tonnes (31,000/400), and in winter about 17 tonnes (13,000/830), average about 100-110 tonnes per EC unit (50,000/470).

For the model the values of Table A2-3 were assessed assuming that all the potential farms (customers) participate in the option (AR4). A minus value means there is an improvement (reduction). For some options, which have a positive effect in other target areas, there may be a negative salinity impact. This appplies to the reduction of (escape) drainage type options (eg, H19, M25).

With water quality the same principles were adopted, however instead of an EC improvement it was assumed that 100% improvement is needed for both horticulture (include. extended) and large area farms (include. vegies). Each option was then valued according to the percentage improvement that would be obtained if all potential participating farms (AR4) adopted the option. Again, there may be negative impacts from some options.

2. Reduction of Accessions

Reduction in accessions may occur from the implementation of many options. As far as mixed farms are concerns, the reduction in accessions for that land use is identified as representing the main objective function in the model. The values believed to be appropriate are based on NSW Agriculture analysis, Coleambally experience or estimated. These values represent the volume for one farm, or participating unit. In a number of cases the reduction may be negative, eg improved soil management may lead to more accessions.

There is a little ambiguity between those options that reduce accessions and those options that remove groundwater (and hence lower watertables). In horticultural farms for instance a reduction in tile drainage flow is sought to lower salt loads in the drains. This may be achieved by switching off of the pumps at some times, or it may be achieved by reducing accessions through better irrigation practices, or even by reducing channel seepage into horticultural farms. When assessing the benefits of some of these options care needed to be excercised that there is no double counting for the final results.

3. Reduction in Drainage Volumes

Reduction in runoff may occur for many options. The values listed represent the volume for one farm, or participating unit. In a number of cases the reduction may be negative, eg BMP's for reducing accessions may lead to increased runoff.

9. OPTIMISATION - UPSTREAM ZONE

9.1. Methodology Used

The data of Chapter 8 and the targets of Chapters 7 were entered in the EXCEL SOLVER model and the calculations initiated. The principle of the optimisation model is based on linear programming. There is one objective function, for instance the maximisation of the reductions in accessions, and an unlimited number of constraints. The constraints used included :

- the EC change from the combined horticulture and mixed farming areas less than zero
- water quality improvement in horticulture has to be more than 60%
- water quality improvement from mixed farms has to be more than 60%
- the drainage volumes reductions from all sources has to be more than 20,000, or 30,000, or whatever value

- the tile drainage flow reductions as a percentage of the historical values has to be more than the precentage drainage reduction at Willow Dam compared to the historical volumes.
- the reduction in drainage from the MIA has to be more than 15% (for example)
- the options used for optimisation all have to be economic.
- the BCR of the options package calculated has to be more than 1.2
- the reductions in accessions from horticulture, or vegetable areas, or extended horticulture has to exceed a certain value.
- the model coefficients operating on the range of farms/units in the model have to be between zero and one.

EXCEL SOLVER basically selects a value for the objective function and then starts changing all the model coefficients to work out whether the constraints are satisfied. Special internal routines help finding a more rapid convergence to the solution. The value of the objective function is being changed until the maximum is found whilst still satisfying all the constraints. At that point there is usually one or more constraints that are only just satisfied, but for many other constraints there may still be some "slack".

Every time the model coefficients are changed all the outcomes of the model are changed. Most of the outcomes are based on the multiplication of the economic or environmental values of the option with the model coefficient and then adding up across all the options. These outcomes are compared to the objective function and constraints build into the model for the scenario in question.

Sometimes the objective function can not be reached without altering some of the constraints to a lower value, under these conditions the solution was "not feasible". This happened for the MIA modeling process. For instance the water quality constraints for horticulture (60% improvement) could not be achieved if another constraint is that only economic option are to be used.

When SOLVER returns its model coefficients for the scenario being modeled, these values and the achieved outcomes are transferred to another spreadsheet and the process restarted for another scenario. A total of 18 scenarios were modeled, see section 9.2.

9.2. Optimisation Procedures - Scenarios Modeled

The targets of Table 9.1 for objectives and constraints were used for the initial modeling process (also see section 7) :

Table 9.1 : Targets for Optimisation Model Process

Factor	ID	Target
Accessions Mixed Farms MIA	AccMix	> 25,000 Ml/year
EC change at Willow Dam	EC	< 0 uS/cm
Water Quality Improvement Horticulture	WQHort	> 60%
Water Quality Improvement LAF's	WQLAF	> 60%
Runoff Reductions Total	ROtot	> 24,000 Ml/year (initially)
Reduction Flow at Willow Dam	ROWD	> 15%
Economics of Individual Options	ECON	> 0 Net Benefit
BCR of Selected Options Package	BCR	> 1.2
Tile Drainage Reduction	TDred	> Other drainage reductions (as%)
Reduction Accessions Horticulture	AccHort	see tile drainage reduction
Reduction Accessions Vegetable Areas	AccVeg	> 2,000 Ml/year (based on 6,000 ha)
Reduction Accessions Ext. Horticulture	AccExtH	> 1,250 Ml/year (*1)

(*1) Reductions in accessions for vegetables and Ext. hort is not highly relevant since effluent has to be kept on farm anyway.

As individual scenarios were being considered it was found that no single scenario gives the required solution. A process has to be followed that leads to the best choice options package. This process is discussed below.

A total of 18 scenarios were used. The model results are provided at Appendix 3. Tables A3-1 and A3-2 gives the modeling coefficients for the BMP's and the other options respectively, Table A3-3 gives the outcomes for the various factors for each scenario and Table A3-4 gives the assumptions and constraints that were used for each scenario.

The first steps were to consider what improvements are being achieved if only the Best Management Practices are considered, or if the adoption rates for the No Plan scenario are being considered. A summary of the results are shown at Table 9.2.

TABLE 9.2 : SUMMARY RESULTS BASE SCENARIOS

	No Plan	With Plan	NoPlan	With Plan	Scene 1	Scene 2
	BMPonly	BMPonly	All	All	MixedAcc	WQHort
Reduction Accessions Gl/yr (*1)	2842	5734	4692	19687	14859	14849
Reduction Runoff Gl/yr	1348	2190	7725	51916	22526	23162
% Reduction at Willow Dam	0	0	3	21	9	9
EC Change	-12	-25	0	-5	-11	-11
WQ horticulture improvement %	15	37	14	33	36	36
WQ LAF improvement %	26	48	27	84	65	66
Crude BCR	1.36	1.35	1.28	1.19	1.28	1.28
Cost/year $m	6712	13002	10702	24713	23430	23460
Net Benefit $m/year	2407	4520	2965	4647	6531	6531

(*1) Excluding Rice Water Use Target Implementation reductions and the effect of deep bore pumping, which mostly has benefits in the southern MIA only. This means the target for the model should be reduced to 20,000 Ml/year, not 25,000 Ml/year.

The combined BMP's for No Plan and With Plan adoption rates by themselves clearly do not achieve the targets of Table 9.1. The No Plan scenario (3rd column), all options, scenario is important because it is the reference against which the final plan will be evaluated. It shows that there are some improvements to be expected compared to the current situation.

The "With Plan" scenario is based on fixed (not modeled) values for adoption rates for all options. These link back to the results of the "cell group" survey and the STURT University report [25]. This scenario could not be considered an optimised package since it is based mostly on perceptions as to what may happen. Interestingly however, the results in column 4 of Table 9.2 indicate that most targets would be met, except the water quality improvement target for horticulture (WQHort).

Scenarios 1 and 2 are for economic options only. Scenario 1 maximises the reduction in accessions from mixed farms. It was found this was 14,850 Ml/year but the target WQ improvement for horticulture had to be lowered to 35.8%. No effort was made to optimise the drainage reduction from the MIA. The model indicates 22,500 Ml/year, but there is probably a lot of slack upwards and downwards. Scenario 2 is based on fixing the accessions reduction from mixed farms to 14,850 Ml/year and then maximising the WQHort. From the model and the input data used it was found this factor will not increase to above 36.1%, which is short of its target.

The next step was to investigate the aspect of reductions in volumes of drainage. For scenarios 3 to 8 of Table 9.3 the constraints for AccMix and WQHort were fixed at 14,850 and 36%.

TABLE 9.3 : SUMMARY RESULTS OPTIMISING FOR RUNOFF

	Scene 3	Scene 4	Scene 5	Scene 6	Scene 7	Scene 8
	Min RO	Max RO	RO=20Gl	RO=30Gl	RO=36Gl	Max BCR
Reduction Accessions Gl/yr	14858	14851	14859	14859	14859	14800
Reduction Runoff Gl/yr	14420	43294	20000	30000	36003	36003
% Reduction at Willow Dam	6	18	8	12	15	15
EC Change	-12	-9	-12	-11	-11	0
WQ horticulture improvement %	36	36	36	36	36	36
WQ LAF improvement %	60	76	69	84	86	60
Crude BCR	1.32	1.33	1.32	1.31	1.32	1.35
Cost/year $m	19571	20538	19857	20798	20956	21091
Net Benefit $m/year	6176	6839	6281	6495	6653	7428

Based on scenario 2, scenario 3 shows that the minimum reduction in drainage volumes would be 14,420 Ml/year and scenario 4 shows that the maximum would be 43,300 Ml/year. These two scenarios use economic options only and still show outcomes beyond the range of the target drainage reduction, which is pleasing. Scenarios 5, 6 and 7 then calculates the model values when the drainage reduction is set at intermediate values of 20,000 Ml/year, 30,000 Ml/year and 36,000 Ml/year. The key factor being watched for scenarios 3 to 7 is the economic outcome for the district. It is found that the net benefits overall increase slightly if drainage reductions are increased further. This is a very important conclusion when considering optimisation between upstream and downstream of Barren Box swamp solutions, see sections 10 and 12.

Table 9.3 does not show which of the drainage reduction options is contributing most to the outcome. Reference is made to Table A3-3 of Appendix 3. As drainage reductions are being increased the recycling option and the pumping from drain options become relatively more important. These two options may be economic but the financial attactiveness may be in doubt. This is not being considered in this context. The economics of the final package is discussed at section 12.

The next step was to discover how the economics of scenario 7 could be improved by setting ROtot at 36,000 and maximising for BCR. It was found from scenario 8 that there would be an increase to 1.35, but this is at the expense of the gains made with the EC change at Willow Dam, which is contrary to the long term objective to reduce salinity.

Scenario 8 represents a base scenario for further evaluation of the preferred plan since it maximises economic gains of the upstream LWMP, recognising that the required volume reductions are achieved, but not all water quality targets and not any improvements in salinity compared to the current standard. The shortcomings need to be explored further, see below.

The final part in the modeling process included the inclusion of non economic options into the model, to see what sacrifices in economic outcomes have to be made to achieve the under achievements in firstly AccMIX, secondly WQHort, and finally, to maximise the EC reduction at Willow Dam. The results for the first two of these factors are shown at Table 9.4.

TABLE 9.4 : SUMMARY RESULTS ACHIEVING OBJECTIVES INCLUDING UNECONOMIC OPTIONS

	Scene 9	Scene 10	Scene 11	Scene 12	Scene 13	Scene 14
	Max BCR	Mix Acc	WQ>60	WQ>80	WQ>max	WQLAF
Reduction Accessions Gl/yr	14800	20000	20000	20000	20000	20000
Reduction Runoff Gl/yr	36003	36003	36003	36003	36003	36003
% Reduction at Willow Dam	15	15	15	15	15	15
EC Change	0	0	0	0	0	0
WQ horticulture improvement %	36	36	60	80	88	36
WQ LAF improvement %	60	60	60	80	98	80
Crude BCR	1.35	1.34	1.30	1.26	1.18	1.33
Cost/year $m	21091	21527	22452	24229	27128	21875
Net Benefit $m/year	7428	7357	6806	6231	4976	7198

Scenario 9 is the same outcome as scenario 8, even though now the model was allowed to also select any of the uneconomic options (it did not). Scenario 10 is based on setting the AccMix at 20,000 Ml/year and maximising for BCR, all other factors being the same. It is found that the Net Benefit to the District drops from $7,43m/yr to $7.36 m/yr, which is only a small change and would probaby be acceptable to achieve this extra environmental benefit. Examination of Table A3-3 reveals that the improvement is being achieved by three factors

- implementation of on-farm seepage control measures
- implementation of subsurface drainage on a percentage of land
- planting of tree corridors.

A decision needs to be made whether such measures are realistic for the final plan. This is discussed at section 9.3.

The following step was to determine whether further improvements in water quality can be made without too much cost. This is shown at scenarios 11 to 14.

Scenario 11 boosts the WQHort achievement to 60%. The large reduction in net benefits (about $0.55 m/yr) reflects the large increase in cost when implementing High Tech. Irrigation systems and Recycling+ Storage on horticultural farms as a means of achieving this. The situation gets worse when improvements of 80% (scenario 12) are made. A 100% improvement proved to be not possible (scenario 13), the maximum achieved being only about 90% is all options are used (at very high cost). This feature suggests that the values used in the model are perhaps somewhat conservative, after all, one would expect that if every option was used the combined improvement potential is well over 100%.

Finally the matter of trying to reduce salinity at Willow Dam was examined. The results are shown at Table 9.5.

Table 9.5 : Optimisation results aiming at Lowering Salinity at Willow Dam.

	Scene 8*	Scene 15	Scene 16
	Scenario 8 Max BCR	Max EC reduction	EC=100 reduction
Reduction Accessions Gl/yr	14800	27,300	14,800
Reduction Runoff Gl/yr	36000	36000	36000
% Reduction at Willow Dam	15	15	14
EC Change	0	-250	-100
WQ horticulture improvement %	36	45	36
WQ LAF improvement %	60	60	60
Crude BCR	1.35	0.92	1.30
Cost/year $m	21.1	38.5	21.9
Benefit $m/year	28.5	36.2	28.4
Net Benefit $m/year	7.4	-2.3	6.5

Scenario 8 is a repeat of Table 9.3, with minor changes in outcome due to some input changes since the previous runs.

Scenario 15 aimed at maximising the potential EC reduction, irrespective of the cost. It is shown that an 250 EC improvement can be achieved, if all horticultural tile drainage is put in evaporation areas, if escape flows are not reduced at all, but the 36 Gl reduction in runoff is achieved from other sources, such as reuse, if sub-surface drainage schemes are adopted in mixed farms, and a host of other measures. The cost to achieve this is extremely high, compared to scenario 8 there is a net cost of $9.7 million per year and the MIA plan is no longer economic.

