Iraq Salinity Project **Technical Report 10**

Salt Management:
The Australian Experience

Reporters:

Wendy Minato, Dr Richard Soppe and Ray Evans

The Iraq Salinity Project is an initiative of Government of Iraq, Ministries of Agriculture, Water Resources, Higher Education, Environment, and Science and Technology, and an international research team led by ICARDA – the International Center for Agricultural Research in the Dry Areas, in partnership with the University of Western Australia, the Commonwealth Scientific and Industrial Research organization (CSIRO) of Australia, the International Water Management Institute (IWMI), Sri Lanka, and the International Center for Biosaline Agriculture (ICBA), Dubai, United Arab Emirates.

This research is funded by the Australian Centre for International Agricultural Research (ACIAR), AusAID and the Italian Government.

This technical report series captures and documents the work in progress of the Iraq Salinity Project, in its seven research themes, working at the regional, farm and irrigation system scales. Technical reports feed into the *Iraq Salinity Assessment*, a synthesis and solutions to solving the problem: Situation Analysis (Report 1); Approaches and Solutions (Report 2) and Investment Options (Report 2).

Key words: southern Iraq, central Iraq, spatial distribution, remote sensing, irrigation, salinity mapping.

This report was written and compiled by Wendy Minato, Dr Richard Soppe and Ray Evans

With Dr Weicheng Wu (Leader), Dr Feras Ziadat (Co-Leader), Dr Eddy De Pauw-International Centre of Agriculture Research in Dry Areas (ICARDA), Richard Soppe (SCIRO) and Alexander Platonov (IWMI).

http://icarda.org/iraq-salinity-project/teaser

Salt Management:
The Australian Experience

Wendy Minato, Dr Richard Soppe and Ray Evans

A contribution to the Iraq Salinity Project

Table of Contents

Introduction

Salinity is the accumulation of soluble salts (predominantly NaCl) in soil and water, usually over an extended period of time. For most people the term has negative connotations, associated as it is with long-term land and water degradation. Problems arise when increasing salt concentrations negatively affect soil and water quality, plant growth, agriculture, the built environment and biodiversity.

Salinisation is both the process and outcome of salt accumulation. The former occurs naturally in conjunction with landscape and soil formation. Salt may come from a number of sources including wind-borne salt from the ocean, salts dissolved in rainwater, marine sediments and weathering of the earth's crust. Although the salt content of rainfall is low, rainfall can be the primary source of salt in some areas (Department of Environment and Resource Management QLD 2011).

Australia's dry climate with low rainfall and high evaporation makes it a naturally salty continent with limited capacity to drain salt and water (Dryland Salinity of Australia Audit, NLWRA, 2000). Changes in land use since European settlement have accelerated the process of salinisation by disturbing the natural hydrology and mobilizing underground salt stores. Extensive clearing of native vegetation for grazing and cropping has increased the amount of water leaking past the root zone and into the groundwater system. A combination of overwatering and insufficient drainage associated with irrigated agriculture has led to saline soils and rising saline water tables. Salt problems associated with agriculture are not new; the decline of civilisations in ancient Mesopotamia has been attributed to silting and salinisation (Jacobsen & Adams, 1958; Hiller as cited in Beresford et al. 2001). More recently it has been estimated that over 6% of the world's land is affected by either salinity or sodicity and the percentage is much higher for cultivated land; nearly 20% of irrigated areas have been estimated to be salt affected.

Although salinity can cause production losses, seasonal variability in rainfall, temperature, solar radiation and the incidence of pest and disease can have a greater effect on yields in the short term. However, salinity can be an important issue for individual landholders depending on the position of their property in the catchment because substantial proportions of individual properties can be affected (ref). Often, landholders become aware of salinity on their land only after observing a gradual loss of productivity over a number of years (Department of Environment and Resource Management QLD 2011).

Salinity rarely occurs in isolation from other natural resource problems such as decreasing soil and water quality, erosion and loss of native vegetation. For example, water coming from areas affected by dryland, irrigation or urban salinity can flow into creeks and rivers causing salinity levels to rise. This reduces water quality, affecting the health of plants and animals and reducing farm income. Poor water quality may also have an impact on town water supply, with social and economic impacts for both rural and urban dwellers in the form of rising council rates and taxes.

Types of Salinity

Primary salinity develops naturally, particularly in areas where rainfall is insufficient to leach salts from the soil and where evaporation rates are high. It manifests as naturally occurring saline areas and saline soils in low rainfall areas which are generally flat and poorly drained (Beresford et al. 2004). Examples are salt pans, salt marshes, the marine plains found around the coastline of Australia, and the salt lakes in central and western Australia (Dryland Salinity of Australia Audit, NLWRA, 2000)[see Figure 1].

Australia has vast reserves of salt stored beneath the land surface, much of it derived from the ocean. Carried inland by wind and rain and deposited in small amounts over long periods of time, salt has slowly leached downwards and accumulated deep in the soil profile. Australian native vegetation is predominantly perennial and deep rooted, well adapted to a dry climate; effective use of available water meant very little runoff or infiltration to below the root zone and so accumulated salt was stored below the root zone, or out of the system.

Secondary salinity is the outcome of changes in land use due to human activities, primarily for agricultural purposes, and is found in both irrigated and dryland agricultural areas worldwide. In non-irrigated farmland in Australia secondary salinity is primarily due to clearing of native vegetation, or land management that has increased groundwater recharge leading to a redistribution of soil soluble salts (Dryland Salinity of Australia Audit, NLWRA, 2000; Peck and Hatton 2003)

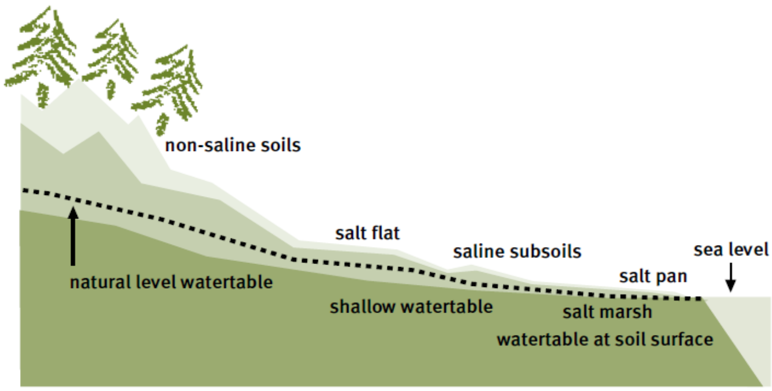

Figure 1: Typical salinity occurrence (Source: DERM QLD 2011)

Dryland salinity occurs in non-irrigated areas, usually because deep-rooted perennial vegetation has been removed from recharge areas for grazing or cropping. Crops and pastures have shallow root systems and shorter growth cycles and use less water, increasing the amount of leakage to the groundwater system (recharge). Extra groundwater causes the watertable to rise, bringing with it dissolved salts that move towards the soil surface and into the root zone. Saline groundwater may reach the surface (discharge) in low-lying areas or at the break of slope, or flow underground directly into streams and rivers (NSW Environment Website, 2012). In some cases this results in white salt scars on the soil surface, particularly in low lying areas such as rivers, streams and wetlands (Dryland Salinity of Australia Audit, NLWRA, 2000)

Dryland salinity may also be caused by the exposure of naturally saline soils such as hyper-saline clays. Sodic soils (soils that have a high concentration of sodium ions relative to other ions such as calcium and magnesium) can also cause salinity. When wet, sodic soils disperse causing soil aggregates to separate and block soil pores. When dry, sodic soils are often hard and dense, and form a crust on the soil surface. The poor soil structure reduces water infiltration and there is little or no leaching of salts below the root zone. Sodic sub-soils can create a perched watertable leading to water logging of the root zone.

