TONKIN CONSULTING

Environment Protection Authority

Sources and Volumes of Water and Pollutants Entering the LMRIA Drainage Channels

www.tonkin.com.au

Table of Contents

Environmental Protection Authority
Sources and Volumes of Water and Pollutants
Entering the LMRIA Drainage Channels

Executive Summary

Tables

Figures

Appendices

Document History and Status

Rev	Description	Author	Rev'd	App'd	Date
A	Draft for comment	DWS	RME	DWS	16/11/06
B	Draft Final Report	DWS	RME	DWS	16/01/07
C	Final Report	DWS	RME	DWS	19/02/07

Executive Summary

This report outlines the work undertaken to estimate the volume of drainage water from a range of sources within each IA before and after rehabilitation. Corresponding pollutant loads have been estimated including what improvements are expected once rehabilitation has been completed.

Models were calibrated against the existing data, including drainage volumes, recorded salinity levels and pollutant concentrations.

This study estimated that the average annual application rates are 22.8 ML/ha before rehabilitation and 14.5 ML/ha after rehabilitation. The irrigation volume totals indicates that approximately a 50% reduction (approximately 50GL) in the volume of water extracted from the river may occur due to rehabilitation. This is a result of a combination of reduced irrigation rates and retirement of areas from production. The calculated reductions do not include extractions for highland irrigation or use of ELMA for land management of the floodplain.

Before rehabilitation stormwater runoff accounted for approximately 2% of the drainage volume, groundwater approximately 6% and irrigation drainage 92% in an average year. However after rehabilitation the stormwater component has been estimated to be approximately 7%, the groundwater component 19% and the irrigation drainage component 74%.

The model estimates that the drainage volume will be reduced by 60 to 70% for the LMRIA. The significant reduction in the proportion of drainage water being estimated from the study is due to increased irrigation efficiency resulting from rehabilitation and the reuse of the collected drainage water. Pollution loads are estimated to be reduced by 70 to 80% for Phosphorous, Nitrogen and E.Coli, apart from Oxidised Nitrogen which will be reduced by 40 to 50% and salt is only reduced slightly (due to groundwater and subsurface irrigation inputs continuing).

The modelling results are extremely encouraging for achieving the goal (of the rehabilitation program in the LMRIA) of improving the quality and quantity of water in the River Murray. Full completion of rehabilitation should also greatly assist irrigators to efficiently manage their water during the current drought conditions and water restrictions.

Recommendations

The following recommendations are made from this study to improve any future modelling and to confirm the results of the modelling presented in this report:

- The current monitoring program being conducted on the LMRIA be continued to confirm so that the improvements from rehabilitation estimated by this study are being achieved in practice.
- Calibration of the drainage pumps flow rates should be undertaken at regular intervals so that future drainage volumes can be calculated with reasonable accurately.
- Periodically review the reductions in drainage and pollutant loads being discharged into the river compared to the model predictions.

1. Introduction

1.1 Background

The Department of Water, Land and Biodiversity Conservation (DWLBC) and the Environment Protection Authority (EPA) are working to improve environmental management, while maintaining a viable dairy farming industry, in the Lower Murray Reclaimed Irrigation Areas (LMRIA). The LMRIA comprises that portion of the River Murray from Mannum to the entrance to Lake Alexandrina, and it includes the active Irrigation Areas (IAs) for dairying from Cowirra (in the north) to McFarlane (in the south at Wellington). A Locality map of the area is shown in Figure 1-1.

The Lower Murray is an important area for dairy production in SA, utilising River Murray water to irrigate land formerly part of the floodplain of the River Murray. There are significant opportunities to improve water management and economic returns, and to reduce the impacts of irrigation on River Murray water quality, through a major reform program that includes the rehabilitation of the water supply and drainage infrastructure in the region.

The LMRIA is one of the largest point sources of nutrients and pathogens to the River Murray in South Australia (Eco Management 2003). Drainage discharges into the River Murray occur from collection (salt) drains that are located in the LMRIA and this drainage water arises from a range of sources, of local and regional origin including:

- Groundwater seepage from the high land, both regional inputs and inputs induced by irrigation mounds
- Stormwater arising from irrigation bays, land adjacent to the IAs, and from local government infrastructure such as roads and urban drainage systems
- Water arising from flood irrigation practices in the LMRIA, both drainage and excess surface irrigation runoff

A conceptual diagram of the main sources of water that is collected in the main drainage channel is provided in Figure 1-2.

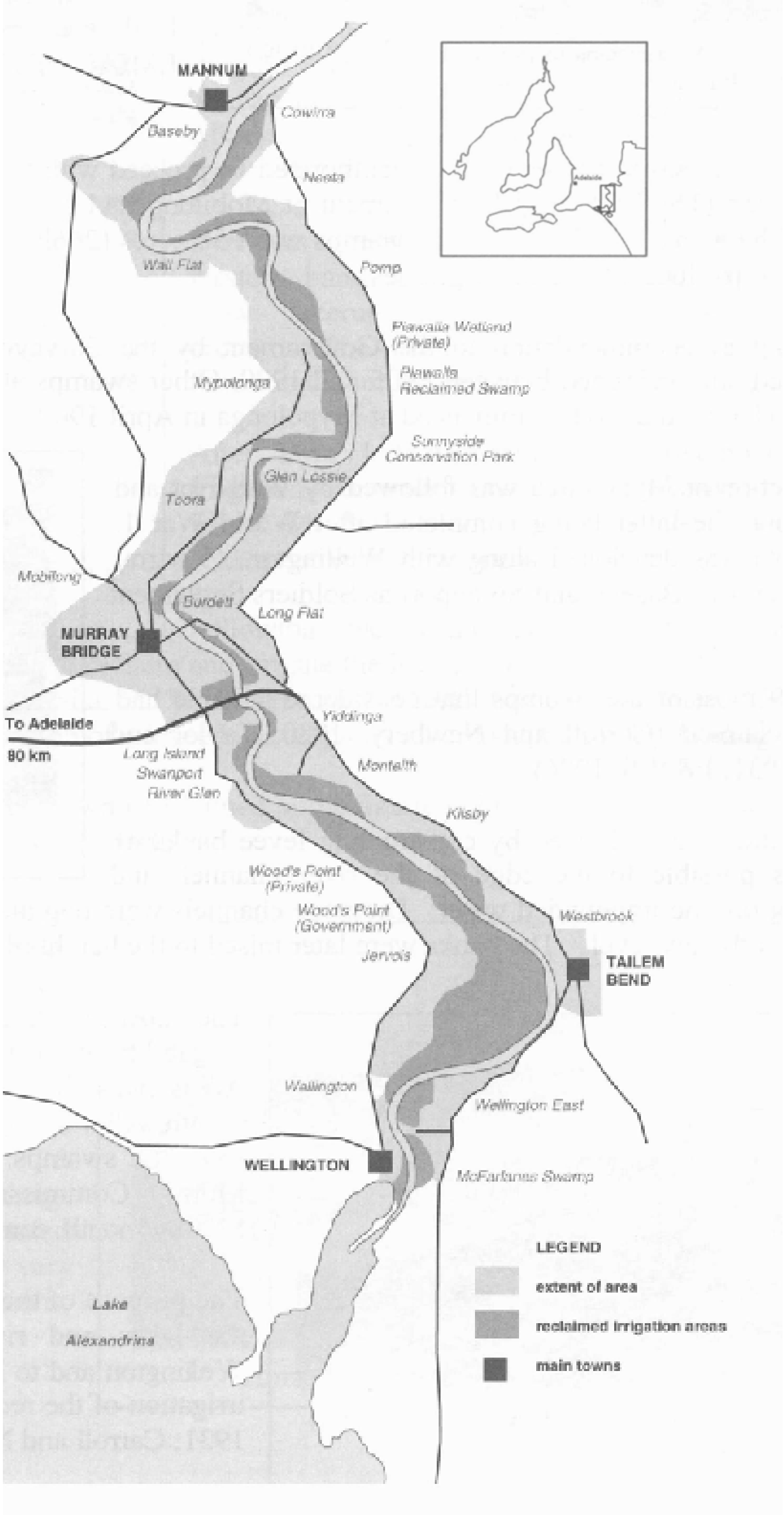


Figure 1-1 Lower Murray Reclaimed Irrigation Areas Locality Map

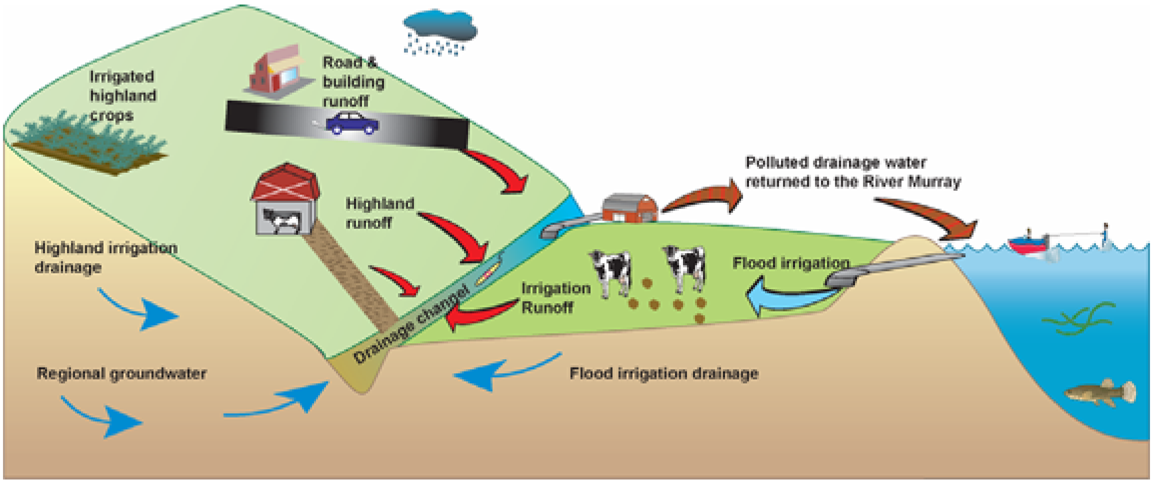


Figure 1-2 Sources of Drainage Water

A mixture of these sources may be present at any one time. During the irrigation season significant amounts of irrigation surface runoff and subsurface drainage are present, while during the non-irrigation season, the proportional contribution from groundwater and stormwater increases. As part of the current LMRIA rehabilitation project, the EPA requires irrigators to retain and reuse on farm any excess flood irrigation water and also the first 5 ML of stormwater per 100 hectares generated from the irrigated property. This involves the construction of a shallow capture drain (toe drain) at the end of each irrigation bay. The surface water captured in this drain would then be reused for irrigation on the floodplain and highland.