The 250 EC improvement applies to Willow Dam flows, not the Barren Box Outfall Drain, which is also affected by swamp evaporation. The reduction may be compared with the request of the Wah Wah LWMP group to lower salinity by 300 EC to 400 EC in the Outfall drain. The numbers of the model and actual situation are not fully compatible, but the order of magnitudes seem about correct. Salt loads such as Lake Wyangan pumping, the sewage works and seepage into drains were not considered in the optimisation model and would have to be added to the typical salinity that theoretically could be expected from an MIA not affected by salinity. This would bring the average Willow Dam salinity to at least 300 EC and the Outfall Drain salinity to about 380 EC. The current average Willow Dam salinity is about 650 EC.

The maximum reduction is not realistic from these data but a 100 EC reduction would be less costly, as shown by Scenario 16 of Table 9.5. The cost of achieving such a reduction would amount to about $ 0.9m/year. The main option to be implemented over and above scenario 8 includes the piping and disposing to evaporation areas of 63% of gazetted horticultural effluent. Whether this is justifiable would need to be decided from an assessment of possible improvements in production in the Wah Wah District. For the purpose of this optimisation report such a study study has not been carried out.

The procedures used is believed to be logical and leading to many observations and conclusions which are helpful when making the decisions for the final package. The selection of the final options is discussed at section 9.3.

9.3. Derivation of Recommended Package

The recommended options package consists of the options identified to be used and the number of units/farms that should implement the option to achieve the desired result. Table 9.2 to 9.4, based on Tables A3-1 to A3-4 provide the basis for this final selection. The discussion below is split between the plan for Best Management Practices and the plan for other options upstream of Barren Box Swamp. Downstream options are further discussed at section 10.

9.3.1 Best Management Practices.

Table 9.6 shows the recommended package for BMP's. When considering the options the comments made at section 8.2 should be kept in mind. The first column shows how many farmers/units at present have not yet adopted the desired practice, partially or fully. The adoption rates of the subsequent columns may be compared against this benchmark.

The next 6 columns in Table 9.6 are arranged according to three rates of adoption :

1. the rate of adoption under the No Plan scenario.
2. the rate of adoption based on the With Plan scenario, here expressed as the additional adoption required over and above the With Plan scenario.
3. the rate of adoption desired over and above the With Plan scenario.

Table 9.6 shows it is assumed that all available BMP options are proposed to be used for as far as can be achieved amongst the farming population. The number of farms expected to adopt the BMP's should be viewed against the number of farms in the area. There are about 100 equivalent 20 hectares Extended Horticultural developments, 600 Horticultural Farms, 600 Mixed farms and about 50 equivalent 100 hectare vegatable farms. Where a farm is larger or smaller the equivalent unit value would change proportionally.

Table 9.5 : Required adoption rates for BMP's and number of farms to implement.

BEST BET MANAGEMENT PRACTICES	ID	Customers (*1)	No Plan %	No Plan Farms	With Plan Farms	Extra Farms (*2)	Total Farms to Adopt
Improved Soil Structure Management	E01	65	0.25	25	20	0	45
BMP's for Reducing Accessions	E02	70	0.2	20	20	0	40
On Farm Seepage Control	E10	25	0.4	10	8	0	18
BMP Fertiliser application management	E11	60	0.1	10	20	0	30
BMP On Farm Pesticide application	E12	60	0.1	10	20	0	60
Improved Soil Management	H01	423	0.25	163	65	0	228
BMP Hort Furrow to reduce accessions	H03	455	0.2	130	130	65	325
BMP Hort Furrow to reduce runoff	H04	360	0.1	60	120	0	180
Controlling Tile Drainage Flow Rates	H08	400	0.1	50	100	0	150
Biological control of pests	H11	455	0.1	65	65	0	130
BMP Fertiliser application	H12	390	0.1	65	130	0	195
BMP On Farm pesticide application	H13	390	0.1	65	130	130	325
Convert LAF farms to Extended Horticulture	M00	60	0.4	40	0	0	40
Protection of Remnant Vegetation	M02	225	0.1	30	105	0	135
Keeping cover crops on salinised land	M05	240	0.2	60	90	0	150
BMP's for Reducing Accessions	M07	434	0.2	124	124	0	248
On Farm seepage control	M14	90	0.15	15	45	0	60
BMP Fertiliser application management	M16	434	0.2	124	124	0	248
BMP On Farm Pesticide application	M17	372	0.1	62	124	0	186
Rice Bay BMP's to reduce runoff	M18	372	0.2	124	62	0	186
BMP Aerial Pesticide Applications	M32	7	0.3	3	2	0	5
Improved Soil Structure Management	V01	25	0.15	8	8	0	15
BMP's for Reducing Accessions	V02	40	0.25	13	13	0	25
On Farm Seepage Control	V10	47.5	0.2	10	13	0	23
BMP Fertiliser application management	V11	35	0.2	10	10	0	20
BMP On Farm Pesticide application	V12	30	0.1	5	10	0	15

(*1) Not already adopting the BMP
(*2) Extra desired adoption to meet a specific target. Whilst many options could be increased here the water quality improvement and reduction in accessions are targeted for extra attention.

The fairly small number of additonal farms for options H11, H12 and H13 expected to adopt the option is the reason that the water quality targets in horticulture could not be achieved in the modeling excercise of section 9.2. Obviously it is desirable that more farms will take part. Similarly it would be desirable if more than 260 farms for option H03 and 150 farms for option H08 took part in the objective to reduce accessions. The values of the No Plan and the With Plan columns in Table 9.6 are based on perceived adoption rates, not on what is required for the final result. The "Extra" columns show which BMP's should be targeted for an extra effort by extension personnel.

9.3.2 Model Options

With the model options the final recommendation is based on four factors :

1. The number of farmers/units not already adopting the option.
2. The rate of adoption for the No Plan scenario
3. The extra rate of adoption based on scenario 8 of the model (section 9.2). This represents what is being achieved using economic options only.

4. The “Extra” rate of adoption required to achieve a larger proportion of the targets which are not being achieved using economic options only (as per section 9.2)

The last factor represents the extra adoption over and above Scenario 8 to give do the best possible job for the plan. The choices are made on basis of outcomes related to Table 9.4 and other considerations. *These will be discussed*.

The presentation is split for each of the four land use categories.

9.3.3. Extended Horticulture

Table 9.7 shows outcomes for extended horticulture.

Table 9.7. Recommended adoption rates for Extended Horticulture based on modeling process.

Model Option	ID	Customers (*1)	No Plan Farms	Scene 8 Extra Farms	Extra Farms/ units	Total Farms to Adopt
Intercepting Supply Channel Seepage + Return	E03	37.5	8	0	0	8
Mole Drainage + Recirculation	E04	12	2	0	0	2
SS Drainage + Disposal by Shandy + Reuse	E05	3	1	2	0	3
SS Drainage + Disposal to Trees/Saltbush	E06	5	2	3	0	5
SSD + Evap	E07	21	6	15	0	21
SSD + Evap + Drainage Disposal & Dilution Flows wet years	E08	50	0	0	0	0
High Tech. Hort Irrigation Systems	E09	70	5	0	0	5
Transfer Salt to Community evaporation areas	E13	1	0	0	1	1
District Channel Seepage Control	E14	2	0	2	0	2

It is shown that the only additional option considered over and above the economic options of scenario 8 is the possible construction of an evaporation basin to accept effluent from on-farm evaporation ponds. The use of dilution flows in wet years to allow by-passing of tile drainage effluent to the drainage system rather than into the (already full) ponds also requires further consideration. These aspects are further discussed at sections 9.5 and 10.

Options with zero required adoption rates over and above the No Plan scenario do not have to be further considered for the LWMP. Aspects of these options are discussed at section 9.4.

All other options for this land use except the prevention of channel seepage at a potential 2 sites actually are on-farm options which will not require joint venturing between government and landholders.

9.3.4. Gazetted Horticulture

Table 9.8 shows the outcomes for gazetted horticulture.

It is shown that none of the options used in the model are recommended for LWMP implementation. The High Tech Irrigation option H09 and the recycling options H05, H14 and H15, all of which would have benefits for water quality improvement and/or reductions in accessions, are not considered economic. If they were forced to be introduced would come at very high cost (Table 9.4). It is not considered useful to provide incentives for these options to that extent, particularly in a climate where the horticultural industry is likely to be subject to a lot of structural adjustment over the next 10-20 years anyway. Further discussion at section 9.5.

Table 9.8. Recommended Adoption Rates for LWMP options specific to Gazetted Horticulture based on Model Results

Model Option	ID	Customers (*1)	No Plan Farms	Scene 8 Extra Farms	Extra Farms/ units	Total Farms to Adopt
Automisation Irrigation	H02	617	98	0	0	98
Recycling Tile Drainage on Farm	H05	475	25	0	0	25
Mole Drainage Horticulture	H06	55	0	0	0	0
Tile/Tubewell Drainage	H07	26	26	0	0	26
High Tech Hort Irrigation Systems	H09	604	33	0	0	32
Reducing Hillslope seepage	H10	12	2	0	0	2
Runoff Recycling 12 mm runoff storage	H14	350	0	0	0	0
Runoff Recycling No Storage	H15	300	0	0	0	0
Better forecasting water demand	H16	0.9	0.15	0	0.38	0.53
Two or Four day water ordering to reduce losses	H18	1	0	0	0	0
Performance Monitoring to reduce escape loss	H19	0.95	020	0	0.38	0.58
Community Evap Areas Hort TD	H20	1	0	0	0	0
District Channel Seepage Control	H21	0.7	0	0	0	0
Integrated Renewal of Systems	H21	617	65	0	0	65

A certain proportion of adoption will be expected anyway, see the No Plan columns of Table 9.8. This includes the implementation of integrated renewal of systems (H21), of which the economics may or may not be sound, dependent on the situation in the MIA. It is not recommended as a Land and Water Management Plan option if the main motive is related to environmental objectives.

The reduction in escape drainage through either better forecasting of demand and/or performance monitoring is a useful option is expected to be adopted to some extent in a No Plan scenario. Even though not shown as per scenario 8 this (very economic) option deserves some investment to create extra capacity in the MIA system to reduce drainage when needed. This aspect is also further discussed at section 9.5.

Options with zero required adoption rates over and above the No Plan scenario do not have to be further considered for the LWMP. Aspects of these options are discussed at section 9.4.

9.3.5 Mixed Farming

Table 9.9 shows the recommendations for MIA mixed farming enterprises. Its presentation is similar to the tables for landuse categories already discussed.

The main feature of Table 9.9 is that more options are involving an “Extra” adjustment over and above the outcome for economic options only. Is several cases the adjustment is negative. There are a number of reasons

For some options an extra adoption over and above scenario 8 is needed to meet the need to maximise the reduction in accessions to groundwater. The extra options selected are extra Rice puddling (M15) where possible, small Irrigated woodlots (M04) extended to about 160 farms, seepage control from on-farm channels whereever appropriate (M06). However the Conversion to Perennial Pasture option (M03) was reduced for the final recommendation, since it was believed that the model assessment was too optimistic (see STURT report [25].

Table 9.9 : Recommended adoption rates for LWMP options specific to Mixed farms in the MIA.

Model Option	ID	Customers	No Plan Farms	Scene 8 Extra Farms	Extra Farms	Total Farms to Adopt
Farm Pumping District Drains	M01	36	4	0	16	20
Conversions to Perennial Pastures etc	M03	558	31	521	-264	289
Irrigated Woodlets in MIA	M04	607.6	19	0	145	164
On Farm Seepage control by Perm. Past.	M06	150	15	0	41	55
Rice Target Water Use implementation	M08	100	0	90	-18	72
Intercepting Supply Channel Seepage + Return	M09	47.5	0	48	0	48
Mole Drainage MIA Large Area Farms + Recycle	M10	100	5	0	0	5
SSD + Evap	M11	97	7	0	0	7
SSD + Disposal to trees + saltbush	M12	100	10	0	0	10
SSD + Shandy + reuse	M13	47.5	3	0	0	2
Rice Puddling	M15	190	0	0	48	48
Drainage Recycling 10 Ml storage	M19	190	10	100	-29	81
Drainage Recycling 12 mm runoff storage	M20	180	0	0	72	72
Drainage Recycling No Storage	M21	160	0	0	0	0
Four day water ordering to reduce escapes	M22	1.00	0.00	0.00	0.00	0.00
Better Forecasting water demand	M23	0.9	0.15	0.69	0.00	0.84
District Pumping District drains	M24	5.4	0	5	-2	3
Performance Monitoring to reduce escapes	M25	0.9	0.15	0.49	-0.12	0.52
Plant Corridors of Trees	M26	10	2	0	4	6
Rice Hydraulic Loading area reduction	M27	36000	0	0	1008	1008
Community Tile Drainage schemes	M28	150	0	0	0	0
Community Tubewell schemes +Evap	M29	150	0	0	0	0
Deep Bore Pumping + Irrigation Use	M30	300	30	270	-270	30
District Channel Seepage Control	M31	12	0	10	0	10

A reduction in Rice hydraulic loading (M27) to the tune of about 1000 hectares or about 3% is expected if the current rules are more firmly applied. The areas targeted would be those instances where there is evidence that seepage from rice fields is affecting other fields or neighbours by more than an acceptable minimum amount. In such instances a 1:4 year rotation or reclassification to non-rice should be applied. No across the board reduction to say 25% hydraulic loading is proposed from the analysis.

With respect to the rice target water use option (M08), this applies mainly in the southern parts of the MIA, where some farms occasionally use more than 16 Ml/ha of water. The criterion may eventually be lowered if better assessment techniques become available.

The drainage recycling option has been boosted to include about 150 farms between options M19 and M20. This option is contentious in the MIA and will only succeed if there is a sufficient amount of incentives/subsidy. The option will ensure that the water quality improvement targets for large area farms will be met reasonably well. In the MIA however there are many farms split into many portions making implementation extremely expensive for those farms. In addition, in those locations of the northern part of the MIA where soil salinity is increasing it is not recommended that recycling be adopted without further research. These factors combined led to the view that recycling would be practicable on about 150 farms in the medium term.

The optimisation process concentrates on the Willow Dam catchment, where water quality and drainage water salinity issues need to be balance with drainage reductions. For catchments draining to the river these considerations do not apply, and a higher proportion of farms may adopt recycling without similar consequences.

Because recycling systems will bring about significant reductions in drainage the recommended strategy needed to be adjusted for some other water saving techniques, eg pumping from drains and escape reductions. This is showing up by the negative numbers in the "extra" column. If this was not done the total drainage savings could be too high in proportion to the tile drainage savings that are expected from Best Management Practices (section 9.3.1).

The recommendation to limit recycling to only about 25% of farms applies for the short to medium term (say 10 years). It is possible that wider adoption could be contemplated after the initial phase if downstream management factors warrant this. For instance, the tile drainage reductions achieved may eventually be more than assumed in this analysis (15%).

With respect to pumping from drains, the recommendation is that District operated pump station be constructed at about 3 additional locations. This will enhance the infrastructure to reduce drainage to Willow Dam when most needed.

9.3.6. Vegetable Farms.

Table 9.10. shows the recommendations for vegetable farms.