Irrigation salinity occurs when there is a localised rise in the level of groundwater caused by the application of irrigation water. Rising water tables transport salts into the root zone affecting plant growth and soil structure. Salt remains behind in the soil when water is taken up by plants or lost to evaporation. As with dryland salinity the problem is compounded by the replacement of native vegetation with crops and pastures. When water used for irrigation is derived from salty rivers or groundwater, additional irrigation is necessary to leach salts past the plant root zone (Podmore 2009b; NSW Government Environment Website 2012).

Inefficient irrigation and drainage systems are a major cause of excess leakage to the water table (Figure 2). Seepage from irrigation channels, drains and dams, and watering causing ponding for long periods, leads to recharge (DPI 2005). Poor water distribution across paddocks leaves some areas under-irrigated (= salt accumulation where water tables are high), and other areas over-irrigated and waterlogged. Groundwater mounds can develop under irrigation areas as a result of leakage from inefficient systems and restrictive layers (Podmore, 2009b).

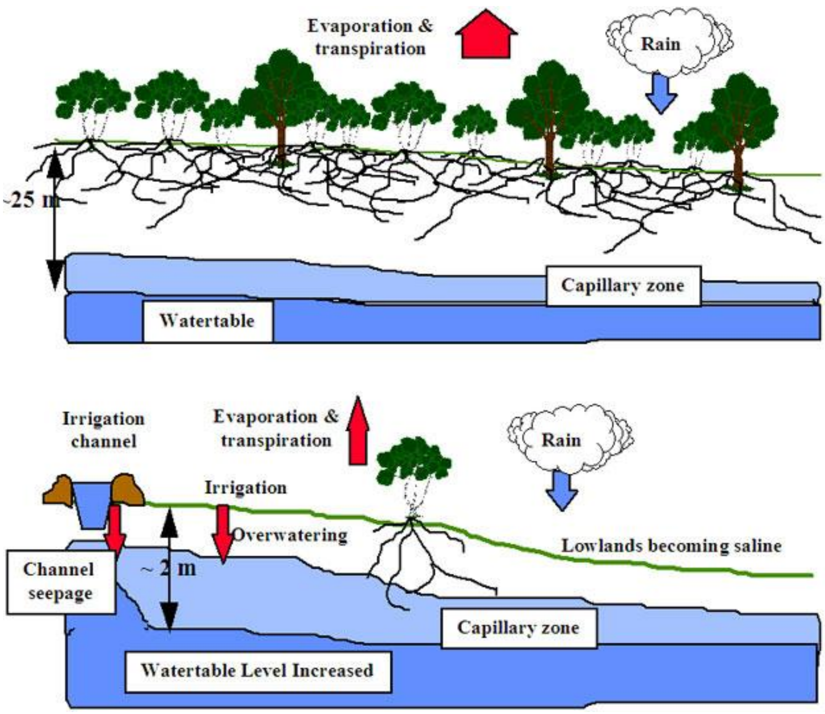

Figure 2: Processes and causes of Irrigation salinity (Source: DPI 2005)

Continual under-irrigation also increases salinity in the root zone and periodic flushing or leaching of the soil is necessary to prevent salt accumulation to levels that limit productivity. Inappropriate matching of crop, soil type and irrigation method can also cause excessive leakage.

Salt

Salts found in soils come from three main sources:

- From the breakdown of parent rock: a very slow process;
- From geological inundation by the oceans; and
- From wind-blown salt, usually in rain water from the ocean.

Salt in rainfall in Australia can range from 20 kg/ha/per annum (usually for inland areas with low rainfall) to more than 200 kg/ha/per annum (usually coastal with high rainfall). For most of Australia, this is the primary source of stored salts (WA Agriculture website, 2012).

The amount of salt stored in the soil profile depends on the ratio of salt input (through rainfall) and output (loss) through leaching or drainage from the catchment. In areas where potential evaporation is high and rainfall is low (semi-arid and arid zones), salt enters the soil profile but is not flushed out. It therefore accumulates, usually below the root zone of native vegetation. Very long periods of time are needed for catchment salt stores to be reduced to the point where the amount entering the system equals the amount leaving the system, that is, a *salt balance* is achieved. The net amount of salt that exits a catchment via stream flow indicates the time it will take for the catchment to flush its store of salt, when compared with the total mass of salt stored in that catchment (ANRA, 2012; WA Ag Website 2012; DERM Salinity Handbook 2001).

Irrigation water adds appreciable amounts of salt, even where the water is good quality (for instance, containing only 200-500 mg/kg of soluble salt). Irrigation water with a salt content of 500 mg/kg (i.e. 500 mg/L) contains 0.5 tonnes of salt per 1,000 m^3. Since crops require 6,000-10,000 m^3 of water per hectare each year, one hectare of land will receive 3-5 tonnes of salt. Because the amount of salt removed by crops is negligible, salt will accumulate in the root zone and, if long term soil health is to be achieved, must be leached by supplying more water than is required by the crops. If overall drainage below the root zone is not adequate, the excess water causes the water table to rise and salts to accumulate in the root zone (Salinity plant stress website 2012).

Measuring Salinity

Salinity is measured by its electrical conductivity. The SI unit of electrical conductivity (EC) is dS/m. Table 4 shows the relationship to other units of conductivity, and to NaCl concentration (10 mM NaCl has an EC close to 1 dS/m). It is common practice in Australia to measure soil salinity as chloride concentration in a 1:5 (dry soil to water) extract.