By June 2008, when reuse systems are constructed on all farms, the drainage volume arising from irrigation practices will be substantially lowered. However, there will still be a substantial amount of water entering LMRIA drainage channels that will be required to be pumped to the River, particularly from subsurface irrigation drainage and groundwater sources.

Historically, 75% of the area was managed by Government and the cost of pumping was met by general rate revenue. The rehabilitation program involves converting from Government ownership to self management by private irrigation trusts, completing engineering rehabilitation works and leading to irrigators being responsible for operations and maintenance of their district. This has led to a requirement for irrigators to make an assessment of the volume of drainage water that is generated from their activities and what volume comes from external sources.

The objective of this project is to provide information on the sources and volumes of water and pollutant arising in the LMRIA drainage channels.

1.2 Study Outline

This study aims to determine reliable estimates of the drainage components that enter the main drainage channel and are pumped into the river. Drainage volumes have been estimated for the pre-rehabilitation scenario (principally before rehabilitation has occurred) and for the post-rehabilitation scenario. In addition, the pollutant load has been estimated for both scenarios. Pollutants estimated include Soluble Phosphorous (SP), Total Phosphorous (TP), Total Kjeldahl Nitrogen (TKN) and Oxidised Nitrogen (NOx), Total Nitrogen (TN), salt and E.Coli.

To estimate the drainage volumes and pollutants being generated from each IA, the study used the methods and models developed from previous studies, including:

- Rehabilitation & Restructuring of the LMRIA (Tonkin Consulting 2001 - 2003)
- LMRIA Irrigated Floodplain Rainfall Runoff Modelling (Tonkin Consulting 2004)

Stormwater runoff volumes were calculated using a daily water balance model incorporating soil moisture stores for the irrigated floodplain, non irrigated floodplain, irrigated highland and dry land areas.

The water balance and pollutant model was used to determine the inflow of groundwater, irrigation runoff and pollutants. Stormwater volumes from the daily water balance model were also included. The model was calibrated against existing data to determine the pre rehabilitation irrigation application efficiencies. This then enabled the volumes of drainage water and pollutants that are discharged into the river to be determined. An outline of the model assumptions and calibration process is provided in Section 2. The results of the modelling is presented in Section 3.

2. Water and Pollutant Modelling

2.1 Introduction

The process used to model each irrigation area in order to estimate the components of the drainage water including irrigation drainage, pollutants and salt has been outlined below and in Figure 2-1.

A continuous simulation model has been used to estimate the frequency and magnitude of rainfall runoff being generated from irrigated floodplain and highland areas, roads and buildings and dry land catchments over a 30 year period.

The modelling process comprised of a number of steps to calculate the runoff component from the irrigated areas. This included using a spreadsheet decision support model to schedule irrigation and a continuous simulation runoff model called “MUSIC” developed by the CRC for Catchment Hydrology to determine the runoff from each surface type for Tailem Bend, Murray Bridge and Mannum. The estimates of stormwater runoff are then incorporated into the water balance and pollutant model for each IA being studied.

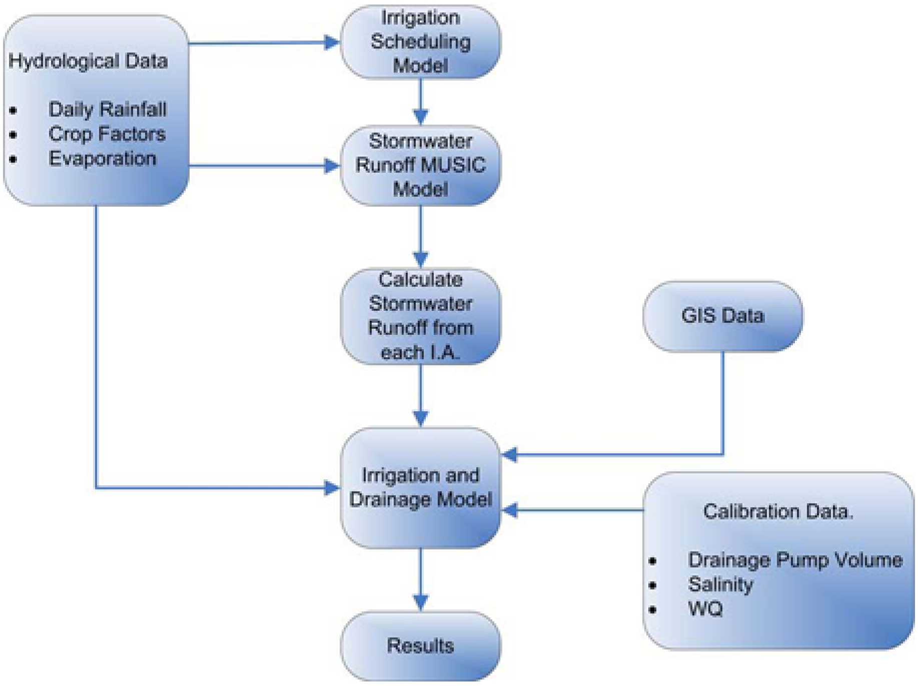


Figure 2-1 Modelling Flow Chart

A spreadsheet water balance and pollutant model (developed for the previous rehabilitation and restructuring concept design projects) was used to determine the drainage volumes and pollutant loads being generated from each IA. The models were calibrated against drainage volumes estimated from recorded pump hours, monitored main drain salinities and pollutant concentrations.

This section outlines how the models were used, the limitations of the calibration data and what model calibrations were performed.

2.2 Model data

2.2.1 Rainfall

Daily rainfall data from Tailem Bend, Murray Bridge and Mannum has been used in the modelling. The average rainfall for the period of modelling as well as the total length of record is shown in Table 2-1.

Table 2-1 Average Annual Rainfall

	Tailem Bend	Murray Bridge PO	Mannum PO
1970-2005	395 mm	370 mm	305 mm
Long Term Average	376 mm	347 mm	295 mm

2.2.2 Evaporation

Evaporation data was used in the modelling process to determine the rate of soil drying principally through plant evapotranspiration. Daily class ‘A’ Pan evaporation data was obtained for the Wellington Pump Station for the 29 year period of record between January 1970 and December 1998. The data was reviewed and gaps in the data filled with average monthly values. To provide representative data for the years between 1999 and 2005 the evaporation data from Blanchetown was modified so the monthly average evaporation was consistent with Wellington data for the previous years of record.

The average annual evaporation for the Wellington PS of 1450mm appeared to be about 20 percent lower than the evaporation data used to determine Water Allocation Plan (WAP) for the area (RMCWMB 2002). The water allocation provided for the LMRIA is considered to be conservative with the theoretical allocation only needed to be exceeded every 5 or more years (Robertson & Wood 2001). This knowledge supports the use of evaporation data which is lower than that provided in the WAP.

The evaporation data at Wellington was multiplied by a factor (increased by 9%) to provide data that is a little closer to the typical values adopted for the WAP at this location. The adopted annual average evaporations are shown in Table 2-2. The evaporations for Murray Bridge and Mannum locations were calculated by using the ratio between Wellington and the other locations based on the percentage differences provided in the WAP.

Table 2-2 Adopted Class A pan evaporation

Location	Multiply Factor	Average Annual Evaporation (mm/ year)
Wellington	1.09	1580
Murray Bridge	1.12	1624
Mannum	1.18	1711

2.2.3 Crop Factors

The crop factors (Kf) for irrigated pasture adopted for this study, provided in Table 2-3, have been based on the WAP. A crop factor is used to convert Class A pan evaporation into a comparable rate of evapotranspiration for a particular crop for a specific location and time of the year.

Table 2-3 Adopted Crop Factors

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.7	0.7	0.7	0.7	0.6	0.55	0.6	0.7	0.8	0.8	0.8	0.7

Crop factors were reduced in some instances/areas to reflect lower rates of irrigation, when applying lower rates of irrigation such as Environmental Land Management Allocation (ELMA) water to the flood irrigated area.

2.2.4 Soil Parameters

Floodplain

The upper soil profile of the irrigated floodplain usually consists of a high moisture holding self mulching clay. Tests have shown that it has a high available water holding capacity (up to 300 mm/m). Therefore an active soil profile of 400mm would give an effective field capacity of 120mm.

Highland

The highland soils are quite variable across the LMRIA. They range from deep sandy profiles to shallow soils underlain by calcrete. Generally the irrigated area would be located in the deeper soil profiles. A field capacity of 50mm is what is expected to be typical of the area.