Table 9.10. Recommended adoption rates for LWMP options specific to Vegetable farms in the MIA.

Model Option	ID	Customers (*1)	No Plan Farms	Scene 8 Extra Farms	Extra Farms/ units	Total Farms to Adopt
Intercepting Supply Channel Seepage + Return	V03	22	3	20	0	23
Mole Drainage + Recirculation	V04	19	5	7	0	12
SS Drainage + Disposal by Shandy + Reuse	V05	5	2	4	0	5
SS Drainage + Disposal to Trees/Saltbush	V06	5	2	4	0	5
SSD + Evap	V07	15	6	9	0	15
SSD + Evap + Drainage Disposal & Dilution Flows wet years	V08	40	0	5	0	5
High Tech. Irrigation Systems	V09	47	0	0	0	0
District Channel Seepage Control	V13	3	1	0	0	1
Transfer Salt to Community evaporation areas	V14	40	0	0	0	0
Recycling + 12 mm storage	V15	35	5	0	24	29

The outcome is that most options relate to reductions in accessions or sub-surface drainage. These matters are a responsibility of the landholder and are unlikely to require incentives except for the extension roles and provision of technical support where needed. To avoid contamination of drainage the adoption of recycling +

storage (V15) should be made compulsory for this land use category.   High tech.

irrigation systems are not considered economic. Where seepage from channels is significant (>50 mm/day) it should be remedied, and this is identified for one site. In some other, less problematic instances it may be possible to intercept the seepage and return this to the channel, however this would require consent by the authority who has legitimate concerns with regard to contamination for downstream users.

9.4. Options Not Included in LWMP

A total of 83 options were considered, although several of these are common between several land categories. The constraints in the model resulted in many options not being selected for further consideration. The reasons were that either the economics were unfavourable, or insufficient environmental benefits were generated, or environmental benefits were off-set by environmental costs, or the cost for each environmental benefit unit value were too small, or the option was not necessary for the target to be reached, or an adoption rate over and above the No Plan scenario rates is not necessary.

Table 9.11 shows the options that have been eliminated following the process of section 9.3.

The only addition compated to what is already discussed is the hillslope seepage reduction option (H10). This option applies to the sandhill horticultural farms where groundwater is unrelated to the regional groundwater system. As is the case for tile drainage in horticultural farms, this option will be implmentated by farmers as needed and as such does not have to be included as a specific option.

Table 9.11. Options not considered for MIA LWMP

OPTION	ID
Mole Drainage + Recirculation	E04
High Tech. Hort Irrigation Systems	E09
Automisation Irrigation	H02
Recycling Tile Drainage on Farm	H05
Mole Drainage Horticulture	H06
Tile/Tubewell Drainage	H07
High Tech Hort Irrigation Systems	H09
Reducing Hillslope seepage	H10
Runoff Recycling 12 mm runoff storage	H14
Runoff Recycling No Storage	H15
Two or Four day water ordering to reduce losses	H18
Community Evap Areas Hort TD	H20
District Channel Seepage Control	H21
Integrated Renewal of Systems	H21
Mole Drainage MIA Large Area Farms + Recycle	M10
SSD + Evap	M11
SSD + Disposal to trees + saltbush	M12
SSD + Shandy + reuse	M13
Drainage Recycling No Storage	M21
Four day water ordering to reduce escapes	M22
Community Tile Drainage schemes	M28
Community Tubewell schemes +Evap	M29
High Tech. Irrigation Systems	V09

9.5. Summary of Recommended Package

In terms of the number of farms that will or ought to adopt the various options under the No Plan scenario and the With Plan scenario, Table A4 -1 of Appendix 4 shows the results of this chapter for Best Management Practices and Table A4 -2 shows the results for the other options.

9.6. Discussion.

The recommended package includes all the BMPs of section 9.3.1 and a variety of other options. The additional options in many cases depend on their implementation on the farmer, for instance recycling systems in large area farms, or sub-surface drainage solutions in extended horticulture. Other options are related to the district level, for instance channel seepage control, escape drainage reductions. Questions may be raised as to how this package is going to be implemented, what the practicalities are, whether or not incentives should be applied to get sufficient adoption, what the alternatives are.

<u>Land Use Categories</u>

<u>Extended Horticulture</u>

With extended horticulture the main issue is the management of sub-surface effluent. Where needed farmers install sub-surface drainage and construct on farm evaporation ponds. The main problem to date has been that these ponds have been too small and farmers too optimistic when judging their ability to reduce accessions to the absolute minimum. Pressures to allow discharge to the drainage system have mounted and has not disappeared despite the conclusion by a community group that evaporation ponds will be accepted as part of the current system of managing salt loads, "but only as a temporary solution".

There are presently about 12-15 of these ponds in the MIA. One of the options considered in this report is to construct a permanent site somewhere near Baren Box Swamp to receive the stored volumes every so often, probably during a low flow period in winter when all ather drainage flows are low. This option (E13) would probably cost about $1 million for a 200 hectares site, which would be sufficient to manage stored effluent from about 30-40 ponds, or 1000 hectares of horticulture with installed sub-surface drainage. This option would need to be subjected to a feasibility study before implementation.

The problem is that even with this facility being available there may be a need to discharge effluent at other times. During wet periods emergencies could occur and there will be requests to allow by-passing of the ponds and discharge to drains. At such times the community evaporation area would be ineffective since flows in the system would be too high. All that can be done is the provision of dilution flows and diversion to Lower Mirrool Creek or any agroforestry option downstream.

The landholder may be responsible for the cost of all these options, but that does not overcome the problem that the infrastructure for managing the salt does not really exist at present. This aspect should be included for consideration of the downstream options scenarios (section 10).

When comparing the cost of a community facility to permanently store salt or the increase of the existing ponds to more appropriate sizes the conclusion may well be that the best alternative is to increase the size of the on-farm basins to perhaps 15-20% of the area of the plantings. This would create more security in the wetter years.

The option to intercept seepage from channels by shallow tile drains with return of effluent to the channel is considered to be an on-farm option equally applicable to extended horticulture, mixed farming and the vegetable areas. In each case the landholder would require approval from Murrumbidgee Irrigation before proceeding. Refusal is likely where water quality impacts to downstream users exist.

Gazetted Horticulture

All the options requiring action by landholders for the LWMP would be implemented under a No Plan scenario, hence there are no on-farm options requiring special attention under the plan. However the failure of high tech. solutions and the recycling options in being acceptable by the community and their poor economics will mean that more attention has to be given to the BMP type solutions to improve water quality from horticulture and the salt loads from drains. It is believed that much can be achieved this way but perhaps incentives, both positive and negative, have to be applied. This is a matter for the LWMP Working Group and Murrumbidgee Irrigation.

Another factor why the expensive solutions are not supported lies with the probable likelyhood for significant structural adjustment in horticulture. Farm incomes are low [72], farm size probably too small, and amalgamation and other changes may be imminent. Under those circumstances it does not make sense to encourage expensive solutions to fix the water quality problem, especially if there are cheaper alternatives not yet fully explored.

The implementation of better systems to reduce escape loss is worthwhile to build infrastructure capacity in this respect for when it is most needed, the wetter periods. At other times the option should not be pursued too hard else the diluting effect of escape drainage on water quality will be missed.

The reduction of tile drainage effluent from gazetted horticulture is also a key towards any possible achievements of lower salinity for the Wah Wah irrigators, which has been their expressed aim (see section 9.2).

Mixed Farming

Aspects of recycling drainage on-farm have already been discussed at section 9.3.5, This also applies for the rice hydraulic loading reduction option. Rice area reductions are costly to farmers income unless he has alternative, equally profitable crops to resort to. This is not the case in those areas of the MIA where a proportion of the farm landscape is already affected by low level salinity. For this reason the proposed method of implementation is by targeting those fields/areas that seem to be causing a problem, see section 9.3.5. Implementation would be feasible by applying sufficent resources, eg one extra rice field officer for a ten year period.

The conversion of some large area farm land to horticulture (M00) is not really a LWMP option, but something that would happen under the No Plan scenario anyway. The environmental consequences have to be accounted for. The adoption by about

50 (20 hectare size) farms over a 30 year time frame is believed to be realistic and probably an under-estimate. The option is listed under the BMP's in section 9.3.1.

The use of irrigated woodlots is not considered economic by NSW Agriculture however is recommended because there are potential environmental benefits not considered in the economic analysis. The small areas totalling 2-5 hectares on each farm may absorb some of the unwanted drainage, provide shelter and a windbreak. A subsidy is probably required to achieve the adoption rate recommended.

The application of measures to reduce escape loss should be integrated between the horticultural channel systems and the large area channel system. The optimisation model suggested that not all potential savings are necessary, hence the main emphasis should be on those locations where the benefits are greatest, and not worry too much about the smaller savings (initially). The model recognised the value of escape water as a diluting factor.

The option to allow farmers to pump drainage from district drains was not selected by the optimisation model to maximise drainage volumes from the MIA. The reason is unclear, but probably related to the fact that there were sufficient other options to reduce drainage to the required target. The escape reduction option for instance gives better economic returns (Table A3-2). Nevertheless, for the recommended plan this option is very useful and has no negative effects as far as the dilution concept is concerned. It is probable that some incentives need to be given for farmers to construct works, whilst variable incentives between wet and dry years could be applied to get the most pumping from drains when it is most needed.

The southern part of the MIA has more accessions to groundwater but also enjoys deeper watertable levels than in the northern parts, and less salinity. To maintain this favourable environment, and to extent it as far as possible in a northerly direction, the rice water use target policy should be implemented fairly strictly. The other option, deep bore pumping to increase leakage is identified in the options package, but not recommended for implementation until the need to confirmed by performance monitoring. This is shown at Table 9.8 by the application of a minus adjustment to the outcome from the optimisation model. Actually, this option became introduced when stepping from scenario 7 to scenario 8, which improved the economics of the package of economic options, but at the expense of a deterioration in salinity at Willow Dam. Deep Bore effluent (at about 600 EC) has a higher salinity than the irrigation supply and 10% of the pumped water could be epected to end up in the drain.

Vegetable Farms

There are no specific issues with respect to the vegetable farms not already discussed at section 9.3.6. The adoption rates for sub-surface drainage solutions in Table 9.9 could be considered a little arbitrary, but since the implementation is entirely the responsibility of the landholder this is not highly important.

9.7 Special Areas

Lake Wyangan

In the Lake Wyangan area relatively more attention needs to be given to some factors. These would include :

- reduction of seepage from channels. This would be covered by a capital refurbishment programme rather an LWMP program.
- reduction in tile drainage to Lake Wyangan and nearby small depressions
- reduction in farm runoff as every Ml of runoff may potentially cost a lot in extra pumping costs.
- reduction in escape drainage from about 3-4 escapes for the same reason.
- incentives to encourage adoption of the above measures

None of these factors have been clearly quantified therefore a performance monitoring program accompanying these solutions would be an important part of the program. Costs estimates of a complete package and economic evaluation is not available. The development of such a program with items, costs and benefits therefore is a first step. Reductions in salt loads from farms would result in reduced salt loads to Lake Wyangan proper and therefore less salt discharge to the Main Drain J system and Barren Box Swamp.

Warburn Area

This area is already receiving attention with respect to the development of horticulture replacing rice areas, the best management options for the wetlands areas and the blue metal quarrie, which is subject to a Development Application and environmental review. Between these issues an appropriate management strategy for the area may emerge. The other general issues are not dissimilar to the rest of the MIA except that the drainage is kept within the area and not passed on to a downstream area.

10. DOWNSTREAM SOLUTIONS

10.1. Objectives Revisited

From the analysis of upstream options it was concluded that drainage volumes from the MIA can be reduced by about 15%, or about 19,000 Ml at Willow Dam without incurring an increased economic cost. It is probable that there even is a small benefit from such actions being taken. This reduction can be achieved without penalty in terms of water quality, which can also be improved, or salinity at Willow Dam, which, from the analysis carried out, may not change much. Improvements in salinity at Willow Dam will come at a cost and can only be contemplated after a follow up feasibility study. There are on-going concerns with regard to salinity management, for instance the effluent from extended horticulture in emergency situations. Seasonal aspects of salinity also need to be considered.

Section 10 focusses on the downstream solution scenarios. It is necessary to contemplate all the requirements and the range of solutions which are technically and environmentally feasible. That part of the downstream solution which is essential for the combined upstream and downstream solutions to be successful should be recognised at this stage so that commencement of negotiations regarding the MIA plan and implementation of the upstream options can commence. There should be no problem if the final downstream solution scenario based on the Northern Hay Plain study is a little bit different due variations in the available extra irrigation options. If economic, in fact these would be useful add-ons to reduce the cost of infrastructure downstream to the beneficiaries upstream.

Section 2 discusses the objectives of the upstream and downstream parts of the MIA LWMPlan. Drainage from the MIA is to be managed sustainably, and within the bounds of meeting environmental constraints posed by the river systems and the Lower Mirrool Creek environments. The constraints for water quality are that pesticides should be below EPA guidelines, and nutrients and salinity low enough to not be of concern. If water from Barren Box Swamp is involved the Alligator weed invasion needs to be controlled and eventually declared eradicated. The constraints for the Lower Mirrool Creek are flooding should not exceed the frequency based on environmental criteria (say 1:5 year), and that landholders needs in this respect are also satisfied.

Because of these constraints the irrigation option downstream tends to get a lot of focus. Dependent on the economics of this option the solution scenarios could swing from a minimum irigation solution to solutions whereby a large additional irrigation infrastructure could be justified.

This wide range of possibilities has tended to be confusing as far as the development of terms of references for downstream studies is concerned. However, the finding of section 9.2 that the combined options to reduce drainage in the MIA by up to 15% are economic solutions reduces the viability of irrigation options downstream considerably. To compete in optimisation the profits of the downstream irrigation solution would have to be sufficient to pay for both the additional infrastructure over and above the minimum (but adequate) solution scenario, as well as the cost upstream of not carrying out the drainage savings. From preliminary work based on

Mactier [24K] it is concluded that this is highly unlikely. The conclusion therefore is that the irrigation option can only be excercised to the extent of the needed solution for the downstream options package to meet the objective and the constraints, and not more. This conclusion precludes the development of large irrigation schemes downstream unless they are viable in their own right, without subsidisation.

Chapter 7 discusses targets for drainage reduction consistent with water quality objectives. Section 7.1 mentions that following initial targets being met the focus could shift towards further improvements during the life of the plan. The results of Chapter 9 do not preclude further savings of drainage in the MIA following a successful implementation of the plan over say the first ten years.

10.2. Flood Control Works

The first element to be considered is that there will be floods of frequency once in ten years or less frequent that will cause problems at Barren Box Swamp and in the Lower Mirrool Creek. The aspect of a spillway at Barren Box Swamp has been investigated. The conclusion was that such a structure is not justified. The structural improvements along the Lower Mirrool Creek to manage these floods have also been considered. [3] [5]. No plan for implementation is available at this stage.