Table 1: Typical salt content of water for different uses

Salinity of Water (EC Units)	**Impact** Rainwater = <50 EC units Sea water = 50 000 EC units
650	Salinity damage can occur to irrigated crops, particularly horticultural crops
800	Based on World Health Organisation standards, 800 EC is considered to be the desirable maximum level for water quality. Above this level, water becomes increasingly unpalatable. Increasing scale problems in water supplies
>1500	Options for consumptive uses of water are restricted. Irrigation of most horticultural crops, leguminous pastures and forage crops is not possible. Direct adverse biological effects are likely to occur in river, stream and wetland ecosystems. Lethal impacts on many aquatic macrophytes and adverse effects on some invertebrate species. Possible sub-lethal effects of riparian vegetation.
>5000	The value that divides fresh water from saline water. Above this level, few crops can be irrigated. Biodiversity is also substantially reduced – most freshwater aquatic fauna cannot survive.

Source: (South Australia. Dept. for Water 2001)

What is EC?

As salt conducts electricity, one of the most widely used and convenient methods of measuring salinity in water is by its electrical conductivity (EC) properties; the higher the EC, the higher the salinity. Typical water salinities in EC units for different uses are given in Table 1. Table 2 provides different measurement units for salinity and their interrelationship.

The salt mass balance for any catchment refers to the equilibrium between the mass of salt entering and leaving the catchment (DERM, 2012). For example, salt entering the catchment in the form of a large volume of water with a low salt concentration (eg rainfall) can be in balance with salt leaving the catchment as a small flow of water of very high concentration. Inputs to a catchment are generally rainfall and areas of irrigation and sometimes diversions from neighbouring catchments (Jolly et al. 1997). Water and salt outputs are usually taken as streamflow, and diversions of water out of a catchment. The ratio of inputs to outputs is a key indicator of a catchment's salinity status. Table 3 shows the average ratios for the MDB.

Table 2: Units for measuring salinity and conversion factors

Conversion factors relating total dissolved salts or pure NaCl to an electrical conductivity (EC) of 1 dS/m (1 deciSiemen/metre) are given, along with equivalent units of various types, old and new.

The conversion of EC of 1 dS/m to total dissolved salts (640 mg/L) assumes a composition of salts that is common in groundwater across the world. The exact factor varies from 530 (if the salt is predominantly NaCl) to 900 (if the salts are formed predominantly from divalent ions).

Measurement and units	Application	1 dS/m is equal to:	Equivalent units
Conductivity (dS/m)	soils	1	1 dS/m = 1 mS/cm = 1 mmho/cm
Conductivity (µS/cm)	irrigation and river water	1000 µS/cm	1 µS/cm = 1 µmho/cm
Total dissolved salts (mg/L)	irrigation and river water	640 mg/L (approx.)	1 mg/L = 1 mg/kg = 1 ppm
Molarity of NaCl (mM)	laboratory	10 mM	1 mM = 1 mmol/L

Source: http://www.plantstress.com/Articles/salinity_i/salinity_i.htmSalt Mass Balance

Table 3: Estimated average annual salt output/input ratios (SO/SI) for selected catchments based on chloride inputs in rain and stream outputs compared with those estimated by Jolly et al (1997).

River	Location	SO/SI Jolly *et al.* (1997a)	Mean EC	Output [Cl]/TDS (kg kg^{-1})	Input [Cl]/TDS (kg kg^{-1})	SO/SI Chloride
Murray	Heywoods	1·88	56	0·11	0·23	0·88
Murray	Yarrawonga	1·26	61	0·14	0·23	0·77
Mitta Mitta	Tallandoon	1·28	56	0·07	0·23	0·37
Kiewa	Bandiana	2·38	50	0·11	0·23	1·16
Ovens	Peechelba East	1·91	77	0·18	0·23	1·54
Murrumbidgee	Angle Crossing	1·40	138	0·14	0·27	0·79
Murrumbidgee	Halls Crossing	1·91	205	0·14	0·27	0·84
Goodradigbee	Wee Jasper	1·93	66	0·11	0·23	0·95
Lachlan	Forbes	4·56	440	0·17	0·23	3·39
Macquarie	Dubbo	2·90	330	0·14	0·30	1·44
Castlereagh	Coonamble	0·61	485	0·23	0·32	0·50

Source: White et al 2009.

Managing Salinity

There are no simple solutions to the problems caused by increased levels of salinity because of the large scale over which it occurs and because of the time lag between cause and effect (CSIRO / CLW Salinity Fact Sheet, 2008). Groundwater can take years to respond to changing inputs and there is a need to consider the complete system—including people and socioeconomic factors. Management strategies that are cost-effective and easy to implement are required.

No one management option will succeed; a mix of protection, prevention, restoration, land use change, engineering and saline resource management techniques is required. Salinity can be managed by prevention, treating the cause, ameliorating the symptoms or a combination of these.

Possible solutions include:

Land use change (generally more applicable to dryland salinity management) to reduce groundwater recharge – this might include the use of high water use crops and pasture, revegetation, increased commercial tree production for large areas of current crop and pasture zones, farming systems that use a combination of annual and perennial plants, companion planting, crop rotation and best practice, new crops specially bred to reduce deep drainage and nitrogen leakage, a means of determining the ideal locations for tree crops, perennials and high value annuals.

Protect those assets (infrastructure, biodiversity, soils, water) that are at risk

Prevention – this will include maintaining natural water balance processes where possible, and the design of new farming and land use systems that manage the salt and water balance

Engineering options such as simple, on-paddock surface water management measures such as banks and drains and larger scale measures such as deep drains, subsurface drains, siphons, windmill & solar pumping, and interception and diversion systems. Subsurface drainage removes excess water from below the ground surface. Common methods are groundwater pumping from suitable shallow aquifers (in irrigation areas) and tile or mole drainage.

Living with and using salt – Salt-tolerant plants for stock fodder, horticulture or agro-forestry, saline aquaculture and extraction of high grade salt (NLWRA, 2000).

Whole-farm plans can be used to protect and enhance environmental features while increasing farm profitability, by integrating natural resource management into day to day farming decisions.

Surface drainage reduces accessions to the watertable as well as providing a wide range of benefits on farms. Surface drainage programs in irrigation areas provide financial and technical support to survey, design and construct subregional community drainage schemes.

Specific steps for managing irrigation salinity

All irrigation farmers can take steps to improve irrigation management. These include:

- Using a whole-farm plan for a structural approach to farm development.
- Matching water application to the needs of pastures and crops.
- Improving pasture and crop growth to use more soil water.
- Watering paddocks in less than 6 hours.
- Draining paddocks as quickly as possible after irrigation.
- Reusing all drainage water in future irrigations.

The Murray Darling Basin

The Murray-Darling Basin drains one-seventh of the Australian land mass (Figure 3), and is currently by far the most significant agricultural area in Australia. In 2005-06 the Murray Darling Basin contained 65% of Australia's irrigated land (1.65 million ha). Most of the Basin is flat, low-lying and far inland, and receives little direct rainfall. The many rivers it contains tend to be long and slow-flowing, and carry a volume of water that is large only by Australian standards.