2.2.5 Drainage Volumes to River

Drainage pump hours have been recorded from July 1976 to December 2005 for a number of areas, particularly the larger IA's. The smaller private IA's have limited data; from 22 years to only a couple of years. Some of these records give the drainage volumes discharged to the River assuming the pumps are operating under design conditions. These estimated volumes do not take into account variations in the drainage channel and river pool levels, impeller wear or reduced pump efficiency.

Recent calibrations of the drainage pumps indicate that the pump efficiency can vary significantly and is dependent on the period since maintenance has been carried out. The rated pump drainage rates were reduced to reflect the average pump performance considering the level of periodic maintenance that has been undertaken. The drainage volumes have been reduced to between 70 to 90% of the drainage volumes calculated on design pump rates.

2.2.6 River Salinity

Average monthly salinity records for the River Murray at Murray Bridge were obtained from DWLBC over a 30 year period from January 1976 to December 2005. The records were used to estimate the salt load being imported through irrigation of pastures on each IA.

2.2.7 Groundwater

The following sources of information were used to assist the estimation and calibration of groundwater movements in each catchment.

It is understood that regional groundwater on the western side of the river is moving more quickly and is more saline than the eastern side with salinity levels between 10,000 and 20,000 mg/L (pers comm, Barnett S., PIRSA).

Desmier & Schrale, (1989) estimated the groundwater salinity and the average daily groundwater discharges on a number of IA’s. The estimates were made based on 99 days of monitoring between May and September 1981. An estimated average discharge that entered the floodplain was calculated by conducting a salt and water balance.

Salinity monitoring of the drainage discharges was also conducted over a period between November 1990 to December 1995. Salinity values were initially taken between 2 to 5 times per month but reduced to 1 to 2 times per month towards the end of the monitoring period with some months being missed altogether.

Salinity monitoring of the drainage discharges for the majority of the IA’s was also conducted over a period between March 2002 and February 2003. A number of the IA’s have continued to be monitored by the EPA to the present day.

Salinity monitoring between 1990 and 1995 was the key data used to estimate the volume of groundwater entering each IA. This is due to the large data set available and covered the majority of the IA being investigated. The groundwater component was determined by conducting a salt balance of the inputs such as irrigation water and groundwater and the output, being the drainage water. The groundwater inflow volume and salt concentration was adjusted until the model salinity concentrations matched the recorded concentrations.

2.2.8 Nutrient Discharge

Water quality monitoring of the drainage discharges for the majority of the IA's was conducted over a period between March 2002 and February 2003 (Eco Management Services 2003). A number of the IA's have continued to be monitored by the EPA to the present day (EPA 2006). This information will be used to calibrate the current pollutant discharges from each IA.

The model was calibrated so that the average pollution concentrations of the drainage pump volumes matched the median concentrations recorded from the water quality modelling for each IA.

Previous work by Murray & Philcox (1995) on the Cowirra IA examined the nutrient and bacterial loads in surface and sub-surface drainage water. The recorded data enabled the development of correlation equations for sub-surface and surface irrigation runoff. The average surface and sub-surface concentrations recorded during the trial for a range of nutrients during grazing are given in Table 2-4.

Table 2-4 Average Nutrient Concentrations During Grazing

Irrigation Runoff	Soluble Phosphorus mg/L	Total Phosphorus mg/L	Total Kjeldahl Nitrogen mg/L	Oxidised Nitrogen mg/L	E coli #/100ml
Sub-surface	1.19	1.41	3.5	1.33	7×10^5
Surface	3.73	3.95	6.59	0.38	7×10^6

The nutrient concentrations given in Table 2-4 were measured in irrigation runoff flowing directly off the end of the irrigation bay. The measurements do not take into account other sources of water that combine with irrigation runoff in the main drain and act to reduce or increase the nutrient concentrations.

The values presented in Table 2-4 indicate that the surface runoff generally contains higher concentrations of nutrients and bacteria than the sub-surface runoff. A significant reduction in nutrient loads to the river can be achieved if the surface runoff can be reduced or intercepted and recycled. The exception to this finding is oxidised nitrogen, which has higher concentrations in sub-surface runoff than surface runoff. The proportional differences in concentrations were used in the model to determine the concentration of the surface and subsurface irrigation water. This was important in estimating the reductions in the pollutant load following rehabilitation and the adoption of best management practices.

2.2.9 Salinity of Irrigation Runoff

Data from the work undertaken by Murray & Philcox (1995) at Cowirra was also used to predict the likely salinity of surface water being captured in the tailwater drain for recycling to the swamp.

2.3 Irrigation Scheduling Model

Floodplain

Irrigation is usually scheduled for flood irrigated pasture when approximately 50% of the field capacity is depleted. Scheduling is also dependent on the dominant pasture types and the condition of the irrigation bays.

Laser levelled bays are mostly planted with a clover /ryegrass dominant pasture which has a relative shallow root depth. Non laser levelled bays are mostly planted with a paspalum dominant pasture with a deeper root depth. Paspalum pastures can tolerate longer duration between irrigations and wetter conditions than clover / ryegrass pastures.

Generally, non laser levelled ground is limited to 14 irrigations per season and laser levelled ground to 16 irrigations per season south of Murray Bridge and 18 irrigations per season north of Murray Bridge. The irrigation interval determined by the irrigation scheduling routine was set so that it mimicked the past irrigation practices on the LMRIA.

Highland

The irrigation of highland pastures has been based on applying irrigations to keep the soil profile close to field capacity. This is done by irrigating when the soil moisture deficit reaches 30mm. This results in a higher frequency of irrigation scheduling and smaller application rates compared to surface irrigation on the floodplain.

Model Assumptions

A spreadsheet based model was developed to determine when irrigation should be scheduled for the farm. The decision to irrigate was determined when the soil moisture deficit reached a specified value (through plant evapotranspiration) following the last irrigation. To incorporate the sequencing of irrigation on the farm and between farms a unit area of farm was divided into thirds with irrigation being applied at different times. This is undertaken to mimic the variation in the soil moisture that would be experienced across the catchment during a rainfall event.

Daily evapotranspiration is calculated using the following formula:

Daily Et = Kf * Epan

Et = Evapotranspiration
Kf = Crop Factor
Epan = Daily class A pan evaporation (modified as provided in Table 2-2)

In developing the scheduling model a number of rules and assumptions were used to determine how irrigations should be scheduled, including:

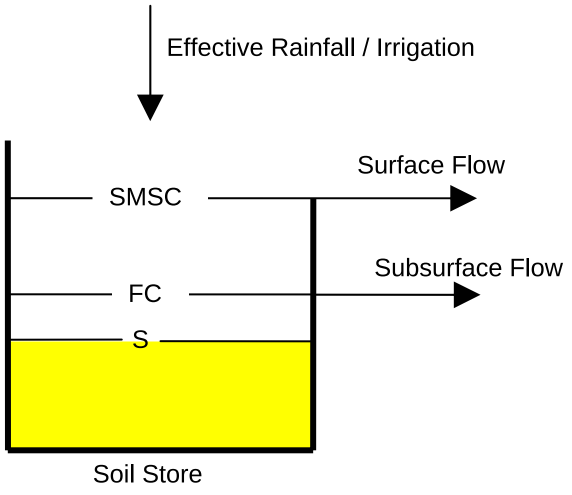
- Irrigation of the first paddock occurs once the soil deficit is below the specified minimum soil moisture deficit.
- The duration between irrigations is adjusted based on modifying the soil moisture deficit to achieve differing average number of irrigations per season.
- The allowable soil moisture deficit is approximately 50% of field capacity for flood irrigation and 30mm deficit for highland irrigation during the irrigation season but is allowed to be higher during winter. This reflects current irrigation practice to allow the pasture to experience a higher soil moisture deficit during winter.
- Irrigation does not occur on a particular day if total rainfall for the day and proceeding 2 days exceed 10mm.
- Irrigation of a particular bay can not occur within 2 days of another irrigation bay (for surface irrigation).
- An initial rainfall loss of 4mm has been applied during the irrigation months and 2mm in the winter months to account for evaporation from foliage and the surface of the soil layer.

2.4 Stormwater Runoff Simulation Model

2.4.1 Irrigated Areas

The MUSIC simulation model applied daily rainfall, the scheduled irrigation application and plant evapotranspiration to the soil profile for a unit area in each region being considered (Tailem Bend, Murray Bridge & Mannum).

The key relationship in the model involves the interaction between the soil profile and the applied water as shown in Figure 2-2. The modelling process assumes that applied rainfall/irrigation initially fills the field capacity of the soil profile and then the Excess Soil Moisture Capacity (ESMC). Any remaining rainfall or applied irrigation in excess of these storages will then be discharged as surface runoff. The ESMC would be discharged as subsurface drainage water.



ESMC = SMSC – FC

SMSC	- Soil Moisture Store Capacity
FC	- Field Capacity
S	- Current Store Level
ESMC	- Excess Soil Moisture Capacity

Figure 2-2 MUSIC Runoff Model Process

The ESMC value reflects the volume of the soil voids and the continuing infiltration rate of the soil once it has become saturated. The estimated value for this parameter on a particular flood irrigated site will be dependent on a number of physical properties, including:

- Soil depth and structure
- Slope of bay
- Unevenness of bay
- Presence and effectiveness of mole drainage
- The continuing infiltration rate of the soil profile once it has become saturated
- Effectiveness of the side drains present on the edges of irrigation bays

For this study an ESMC of 5mm was used for modelling the floodplain. However as the surface and subsurface runoff was combined to give a total stormwater runoff, the adopted value was not critical for this study. The value adopted is more important where surface and subsurface runoff needs to be separated.