10.3. Management of Volumes in Dry and Wet Years

Apart from floods there is a history of releases from Barren Box Swamp which relate to normal drainage from the MIA. This drainage is worst in wet years and years with a lot of rainfall rejections in the MIA system. Even after implementation of drainage reduction strategies in the MIA this problem will continue, albeit at a much lower frequency.

The conclusions of this report show the following

1. Drainage from the MIA can be reduced by about 15%, reducing the frequency and duration of floodway use and costs to Lower Mirrool Creek landholders without impairing the security of supply to Wah Wah irrigators.

2. If implementation is successful the volumes available for extra irrigation will be smaller and also be less frequent. As a result this option probably will become less attractive than at present.

3. There will still be a frequency of about once every three to four years that there will be an excess of drainage over demand.

The second and third point are complementary in some ways. The irrigation opportunities exist but can not overcome the drainage excess in wet years. A basic quantity always occurs.

Another factor is the Benerembah Stage 4 implementation. It is agreed that these works should be implemented, however drainage volumes between wet and dry years are very difficult to manage if it is discharged to the Barren Box Outfall Drain and the Wah Wah District.

The Wah Wah supply system has several escapes but none of these is being used without causing flooding of a depression (Berangerine Swamp) or a natural (dry) water course (Wah Wah Creek). The undesirable escape diversions are greatest when weather conditions change unexpectedly.

Some means of disposing unwanted drainage flows without environmental impact is highly desirable.

10.4. Management of Drainage Water Salinity

The water quality to Wah Wah is affected by several factors, each requiring attention, but salinity is probably the main factor of concern. Even though salinity is not expected to increase, the salinity to the southern part of Wah Wah is claimed to cause a problem. Whilst this has not conclusively been demonstrated by Hassall [12], and there is very good evidence that too low a salinity also has a negative effect on crop growth on sodic soils, it seems desirable to reduce the salt loads to Wah Wah if possible. The Wah Wah LWMP committee desires to achieve a 400 EC salinity in the supply to Wah Wah, however section 9.2 shows that such a large reduction is unlikely to be technically and economically feasible.

The main options to improve salinity downstream relate to the MIA LWMP, and by diverting the more saline winter flows away from Barren Box Swamp.

The winter diversion option was discussed by KinHill [23], who dismissed it in situation where a channel to the river is a possibility. However, at present this is not the preferred solution scenario.

The improvements in salt loads from horticulture will mostly be related to irrigation accessions, and rainfall induced tile drainage may not change much. This means that the winter tile drainage salt loads will not show much improvement, except for the long term decline in groundwater salinity under horticultural farms. The urgency to do something about winter drainage continues to exist even with implementation of the MIA plan.

Agroforestry has been promoted as an option to manage moderately saline winter flows in Mirrool Creek. The risk of salts building up in the soil of possible agroforestry plots has been investigated by Tiwari [54]. He concluded that the risk of this is small where salinity of up to 2.0 dS/m is used once a year. In fact the saline water will allow more infiltration where the soil sodicity is very high, a feature of the non-selfmulching clay plains of Wah Wah S&D district. Where the leaching achieved is close to zero only, the lifespan of plantations may be limited to about 20 years in a worst case scenario.

A minimum of 6,000 Ml/year of the more saline winter flow component is available every year. but in some years volumes of 25,000 Ml (median) and more of lesser salinity could be available.

The option of tree plantations will only be useful if the economics are reasonably sound in the long run. Joint venturing arrangements etc are being considered and discussed at present. The feasibilty wil be investigated as part of the Norther Hay Plains study.

If export of salts from the Lake Wyangan basin by pumping during winter is to be continued the agroforestry option becomes even more urgent for at least that proportion of the winter flows.

Other options of managing salinity during winter include the use of the Lower Mirrool Creek (an undesirable No Plan type solution), and diversions to the river via a channel. Section 10.8 describes the possible scenarios.

10.5. Barren Box Swamp Management

To minimise the frequency and duration of downstream releases to the floodway the management of Barren Box Swamp needs to be optimised also. The main issue is that there are (many) periods of excess drainage eventually followed by (less frequent) periods of a shortage. Barren Box Swamp is meant to be a buffer between these periods but in practice this potential may not have been very effectively used because of the limited operating range.

One way of increasing the range of operation would be a pump station on BBS which will pump into the Wah Wah Main. With a pump of say 150 Ml/day the range of operation could be increased with confidence from about 25,000 Ml (65,000-40,000) to 45,000 Ml (65,000-20,000), which is an 80% increase. A pump station similar to Benerembah Stage 1 would cost about $500,000. An electricity supply is available nearby on the south side of the swamp (Murrumbidgee Electricity). With a very low swamp the combined supply of Mirrool Creek, the extra 150 Ml/day from the pump, and the MIA system overflow potential should be sufficient to satisfy Wah Wah demand.

Pumping of volumes from Barren Box Swamp into the Wah Wah Main would have additional benefits in that more of the water from Mirrool Creek may be directed through the swamp, instead of directly into the Wah Wah Main. This will cause a higher degree of dilution of the swamp water and a more equal sharing of the salt loads in the system between the southern part of Wah Wah and the northern part. The end result would be that the water quality standard to southern Wah Wah would improve, at the expense of a small deterioration in the northern part.

10.6. Irrigation Options

The section on objectives commented that the first aim of the MIA plan downstream of Barren Box Swamp really is to solve the drainage problem generated in the MIA in an environmentally friendly way. The beneficiaries of this are Murrumbidgee Irrigation landholders and the wider community. If this objective can be achieved by incorporating the irrigation option, then this third party may benefit as well. The extent by which it benefits is a measure for the proportion of costs downstream it may be able to contribute to the minimum solutions scenario. If extra works are planned over and above the minimum solutions scenario then the additional costs could be 100% the responsibility of the irrigation solution beneficiaries.

The KinHill study was complemented by an irrigation potential survey of lands in the Wah Wah District, which found there is a lot of potential to use extra water if available. Surveys indicate landholders are interested but not in a position to make large contributions towards channel systems, or even to purchase the water that would make their intended enterprise more secure than the situation where they would have to rely on “off-allocation” only. The latter was (and is) in fact one of the main stumbling blocks during discussions on these options.

The MIA plan needs to answer a number of questions before it can be negotiated and implemented :

Q1 : How much excess drainage will really still occur in wet and dry years after implementation of the reductions in the MIA ?

Q2 : What is the minimum solution in Wah Wah to manage excess drainage from the MIA ? How much does it cost ?

The minimum solution of Q2 probably includes agroforestry, use of the existing S&D channel system to maximise irrigation without providing water entitlements, and the dumping of remaining water into the Lower Mirrool Creek (top end). The economic costs include the cost of agroforestry subsidisation and on-going costs to landholders along the floodway if the frequency of flooding is more than acceptable. The current position of landholders along the Lower Mirrool Creek seems to be that short duration flooding at a once every 3-4 years is acceptable especially if it occurs during autumn. This is not inconsistent with the environmental requirement (about 1:5 years).

If the hydrological studies show that on bais of the minimum solution scenario this frequency cannot be achieved, then the irrigation option must be adopted on a larger scale to use more or most of the excess drainage. This then leads to the following questions :

Q3 : How much extra water needs to be used by irrigation to achieve the flooding frequency constraint ?

Q4 : What infrastructure enhancement is needed to achieve this ?

Q5 : Do landholders have to be provided with water entitlements as an inducement in addition to the infrastructure being provided ?

Q6 : What are the costs and the benefits ?

The process assumes that the solutions being sought are for the benefit of the MIA farmers and the wider community. However at questions 4 and 5 the irigation option comes in and it is reasonable to assume that these third party beneficiaries should contribute to a reasonable extent. For instance it may be reasonable that landholders buy their own water entitlements if they want more security of supply. Murrumbidgee Irrigation could guarantee supply of these entitlements up to a certain volume based on the 0.75% of capacity rule.

If the local landholders desire a larger channel still, then this could be considered if the local group indicates and is willing to contribute the extra cost.

Some tradeoff for easements to flood could be offered and incorporated to those landholders affected by Lower Mirrool Creek flooding in the future.

If for the minimum solutions scenario to solve the MIA drainage problems a channel upgrading is necessary and there is a choice between two routes, it is obvious that the route with the most potential for increased irrigation should be followed.

One drawback of the irrigation option versus the agro-forestry option is that the demand for water will always be less in wet periods with the irrigation options, whilst with the agroforestry option there is more scope to give more water to the trees in wet periods, and less in drier periods (the latter with some penalty for growth rate).

The discussion of this section precluded the use of the channel to the river option. More discussion on that aspect is at section 10.8.

10.7. Multicell Swamp

The Multicell swamp concept and the pipelining of the Wah Wah S&D supply options really are means of freeing up water which could then be sold to those willing to buy. The economics of these extra options should stand or fall on their own merits. Another benefit of the Multicell Swamp is in terms of a reduced evaporation concentration of salts. This is estimated to be about 80 uS/cm per year for the whole swamp, so the saving may be about 40 uS/cm in a dry year if half the swamp is empty (valued at about $100K/year).

10.8. Scenarios For Managing Regular Drainage

Four scenarios exist with respect of managing the regular drainage excess below Barren Box Swamp.

<u>1. No Action Scenario.</u>

This means the leaving of things as they are. There would be on-going costs to Lower Mirrool Creek landholders. These costs may be estimated from the expected future flooding regimes. Where the landholders utilise the flood waters the net costs would be reduced for that factor.

According to the KinHill report [20] the costs of flooding to landholders currently amounts to $470K/year. Capitalised at 7% this adds up to $6.7 million. If it was decided to negotiate easements to flood the consideration should be based on the actual frequency and duration of occurrence rather than a nominal estimated value, because the former alternative provides a stronger incentive for Murrumbidgee Irrigation to improve the upstream drainage management.

If MIA drainage is reduced by 15% the $470K cost value would be reduced considerable, probably to less than $150-200K/year on average.

Notes: # This scenario does not provide a satisfactory solution for environmental issues along Lower Mirrool Creek.
The downstream community including potential new irrigation customers may not be satisfied

<u>2. Minimum Solution Scenario</u>

This scenario includes :

- Agroforestry to manage moderately saline winter flows (about 2,000 ha)
- Irrigation option using existing channel system
- Some on-going flooding costs to Lower Mirrool Creek landholders

The approximate costs would be :

Channel to agroforestry areas - bypass prior stream section	$ 1.0 m
Agroforestry development - 2000 ha at $2K/ha	$ 4.0 m
Costs to landholders for continuing minor flooding ($125/yr)	<u>$ 1.8 m</u>
Total (capitalised)	$ 6.8 m

These costs do not include the cost of land to grow agroforestry and maintenance and water costs. However there are benefits that are expected to offset these components.

Benefits include :

- Some irrigation achieved (up to 10,000 Ml of extra allocations can be supplied through the existing S&D channel system using 0.75% formula).
- Significant excess drainage and about 6,000 Ml of winter drainage absorbed by the agroforestry
- Lower Mirrool Creek environment protected much better than for No Action Scenario
- Agroforestry products.

Each Megalitre of drainage prevented of going to the Lower Mirrool Creek environment may be valued at about $15/Ml.

Problems :

- There is uncertainty regarding the adequacy of salt management by means of agroforestry
- The environment may still not be fully protected (flooding still 1 in 3-4 years ?)
- Complicated deals to get the agroforestry going unless subsidised.
- community may not be fully satisfied.
- Benerembah Stage 4 drainage and Wah Wah escape drainage still not under control.

3. Enhanced Irrigation Solution

This is equal to scenario 2 but with a 200 Ml/day channel to facilitate the irrigation option and to distribute Barren Box Swamp releases to various points along the Lower Mirrool Creek.

The approximate costs would be :

Channel along 1/8 route ($2.5m) or 2/8 route ($5.4m)	$ 5.4 m
Agroforestry development 2000 ha at $2K/ha	$ 4.0 m
Costs to landholders for remaining flooding costs ($100K/yr)	$ 1.4 m
Total (capitalised)	$ 10.8 m

Benefits :

- More drainage absorbed by irrigation than for scenario 2. About 25,000 Ml of allocations can be accomodated for regular supply.
- Lower Mirrool Creek environment protected better. Flooding less than 1 in 5 years is likely to be achieved.
- Agroforestry products
- Maximised irrigation considering volumes available.

Problems :

- Still uncertainty regarding salt management
- Complicated deals regarding agroforestry unless subsidised (as for 2)
- Source of allocation to be purchased by landholders.
- Wah Wah escape drainage management and Benerembah Stage 4 drainage variations still not under control.

Notes : # The Multicell Swamp option would free up 10-20 Gl/year of water in dry years but is not likely to be an economic solution to the allocation issue.
The pipeline option for S&D channels will free up water every year including wet years when the saving is not needed. It is also unlikely to be economic.
As far as the allocation issue is concerned, it should be possible to negotiate the sale of saved water upstream in the MIA to the landholders concerned, especially since an environmental benefit for this action may be demonstrated.

4. Channel to River.

A channel to the river may be inevitable from the following perspectives :

1. the agroforestry option may be sufficient to divert a large enough proportion of the moderately saline winter flows, particularly in wetter years.
2. the management of Benerembah Stage 4 drainage during the irrigation season and especially during the off season.
3. The management of higher levels in Barren Box Swamp when the diversion of regular drainage excess to the Lower Mirrool Creek is undesirable.

The greatest fears of the downstream community seems to relate to water quality, weed invasion and the probability that once a channel is available the agency responsible will no longer have an incentive to lift the game of drainage management. The Lowbidgee and Red Bank Weir landholders are concerned that increased concentrations of salt in the river would affect their irrigation practices and the health of Red Gum forests.

For the first of the above reasons a 100 Ml/day capacity would be sufficient. For the second reason a 50 Ml/day channel would be sufficient. For the third reason to build a channel a 200 Ml/day size would be a minimum. The KinHill study assessed that a 200 Ml/day size actually would achieve a reduction in floodway use to less than once every about 6 years, and this is for the assumption that there is no drainage reduction in the MIA.

Costs of a 200 Ml/day channel, commencing at Barren Box Swamp:

1.	Channel 600 Ml/day was $5.5m without the 100 Ml/day extension to Western Wah Wah. A 200 Ml/day channel is about 70% in costs	$ 3.8 m
2.	Remaining costs to LMC landholders ($75K/yr)	$ 1.0 m
3.	EC credit costs (10000 Ml/year winter flow at 1000 mg/l increase at $30/tonne. This is about 3 uS/cm at Morgan or	$ 3.0 m
	Total (capitalised)	$ 7.8 m

Note : The cost of the channel from Wah Wah S&D channel 2 to the river would be much less than $3.8m. No cost estimate is available but based on distance it wold be about $1.0 million.