Quick Facts

- Catchment area for the Murray and Darling rivers and their tributaries
- Total of 23 river valleys
- Basin area over 1 million square kilometres
- 14% of total area of Australia
- Annual average rainfall 530,618 gigalitres; 94% of rainfall evaporates; 2% drains into the ground; 4% ends up as runoff
- The basin generates 39% of the national income derived from agricultural production
- Produces 53% of Australian cereals grown for grain, 95% of oranges, and 54% of apples
- Supports 28% of the nation's cattle herd, 45% of sheep, and 62% of pigs.

(MDBA website)

The water in the Murray-Darling river system comes from a very small percentage of the Basin area, mainly along the southern and eastern rim. Almost 86% of the catchment area contributes very little, or no regular run-off water to rivers. The rivers have very low gradients over most of their lengths, which cause them to flow slowly as they meander across the vast inland plains.

Figure 3: Murray Darling Basin (Source: Wiki)

Basin Level

During the 1980s issues of environmental health, sustainability, water availability and water quality emerged as significant issues in Australia. Symptoms of resource degradation such as declining water quality, increasing salinity, toxic algal blooms and loss of biodiversity became more evident.

About the MDBC

The Murray-Darling Basin Authority is the principal government agency in charge of managing the Murray-Darling Basin in an integrated and sustainable manner. The Authority (MDBA; also previously known as the Murray Darling Basin Commission) is the statutory agency that manages, in conjunction with the Basin states, the Murray–Darling Basin's water resources in the national interest. The Authority reports to the Australian Government Minister for Sustainability, Environment, Water, Population and Communities.

With the creation of the Authority in 2008, for the first time, a single inter-governmental body assumed responsibility for planning the integrated management of water resources of the Murray-Darling Basin. In addition to the Commission's former functions, the Authority's role includes:

- preparing the Basin Plan, for adoption by the Minister for Sustainability, Environment, Water, Population and Communities, including setting sustainable limits on water that can be taken from surface and groundwater systems across the basin;
- implementing and enforcing the basin plan;
- advising the minister on the accreditation of state water resource plans;
- developing a water rights information service which facilitates water trading across the Murray-Darling basin;
- measuring and monitoring water resources in the basin;
- gathering information and undertaking research; and
- educating and engaging the community in the management of the basin's resources

MDB Salinity & Drainage Strategy (1988)

Level: Basin

Objective: To maintain water quality of the Murray River, prevent future land degradation and conserve the environment with respect to salinity

Method: Four programs consisting using land management techniques and operating rules regarding use of saline water

Due to rapidly rising salinity levels in the Murray river the Murray Darling Basin Commission developed the "Salinity and Drainage Strategy" in 1988 (MDBC, 1989).

The Salinity and Drainage (S&D) Strategy was an interstate program of action coordinated by the Murray-Darling Basin Commission. Acceptable guidelines for managing salinity and drainage along the Murray River were put together with the cooperation and input of community, industry and government representatives from the states of NSW, Vic and South Australia, and the Federal Government (DSE, DPI, 2005).

The specific objectives of the Strategy were to:

- Improve water quality in the River Murray;
- Control existing land degradation, prevent further land degradation, and where possible rehabilitate land resources;
- Conserve the natural environment and preserve sensitive ecosystems with respect to salinity.

The S&D Strategy program consisted of four main elements:

- Salt interception schemes - interception of saline groundwater before it enters the river;

- New operating rules for some storages to reduce the loss of water through evaporation and thereby reduce river salinities;
- The development of improved land management techniques, more efficient irrigation technology, and new crops for saline environments; and
- Land management schemes to control land salinisation and waterlogging.

The Strategy aimed to strike a balance between reducing river salinity in the lower Murray, with benefits for the 1.25 million urban, industrial and irrigation consumers in South Australia, while also providing the opportunity to control waterlogging and land salinisation in upstream irrigation areas of New South Wales and Victoria. The strategy was based on a balance between engineering (interception schemes) and non-engineering (land and water management) solutions (MDBC, 2003). An accounting framework was developed to "license" all existing and new salt inputs into the Murray River system, making all States accountable for future actions leading to salt inputs to the river. It also ensured that communities did not undertake activities that worsened salinity problem in other areas (MDBC, 2003). Any new salt inputs would first have to be offset by salinity credits earned by stopping existing saline drainage to the river, thus maintaining the 1988 salinity position. This strategy led to a situation in which all new irrigation development from 1988 onwards had to be undertaken with highly controlled drainage. Thus irrigation water use has increased and drainage has effectively been restricted; this ultimately has contributed to reduced river flows.

The S & D Strategy was a milestone in the management of natural resources in Australia in that it was the first time that state governments agreed to jointly tackle a specific problem across borders, including an agreement to spend funds outside of their jurisdiction (NSW Salinity Strategy, 2000).

Salinity Audit

In late 1999, the Murray Darling Basin Ministerial Council released the Salinity Audit of the Murray Darling Basin, which included a review of the 1988 Salinity & Drainage Strategy. The audit was more sophisticated than earlier work in that it took into account climatic variations and diversions and used modeling to predict future trends rather than just describing historical trends. The overall basin audit was based upon predictions undertaken by each state government (NSW Salinity Strategy 2000).

This audit provided information on salinity trends, river valley by river valley, for salt mobilisation in the landscape and its expression in rivers. It predicted significant increases in river salinities and salt loads in the Murray and Darling Rivers and the major catchments of these rivers. Average river salinities in key tributary rivers were predicted to rise significantly, endangering their use for irrigation and urban purposes within 20 to 50 years, and about 3.4 million ha of land in the eastern and southern regions of the Basin will be salt-affected within 50 years (Murray Darling Basin Commission, 2001)

If no intervention was to occur, the reduction in lower River Murray salinity achieved over the last decade would be cancelled out within 20 to 30 years, and median salinity levels would exceed the

Australian Drinking Water Guidelines for good quality water within 50 to 100 years (Murray Darling Basin Commission 2001).

A key finding of the salinity audit was that much of the mobilised salt was not being exported via the rivers to the sea but rather stays in the landscape or is diverted into irrigation areas and floodplain wetlands (MDBC Salinity Audit)

In addition to an increased understanding of salinity impacts on assets and values the audit led to the development of methodology for setting salinity targets within the basin (NSW Salinity Strategy, 2000)

Basin Salinity Management Strategy (BSMS)

The 1999 Salinity Audit found that the Salinity & Drainage Strategy had significantly improved salinity levels in the River Murray. However, the gains would be offset by large increases in salinity from the dryland areas of the basin if the combined impacts of irrigation, dryland, and natural salinity were not managed using a coordinated basin-wide approach.