The following parameters were adopted for the modelling of the floodplain and highland areas of the LMRIA.

Table 2-5 MUSIC Modelling Soil Moisture Store Parameters

	Field Capacity	SMSC	ESMC
Floodplain	125	120	5
Highland	50	60	10

In analysing the scheduled irrigation and rainfall data, the MUSIC model assumed the following:

- rainfall and irrigation occurs over a 12 hr period (ie a 12 hr time step is used in the calculations)
- An initial loss of 4mm has been applied during the irrigation months and 2mm in the winter months to account for evaporation from foliage and the surface of the soil layer.
- ESMC storage is dissipated over approximately 24 hours after irrigation is completed.
- Infiltration capacity of the soil profile is unlimited before the soil moisture storage capacity is filled.

The model was used to generate runoff volumes off the floodplain at Tailem Bend, Murray Bridge and Mannum for a number of irrigation scheduling scenarios (laser levelled and non laser levelled ground and application of ELMA). The irrigation runoff was removed from the data before the rainfall runoff component were analysed.

2.4.2 Dryland Areas

MUSIC was also used to model the runoff from the dryland areas by incorporating appropriate soil moisture store parameters (FC = 50mm, SMCS = 60mm) within the model and applying the daily rainfall. Runoff occurs once the soil moisture stores have been filled.

2.4.3 Impervious Areas

Impervious areas such as roads and buildings were classified as directly connected or indirectly connected to the drainage channel. Aerial photography and GIS techniques were used to determine the impervious area for each catchment.

Directly connected impervious areas are those that are located adjacent to the floodplain drainage channels or where the runoff from an area is conveyed to the floodplain via piped, formal open channel or creek. An initial loss of 1mm was applied to each day of rainfall on these areas.

Indirectly connected impervious areas are those that flow over pervious surfaces before it reaches a main water course or drainage channel. An initial loss of 5 to 10 mm was applied to daily rainfall for these areas. The initial loss chosen was dependent on where the indirectly connected areas are located within the catchment.

2.4.4 Stormwater Runoff Estimates

The MUSIC model runoff estimate for each land use was collated in a spreadsheet for each region. The total volume of runoff was estimated by determining the area of each land use, multiplying it by the unit runoff and summing up the total runoff for each day. A monthly summary was then collated for the 30 year simulation period for each irrigation area being considered ready for including into the water and pollutant model.

2.5 Water Balance & Pollutant Model Development

A water balance and pollutant model was developed to simulate the various processes that occur within the floodplain, using a monthly time-step. These processes include groundwater movements and irrigation requirements. The results from the daily water balance model were used to estimate the drainage volume that is generated for each IA. Irrigation requirements take into account moisture uptake, surface irrigation runoff and sub-surface irrigation runoff. The model predicts the quality and quantity of pollutant wash-off and drainage water being discharged back into the river based on the current management practices being simulated over a 30 year period (Between 1976 and 2005 – the length that drainage volumes have been recorded).

The model was also used to investigate the drainage volumes and pollutant loads being discharged to the river under the post rehabilitation scenario.

2.6 Model Calibration

To verify that the model provided reliable results, it was important to calibrate the model to the available data. Recorded drainage volumes, nutrient concentrations and salinities were used for this process.

2.6.1 Drainage Water

The drainage volumes calculated by the model were calibrated against the available drainage records. This enabled an estimate of the past irrigation efficiency to be calculated for each IA. The irrigation practices that were identified during the development of the EIMP's were incorporated into the modelling where it was considered appropriate. For example, the McFarlane IA uses the floodplain to grow winter and summer crops. The irrigation scheduling regime is different to that of permanent pasture. A number of other irrigators limit the number of irrigations on their pasture which limits plant growth. This may be due to not having time to irrigate regularly or only requiring limited pasture growth due to the low stocking rates.
The modelled drainage volumes have been compared to the drainage records for the Monteith and Woods Point IA's as shown in Figure 2-3 and Figure 2-4. The figure also shows the stormwater runoff and groundwater components contributing to the total drainage volume that has been calculated by the model.

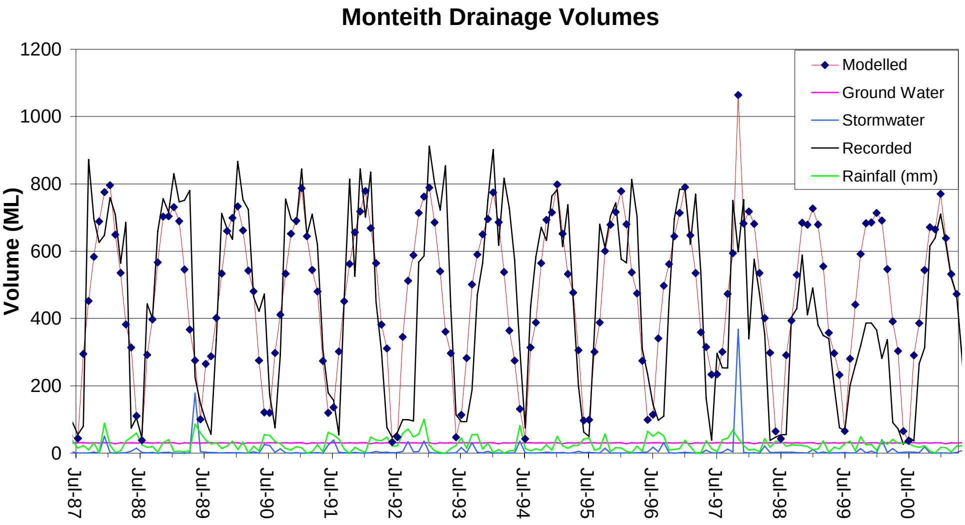


Figure 2-3 Monteith Volume Calibration

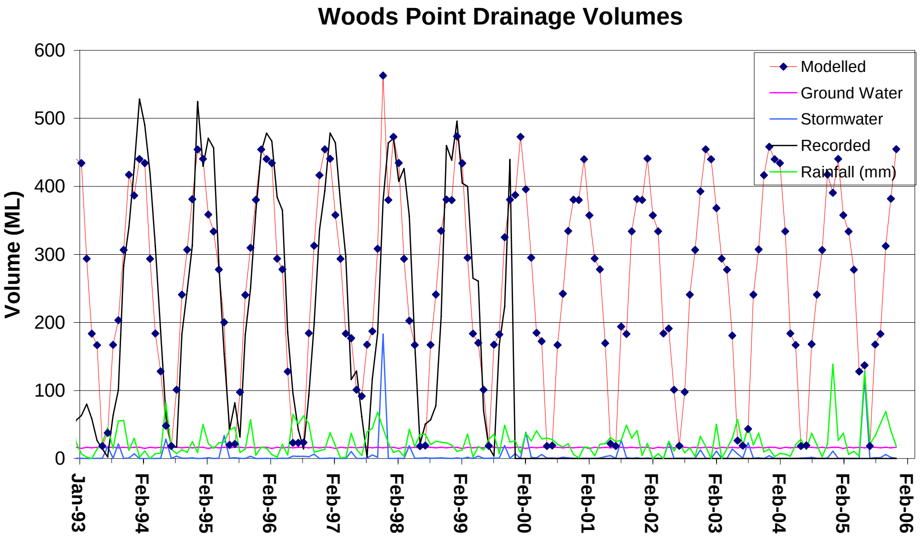


Figure 2-4 Woods Point Volume Calibration

2.6.2 Salinity

The groundwater consists of the regional groundwater together with irrigation induced groundwater where irrigating the highland for pasture, horticulture or other crops occur. The model used a salt and water balance method to estimate the volume of groundwater entering the drainage system. The modelling assumed that the salt concentration within the soil was maintained ie salt entering from the regional groundwater table and through flood irrigation water was discharged into the River and did not result in a build up of salt concentration within the soil. Salinity calibrations for a number of IA's are shown in Figure 2-5 to Figure 2-9.

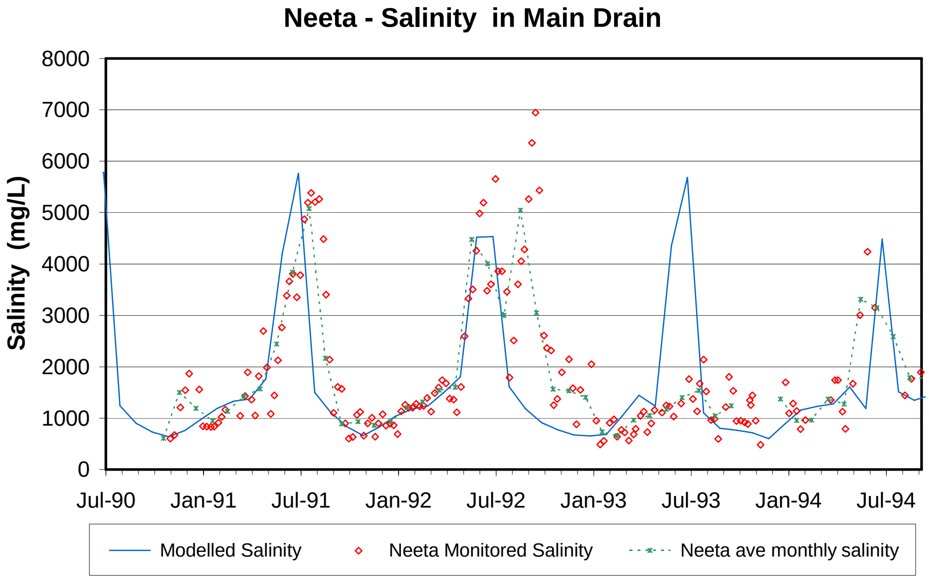


Figure 2-5 Neeta Salinity Calibration

The figures show the modelled salinity compared with the recorded flow weighted average monthly salinity. The monitored salinities are also provided to show the variability of the salinity levels within the main drainage channel.