Benefits.

- The uncertainty regarding agroforestry is removed. Actually, implementation is no longer essential (but still desirable to reduce use of the channel.
- winter disposal of moderately saline drainage is secure, particularly the aspect of high variability between dry and wetter years.

- Irrigation potential in Western Wah Wah still exists and can be exploited, but subsidised water allocations do definitely not have to be provided.
- The impact in the Lower Mirrool Creek environment is least of all four scenarios.

Problems.

- Cost EC units, however the NSW government may already have paid for these
- Water quality from the MIA presently is not yet under control. The lowest pesticide concentrations are during late autumn and winter.
- Alligator weed can not yet be considered eradicated.
- Impacts to Lowbidgee and Red bank weir areas have not been re-assessed.

10.9. Recommended Package

From the above discussion a minimum desirable package can now be formulated and included in the MIA plan. The implementation would occur in stages, the commencement of some of which is dependent on certain conditions being met. The recommended package consists of :

1. Implementation of the agroforestry option by planting 200 hectares per year.
2. A pump station on Barren Box Swamp with a capacity to lift 150 Ml/day into the Wah Wah Main.
3. Upgrading of the channel 2 system to a 200 Ml/day capacity, linking it to channel 8, reducing to a smaller size downstream of this junction, and no upgrading downstream of the Cobb Highway.
4. Negotiating and preparing agreement on future flooding loss occurrence in the Lower Mirrool Creek area with the landholders concerned on a cost per hectare per occurrence basis, with reductions for any benefits derived.
5. Permission to landholders along upgraded and existing S&D channels to purchase water entitlements if they wish, up to the capacity of the channel system to deliver.
6. Encouragement of use of off-allocation flows from Barren Box Swamp by practical pricing mechanisms, dependent on supply and demand changes over time.
7. Building of a 200 Ml/day channel to the Murrumbidgee River from the Channel 2 system. This includes a takeoff structure at Channel 2 and provisions to control any backflooding from the river if necessary.

Item 1 may be implemented in a number of ways. The preferred solution at present seems to include the purchase of a farm or land. Alternatively, landholders may be subsidised for establishing the plantings and provided with a volume of off allocation water up to three times a year, one time of which has to be during winter.

Item 7 may only be implemented after improvements in water quality from the MIA have been achieved. The channel would not be owned by Murrumbidgee Irrigation but by a trust including DLWC and EPA, who would be the only authority entrusted to make decisions regarding its use in specific seasons or conditions.

10.10. Evaluation

The costs of the recommended package would add up to about 14.4 million including $4.0m for agroforestry, $6.4m for upgrading channels, $1.0 million (capitalised) for continuing compensation, $0.5 million for a pump station on Barren Box Swamp, and $3.0m for EC credits. The benefits have to be judged in terms of :

- Elimination of the agricultural costs in Lower Mirrool Creek, capitalised at a maximum of $6.7 m if there were to be no drainage reduction from the MIA
- Reduction in environmental costs in Lower Mirrool Creek (wetlands health and groundwater accessions).
- Irrigation opportunities for landholders in Western Wah Wah.
- More appropriate management of salinity from the MIA. Increased opportunities to Wah Wah growers to grow higher value crops.

This discussion does not complete the evaluation of the downstream options. Many of the values provided here are insufficiently accurate to make final decisions. However from the discussion a clear conclusion emerges in that a significant injection of capital funds is needed to overcome the shortcomings of the MIA drainage system. This capital can not be expected to be generated by new irrigation opportunities. The benefits extend to the wider community and the upstream MIA irrigation community.

11. ENVIRONMENTAL BENEFITS OF RECOMMENDED PACKAGE

11.1 Soil Salinity Improvements

Soil salinity improvements are not targeted for the gazetted and extended horticultural areas, it is assumed this factor will be taken care of by systems already in place. However another 5% of gazetted horticulture may be tile drained, and this will create an inevitable salt load to the drainage system to the order of 10 EC units (1000 t/year from 500 hectares). In extended horticulture soil salinity will be controlled, but effluent will have to be kept on farm, except in emergencies. In vegetable areas soil salinity may be a problem requiring attention and this may be achieved by a combination of subsurface drainage solutions and disposal to on-farm evaporation or reuse (section 4.4).

Mixed farming is receiving a major focus in the optimisation. Section 5.1 shows how an average future salinity outlook from 28% to 20% can be achieved by a 25 Gl/year reduction in accessions, which would have to be spread evenly across the MIA. This means that options such as the deep bore option (M30) and rice target water use implementation (M08) should be excluded because these options tend to be effective to the south of the MIA only.

The optimisation model, after the adjustments of section 9.3 calculates that the reduction in accessions is 15,800 Ml/year, plus another about 5,500 Ml/year in the southern part for option M08. The shortfall in the northern part is about 4,000 Ml/year. This has to be accepted since none of the options that could further improve the situation are economic.

Land salinity with the identified options would still increase to an average of about 22% of the irrigated landscape affected overall and significantly higher in the northern parts (section 5.1).

For large area farms the situation in terms of accessions may be summarised as shown in Table 11.1.

Table 11.1 : Reduxtion in accessions to groundwater due to adoption of LWMP

Accessions to Watertable	Now	No Plan	With Plan	Change
Channel Seepage	12,000	11,230	10,040	1,960
Mixed Farming Areas	96,000	91770	76,660	19,340
Total Megalitres	108,000	103,000	86,700	21,300

Considering the only small agricultural loss suffered as a result of salinity this outcome is considered satisfactory.

11.2 Drainage Volumes Saved

The evaluation process resulted in Table 11.2, which shows the drainage reduction outcomes compared to the targets.

Table 11.2. Drainage volumes saved by options package compared to target

Factor	**Achieved**	**Target**
Escapes	12,100	11,000
Farm Runoff (*1)	29,100	11,000
Tile Drainage	1,700	3,000
Reuse Pumping	7,500	12,000
Total (*1)	50,400	37,000

This table requires some qualifications:

- The near 10,000 Ml/year reduction in escapes includes measures to reduce these flows (H16, H19, M23, M25), but also an increase in escape volumes where improved on-farm efficency (H03, H04) results in a loss in channel efficiency.

- It is estimated that substantially in excess of 10,600 Ml/year of drainage reduction could be achieved by increasing the amount of performance monitoring (SCADA systems) or the better forecasting of demand method. This is only desirable at times that there is a problem with excess drainage.

- The large reduction in large area farm runoff is due to the expected implementation of a significant number (about 200) of recycling systems over the next 10 years. However, a significant proportion of these systems (50-60) will be located in catchments draining to the river from the Yanco area.

- During implementation the reduction in escape reduction and reuse pumping has to be kept below the potential reduction, else the salinity of Mirrool Creek at Willow Dam will increase, because the requirement that tile drainage reductions as a proportion of total reductions will not be met.

- The tile drainage reduction (1,700Ml=15%) is achieved without by going to the maximum achievable with BMP's in horticulture.

The increasing of the recycling option to more than 200 systems becomes feasible after say about 10 years, when it may have been demonstrated that tile drainage reductions to over 15% can be achieved. Under that scenario however the deliberate escaping of water from the MIA system to supply the Wah Wah demand will become a more frequent operation. There may be not significant problems in that operation if the volumes saved on-farm result in freeing up capacity in the MIA supply system.

It is useful to increase the capacity to reuse MIA drainage within the MIA to the tune of 12,000 Ml/yr or more, firstly by encouraging farmers to pump from drains and secondly, by constructing district pumps to transfer water from drains to supplies upstream of Willow Dam. However this potential would not always be used in drier years. For design purposes the water quality needs of end users should always be considered. The average savings actually achieved for these two factors therefore may be less by half compared to what is shown at Table 11.2.

Table 11.3 summarises the overall outcome.

Drainage Volumes in the MIA	Now	No Plan	With Plan	Change
Escape volumes	115,000	111,800	102,900	12,100
Farm Runoff	120,000	116,300	90,900	29,100
Tile Drainage	11,000	10,450	9,300	1,700
Total Megalitres (*1)	251,000	243,300	215,000	36,000 (*2)

(*1) The total MIA drainage is not the same as the sum of the three items.
(*2) : Average year. however the actual capacity to reduce drainage may be increased to 50.4 Gl/yr

In conclusion, the recommended package achieves its targets for the MIA LWMP with a safety margin for some options not being implemented fully.

11.3. Water Quality Improvement

The improvements are expressed as a percentage improvement on the scale of the current problem. Section 7.7 suggests that a 60% improvement at least is needed.

The evaluation is basically qualitative, however the model calculates that if all recommended options are implemented the improvement for horticulture would be 44% and for large area farms 80%.

For large area farms this would be satisfactory as an interim target for the MIA LWMP. The results should be achieved within 10 years. Perfomance monitoring will be important to decide whether this result is being achieved.

For horticultural farms the target is not being reached because the options which could be beneficial are not economic and/or acceptable by the community. However it is possible that the combined contingency monitoring effort and BMP implementation will achieve a better result than indicated by the optimisation process.

Contingency monitoring and biomonitoring will show whether these targets are being achieved for the MIA. If not, alternatives such as the adoption of more widespread recycling may be inevitable.

11.4. Drainage Water Salinity

The aim of the MIA LWMP is to maintain drainage water salinity at Willow Dam at current levels, and preferably, to improve it. It was recognised that the contrbutions in salt loads from mixed farms may increase, whilst a reduction may be possible from horticultural farms. The model calculations show the following:

reductions from gazetted horticulture	25 units
increases from gazetted horticulture	10 units
increases from mixed farming	7 units
Total Improvement	8 units

The increase from gazetted horticulture is due to extra subsurface drainage that will be installed without restrictions in about 5% of the land.

The 25 units improvement includes a negative small allowance for extended horticulture when evaporation ponds are are allowed to be bypassed in an emergency situation (E08) for a brief period, supported by dilution flows which would have to be made available.

The 8 units deterioration in salinity from mixed farming relate mainly to vegetable growers who may adopt similar option and bypass their evaporation ponds in similar emergencies. Another factor included is an allowance for salt loads fom farms with mole drainage and partial recycling only.

The runoff salinity from large area farms depends on the final assessed land salinity as per the recommended plan. Since the land salinity in 30 years will not be 28% of the landscape but only some 22% it is expected that there will be a further improvement of some 10 EC units compared to the No Plan scenario, which costs about 30 EC units (see section 7.5, item 3).

This only small improvement does not meet the long term aim of the Wah Wah community, who plan for a reduction of salinity to 400 EC. Chapter 9.2 showed that the maximum reduction achievable is about 250 EE at Willow Dam, however the evaluation of the optimisation model shows that comes at horrendous costs. If a smaller reduction of 100 EC was aimed for the costs would be much less, about \$0.9m/year in the upstream part of the MIA. A feasibility study is being proposed to firm up the values and to assess the benefits that could offset the costs.

If substantial volumes of drainage much in excess of the target in this report are achieved then the risk that salinity at Willow Dam will increase rather than decrease is real. This feature has already occurred in Coleambally where the planned for reduction in drainage was only about 20%, but in fact a 80% reduction occurred during 1995, and salinity in the Coleamblly Outfall Drain increased to 700 EC. Volumes saved by various measures for a significant proportion may need to be kept in reserve for these dilution flows. In the end the problem with excess drainage may be less important than the problem with too high salinity.

11.5. Downstream Excess Drainage Volumes

Section 6.3 discussed target drainage reductions at Willlow Dam. Table 11.4 shows how these targets have been achieved with the recommended package of options.

Table 11.4. Achievements versus targets for overall MIA drainage reduction

Factor	Achieved (*1)	Target
MIA Drainage Reduction	41.0 (*2)	24-36
% Reduction atWillow Dam	17	10-15
Willow Dam Flow reduction	21	14-19
% Use Floodway Remaining	64%	64%

(*1) Gl per average year
(*2) The 50.4 GL of Table 11.2 adjusted downwards for by half for escape flows and farmers reuse systems.

These results are satisfactory. As discussed at secton 7.3 there is litle gain in achieving more than the above targets because that would result in a reduction in Wah Wah security of supply without reducing the percentage use of the floodway (freqency and duration) much further. After all, in excess of 80% of drainage flows arriving at Wilow Dam in an average year is already being reused, even in the No Plan scenario.

The mean annual Wah Wah shortages would increase from 3.55 Gl/yr to aabout 6.5 Gl/year if the implementation is as suggested here. This is not a significant increase. Extra diversions from the river would increase from 7.55 Gl/year to about 14.6 Gl/year (Table 7.1). This extra water would be conveyed through the Sturt Canal, the Main Canal and through Mirrool Creek from East Mirrool Regulator, probably without great difficulty. Downstream options are discussed at Chapter 12.

11.6. Lower Mirrool Creek Benefits

The large reductions in the frequency of flooding in the Lower Mirrool Creek will reduce the agricultural costs to landholders, but will also have environmental benefits.

As far as the wetlands habitats are concerned, the reversal to a lower frequency of flooding will involve changes in species growing in the environment. The old habitats are unlikely to be recovered, but the occurrence of Cumbungi will be reduced and this may lead to greater diversity. There is no prediction what the actual changes may be.

One of the main environmental benefits will be a reduction in the areas and durations of flooding. This will cause reductions in groundwater accessions. It is likely that the reduction due to the regular flooding factor will be in excess of 80% if the drainage reductions predicted are realised, and the recommended downstream options implemented.

The incidence of water reaching the Lachlan River may not be reduced by a large amount since these occurrences were restricted to the more significant flood events only anyway.

11.7. Other Natural Resource Management Benefits

There will be some emphasis on treating the natural resources of the MIA in a better way. Farmers will be encouraged to protect any remnant vegetation that may be left on their farms. There will be some establishement of Tree Corridors at appropriate locations, which may enhance habitat for birds and other animals. The farm irrigated woodlots, whilst not natural habitat, should also have some value in this respect.

The major wetlands of the MIA (there are six of them) will be examined to decide whether simple management applications can improve these areas from a natural resource point of view. This may include the re-diversion of drainage where possible. It should be remembered however that the MIA is an agricultural production entity and that priorities may not always favour the natural environment first.

Agroforestry options downstream of Barren Box Swamp will generally enrich the environment.

Better pesticide control management techniques could positively affect the balance between desirable and undesirable insect species. Poisoning of non harmful species may diminish. The aquatic ecology of the MIA waterways could improve significantly.

11.8. Environmental Disbenefits

Environmental disbenefits of the proposed combined package for upstream and downstream solutions includes the following :

- Use of on-farm evaporation areas in extended horticulture. This disbenefit is more a threat than actual damage to the environment.

- If a channel to the river becomes a reality it is likely that there will be some impacts in terms of water quality. These impacts will be small if the use of the channel is restricted to last resort management and during specific seasons only (eg May to August).