The Basin Salinity Management Strategy (BSMS) (2001-2015) is a basin-wide agreement that establishes salinity targets for the main river and the tributary valleys of the system. The BSMS requires that responsibility for protecting key natural resource values be shared by both valley communities and the States. The strategy is consistent with the principles of the Integrated Catchment Management Policy Statement (ICM).

The BSMS has four main objectives that will be achieved through the applications of actions to meet salinity targets:

- To maintain the water quality of the shared resources of the Murray and Darling Rivers; river salinity to be maintained at <800 EC for 95% of the time at Morgan, SA;
- To control the rise in salt loads in all tributary rivers of the Murray-Darling Basin; end of valley targets to be met;
- To control land degradation and protect important terrestrial ecosystems, productive farm land, cultural heritage and built infrastructure at agreed levels basin-wide (expressed as within-valley targets); and
- To maximise net benefits from salinity control across the Basin

Much of the strategic implementation is in the hands of the catchment communities and is guided by salinity and catchment management plans.

Under the previous Salinity & Drainage Strategy (1998), individual states were accountable for increases in salinity resulting from irrigation development since 1988. The new BSMS made the States accountable for the impacts of development post 2000. This strategy differentiates between accountability to offset the salinity impacts of future actions (new development) and responsibility to offset the salinity impacts of past actions (Murray Darling Basin Commission 2001; South Australia. Dept. for Water 2001).

A key feature of the BSMS is the adoption of salinity targets to be met by 2015. For every tributary river valley a “cap” was set on the total salt that could leave the catchment. Eight strategic actions were also part of the strategy:

- Identification of values and assets at risk;
- Setting salinity targets;
- Managing trade-offs with the available within-valley options;
- Implementing salinity and catchment management plans;
- Redesigning farming systems;
- Targeting re-afforestation and vegetation management;
- Constructing salt interception works; and
- Ensuring basin-wide accountability, monitoring, evaluation and reporting.

BSMS Salinity Registers

An important feature of the BSMS is the salinity-based accounting system, the BSMS Salinity Registers.

The Salinity Registers allow states to continue to pursue economic development (such as expanded irrigation areas) providing that each government maintains its river salinity impacts in balance or in credit. While actions such as irrigation can generate a debit on the Salinity Registers, credits may be achieved by investment in infrastructure or by changed management practices. Typical examples of credit actions are investments in salt interception schemes, or changes to land and water management practices that reduce in-stream salinity levels.

Annually, each State and Territory Government provides information to the MDBA on activities that have significant salinity effects for the year. The MDBA calculates the salinity cost of these activities and updates the Salinity Registers which are then subject to an annual independent audit.

To date, each state government has maintained its register entries primarily in credit whilst also providing opportunities for economic development that are essential to sustain viable regional communities. The concept of an accounting system that requires actions that increase salt to the river to be offset by activities that prevent salt from entering the river is relatively simple. However, the computer models and methods associated with the calculation of the Salinity Registers are technically complex, particularly the need for predictions of impacts in the years 2050 and 2100. South Australia invests in this partnership with the MDBA on an ongoing basis to ensure its registers' balance is based on best available data.

Reporting

Reporting plays a critical role in demonstrating transparency and that partner governments are committed to delivering on their responsibilities under the strategy. Reporting provides an annual update of the Salinity Registers, summarises monitoring programs, and shows progress in catchment actions and improved knowledge. An annual salinity audit of each jurisdiction and the MDBA office also provides an independent assessment of progress and compliance with the commitments to the strategy, as laid out in the Murray-Darling Basin Agreement.

Salt Interception Schemes

Salt interceptions schemes are large-scale pumping schemes that divert saline groundwater and drainage water before it enters the rivers. In most cases a bore and pump system extracts the groundwater and pumps it to a salt management basin well away from the river.

Under the BSMS a joint works program of salt interception schemes was initiated to offset predicted future increases in average daily salinity. Each of the salt interception schemes has defined operating targets that relate to their predicted salinity impacts at Morgan (Figure 4). In total, the salt interception schemes that were part of the joint works program for the period July 2001 to June 2002 prevented over 450,000 tonnes of salt from entering the river (BSMS, 2003).

Capping water diversions in the MDB (1993)

Average flow to the sea under natural conditions in the MDB is estimated to be in the order of 14,000 GL/year, (MDBC 2000). Primarily as a result of the expansion of the irrigation industry, water use over the last 100 years has increased such that 11,000 GL/year of this natural flow is being diverted (MDBC, 2000). A 'Cap' was imposed on water diversions for irrigation to prevent further reductions in river flow. The 'Cap' limits annual diversions to those that would have occurred with the level of irrigation infrastructure existing in 1993/94 (MDBMC 1995). This cap has meant that further expansion of the irrigation industry can only be achieved through more efficient use of existing diverted water resources.

End of catchment water quality targets (2001)

A key feature of the BSMS was the adoption of salinity targets for each tributary valley and a basin salinity target at Morgan, South Australia (Figure 4). The salinity level of the water in the Murray River at Morgan was identified as one of the key factors in setting the benchmark for 'average' acceptable Murray River water quality. Salinity levels in the River Murray vary naturally depending on the time of year. The river also becomes more saline as it travels downstream and interacts with groundwater that naturally seeps into the river system (DSE, DPI, 2003)

Morgan is upstream of the major urban and industrial off-take from which the city of Adelaide sources its water. The aim of the basin target is to maintain salinity levels at less than 800 EC for 95 percent of the time over a period representing the normal range of climatic variability. These targets themselves do not represent the full range of outcomes sought, but they are a way of measuring progress towards achieving the Strategy's objectives. While end of valley targets allow for further rises in salinity, they are in effect a ‘cap’ on salinity that will go some way towards protecting key values and assets in the valleys, and also encourage the states to meet their obligations to protect the shared rivers (MDBC, 2003).

Keeping salt out of rivers has led to policies in irrigated areas that restrict the mobilisation of salt, impose strict controls on the installation of subsurface drainage, recycling on-farm drainage and restrictions upon the disposal of saline water within an irrigated area. For example, since 1982 in the MIA, new subsurface drainage systems are required to use an on-farm evaporation basin. These restrictions reduce the drainage water leaving farms in irrigated regions. Where these controls have been imposed to the extent that the saline drainage is a small proportion of the total drainage and hence is greatly diluted, then drainage water can be returned to the river system. However, where large volumes of saline water are disposed of into surface drains the dilution from other sources is less easy to achieve, hence return to the river is restricted and reuse within the irrigated area is a necessity.

When trying to control salinity in the River Murray there have been conditions imposed on irrigated areas regarding timing of disposal, e.g. Shepparton Irrigation Region (SIR). This timing of disposal recognises that the saline flows from irrigated regions need to be diluted by high flows in the river. In times when river flows are low the opportunity for disposal of irrigation drainage is restricted and hence there is less drainage to the river. Balancing the requirement to have flows into the river and the salinity of those flows is critical. The more restrictive the quality parameters applied to return flows to rivers have become, the lower the drainage volumes.