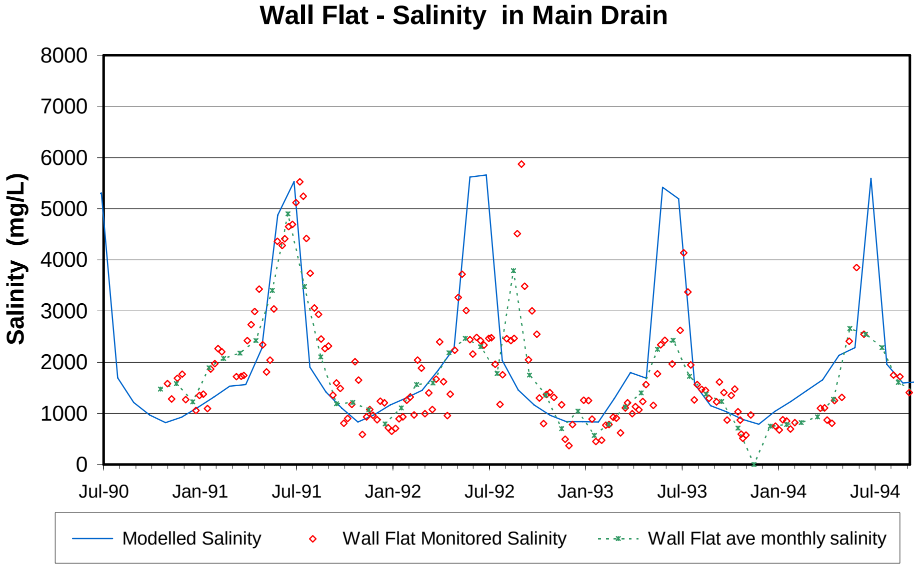


Figure 2-6 Wall Flat Salinity Calibration

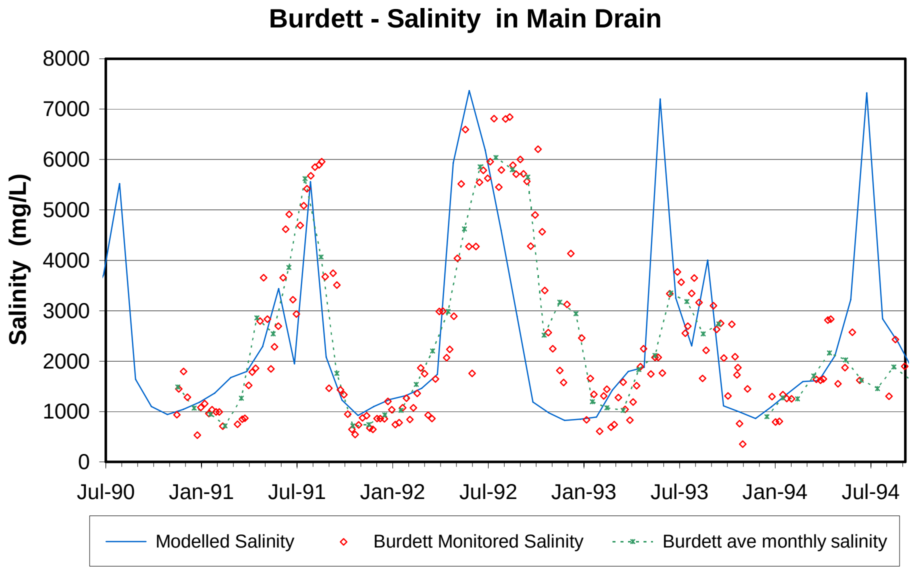


Figure 2-7 Burdett Salinity Calibration

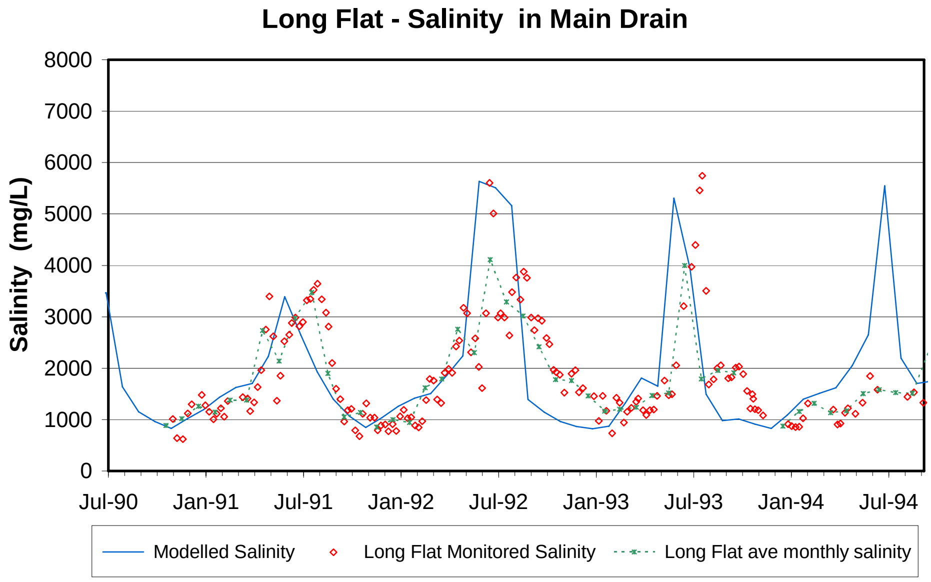


Figure 2-8 Long Flat Salinity Calibration

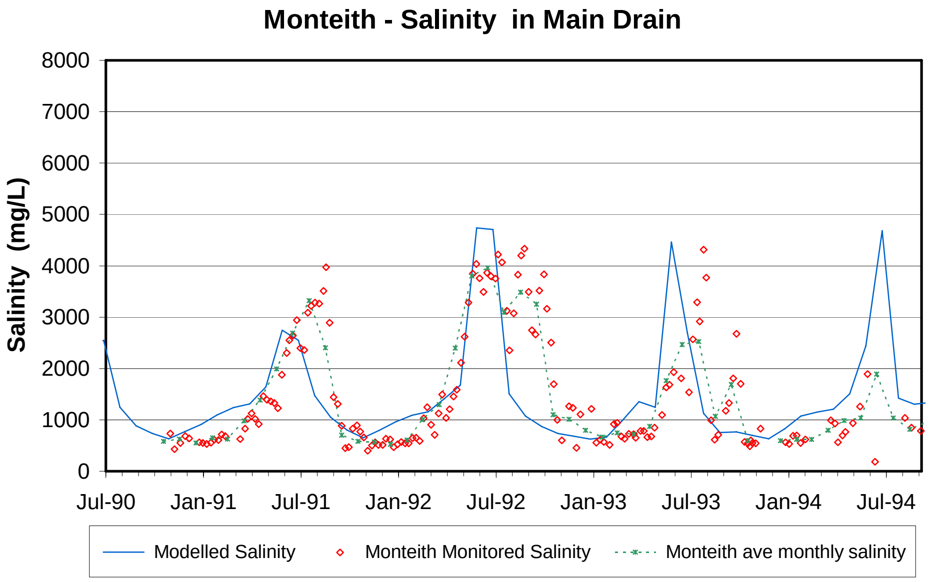


Figure 2-9 Monteith Salinity Calibration

2.6.3 Pollutant Modelling

Water quality monitoring of the drainage discharges for the majority of the IA's was conducted over a period between March 2002 and February 2003. A number of the IA's have continued to be monitored by the EPA to the present day. This information was used to calibrate the current pollutant discharges from each IA.

The pollutant concentrations in the model were adjusted so the average values in the modelled drainage water closely matched the median pollutant concentrations recorded in the main drain for each IA. The average pollutant concentrations generated from the modelling is shown in Table 2-6.

Table 2-6 Modelled Average Pollutant Concentrations

Irrigation Area	Average Water Quality in the Main Drainage Water				
	Sol P mg/l	TP mg/l	TKN mg/l	Nox mg/l	E.coli #/100ml
Cowirra North	1.5	2.3	4.7	0.52	2.0E+05
Cowirra	1.7	2.7	5.4	0.61	2.3E+05
Baseby	0.9	1.4	3.0	0.22	7.4E+04
Neeta North	0.5	1.0	2.2	0.26	4.5E+05
Neeta	0.6	1.0	2.3	0.25	4.7E+05
Wall Flat	0.6	0.9	2.1	0.16	1.4E+05
Pompoota	0.7	1.1	2.6	0.15	9.1E+04
Mypolonga Nth	1.0	1.3	3.5	0.40	4.6E+05
Mypolonga	1.0	1.3	3.4	0.43	4.5E+05
Glen Lossie	0.8	0.9	1.6	0.25	5.9E+04
Toora	0.1	0.2	0.9	0.09	9.2E+03
Burdett	0.4	0.6	1.6	0.04	1.8E+04
Long Flat	0.9	1.2	3.8	0.11	9.5E+04
Long Island	0.6	0.9	2.3	0.16	1.6E+05
Yiddinga	0.6	0.8	2.1	0.08	7.5E+04
River Glen	0.9	1.2	3.3	0.48	3.1E+05
Monteith	0.8	1.0	2.6	0.40	1.7E+05
Woods Point	1.2	1.4	3.9	0.62	1.3E+05
Jervois	0.7	0.8	2.2	0.19	1.7E+05
McFarlane	0.4	0.6	1.3	0.14	4.1E+03

2.6.4 Post Rehabilitation Model Scenario

The post rehabilitation model assumes that irrigation is applied at a rate of 1ML/ha which equates to approximately 65% irrigation efficiency. The water in excess of the field capacity comprises of surface and subsurface drainage. The proportion of each is dependent on a number of factors including the composition of the soil profile, presence of mole and side drains and the slope of the bay.