12. ECONOMICS OF RECOMMENDED PACKAGE

12.1. Methods Used

The optimisation process incorporates economic analyses of the various options to be considered. This was to ensure that differences in the relative economic attractiveness of options was recognised within the optimisation model, and to enable preliminary assessments of the total costs and benefits of the plan to be made.

These analyses are considered to be only indicative. This is because detailed economic analyses were only available for a very small proportion of the 83 upstream options considered within the optimisation process. The economics of several downstream options is still subject to feasibility study. The level of economic analysis conducted wihin the development of the MIA LWMP may eventually need to be enhanced to ensure that the assessments are consistent with Treasury standards.

The economic data utilised within the optimisation model were based on information from various studies and reports relevant to the LWMP. Economic evaluations which had been completed on a per unit basis (eg per farm, or per hectare) were modified so that district outcomes could be estimated when adoption levels were applied. This was achieved by spreading the capital cost over the relevant period of adoption, and phasing the introduction of all other costs and benefits over the same period. The disadvantage of this method is that all costs and benefits for any particular option (other than capital costs) are assumed to remain constant throughout the project period. This analysis also assumes that implementation of all options commences in year 1 of the project period. This may result in the net present value of costs and benefits being over-estimated. This procedure was adopted for all non-BMP options.

In addition to financial costs and benefits, environmental benefits and costs of the options were evaluated. This was undertaken so that the outcomes of the evaluations approximate the true economic implications. The factors considered included the value changes to quantities of groundwater accessions, surface drainage, tile drainage and salt loads. The values attached to these parameters are discussed in section 12.2. Other factors, such as changes in water quality in terms of pesticides and nutrients have not been quantified. These should however, still be considered when comparing the relative and absolute economic attractiveness of the options.

Evaluation of the downstream options have not yet been undertaken because the the Northern Hay Plains study is still in progress. However an estimate of the capital costs of the recommended package may be found at section 10.

There are a range of other items which need to be included in the overall evaluation of the LWMP. These include overheads associated with implementation of the plan, including the cost of performance monitoring, research, plan management, and the costs and benefits of ensuring the rapid uptake of the BMP's.

12.2. Environmental Benefits and Costs

The environmental benefits used may be derived from Table 12.1 below:

Table 12.1. Value of environmental factors

Factor	Value
Value of Water	$ 40/Ml
Value of Drainage flow saved	$ 15/Ml
Value of Accessions saved	$ 60/Ml
Value of Salt Load not discharged	$ 28/tonne

Some comments on these values is provided below.

The economic value of water in the Murrumbidgee Valley is estimated to be $ 40/Ml (NSW Agriculture). This value represents the marginal value product (MPV) of a Megalitre of irrigation water. It is based on the net benefit which can be generated from the use of a unit of water, when released from its present use. The MPV of water deliveries to Mirrool, Yanco and Benerembah was estimated using a regional linear programming model representing agriculture within the MIA. This method assumes that the MPV of water supplied to these areas is greater when it is used within the MIA than it would be if used elsewhere.

The economic value of drainage flow saved relates to the cost of having to discharge water into the Lower Mirrool Creek environment. The Mactier study for KinHill [24K], which is based on a landholder survey, suggests these costs add up to $470K/year. However some benefits to landholders from flooding were also identified. these are estimated to be about $100K/year. The net $370K cost when divided into the average volme released from Barren Box Swamp (24,000 Ml), produces a value of $15/Ml. It needs to be remembered however that this benefit will only apply for the first 24,000 Ml. The optimisation procedure suggests that 36,000 Ml may be saved in an average year. The average benefit gained per Ml runoff saved is therefore about $10. As a simplification this average figure is used within the optimisation model.

Notes :The assessment of this report did not use the value of $40/Ml exactly

- *Escape drainage saved, farm irrigation runoff saved, channel seepage saved and groundwater accessions saved, if achieved consistently over time would represent a volume kept in the system and available for use by potential irrigators. These savings represent a value close to $40/Ml. A value of $35 was used.*

- *The rainfall component in tile drainage saved or rainfall runoff saved can not be reused within the reference area and would only represent a value to the downstream irrigators of the MIA system (unless the water can be recycled back to the river via a channel, which can not be assumed at this stage). This water tends to be a little worse in quality by the time it gets to Willow Dam and it may be argued that in much of the Wah Wah District, or the Western Wah Wah area for that matter, the potential for high value production levels is significantly less. Horticulture and many high value crops may not be feasible. Therefore the value of this type of water must be less. A value of $20/Ml was used.*

- *Of course, with tile drainage the savings to be made relate to the irrigation accessions component, which can be reduced. The optimisation process assumed that there is little scope to reduce the rainfall accessions component of tile drainage. Hence for tile drainage a $35/Ml was used but for farm runoff, which has both an irrigation component and a rainfall component, a value of $27.5 ((35+20)/2) was used.*

- *The economic value for loss in the Lower Mirrool Creek environment was reduced further to account for the distribution between wet and dry years. Even if 24,000 Ml on average is prevented to be discharged there will still be some flooding events and occasional loss is likely.. The $10/Ml economic benefit value was reduced by one sixth to $8.30/Ml.*

The economic value of accessions saved was determined for the assessment of the No Plan scenario and found to be about $60/Ml by NSW Agriculture (pers comm. Phil Pagan). The value actually varies over the lifetime of the project. It is based on the logic applied in PJ Jacobs and Associates (1994), where it is assumed that an increase in accessions of 1 Megalitre imposes a cost that is equivalent to the benefit derived by withdrawing 1 Megalitre by spearpoint pumping. These benefits are based on the agricultural cost of land salinisation predicted within the current trends scenario evaluations (NSW Agriculture 1995) and the assumption that each 1 Ml of groundwater pumped can be expected on average to protect 5 hectares from high watertables.

The economic valuation of salt loads not discharged has two possible sources. Firstly, the Ranking of Options report, appendix 2 [47] derives a value of $30/tonne. This is based on a very basic assessment of production loss in Wah Wah due to increases in supply salinity levels above 350 mg/L. Secondly, the Hassall study [20] carried out a more detailed assessment of losses due to salinity in the Wah Wah District and came up with a value of $28/tonne.

Since one EC unit (1 uS/cm) at Willow Dam represents about 150 tonnes, the value per EC unit change would be about $4500. This value was actually used in the analysis.

Where a savings item includes more than one environmental benefit these were added up together, for instance with tile drainage reductions there is a potential water saving, there is a reduction of flow to the floodway lands, and there is a reduction in the salt load to the Mirrool Creek system. The total saving per Megalitre containing 1.5 tonnes of salt may be $40+$10+1.5x$28 = $92/Ml.

12.3. On-Farm Options

The economics of on-farm options concern the Best Management Practices and the other, modeled, on-farm options. Table A5-1 and Table A5-2 of Appendix 5 provide detail of NPV’s of benefits and costs for the individual options based on the discussion of section 12.1 and 12.2. NPV’s shown therefore are per unit of adoption (eg one farm).

The costs and benefits of Best Management Practices are based on an estimation of the effort and expenses required for implementation, this includes usually some cost for upgrading equipment to do a better job. After adding up the costs for all farms the total costs were determined and these are shown at Table A5-3 of Appedix 5. The summary of this analysis is shown at Table 12.2.

Table 12.2 : Annual Costs and Benefits of BMP's for MIA LWMP package ($K/year)

	Costs	Costs	Costs	Benfits	Benfits	Benfits
	NoPlan	**With Plan**	**Total**	**NoPlan**	**With Plan**	**Total**
Extended Horticulture	214	258	472	375	435	810
Gazetted Horticulture	1392	2511	3903	2378	3975	6353
Mixed Farming	4888	3955	8843	6165	4951	11115
Vegetable Growing	163	182	345	223	253	475
Total	6657	6905	13562	9140	9613	18753

It follows from Table 12.2 that millions of dollars have to be spent in the MIA to achieve the desirable environmental outcomes. The main costs relate to better management to reduce accessions, this includes whole farm planning, landforming and on-farm drainage. The next highest cost relates to pesticide management. This includes the use of better equipment and more time/care. Table 12.2 suggests that the benefits will outweigh the costs. It needs to be noted in this context that the values for the analysis are not based on rigourous examination of all items, and could easily be out by a significant proportion.

It would be the task of NSW Agriculture and extension officers promoting BMP's to more accurately demonstrate the real values in BMP's, including environmental benefits.

The cost of employing extension officers, farm chemical use training and irrigation management courses, etc have not been included in the above estimates.

With respect of the other on-farm options NPV's were calculated as per section 12.1. The details may be found at Table A5-4 whilst Table 12.3 summarises the results.

Table 12.3 : NPV's of On-Farm Options for main land use categories for MIA LWMP package

Land Use Category	Cost No Plan	Cost With Plan	Cost Total	Bfits No Plan	Bfits With Plan	Bfits Total
Gaz+Ext Horticulture	10.0	9.2	19.2	7.9	5.6	13.5
Mixed + Vegetables	4.7	27.9	32.6	5.0	39.6	44.6

Most of the expenditure is in the large areas farms. The biggest ticket items are the economic costs of rice options (NPV $ 6.8m), irrigated woodlots on about 150 farms ($ 9.7 m), recycling systems on about 170 farms ($ 4.8 m) and the conversion of pastures to perennial types ($ 4.1m). The implementation of these items is over 10 or more years.

The cost of the plan would be increased in the future if the tile drainage savings achieved are above current estimates and downstream water salinity is improving sufficiently. In that case many more subsidised recycling systems in large area farms could be implemented.

The rice options will be implemented on a regional level but the costs will be incurred by the landholders, hence inclusion in the on-farm category seems appropriate.

The benefits are substantially in excess of costs but they do include environmental benefits except water quality.

12.4. Regional Upstream Options

The regional options were analysed using the methodology of section 12.1. The detailed NPV's for district totals may be found at Table A5-5. Table 12.4 summarises the results.

Table 12.4. Net Present Values of costs and benefits for Regional Options of MIA LWMP package

Land Use Category	Cost No Plan	Cost With Plan	Cost Total	Bfits No Plan	Bfits With Plan	Bfits Total
Gaz+Ext Horticulture	13.0	1.0	14.0	14.4	1.2	15.6
Mixed + Vegetables	0.7	2.6	3.4	1.5	7.4	8.9
Total	13.7	3.6	17.4	15.9	8.6	24.5

The cost of implementing regional options for the MIA Plan, at $3.6 million, is very low compared to other plans. The main ticket items are the implementation of better systems to manage escape drainage (NPV $1.5 m), and district channel seepage control (NPV cost $0.6m). Building a capacity to pump from drains would cost about $1.0m (NPV).

The cost of some items may be requested later, for instance a feasibility study is planned for a community evaporation area to take effluent from extended horticulture.

Except for the seepage control option none of these options has been subjected to detailed economic analysis. The seepage control option analysis found the option using clay lining not economic, however the optimisation study assumed that only about 12 high seepage sites (with the most benefit) would be treated and not some 44 sites as assumed in the economics report [8]. Under these conditions the economics of this report considers the option economic (just).

The regional options do not include the cost of performance monitoring, estimated to be at least $0.8 million/year, research and more detailed feasibility studies.

12.5. Downstream Management Options

The options to manage MIA drainage downstream were discussed at section 10. The capital cost of the main items in the recommended package are repeated at Table 12.5.

The benefits of the downstream package relate to the Lower Mirrool Creek, which are flooding costs and environmental costs. The discussion of the economics of the upstream options of sections 12.2., 12.3 and 12.4 have already used the agricultural benefits of reducing drainage, this can not be used again. However the environmental benefits to wetlands in Lower Mirrool Creek and reduced groundwater accessions have not been converted to a value, neither has the water quality improvement in MIA drainage.

Table 12.5 : Capital costs of implementing downstream options package (*1)

Capital Item	NPV Implementation Cost
Flood management guidelines	NA
Agroforestry 2000 ha over 10 years	$ 3.74
Pump Station on Barren Box swamp	$ 0.50
Upgrading Channel 2 and onto Channel 8	$ 3.35
Construction of 200 Ml channel to River	$ 0.51
Continuing cost of flooding to LMC Landholders	$ 1.0
EC Credits	$ 3.0
Total Costs	$12.1

(*1) Preliminary. The outcomes of the Northern Hay Plains study may result in a different mix of options and costs

Other benefits of having a more extensive infrastructure downstream would be in terms of easier management, whilst the irrigation option and the agroforestry options will produce benefits of their own.

The combined NPV benefits of the MIA upstream options package as identified above is $ 57.8m whereas costs are $ 38.4m. This gives some flexibility for incurring costs for the needed downstream implementation.

Despite these other benefits there is a large expenditure here that may be difficult to justify. The main argument would be that the MIA drainage system requires to be upgraded to the standard expected for an area with an intensive irrigation industry such as exists.

12.6. Wah Wah LWMP

The Wah Wah LWMP has not yet been completed, hence there are no values for costs and benefits at this stage. Most of the options to be considered for implementation would be on-farm type options such as whole farm planning, landforming and improved on-farm management. It is also likely that the criteria for managing rice land suitability will be revisited. Recycling systems with storage options are likely to become highly desirable on all of the about 70 irrigation farms, to prevent drainage escaping to wetlands and the Wah wah Creek. There may be some sites where channel seepage should be treated but the small rates of seepage occurring in many places would not be economic to treat.

It would not be difficult to make some preliminary cost estimates of these needs. The financial benefits would be not unlike those in the MIA although the value of water saved for some options may be less. On the other hand, the environmental benefits may well be greater.

12.7. No Plan versus With Plan Scenarios

The economics outcomes discussed at sections 12.3 and 12.4 were carried out on the adoption rate for the LWMP for the No Plan and the With Plan scenarios separately. The number of units or farms expected to adopt any option and the additional number expected to adopt the option may be found at Tables A4-1 and A4-2. It is found that for most of the options discussed at sections 12.3 and 12.4 most of the adoption will only occur if there is an LWMP.

The cost to landholders for implementing the No Plan scenario has been included and it is shown this will involve a quite substantial investment for better farm management. The soundness of the investment has not be judged, but a guide may be found at Table A5-4 and A5-5. There are important environmental benefits flowing from the No Plan scenario. Section 9.2 discusses these benefits.

For the Coleambally LWMP the savings in accessions on mixed farms was entered in the Soil Salinity Assessment model and subsequently into the NSW Agricultural model to assess the impact on farm production overall. This has not yet been done for the MIA plan. Considering the relatively small benefits that may be gained this excercise may not be worthwhile. However, from a cursory examination it is concluded that about 60% of the likely increase in salinity (from 18 to 28% of landscape affected) will be prevented in the plan is successful. A quick analysis could use this outcome on the salinity cost assessment for the No Plan scenario over the 30 year period.