The partner Governments nominated an interim set of end-of-valley targets for stream salinity and salt loads, and these were considered by catchment communities during the public comment period for the draft Strategy. Each State set its own program for finalisation of targets.

While there is a need for targets to be adaptive, they will only be changed where there is adequate justification. This will provide certainty and integrity for the Strategy and will ensure that stakeholders' efforts are directed to finding creative and innovative ways to meet the targets. In some parts of the Basin, end-of-valley target sites will be augmented with ‘interpretation sites’ to assist in attributing salinity to its source, however these sites will not include targets or specific accountability provisions.

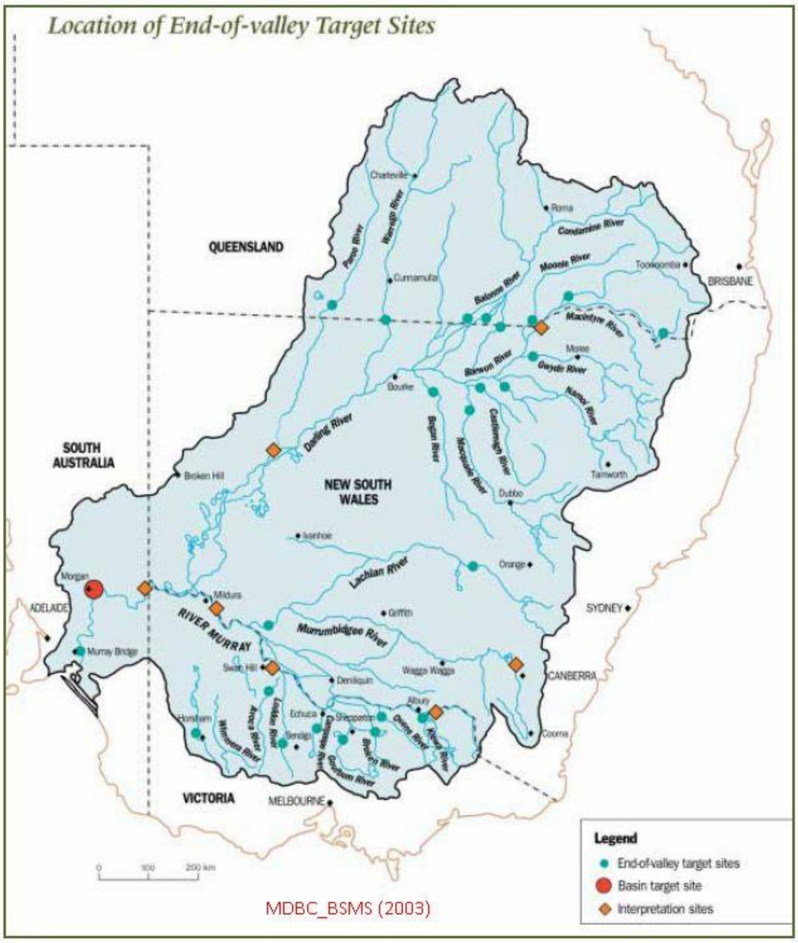

Figure 4: Locations of target sites through the MDB (Source: MDBC_BSMS, 2003)

The Living Murray Initiative (2002)

In response to community concerns regarding the health of the river system the Murray Darling Basin Commission instigated the “Living Murray” initiative. This program is aimed at what constitutes a healthy working river and what is needed to achieve it. “It's about protecting the things the River Murray means to Australians: prosperity, irrigation, industry and clean water, natural landscape, history, culture and tradition.” (MDBMC, 2002)

As part of the initiative there have been calls by the community to return some water which is currently being used for consumptive purposes to the Murray River. This “environmental water” will be required for flushing the river system, mimicking natural flows to protect icon species such as the Murray Cod fish and for floods to regenerate natural wetlands and vegetation on the floodplains.

The call has seen irrigators, the major consumptive users, targeted with demands for up to 1500 GL of water to be taken for environmental flows each year. This constitutes a significant proportion (13%) of the annual 11,431 GL irrigation allocation. A recent meeting of the Council of Australian Governments (MDBMC, 2003) endorsed the recovery of an initial 500 GL of water to protect six significant environmental sites on the river Murray.

Institutional arrangements amongst the various partners are shown in Figure 5.

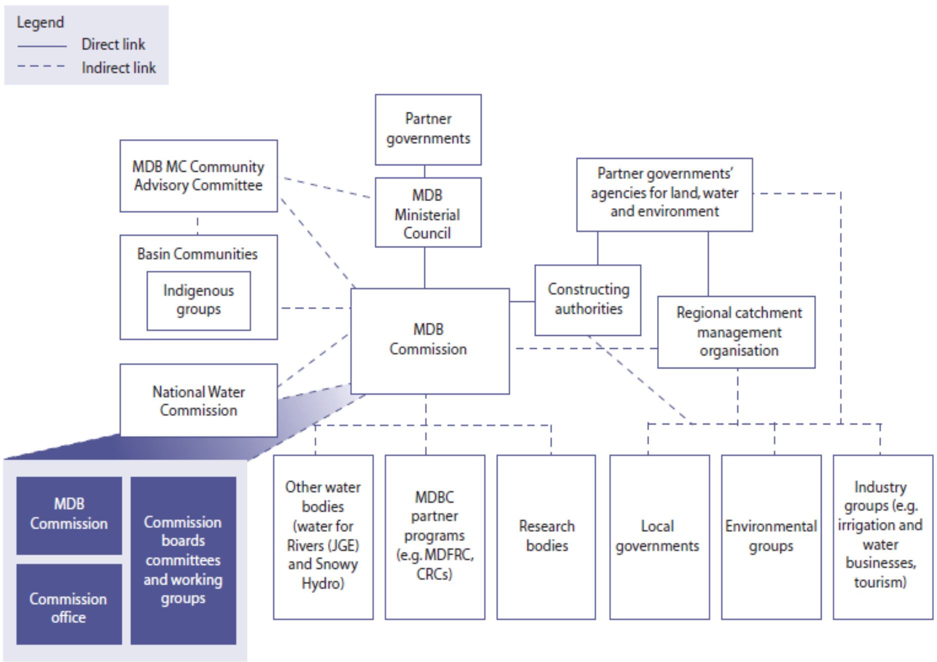

Figure 5: Outline of institutional arrangements for The Living Murray (Source: MDBMC, 2002)

State Level

At a national level, the major salinity initiative was the National Action Plan for Salinity and Water Quality (NAPSWQ), a joint partnership between the Commonwealth and States where each provide 50% of the funding. The purpose of the NAP was to identify high priority, immediate actions to address salinity and deteriorating water quality in key catchments across Australia. All of the basin states (NSW, Victoria, SA and Queensland) introduced salinity initiatives. The implementation of State and national salinity plans was critical to the success of the BSMS (MDBA_BSMS, 2003).