A relationship between surface and subsurface drainage has been derived from experimental data obtained from research on the Cowirra IA (Murray & Philcox 1995). This relationship indicated that a relatively high proportion of the irrigation runoff is derived from subsurface drainage, probably reflecting the presence of an efficient subsurface tile drainage system installed as a component of the trial. The results indicate that 0.2ML/ha of subsurface drainage water needs to occur before any surface drainage occurs. At post rehabilitation application efficiencies of 1ML/ha the relationship shows that over 2/3 of the irrigation drainage water would be subsurface and 1/3 surface flow. At irrigation application efficiencies of 50% (approx 1.3 ML/ha) approximately half would be surface drainage and half subsurface drainage.

Anecdotal evidence (eg limited or no flows in side drains after irrigation) (pers comm, Phil Price & Martin Philcox) indicates that it is likely that a higher portion of the drainage water occurs as surface runoff. Therefore the relationship was modified as shown in Figure 2-10 in order to more closely reflect this evidence.

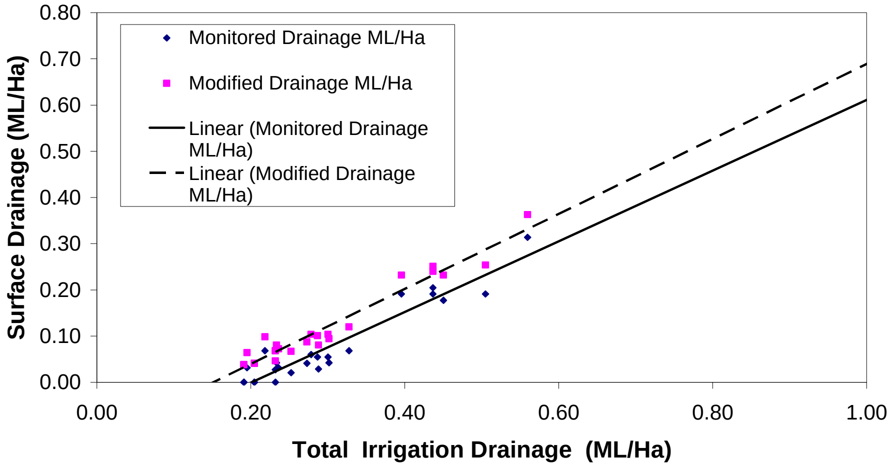


Figure 2-10 Surface Irrigation Drainage Relationship

The modelling assumes that the majority of the surface drainage water is captured and reused on the irrigated floodplain. The subsurface irrigation water is directed to the drainage pumps, via the drainage channel, and discharged to the river.

To model the post rehabilitation scenario, the phosphorus and nitrogen levels were increased by between 10 and 30% for the subsurface and surface concentrations compared to the pre-rehabilitation scenario. This is to take account of reduced drainage volumes and the likely increase in stocking rates and therefore increased fertiliser application rates, particularly phosphorus.

3. Modelling Results and Analysis

3.1 Water Application Efficiency Results

The water application efficiencies have been estimated for the pre and post rehabilitation scenarios as shown in Table 3-1. The average application efficiency provided in the table is a measure of the irrigation losses including seepage, runoff and evaporation, compared to the total volume that is applied for growing pasture. This calculation only considers the application efficiency of each irrigation (i.e. how much is used for plant growth and how much is lost through surface and subsurface drainage). The calculation is strictly not estimate of irrigation efficiency compared to the available water allocation but for many IA it would provide a reasonable estimate of the overall efficiency that could be achieved. Where the number of irrigations per annum is limited, (eg applying ELMA or less than full application) the actual theoretical efficiency would be higher than quoted for pasture irrigation.

Table 3-1 Water Application Efficiency

IA	Pre - Rehabilitation Efficiency	Post - Rehabilitation Efficiency
Cowirra North	50%	82%
Cowirra	51%	80%
Baseby	57%	81%
Neeta North	56%	81%
Neeta	52%	81%
Wall Flat	43%	79%
Pompoota	46%	79%
Mypolonga North	43%	80%
Mypolonga	52%	80%
Glen Lossie	59%	84%
Toora	50%	80%
Burdett	50%	82%
Long Flat	57%	80%
Long Island	52%	79%
Yiddinga	43%	80%
River Glen	59%	78%
Monteith	43%	80%
Woods Point	48%	78%
Jervois	41%	79%
McFarlane	59%	74%
Average	51%	80%

An estimate of the average volume of water that is extracted from the river for irrigating the floodplain pre and post rehabilitation scenarios has been extracted from the model and is shown in Table 3-2.

Table 3-2 Extractions from River for Flood Irrigation

Irrigation Area	**River Water Extractions**			**Application Rates**	
	Pre - Rehabilitation (ML / year)	**Post - Rehabilitation** (ML / year)	**Reduction**	**Pre - Rehabilitation** (ML / year)	**Post - Rehabilitation** (ML / year)
Cowirra North	4,448	2,553	43%	23.5	16.2
Cowirra	1,647	1,126	32%	23.5	16.1
Baseby	1,131	1,101	3%	16.9	14.7
Neeta North	957	743	22%	17.4	13.5
Neeta	5,417	3,956	27%	21.8	15.2
Wall Flat	6,061	3,122	48%	24.9	15.5
Pompoota	3,607	1,770	51%	22.5	15.1
Mypolonga Nth	6,556	2,001	69%	22.9	13.3
Mypolonga	4,966	2,819	43%	18.3	13.9
Glen Lossie	2,499	302	88%	16.7	13.7
Toora	2,841	774	73%	19.9	13.3
Burdett	552	161	71%	13.1	8.9
Long Flat	2,546	1,939	24%	19.7	15.0
Long Island	1,187	832	30%	16.5	11.6
Yiddinga	1,466	939	36%	22.6	13.8
River Glen	3,035	2,152	29%	18.6	13.5
Monteith	9,443	4,866	48%	24.5	14.3
Woods Point	5,372	3,794	29%	20.5	14.1
Jervois	40,097	17,667	56%	26.9	14.7
McFarlane	1,354	1,506	-11%	12.0	10.7
Total	105,183	54,124	49%	22.8	14.4

The average annual application rate for the pre and post rehabilitation scenarios has been estimated to be 22.8 ML/ha and 14.4 ML/Ha, respectively, for the LMRIA area.

The irrigation volume totals indicates that approximately a 50% reduction (approximately 50GL) in the volume of water extracted from the river may occur due to rehabilitation. This is a result of a combination of reduced irrigation rates and retirement of areas from production. This value does not include extractions for highland irrigation or for the use of ELMA for land management of the floodplain. The above extraction rates have been based on applying irrigation applications of 1Ml/ha which should produce reasonable volume of runoff which needs to be captured in tail water drains. The average water use of 0.63 ML/ha/ irrigation for a fully rehabilitated area at Woods Point has been measured in recent EPA trials. This compares well to previous data for a similar trial reuse system at Cowirra (0.7ML average application rate) EPA (2005). Therefore the 1ML/ha application figure used in this modelling study may be a conservative estimate.

3.2 Drainage and Pollutant Discharges

The modelling analysis has been used to estimate the volume of drainage water that has been discharged into the river is shown in Table 3-3 for a range of sources before rehabilitation has occurred.

Table 3-3 Estimated Drainage Volumes from Key Sources Pre Rehabilitation

	Stormwater				**Groundwater**			**Total**
Irrigation Area	**LMRIA Floodplain (ML/year)**	**Highland Irrigation (ML/year)**	**Roads & Buildings (ML/year)**	**Dryland (ML/year)**	**Regional (ML/year)**	**Irrigation Induced (ML/year)**	**Irrigation Drainage (ML/year)**	**(ML/year)**
Cowirra North	29	3	4.9	41	80	23	2,066	2,248
Cowirra	10	1.4	1.2	3	42	9	631	698
Baseby	14	3.0	3.6	50	80	30	496	676
Neeta North	8	0.0	0.6	4	40	0	422	475
Neeta	36	20	8.5	40	96	130	2,624	2,955
Wall Flat	32	15	12	9	202	153	3,448	3,871
Pompoota	24	5.3	7.6	16	96	35	1,932	2,116
Mypolonga Nth	38	22	16	11	90	432	3,781	4,390
Mypolonga	33	6.8	14	13	94	180	2,407	2,747
Glen Lossie	25	4.5	5.4	12	171	30	1,022	1,269
Toora	20	1.8	5.4	10	69	9	1,446	1,561
Burdett	4	0.0	18	4	31	0	277	333
Long Flat	19	2.7	9.5	5	67	18	1,107	1,228
Long Island	10	2.4	68	4	23	16	570	695
Yiddinga	10	1.8	8.5	14	35	12	831	912
River Glen	21	18	4.3	11	48	57	1,242	1,400
Monteith	53	18	22	13	224	144	4,638	5,111
Woods Point	36	23	7.6	3	139	54	2,787	3,049
Jervois	212	19	42	20	447	206	21,810	22,755
McFarlane	15	0.0	1.5	2	40	0	553	611
Total	648	168	260	282	2,113	1,538	54,092	59,102
Proportion	1.1%	0.3%	0.4%	0.5%	3.6%	2.6%	91.5%	100%

Before rehabilitation stormwater runoff accounted for approximately 2% of the drainage volume, groundwater approximately 6% and irrigation drainage 92% in an average year. However after rehabilitation the stormwater component is approximately 7%, the groundwater 19% and the irrigation drainage component 74%. The total drainage volumes are significantly reduced following rehabilitation. This reduction has been achieved through improved irrigation efficiency due to rehabilitation and the reuse of the collected drainage water. The catchment maps showing the catchment area and runoff contribution from each main source for each IA is shown in Appendix A.