12.8. Economic Benefits and Cost of MIA plan

Table 12.6 shows the overall assessed preliminary economics of the MIA LWMP package, as defined by the process of this report.

Table 12.6. Overall Benefits and Cost upstream of Barren Box Swamp (NPV $m)

Options Package	NPV Costs	NPV Benefits
Best Management Practices (*1)	$ 85.7	$119.3
Other On-Farm Options	$ 27.9	$ 39.6
Regional Options	$ 3.6	$ 8.6 (*3)
Downstream Options	$12.5 (*2)	N/A
Wah Wah Plan	N/A	N/A
Total	>$129.7	>$167.5

(*1) Present value of annualised costs and benefits at 7%
(*2) NPV of about $ 15.0 million cost over 10 years, at 7%
(*3) Environmental benefits in this value overestimated, see section 12.9.

Whilst engineers and economists have to re-appraise the numbers the current assessment suggests that the overall economics of the MIA LWMP is fairly sound, even if most of the BMP costs and benefits were excluded. The absence of costs and benefits for the Wah Wah area and additional values for the downstream benefits do not substract from the general conclusion.

12.9. Reconciliation of Environmental Benefits and Costs

In the analysis based on individual options and then adding up the costs and the benefits it is always possible that some benefits are counted twice. This may give an overly optimistic result for the economic analysis of the final plan.

During the process the following actions were taken to avoid the problem :

Soil salinity benefits.

The method used was to identify accessions saved by options. When the combined package reaches the target the optimisation avoids adding extra options or parts of options. However, between on-farm options it is possible that there is competition for the same volume to be saved. With agronomic options different padocks are used each year, hence the double counting seems unlikely. With sub-surface drainage options there are often alternatives which could be used on the same farm. The problem of double counting environmental benefits in that instance was overcome by splitting the number of available farms for each sub-surface drainage option at the beginning of the modeling process. Therefore, it was not possible to get implementation on more farms than available. In conclusion, for this factor not much if any double counting is believed to have occurred.

Runoff Benefits.

The values for the individual options for individual farms/units was the same as the values used in the optimisation model. This effectively avoids inconsistencies in the counting of runoff benefit. In addition, the benefit value per Ml saved was corrected by a factor 0.66 for the fact that an average of 36,000 Ml/year of drainage may be saved, but the maximum floodway benefits should not be extended to more than about 24,000 Ml/year. For each item the savings per unit or farm are additive, double counting is not possible.

However, Section 11 identifies that if the recommended package is implemented the capacity to save runoff drainage will be 44,600 Ml/year. Even though only 36,000 will actually be saved, the economics have been applied to the higher figure. This suggests that the environmental benefits are over-estimated by about 24% for the runoff factor. A correction for this has not yet been made to the final assessment of Table 12.6.

Tile Drainage Benefit

Only very few options are available with regard to tile drainage reduction. It is unlikely that double counting has occurred.

EC Benefits

For some options a salinity benefit is expected, for others there has been a cost. Overall the optimisation model shows an 8 EC unit change (section 11).

General

Whilst the above discussion would demonstrate that there is no significant problem with double counting of environmental benefits there are other issues to be discussed. The optimisation procedure involved the assessment of environmental benefits and costs of all options for all farms who may contribute. This involved certain options belonging to the No Plan scenario only, and the same or other options being part of the With Plan scenario. The economics evaluation relates only to the With Plan extra part of all the environmental benefits and costs. There may be a difference.

For instance, the oficial LWMP plan does not have the option for the further installation of tile drainage in horticultural farms. However it will happen to some extent under the No Plan scenario costing some 10 EC units at Willow Dam. This cost is not counted in the LWMP, but is part of the No Plan scenario environmental cost.

The issue is not serious but means there may be some offsets of environmental benefits and costs between the No Plan and With Plan scenario. It is not a double counting issue.

The downstream options as discussed by the previous KinHill study [23] used the environmental costs incurred in the Lower Mirrool Creek as justification of the channel proposals. This has not happened during the discussion of section 10 and 11.

The use of linear programming techniques is reported to possibly lead to over-optimistic results as to what may be achieved in practice. Actual adoption rates will always vary from the finely tuned recommendations based on these models alone. For the MIA plan the recommendation is for implementation over and above the minimum requirement, mainly to offset the problems related to climatic variation between years. This would also have addressed some of the concern regarding the techniques used.

A final important point to make is that not all environmental benefits have been converted into an

13. RISK ANALYSIS

The proposed MIA LWMP is very complex and contains mutiple objectives and multiple solutions. Interactions occur between options and between the upstream and downstream recommended packages. If there is to be a systematic approach to achieve the various objectives and significant investment is required, then it is reasonable to ask what the risk factors are that would cause significant under achievement. Further, the effect of external factors on the plan should be investigated.

The optimisation project targeted the upstream options package and considered the downstream possible solutions package in view of what progress has been made in that respect. A detailed sensitivity analysis of all possible factors has not yet been made. The discussion below provides an answer to some of the most important What If questions.

<u>What if the Soil Salinity target will not be reached.</u>

This could be due to the target reduction in accessions not having been reached. This in turn depends on the effectiveness that a number of options will be implemented. These include the pasture conversion option, the stricter application of rice environmental guidelines, channel seepage control effectiveness and the success of irrigated woodlot plantations (% adoption). All these factors involve a fair degree of commitment of all concerned, and not only from a financial perspective.

If there was an underachievement in the reduction in accessions the salinity of the land is likely to continue creeping higher. Judging form the economics analysis by

NSW Agriculture this will affect agricultural production for the current cropping system by only a small amount, but the potential to grow other crops in the future would be reduced. In the latter respect it needs to be noted that this potential is limited anyway due to the nature of the clay soils. Secondly, sub-surface drainage solutions with on-farm disposal would always provide a solution where high value crops are involved. In high watertable areas with significant rainfall events sub-surface drainage is always an option that requires consideration.

Another uncertainty involves the lump parameter type water balance and soil salinity assessment models used to assess salinity over the 30 year period. The link between accessions reductions and long term salinity is based on regressions with significant standard error in the estimation. Nevertheless, the potential error with other known models is possibly even greater.

What If the drainage water salinity predictions are in error ?

Increased salinity of the land will also result in higher salinity of the drainage runoff. Of course the error in the estimations may be in either direction. In the MIA the overall situation is expected to stay about the same, but this depends on improvements in the tile drainage salt load. The 15% reduction compared to a high benchmark seems easy to achieve, but there are also additons, for instance in not planted gazetted horticultural land that is not yet tile drained, but which is claimed to possess a "drainage right" just because it is gazetted horticulture. Nothing would stop the tile draining of this land followed by the growing of vegetables with high accessions and discharges.

The increases in runoff salinity from mixed farming land are based on the soil salinity prediction model mentioned in the previous section, and therefore subject to similar errors.

The risk that salinity may be higher than predicted would have downstream consequences. This is one of the reasons the downstream package is recommended to go further than the bare minimum and includes the channel to the river option as an option to be used in the future if the conditions become conducive to such action. The first target would be to reduce uncertainty regarding winter flow and the Benerembah Stage 4 drainage.

What If the 15% tile drainage reductions are not achieved ?

This would be quite serious. The 15% drainage reduction from the MIA as a whole would be at risk since otherwise there would be a water quality degradation, including the salinity aspect. The other drainage volumes reductions would no longer be appropriate and the investments made no longer fully justified. This includes the investments in on-farm storages which tend to save large volumes of water. If the MIA drainage reduction is at risk, then the downstream options package is at risk. However it should be considered that the recommended package for downstream represents probably a larger investment than needed as a minimum solution (section 10).

The risk that the salt load will not be achieved would be considered small if additional measures are adopted, such as the Tradable Drainage Quota concept, or other institutional measures would could be an incentive to adopt better practices.

The tile drainage reduction element is a key component of the LWMP.

What If the on-farm recycling storages are not implemented as planned ?

The plan provides for the construction of systems for about 200 farms in an area with about 600 farms. This is a small proportion compared to other LWMP area. The number is kept small because the drainage reduction volumes should not be cut back more than the link with horticultural tile drainage allows, and because there are many farms in the northern part of the MIA where implementation may be impractical due to farm layout reasons, ot because there may be a soil salinity problem which could make the recirculation option risky for the farm in question.

If there are sufficient financial incentives it is likely that the target will be reached and, in due course, exceeded. On the other hand, if there is a shortfal, then the water quality issue in the MIA will not be improved as much as hoped for. This in turn could have implications downstream.

What If water quality targets are not met ?

The MIA system impacts on the river system for only a small proportion (10-15%) of its drainage. The water quality impacts on the Mirrool Creek system and the Wah Wah District exist but the economic impacts have yet to be demonstrated. Stock dams in the Wah Wah S&D district would continue to suffer algal blooms. Barren Box Swamp water is usually lower in pesticide residues than Mirrool Creek at Willow Dam due to much longer retention times. Therefore floodwaters from Barren Box Swamp would have a much lower downstream impact as far as water quality is concerned. Nutrients in Lower Mirrool Creek have not been known to be a problem.

Of course any failure to meet water quality targets would affect the choices available downstream with excess drainage management. For instance, the channel to the river option could not be contemplated.

What If the hydrological predictions for flows downstream of Barren Box Swamp are wrong ?

The models used are based on 70 years of rainfall data including dry and wet periods. The frequency predictions based on this record are below the experiences over the last few years, however it needs to be noted that the flood release policy procedures have not always been consistent.

The predictions are based on a model which tries to simulate the MIA system, however inevitably some assumptions may be in error. Any errors in assessment could have an effect on the frequency of flooding, the volumes to be disposed off, the size of the agroforestry required etc.

If the What If question was answered in the affirmative then the likely error is most likely towards there being more excess drainage rather than less. Such an error may not be serious since the downstream options package allows for an extra capacity to deal with such instances.

What If the Agroforestry option does not live up to expectations ?

The expectation is that the agroforestry option will absorb a significant part of the moderately saline winter flow, and also absorb significant volumes of other excess drainage at other times of the year. This expectation would become unstuck in very wet winters when the soil of the tree plots is already wet, despite good drying out in autumn by the trees. In that case the water would need to be diverted to the floodway and Lower Mirrool Creek (or the channel to the river option).

The chances that salts will accumulate to too high levels would only occur if site selection was poor and the salinity of the winter watering exceeds about 2,000 uS/cm. The research by DLWC (Tiwari [54]) has allayed much of this fear.

The required optimum size of the area required to be planted and the maximum/minimum volumes that may be applied in wet/dry years are being addressed by Statistical Hydrology but some of the uncertainties will remain until after establishement. On the other hand, the investment will be made over a ten or more years program and there is sufficient scope to make adjustments to this solution over time. If it is discovered that the option is failing in its expectations the alternative, namely river disposal will become a more essential part of the solution.

<u>What If the Irrigation option is less popular than stated.</u>

It is premature to answer this question since the Northern Hay Plains study is still to commence. Much will depend on delicate negotiations between the parties. However, once the basic infrastructure is provided by the two groups who are the principal beneficiaries, there seems little risk that the irrigation option will not be taken up by the third group, the new irrigators. This may even be achieved in conjunction with the making available of land for the agroforestry option. The landholders concerned may be given an opportunity to purchase water entitlements from savings made upstream.

<u>What is the Risk of proceeding with the Upstream LWMP package before finishing the Downstream LWMP.</u>

The upstream areas impact on the downstream areas, not vice versa. The changes proposed are in the direction of increased net economic benefits upstream and reduced cost of the required package downstream. There is no further improvements that can be expected from the upstream package without violating some of the constraints that exist, or realistic targets that can be achieved. There seems to be no reason at all why the upstream package should not now commence implementation, except for externalities unrelated to land and water management.

As far as the Wah Wah LWMP is concerned, this is being treated separately, but in fact the area is not much different as far as its treatment is concerned than the Lake Wyangan area, or the Warburn area. These areas also require special treatment, the detail of which is still to be worked out. The Wah Wah area does not impact on the MIA whilst the constraints on the MIA plan to secure Wah Wah water quality have been addressed. There are no plans to allow impacts from the Wah Wah plan area on other external areas, all problems are expected to be managed internally. No large capital expensive solutions are foreseen, except if there was to be a lowering of the target salinity level in the Wah Wah supply over and above the expected improvements to be achieved by the proposed LWMP package.

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APPENDIX 1. UPSTREAM ON-FARM AND REGIONAL OPTIONS

The options are briefly discussed below, just to get an overview of what they are. For more information see the references. The economic and environmental values are at Appendix 2.

1. Mixed farming

In the MIA ir was assumed tha there are about 650 220 hectares farms. The adoption rates between parts of districts vary, for example recirculation is more prevalent in Benerembah. Of course, for any option to be effective the adoption needs to be reasonably spread across the district, especially where the problems are greatest. This is not easily achievable for some options (rice target water use, deep bore pumping, conversion to horticulture).

Option	Ref.	Description
M00	30/17	Convert LAF to horticulture or vegetables. Attractive Ec.&Env. where rice accessions are an issue. Limited potential on TRBE soils. Marketing opportunities will limit this option most.
M01	7, 42	Farmers pumping from drains. There should be about 40 farms who could implement. May need internal recycling to benefit. Water quality is an issue in some months along some drains.
M02	16	Protection Natural Vegetation. Not an option for reducing accessions (enhancing discharge) perse, however useful in the context of improving natural environment where possible.
M03	30/29	Replacing annual by perennial pastures. Deeper root system will lower watertable. Appropriate grazing required towards winter. Economics appear attractive
M04	30/15	Irrigated woodlots. Appear less attractive economically, but are effective in lowering WT's
M05	30/14	Managing saline lands. Once saline it is important to avoid the runoff to reach the drains. Cover crops and banking helps.
M06.	14, 30/29	On Farm Seepage control by permanent pastures. In a few situations this is useful. Economic. Was favoured option in Jemalong for many years.
M07	30	BMP's reducing accessions. Include many actions, whole farm planning, landforming irrigation design and management, paddock drainage. Applies to non rice crops. Important option for pastures wheat and row crops. Runoff may increase.
M08	66	Rice Target Water Use. Elimination of high consumptive crops is desirable. Mostly an option in deeper watertable areas, not the areas now salt affected.
M09	8,46,5 5	Intercepting Channel Seepage + Return. Should have potential in locations where salinity effluent can be kept low (<1.5 dS/m). In mixed farms however economics less favourable.
M10	31,32	Mole Drainage + recycling. Best subsurface drainage option in LAF, however possibly not sound in rice and pastures situation.
M11	4,9	Subsurface Drainage and evaporation areas. As an on-farm option this is not assessed to be economic. Would solve problem
M12	30/12 63	as M11 but disposal to trees + saltbush. Only where salinity effluent is less than 5,000 uS/cm (Leeton area). May be economic if spearpoint feasible.
M13	30/11 63	as M11 but disposal by reuse and shandy. Feasible where salinity effluent < 3,000 uS/cm. Not many locations, perhaps in Leeton, but there soil salinity to low. Economics marginal for this landuse since water not scarce as in Berriquin.