Under the Basin Salinity & Drainage Strategy each state was accountable for ensuring that land and water management planning in irrigated areas, activities affecting point sources, and specific works implemented since January 1988 did not lead to an overall increase in salinity in the shared rivers. The governments of New South Wales, Victoria, South Australia and the Commonwealth made a commitment to ensure that salinity at Morgan in South Australia should be less than 800 EC, 95% of the time.

The MDBC introduced a system of salinity credits and debits to manage the state accountabilities. A state receives a salinity credit for any works or planning measures that reduce average salinity at Morgan by more than 0.1 EC. The credit or debit is equal to the expected increase or decrease in salinity. Each state must remain in credit to ensure that they don't contribute to an increase in salinity at Morgan (NSW Salinity Strategy, 2000)

The governments of NSW, Victoria and the Commonwealth also agreed to jointly fund suitable salt interception and drainage diversion schemes. In exchange NSW and Victoria could undertake developments that would increase the average salinity at Morgan by 15 EC each.

Since 1988 the States of NSW, Victoria and South Australia, together with the Australian government, have funded the construction of 18 salt interception schemes, all but one located along the Murray River. There is one other located on the Upper Darling. Collectively these prevent approximately half a million tonnes of salt per year from reaching the River Murray (MDBC brochure, 2008)

All state governments in Australia have endorsed a range of policy frameworks, institutional arrangements and implementation processes for integrated catchment planning and management (ICM). This is an approach that aims to integrate community involvement, technical knowledge, organisational structure and policy objectives. Salinity management is based on this community-based collaborative model of governance although the models are largely experimental and vary significantly between states (see Table 4)because of the difficulty of translating the concept of integrated management from theory to practice (Bellamy et al. 2000).

Restructuring of agencies with responsibilities for Natural Resource Management has been common across all states. However lack of coordination within and between agencies is a common problem. Catchment bodies do not necessarily have a lead role for coordinating catchment management and most are inadequately resourced to undertake what is expected of them (Bellamy et al. 2002).

Table 4: Key features of catchment management at the state level

	Resource use context & governance
New South Wales	A high proportion of NSW sits within the Murray Darling Basin. Salinity issues are important. Parallel processes in vegetation management and water resource management make an integrated approach to catchment management problematic. Catchment management bodies have a key role in catchment planning but do not have formal powers to implement the plans.
Victoria	Victoria has a history of problems with salinity, soil structure decline and reduced water quality. The significant impact of salinity on the economic/social structure of rural Victoria has given priority status to ICM. Community awareness of catchment issues is high and Landcare has been a catalyst for community and government partnerships to address NRM issues.
South Australia	South Australia's major surface and groundwater resources originate in upstream states. SA has been very proactive in developing intergovernmental partnerships with these states for both surface and groundwater management.

Queensland	Salinity has not been a compelling issue on which to focus community attention although dryland salinity is an emerging issue. 25% of the Murray Darling Basin lies in Queensland and important surface and groundwater resources for NSW and Victoria originate in this state

(Source: Bellamy et al. 2002)

According to Bellamy and others (2002) the historical resource use context for ICM has been a significant factor in the development of state approaches to salinity and catchment management. The primary motivation for active management of natural resources across Australia has been (until the more recent focus on biodiversity) to protect and enhance agricultural productivity and decision making tended to involve mainly those with rural interests and agency staff.

Different states have had different priority issues. For instance South Australia, being at the lower end of the Murray Darling Basin System, has focused on issues of water quality and quantity. In Victoria the economic impact of salinity, reduced water quality and severe flooding related to the extensive clearing of native vegetation were issues that shaped that states involvement in ICM.

New South Wales

NSW released "Taking on the Challenge: NSW Salinity Strategy" in August 2000. Its objective was to slow down the rate of increase in salinity within 10 years, and to meet targets reflecting salinity levels that the State was prepared to live with and could afford. The strategy built on work already completed by local and regional communities and was based on a shared responsibility between land managers, businesses, industry, rural and urban communities and all levels of government (NSW Department of Land and Water Conservation 2000; Murray Darling Basin Authority 2012).

The NSW Salinity strategy used an integrated landscape management approach in which native vegetation, soils and water must be managed together in order to achieve reductions in salinity increases. In order to do this, the strategy outlined eight "tools" in which to deliver a single framework for salinity management. These included developing targets, providing market based solutions and planning and scientific knowledge of salinity. The tools were designed to be flexible to adapt to new scientific knowledge over time and find regional solutions to the salinity problem.

NSW has a very varied set of catchments and terrain including a major portion of the Murray Darling Basin. The National Land & Water Resources Audit (2001) found salinity to be at serious levels in that there was a risk of an 8-fold increase over the next 50 years in the Murray, Murrumbidgee, Lachlan, Macquarie and Hunter Rivers mostly on agricultural land.

Victoria

Victoria released its Salinity Management Framework: Restoring our Catchments in August 2000. The direct cost of salinity within Victoria was estimated to be $50million per year, with some 140,000ha of irrigated land and 120,000ha of dryland areas significantly affected (The Department of Natural Resources and Environment VIC 2000). The framework that Victoria developed supported the National and Murray Darling Basin Salinity Strategies and acknowledged that there is a shared responsibility with other jurisdictions to ensure that salinity is managed sustainably. The overall outcome for the framework was that "communities have improved prosperity and quality of life through strategies which maximize opportunities for ecologically sustainable land uses and which minimize the social, economic and environmental impacts of salinity".

The framework concluded that a review of salinity management plans was vitally important in order to capitalize on new information and that the responsibility for that lay with the catchment management authorities.

The targets the CMAs set out to achieve would be implemented through the Salinity Management Plans and Regional Catchment Strategies established by the local community groups and the Catchment Management Areas across the State. The assumption was that effective salinity management required a fundamental understanding of the local catchments which differ in soil type, rainfall, run-off and recharge rates and the extent to which salinisation was occurring (The Department of Natural Resources and Environment VIC 2000).

Victoria, more so than other states, has had a long history of a catchment approach to natural resource management. Broad-based community involvement in programs to address environmental degradation was occurring long before catchment management became standard government policy (Bellamy et al. 2002).

South Australia

South Australia released its "South Australian River Murray Salinity Strategy" in June 2001. The strategy had four main goals:

- Irrigation will not impact on salinity in the River valley;
- The health of the floodplain and wetlands will be enhanced and protected from the impacts of salinity;
- Regional groundwater discharge into the river valley will be managed to minimize river salinity impacts; and
- Decisions will be made on the best available knowledge.