The volume of stormwater is a small proportion of the total drainage volume being generated for most IA's. This difference can be explained by comparing a typical irrigation application with a similar magnitude rainfall event, ie a typical irrigation event after rehabilitation will be approximately 100mm application depth which applies the same depth of rainfall as a 100 year 24hr event. The irrigation event occurs numerous times in an irrigation season with the potential to generate significant volumes of drainage water. On the other hand, rainfall is much more infrequent and less intense than an irrigation event resulting in limited or no runoff. Runoff is most likely to occur if a bay has a high antecedent moisture level due to recent irrigation. The modelling has indicated that rainfall runoff from the flood irrigated areas occurs approximately 2, 3 and 4 times per year on average at Mannum, Murray Bridge and Tailem Bend, respectively.

Impervious surfaces, such as roads, buildings and urban areas, have a much higher frequency of runoff (over 50 times per year) than the pervious surfaces. However the actual volume of runoff is still small as a proportion of the total catchment area. Roads often concentrate and channel water which can give the appearance that these areas generate large volumes of runoff, however the volumes are small compared to the total drainage water being created through irrigation.

The model was also used to predict the pollutant discharges that are pumped into the river for the pre-rehabilitation and post rehabilitation scenarios as shown in Table 3-4 and Table 3-5. The tables show the area that has been assumed to be irrigated in each scenario and the annual average drainage volume and pollutant load being discharged into the river for each IA.

Table 3-4 Pre Rehabilitation Loads

Irrigation Area	Irrigated Floodplain (Ha)	Discharge to River							
		Drainage (ML/year)	**Sol Phos** (Kg/year)	**T Phos** (Kg/year)	**TKN** (Kg/year)	**NOx** (Kg/year)	**TN** (Kg/year)	**E.Coli** (#/year)	**Salt** (tonnes/year)
Cowirra North	189	2245	3369.2	5200	10448	1174	11622	4.7E+15	2,745
Cowirra	70	698.1	1204.7	1860	3743	425	4168	1.7E+15	1,170
Baseby	67	672.3	611.6	900	2029	144	2173	5.5E+14	2,023
Neeta North	55	475.3	251.6	463	1045	122	1168	2.4E+15	563
Neeta	248	2945	1628.1	2991	6672	728	7400	1.5E+16	3,181
Wall Flat	243	3870	2226	3405	8153	634	8787	5.9E+15	5,236
Pompoota	160	2115.0	1540.7	2263	5549	321	5870	2.1E+15	2,267
Mypolonga Nth	286	4390	4342	5823	15009	1724	16733	2.3E+16	4,561
Mypolonga	271	2746.6	2680	3598	9411	1193	10604	1.4E+16	3,045
Glen Lossie	150	1266.3	976.8	1079	1974	312	2285	8.1E+14	3,256
Toora	143	1573.0	223.6	274	1322	140	1462	1.5E+14	1,741
Burdett	42	332.3	131	188	521	13	534	4.4E+13	495
Long Flat	129	1226.7	1085.1	1437	4720	136	4856	1.3E+15	1,709
Long Island	72	692.6	388	641	1597	114	1712	1.2E+15	792
Yiddinga	65	911.7	538.3	741	1891	77	1968	7.3E+14	1,054
River Glen	163	1396	1278.8	1721	4611	677	5288	4.8E+15	1,866
Monteith	386	5106	3872	5050	13344	2039	15383	9.2E+15	6,505
Woods Point	262	3048	3512.6	4398	11914	1880	13794	4.7E+15	3,166
Jervois	1490	22748	15709	19218	50304	4313	54616	4.1E+16	20,067
McFarlane	113	610.0	265.5	352	764	85	849	2.0E+13	766
Total	4604	59067	45833	61602	155,021	16,251	171,272	1.3E+17	66,211

Table 3-5 Post Rehabilitation Loads

Irrigation Area	Irrigated Floodplain (Ha)	Discharge to River							
		Drainage (ML/year)	**Sol Phos** (Kg/year)	**T Phos** (Kg/year)	**TKN** (Kg/year)	**NOx** (Kg/year)	**TN** (Kg/year)	**E.Coli** (#/year)	**Salt** (tonnes/year)
Cowirra North	158	775	889.1	1244	3165	651	3815	1.2E+15	2,135
Cowirra	70	350.5	401.6	563	1455	313	1768	5.7E+14	1,007
Baseby	75	446.0	296.0	397	1140	137	1277	2.5E+14	2,015
Neeta North	55	234.9	95.3	159	461	92	553	9.0E+14	492
Neeta	260	1291	508.2	835	2466	492	2958	4.9E+15	2,694
Wall Flat	202	1203	432	597	1857	276	2133	1.1E+15	3,193
Pompoota	117	650.1	376.8	502	1635	167	1802	4.8E+14	1,651
Mypolonga Nth	150	1120	503	608	2138	523	2660	3.0E+15	3,028
Mypolonga	203	1081.1	717	872	3012	723	3736	4.3E+15	2,325
Glen Lossie	22	318.5	89.7	87	205	49	253	8.2E+13	2,512
Toora	58	324.5	28.2	31	200	41	241	2.3E+13	1,045
Burdett	18	94.5	20	26	95	4	100	7.9E+12	362
Long Flat	129	619.0	483.7	583	2522	120	2643	6.3E+14	1,506
Long Island	72	337.2	134	202	672	89	761	4.5E+14	685
Yiddinga	68	321.7	146.1	183	637	50	687	2.1E+14	878
River Glen	160	712	521.3	636	2215	550	2765	2.2E+15	1,571
Monteith	341	1717	848	1006	3622	1072	4695	2.3E+15	4,964
Woods Point	270	1197	1032.5	1185	4323	1300	5622	1.6E+15	2,640
Jervois	1200	5476	2349	2642	9363	1806	11169	7.1E+15	12,518
McFarlane	141	495.5	251.2	302	810	106	917	1.6E+13	819
Total	3769	18764	10123	12659	41,993	8,561	50,554	3.1E+16	48,042

The reductions in drainage volumes and pollutant loads being pumped into the river are illustrated in Table 3-6.

The reduction in the pollutant loads are based on achieving a reasonable estimate of current discharges to the river and having an understanding of the impact that rehabilitation will have on future pollutant loads. These results will need to be verified by continuous monitoring of pollutant discharges prior to and following rehabilitation.

Table 3-6 Changes to Drainage and Pollution Loads

Irrigation Area	**Reduction after Rehabilitation**								
	Irrigated Floodplain	**Drainage**	**Sol Phos**	**T Phos**	**TKN**	**NOx**	**TN**	**E.Coli**	**Salt**
Cowirra North	16%	65%	74%	76%	70%	45%	67%	74%	22%
Cowirra	0%	50%	67%	70%	61%	26%	58%	66%	14%
Baseby	-12%	34%	52%	56%	44%	5%	41%	54%	0%
Neeta North	0%	51%	62%	66%	56%	25%	53%	62%	13%
Neeta	-5%	56%	69%	72%	63%	32%	60%	68%	15%
Wall Flat	17%	69%	81%	82%	77%	56%	76%	80%	39%
Pompoota	27%	69%	76%	78%	71%	48%	69%	76%	27%
Mypolonga Nth	48%	74%	88%	90%	86%	70%	84%	87%	34%
Mypolonga	25%	61%	73%	76%	68%	39%	65%	70%	24%
Glen Lossie	85%	75%	91%	92%	90%	84%	89%	90%	23%
Toora	59%	79%	87%	89%	85%	71%	84%	85%	40%
Burdett	57%	72%	85%	86%	82%	66%	81%	82%	27%
Long Flat	0%	50%	55%	59%	47%	11%	46%	50%	12%
Long Island	0%	51%	65%	68%	58%	22%	56%	63%	14%
Yiddinga	0%	65%	73%	75%	66%	35%	65%	71%	17%
River Glen	2%	49%	59%	63%	52%	19%	48%	55%	16%
Monteith	12%	66%	78%	80%	73%	47%	69%	75%	24%
Woods Point	-3%	61%	71%	73%	64%	31%	59%	66%	17%
Jervois	19%	76%	85%	86%	81%	58%	80%	83%	38%
McFarlane	-25%	19%	5%	14%	-6%	-26%	-8%	22%	-7%
Total	18%	68%	78%	79%	73%	47%	70%	77%	27%

It is evident that the interception of the surface water for reuse on the floodplain reduces the nutrient and bacterial load being returned to the river. This reduction is a result of capturing surface water which contains the highest concentrations of nutrients and bacteria, particularly following fertiliser application. Research completed by Nexhip, et al (1999) at the Institute of Sustainable Irrigated Agriculture shows that careful management of water, particularly after fertiliser application, can reduce annual nutrient loads by over 70%. This is in good agreement with the predictions in this modelling study.

The modelling also indicates that the reduction in oxidised nitrogen discharged to the river is lower than for other pollutants. This is because the subsurface irrigation drainage water contains higher concentrations of oxidised nitrogen than the surface drainage water. The principal mechanism available for reducing the load of oxidised nitrogen discharged to the river is to reduce the volume of drainage discharge through best management practices.