M14	30/8	On Farm Sealing Channels. Necessary in limited instances in MIA, otherwise not economic.
M15	22 30/27	Rice Puddling. Where land is under threat of becoming re-classified due to high water use this is an attractive option.
M16	30/25	BMP Fertilisers. Includes careful application and cultivation. The environmental benefits are small considered to what is needed with pesticides reductions.
M17	30/25	BMP Pesticides management. Many actions may improve situation considerably. Could also be economic.
M18	30/25 30/6	BMP's Rice Runoff. Purpose is to reduce pesticide contamination during Molinate season. Alternative to reuse systems, but economically far more feasible, albeit perhaps less effective.
M19	30/6 14	Drainage Recycling 10 Ml storage. Will capture runoff and prevent much of possible contamination to drains Salinity build up on-farm a possible issue. Volume drainage saved other benefit for LWMP.
M20	30/6 14	As M19, but 26 ML storage, which is 12 mm for a 220 ha farm.
M21	30/6 14	As M19, but no storage. Becomes less effective, not considered economic
M22	17	Four Day Water Ordering. Not popular with landholders. If these is a real risk of wrong timings irrigation, then even a 1-2% yield loss would make option unacceptable.
M23	17	Better Forecasting Demand. At little cost there could be significant escape drainage savings.
M24	7	District Pumping Drains. Economics of medium sized stations looks OK. If pumps operated when high swamp then this option is targeting the optimal times when it is needed, attractive from this viewpoint.
M25	17	Performance Monitoring Escapes. This is very economic for the Coleambally Plan [46], hence probably also for the MIA plan. The volumes capabale to be saved may be significant, but there could be a water quality effect to be compensated for.
M26	16	Plant Corridors of trees. In several locations this should be feasible, some small on-farm areas could also be planted where possible. The economic benefits may be less than cost, hence will require incentives.
M27	66	Rice Hydraulic Loading reduction. This will give a proportional saving in accessions (ave 1.4 Ml/ha). Could reduce farm income where no alternative profitable cropping system exists. Ultimate consideration if other options fail?
M28	9	Community Tile Drainage Schemes. Tile drains on farms connected by pipelines to evaporation areas. Too costly an option. Would be effective.
M29	4	Community Tubewell drainage schemes. See M28. Not economic
M30	61	Deep Bore Pumping + reuse. Economic in CIA but benefits mostly via water sales. Benefits areas without salinity problem in MIA most. Good for long term protection there. High capital + operating costs. Some salinity impacts.
M31	8,45	District Channel Seepage control. Clay lining proven economic in Coleambally where seepage > 50 mm/day. Not many sites in MIA. Still needed where seepage 20-50 mm/day ? Or interceptor drains?
M32	?	BMP's Aerial Chemical Application. A proportion of the problem in drains is due to overspray or drift. BMP's are essential. Cost effective if chemicals saved, but operations more often disrupted. Code of practice and policing needed. RIACTF action

2 Gazetted Horticulture

In the MIA there are about 650 gazetted horticultural farms each having a size averaging about 10-25 hectares. The total horticultral area is perceived to consist to 20 hectare units. The options are briely described below.

Option	Ref.	Description
H01	30/40 30/41	Improved soil management. More a productivity option than LWMP. Will be implemented. Some extra accessions could occur. Not highly significant as option (already No Plan)
H02	30/2	Automisation Irrigation. Will expand even though not perceived very economic at present. Labour saving highest incentive. Accessions could be controlled best if combined with high tech irrigation (assumed)
H03	30/31 30/32 30/33	BMP's Horticultural reduction accessions. This is key to reducing tile drainage flows. Could be economic but extra labour input likely to be required. Involves property planning, irrigation systems, scheduling, furrow design flow rates, management.
H04	30/33	BMP's to reduce runoff. Option coincides with H03. However runoff is less harmful environmentally than tile drainage flow (previous practice of banking bottom end farm to end).
H05	30/6 30/11	Recycling Tile Drainage on farm. Not popular, has potential where EC <say 2000EC. Economics probably not good.
H06	33	Mole Drainage Horticulture. Method mainly recommended for vegetable areas, but some potential in vines may exist. Farmers are likely to opt for more complete watertable control in horticulture. Economics poor if yield loss compared to tile drains.
H07	30/34	Tile Tubewell Drainage. 85% already drained. Another 5% may be needed. Economics very sound, but involves downstream salt load.
H08	30/37 30/38	Controlling Tile Drainage Flows. Possible and not expensive option to reduce salt load. However if any effect on crops at all then this becomes a liability. Some application. BMP irrigation with check on WT depth preferred option.
H09	30/2 30/32	High Tech. Irrigation Systems. Good potential to reduce accessions significantly. Costs and benefits in balance at present. Labour saving may see greater application in future.
H10	30/36	Reducing Hillslope seepage. Relevant for Corbie Hill and sandhills. Small area has problem. Combination BMP's and sub-surface drainage. Possibility of discharge to trees. Economics probably OK
H11	30/39	Biological Control of pests. Already adopted in citrus. Good potential for expansion however research backup needed. Would eliminate pesticide runoff where adopted.
H12	30/39	BMP Fertiliser Applications. Applying in such a way that runoff contamination is avoided. Should be possible and economic once farmers know what to do.
H13.	30/39	BMP Pesticides application. Realm RIACTF. There should be good potential to reduce pollution, and is main alternative to expensive and unpopular recycling + storage. Educationand other incentives needed for adoption.
H14	30/6	Runoff recycling + storage. Rejected as uneconomic by landholders to date. Land loss and potential seepage are issues. Would be quite effective in reducing pollution, however level of problem not completely quantified yet.
H15	30/6	Runoff Recycling No storage. Likely to be less effective in horticulture with intermittent irrigation. Not economic either.
H16	17	Better Forecasting Water Demand. Low cost, probably effective solution to avoid or lower overordering habits to provide irrigation supply service.

H17	17	Two to Four day ordering. This could reduce escapes also and is inexpensive, however a possible yield loss is foreseen, which makes this option less desirable.
H18	12	Performance Monitoring Escapes (SCADA) This is very economic for the Coleambally Plan [38a], hence probably also for the MIA plan. The volumes capabale to be saved may be significant, but there could be a water quality effect to be compensated for. Very worthwhile in some systems, eg Lake Wyangan.
H19		Community Evaporation Areas to Take Tile Effluent. Pipelines and evaporation areas needed. Could cost $20m. Effective in reducing salt loads but considered uneconomic.
H20	30/9	District Seepage Control. Concrete channels a problem now, require replacement. Costs high. Economics not always certain. High value crops needed. Opportunities to convert to integrated renewal of systems (H21).
H21	17 30/32	Integrated Renewal of Systems. Channels renewd and on farm irrigation systems converted to high tech. Economics close to break even. Involves savings of runoff, accessions, tile flows, escapes, however last not eliminated.

3 Extended Horticulture

The horticultural areas extended into large area farms vary in size from 20-200 ha. For the purpose of this excercise the area is preceived to consist of 100 units of 20 hectares each. This area involved may double (and hopefully more than double) over the lifetime of the plan. In terms of LWMP this has little impact, each unit is assumed to involve a low environmental impact, at least that is the basis on which the approval for development is given.

Option	Ref.	Description
E01	30/13 30/26 30/40	Soil structure management. Should always be implemented where farm still viable. Environmental effects mostly coincidental.
E02	30/22	BMP to reduce accessions. Better irrigation practices in extended horticulture already a requirement. Slight negative runoff effect, lower land salinity should also show lower runoff salinity.
E03	8,55	Interception drainage and return to channel. Should have potential in locations where salinity effluent can be kept low (<1.5 dS/m).
E04	30/24 33	Mole Drainage + Recirculation. Good prospects for vegetable areas, but less likely for EH, however not rejected for grapes. Economics OK unless there is yield loss. GRW salinity must be acceptable.
E05	30/34 30/11	Subsurface Drainage + disposal by shandy + Reuse. Only where grw salinity low. Economics sound. Will fix any problem with waterlogging whilst salinity is unlikely to be a problem.
E06	30/34	Subsurface drainage + disposal to trees and saltbush. Valid for intermediate salinity range 2-5 dS/m. Could be cheaper that evaporation areas disposal option. Economic for EH
E07	30/34 31,32	Subsurface drainage and evaporation disposal. Main means of managing watertables and salinity. E05, E06, and E08 are alternatives for specific conditions. Effective and considered economic where needed. No drainage salinity effect if executed correctly.
E08	20	Subsurface drainage and evaporation areas, but permission to discharge to drains in emergency years provided dilution flows are made available to avoid d/s salinity standard exceedance. Overcomes fears regarding viability evaporation areas in wet years. Economic according to Hassall. EH protected.

E09	30/32	High Tech Irrigation systems. Expensive and not everyone considers these economic. Labour saving main advantage. Good potential to reduce tile drainage volumes and size evaporation areas. Farm runoff should also be less.
E10	30/36	On Farm Seepage control by sealing channels. This will be contemplated where permanent plantings under threat. Not likely to be frequently needed. EH is likely to have pipelines where permeable soils occur. On clay soils no problem. Economics depend on damage being caused. Not a major option.
E11	30/39	BMP fertiliser applications. Placement in such a way that runoff contamination is avoided. Most cost in terms of care taken (labour). If fertilisers are saved as well this may be economic.
E12	30/39	BMP On Farm Pesticide application. Very important for WQ improvements where recirculation + storage is rejected as being suitable. Care main ingredient to success. Some equipment upgrading needed (perhaps) Economics good if pesticide usage is also reduced.
E13		Transfer salts to community evaporation areas. If many evaporation ponds exist the option to allow annual transfer of salts during end June to permanent site near Barren Box could be considered. Only about 100-200 ha needed. Cost could be acceptable if the evaporation disposal option takes off and more security is needed for downstream protection. Economics, basically poor, to weighed up against this advantage.
E14	8,55	District Channel Seepage control. Where needed this needs to be implemented. Economics will be OK at lower level of seepage that for Mixed farming (M31). Number of sites not likely to be great, hence not a major LWMP option.

4. Vegetable Growing Areas

The vegetable areas comprise about 5,000 ha, and is perceived to consist of 50 100 hectare units. The main crops are carrots, onions and tomatoes.

Option	Ref.	Description
V01	30/13 30/26 30/40	Soil structure management. Should always be implemented where farm still viable. Environmental effects mostly coincidental.
V02	30/22	BMP to reduce accessions. In vegetable farms furrows often too long and irrigation too slow. Better irrigation practices desirable, even sprinkler may be considered. Slight negative runoff effect, lower land salinity should also show lower runoff salinity.
V03	8,55	Interception drainage and return to channel. Should have potential in locations where salinity effluent can be kept low (<1.5 dS/m).
V04	30/24 33	Mole Drainage + Recirculation. Good prospects for vegetable areas. Economics OK. GRW salinity must be acceptable. Not all soil types are suitable, but Selfmulching clays not bad.
V05	30/34 30/11	Subsurface Drainage + disposal by shandy + Reuse. Only where grw salinity low. Economics sound. Will fix any problem with waterlogging whilst salinity is unlikely to be a problem.
V06	30/34	Subsurface drainage + disposal to trees and saltbush. Valid for intermediate salinity range 2-5 dS/m. Could be cheaper that evaporation areas disposal option. Economics probably OK

V07	30/34 31,32, 63	Subsurface drainage and evaporation disposal. Main means of managing watertables and salinity. V05, V06, and V08 are alternatives for specific conditions. Effective and considered economic where needed. No drainage salinity effect if executed correctly.
V08	20	Subsurface drainage and evaporation areas, but permission to discharge to drains in emergency years provided dilution flows are made available to avoid d/s salinity standard exceedance. This option is recommended for EH but not yet for the vegetable areas. No permanent plantings involved and crop damage not as serious for these more infrequent occasions. Economics less favourable than for EH..
V09	30/32	High Tech Irrigation systems. Expensive and probably not economic for vegetables. However irrigation systems should be designed and managed well and include recirculation to avoid pesticide runoff.
V10	30/36	On Farm Seepage control by sealing channels. This will be contemplated where seepage is serious, however not frequent for vegetable farms. Economics usually poor to fair.
V11	30/39	BMP fertiliser applications. Placement in such a way that runoff contamination is avoided. Most cost in terms of care taken (labour). If fertilisers are saved as well this may be economic.
V12	30/39	BMP On Farm Pesticide application. Very important for WQ improvements however recirculation may be needed to ensure WQ improvements to 100%. Care main ingredient to success. Som Economics good if pesticide usage is also reduced.
V13	45	District Channel Seepage control. Where needed this needs to be implemented. Economics will be OK at lower level of seepage that for Mixed farming (M31). Number of sites not likely to be great, hence not a major LWMP option.
V14		Transfer salts to community evaporation areas. If many evaporation ponds exist the option to allow annual transfer of salts during end June to permanent site near Barren Box could be considered. Only about 100-200 ha needed. Cost could be acceptable if the evaporation disposal option takes off and more security is needed for downstream protection. Economics, basically poor, to weighed up against this advantage. Mostly an option for EH since Mole drainage + recirculation is recommended for vegetbles.

APPENDIX 1

DESCRIPTION OF OPTIONS

APPENDIX 2

DATA FOR OPTIMISATION MODEL

Table 1 a :	Adoption Rates for Best Management Practices
Table 1 b :	Adopion Rates for Optimisation Options
Table 2 a :	Economic Data for Best Management Practices
Table 2 b :	Economic Data for Optimisation Options
Table 3 a	Environmental Impact Data for Best Management Practices
Table 3 b	Environmental Impact Data for Optimisation Options

APPENDIX 3

OPTIMISATION MODEL RESULTS

Table 1:	Model Coefficients for Best Management Practices
Table 2 :	Model Coefficients for Optimisation options for all Scenarios Modeled
Table 3:	Achievement towards Environmental Targets for Scenarios Modeled
Table 4 :	Objective Function and Constraints u

APPENDIX 4

PREFERRED PLAN SCENARIO

TABLE 1 :	Adoption Rates for Best Management Practices
TABLE 2 :	Adoption Rates for Optimised Options

APPENDIX 5

RESULTS OF ECONOMICS ANALYSIS

Table 1 :	NPV of Costs for Options used
Table 2 :	NPV of Benefits for Options used
Table 3 :	Best Management Practices Annualised Costs and Benefits of Preferred Package
Table 4.	On Farm Optimisation Options Number of Farms/Units to Adopt and NPV's of Costs and Benefits
Table 5.	District Optimisation Options Number of Units to Adopt and NPV's of Costs and Benefits