3.3 Accuracy of Model Estimates

An analysis of the key parameters used to undertake the modelling has been provided below. A qualitative estimate of the reliability and consistency of each parameter and the potential impact that this reliability has on the results of the modelling is provided below.

Stormwater Runoff Modelling

Parameter	Reliability	Impact	Comment
Evaporation	M	L	Significant variation in daily evaporation. Pan evaporation modified to achieve values for each zone of the LMRIA
Rainfall	H	L	A number of rainfall stations are distributed across the LMRIA
Soil Parameters			
- Floodplain	H	L	Good understanding of soil properties. Has a relatively uniform profile across the LMRIA.
- Highland	L	M	Highland soil properties extremely variable across the LMRIA. Limited data available to determine suitable soil moisture storage parameters. Largest impact occurs with an underestimation of significant events.
Irrigation schedule	M	M - H	How irrigation is scheduled can have a significant impact on the volume of rainfall runoff that is generated from an area. The modelling assumes that the bays are irrigated in 1/3 sections at a time. In practice, irrigation will be spread over a wider number of days. This will result in stormwater runoff occurring more frequently than shown in the modelling. However the total volume of runoff may not change significantly over an average year.
Irrigation practices	M	H	Significant runoff volumes can be generated from stormwater runoff when irrigation proceeds a rain event. The highest risk occurs when the majority of the bays are irrigated together. Also produces a higher risk for the post rehabilitation option due to size of tailwater drains.

Stormwater Runoff Modelling

Parameter	Reliability	Impact	Comment
Catchment area -Irrigated floodplain	H	L	Taken from GIS data developed from Rehabilitation Concept plan
- Irrigated highland	M	M	Taken from GIS data developed from Rehabilitation Concept plan
- Roads and buildings	M	L (M)	Estimated from aerial photography. Impact considered to be medium for IA having areas of urban catchments and roads.
- Dry land	H	M	Modelling may overestimate runoff from frequent events but underestimates runoff for significant rainfall events.

Water Balance & Pollutant Modelling

Parameter	Reliability	Impact	Comment
Evaporation & Crop Factors	M	L	Use average monthly evaporation data to determine irrigation scheduling. Crop factors adjusted to achieve # of irrigations / annum
Rainfall	H	L	Use monthly totals to determine portion of effective rainfall to determine irrigation scheduling requirements.
Area of Irrigated Floodplain	H	L	Irrigated floodplain varies over time (particularly recently as water traded).
Irrigation Scheduling	M - L	H	The modelling of the post rehabilitation scenario has been based on irrigating to achieve optimum pasture production (except where current practices differ). Changes in practices will change the drainage volume generated and discharged to the river
Drainage volume calibration data	M - L	V/H	Derived from drainage pump run hours and an assumed pump operating efficiency (actually efficiency varies over time and is dependant on level of maintenance and servicing that occurs for each pump).
Drainage salinity calibration data	M	M	Weekly to monthly grab samples. Salinity readings used to estimate regional groundwater inflows where more detailed and reliable studies are not available. Modelling assumes all salt entering floodplain is discharged into the river.

Water Balance & Pollutant Modelling

Parameter	Reliability	Impact	Comment
Irrigation Application rates	M	M - H	The modelling assumes that the irrigation application rate is 1.0ML/ha. The actual irrigation rates will vary from bay to bay and from farm to farm. A number of farms have achieved application rates of around 0.6 to 0.7 ML/ha. Therefore the above analysis may be conservative, particularly if a majority of irrigators achieve this level of application. However the long term sustainability of applying lower application rates is still unknown.
Pollution Load			
Pollutant calibration data	M	H	Weekly to monthly grab samples taken for most IA's. The pollutant load being generated for each area was calibrated using the recorded data that is available.
Salt Load calibration data	M	M	Salt discharges calibrated against limited data. Estimates based on a number of assumptions which would impact on the overall estimate of groundwater inputs.
Irrigation runoff relationship	M	M - H	Post rehabilitation drainage volume is dependant on the proportion of drainage water that enters the drainage channel via subsurface movement. The modelling assumes that tailwater drains only intercept surface runoff.
Pollutant runoff relationship	H	H	If the assumed differences in concentration for subsurface and surface drainage changes the reduction in pollutant loads will change.

It should be highlighted that input data used in the model directly impacts on the predictions of nutrient discharge to the river and pasture production using drainage water. Errors in this data may significantly alter the results estimated using the model.

4. Summary & Recommendations

This report outlines the work undertaken to estimate the volume of drainage water from a range of sources within each IA before and after rehabilitation. Corresponding pollutant loads have been estimated including what improvements are expected once rehabilitation has been completed.

Models were calibrated against the existing data, including drainage volumes, recorded salinity levels and pollutant concentrations.

This study estimated that the average annual application rates are 22.8 ML/ha before rehabilitation and 14.5 ML/ha after rehabilitation. The irrigation volume totals indicates that approximately a 50% reduction (approximately 50GL) in the volume of water extracted from the river may occur due to rehabilitation and restructuring. This is a result of a combination of reduced irrigation rates and retirement of areas from production. The calculated reductions do not include extractions for highland irrigation or use of ELMA for land management of the floodplain.

Before rehabilitation stormwater runoff accounted for approximately 2% of the drainage volume, groundwater approximately 6% and irrigation drainage 92% in an average year. However after rehabilitation the stormwater component has been estimated to be approximately 7%, the groundwater component 19% and the irrigation drainage component 74%.

The model estimates that the drainage volume will be reduced by 60 to 70% for the LMRIA. The significant reduction in the proportion of drainage water being estimated from the study is due to increased irrigation efficiency resulting from rehabilitation and restructuring and the reuse of the collected drainage water. Pollution loads are estimated to be reduced by 70 to 80% for Phosphorous, Nitrogen and E.Coli, apart from Oxidised Nitrogen which will be reduced by 40 to 50% and salt is only reduced slightly (due to groundwater and subsurface irrigation inputs continuing).

The modelling results are extremely encouraging for achieving the goal (of the rehabilitation program in the LMRIA) of improving the quality and quantity of water in the River Murray. Full completion of rehabilitation should also greatly assist irrigators to efficiently manage their water during the current drought conditions and water restrictions.

Recommendations

The following recommendations are made from this study to improve any future modelling and to confirm the results of the modelling presented in this report:

- The current monitoring program being conducted on the LMRIA be continued to confirm so that the improvements from rehabilitation estimated by this study are being achieved in practice.
- Calibration of the drainage pumps flow rates should be undertaken at regular intervals so that future drainage volumes can be calculated with reasonable accurately.
- Periodically review the reductions in drainage and pollutant loads being discharged into the river compared to the model predictions.

5. References

Barnett, S (2000) *Personal Communication*

Desmier RE, Schrale G (1989), 'Saline Accretions to the Lower Murray River from Irrigated River Flats 1980 - 1983', Technical Report No. 145, SA Dept of Agriculture.

Eco Management Services (2003), 'Water Quality Monitoring to Examine Return Water Characteristics and Pollutant Loads', Report prepared for LMI.

Environment Protection Authority (2006), 'Letter to Irrigators regarding Lower Murray Water Quality Monitoring Project'

Murray P & Philcox M (1995), 'An assessment of Irrigation Runoff Quality Draining from Flood Irrigated Dairy Pastures of the Lower Murray'.

MUSIC 'Model for Urban Stormwater Improvement Conceptualisation Ver 3' CRC for Catchment Hydrology, Urban Stormwater Quality Program.

Nexhip KJ, Mundy GN, Collins MD & Austin NR (1997), 'Development of nutrient water quality targets for irrigated pasture sub-catchments'. Final Report Project I5037, Institute of Sustainable Irrigated Agriculture.

Philcox, M (2000) *Personal Communication,* MBP Consulting

Price, P (2000) *Personal Communication,* Price Merrett Consulting

River Murray Catchment Water Management Board (2002) 'Water Allocation Plan for the River Murray Prescribed Watercourse'.

Tonkin Consulting (2001) 'Monteith Irrigation Area, Rehabilitation and Restructuring Options. Final Report.' Lower Murray Irrigation Action Group.

Tonkin Consulting (2001) 'Wall Flat Irrigation Area, Rehabilitation and Restructuring Options. Final Report.' Lower Murray Irrigation Action Group.

Tonkin Consulting (2002) 'Mypolonga Irrigation Area, Rehabilitation and Restructuring Options. Final Report.' Lower Murray Irrigation Action Group.

Tonkin Consulting (2002) 'Long Flat Irrigation Area, Rehabilitation and Restructuring Options. Final Report.' Lower Murray Irrigation Action Group.

Tonkin Consulting (2003) “Long Island Irrigation Area, Rehabilitation and Restructuring Options. Final Report’ The Department of Water, Land & Biodiversity Conservation

Tonkin Consulting (2003) “McFarlane Irrigation Area, Rehabilitation and Restructuring Options. Final Report’ The Department of Water, Land & Biodiversity Conservation

Tonkin Consulting (2003) “Baseby Irrigation Area, Rehabilitation and Restructuring Options. Final Report’ The Department of Water, Land & Biodiversity Conservation

Tonkin Consulting (2004) ‘LMRIA Irrigated Floodplain Rainfall Runoff Modelling’ Environmental Protection Authority.

Tonkin Consulting (2006) ‘Environmental Improvement and Management Plan, Lower Murray Reclaimed Irrigated Areas’ Environmental Protection Authority.

Woods, M (1999), 'Improved Irrigation Practices for Forage Production', NRE, Institute of Sustainable Irrigated Agriculture, Tatura, Vic. Module 2, Alternative Irrigation Technologies, Desk Top Analysis, Draft Final Report (since accepted).

Appendix A

Catchment Summary Maps