To achieve these goals, salinity management was guided by a set of principles. These included managing water resources sustainably, developing and maintaining partnerships between all levels of Government and the community, and adopting appropriate levels of salinity management to protect natural resources for the future. The principles were consistent with those set out in the Murray Darling Basin Salinity Strategy (Murray Darling Basin Commission 2001; South Australia. Dept. for Water 2001).

Within South Australia actions to control the volume of salinity within the River Murray include:

- salt interception schemes;
- improving irrigation efficiency;
- revegetation;
- salinity zoning and planning;

- altering land-use and modernising farming systems; and
- securing and managing sufficient water flow to dilute and flush salt out of the River system.

Such activities are often undertaken in collaboration with the community as outlined in locally-based management plans.

There are five operational Salt Interception Schemes in South Australia, with a further three under construction at Murtho, Loxton Highland and Pike.

Salinity has been one of the most critical NRM issues facing South Australia. Although the South Australian portion of the Murray Darling Basin is only about 7% of the state, the basin is the state's primary water resource with the River Murray supplying 95% of the state's population. Groundwater resources also extend beyond this state's borders and so there are inter-governmental partnerships with upstream states including the Groundwater (Border Sharing) Agreement, the Lake Eyre Basin Agreement, and the Great Artesian Consultative Committee (Bellamy et al. 2002)

Queensland

Queensland was actively involved in the planning and implementing of the NAP (Department of Environment and Resource Management QLD 2012). Queensland would deliver outcomes, including minimization of salinity, through existing initiatives including vegetation management, water reform and improved land management practices. Salinity science work plans were developed that support community groups in their development and implementation of strategies to address salinity and water quality. Both salinity and water-quality outcomes will be delivered within the framework of integrated catchment management and the NAP (Murray Darling Basin Commission 2001; Department of Environment and Resource Management QLD 2012).

Queensland was the last state to join the Murray Darling Basin agreement in 1992.

Regional Level

Under the Murray Darling Basin Salinity Strategy and State salinity initiatives, regional organisations will develop salinity or catchment management plans that will cover among other things, performance measures, agreed outcomes, accountability and reporting mechanisms and compliance measures. It is expected that, once a plan has been accredited under the NAP, it will meet the requirements of this Strategy and State initiatives and consequently attract an appropriate level of investment from Governments and the communities. As there is broad consistency between the requirements of the NAP, the Murray Darling Basin Salinity Strategy and State salinity initiatives, this will ensure that plans and resources for regions outside the NAP will be consistent with those for regions covered by the NAP.

Regional catchment strategies

The introduction of the Catchment and Land Protection (CaLP) Legislation in 1994 meant that regional level catchment management authorities (CMA) were required to prepare a Regional

Catchment Strategy (RCS) and to co-ordinate and monitor its implementation. The distribution of catchment management authorities is shown in Figure 6

Figure 6: Catchment Management Areas within the Murray Darling Basin (Source: Murray Darling Basin Authority 2012)

The catchment strategies are the blueprint for integrated natural resource management across a geographic area. These documents have a major influence on the investment decisions made by the Commonwealth and State governments and the community in terms of NRM and sustainable regional development. They provide the context in which the CMAs work with Commonwealth and State agencies, rural and urban water authorities, landholders, local government and the wider community. Widespread consultation and input is required from a range of stakeholders. RCSs recognise a catchment's natural assets along with current and emerging threats. They prioritise the actions and works that must occur to address threats, so that effort and funding is directed where it is most needed. All catchment strategies have a whole of catchment approach that takes into account the natural environment and the socio-economic context.

Regional Catchment Strategies typically incorporate other strategies for managing particular districts or particular issues that were originally standalone documents prior to the formation of the CMAs. In many cases the prior strategies were pilots for areas within the Murray Darling Basin, developed during the late 80s and early 90s, and well advanced in their implementation.

Murrumbidgee Catchment Management Area– MIA and CIA

Both the Murrumbidgee (MIA) and Coleambally (CIA) Irrigation Areas have extensive areas with water tables less than 2 m from the ground surface. Shallow water tables have little detrimental effect on the (predominant) rice crops but significant areas of remnant and roadside vegetation have been affected by seepage as were perennial horticulture areas prior to sub surface drainage installation.

Drainage in the rice growing areas:

In some MIA areas where rice is the main crop, experimental subsurface drainage was trialled using shallow groundwater pumping to decrease the risk of water-logged and saline conditions affecting farming operations and crops other than rice. Shallow spearpoints were installed but extraction was discontinued due to the high salinity of the discharge water and uncertain benefits in a rice-based farming system. Shallow vertical pumping and horizontal drainage have also been tried with extracted water discharged to evaporation basins and some reuse. More extensive drainage has not proceeded due to the high costs compared with relatively low benefits in a rice-based farming system. Assessment of very low drainage rates for this type of cropping system is an area for future research.

In the Coleambally area experimental deep groundwater pumping (>120 m) has been undertaken to assess the benefits for salinity control. There appeared to be a drawdown of 0.1 – 0.3 m over several years, within 2 km of the experimental bore. The effect of such small draw down on salinity control is uncertain. It is clear that the linkage between deep and surface aquifers is poor at the experimental bore location and, thus, there is relatively limited potential for deep pumping to assist in salinity control in that area.

Drainage in the horticultural areas:

The MIA has approximately 10,000 ha of horticultural plantings with horizontal subsurface drainage. The impetus to install drainage came in the mid-1950s when 50% of the tree crops were killed by waterlogging after two successive years of above average rainfall. This led to a concerted research effort into horizontal 'tile' drainage and a system of Government loans for implementation. The research developed drainage criteria, methods for site investigation (hydraulic conductivity) and nomographs for design.

Until recently, it has been standard practice to install subsurface drainage in all perennial horticulture, almost all of which was irrigated with surface furrow systems. Some newly established vineyards using drip irrigation have not installed subsurface drainage although the viability of this has not been tested in the long term. Water from perennial horticulture (~ 2 – 12 dS/m) tile drains is pumped from a central collection well via electric pumps on each farm and discharges into the surface drainage open channel system. This drainage water mixes with all other drainage (both surface and subsurface) from the region and flows via Mirrool Creek to Barren Box Swamp. This extensive holding basin is used as a supply source for the Irrigation Districts to the west of the MIA. Excessive drainage during the early 1980s led to a moratorium on additional drainage so that new horticultural developments have had to manage their discharge on farm using evaporation basins. This has led to the development of 15 on farm evaporation basins in the area.

The major issue facing the area is subsurface drainage effluent treatment and storage. Volumes from existing systems need to be reduced and future systems will have to use evaporation basins. An overall drainage management plan is required for the area.

North Central Catchment Management Area

North Central Catchment Management Area is located in north central Victoria and covers an area of 30,000km^2 of which 32,000ha of land is affected by salinity (North Central Catchment Management Authority 2003; North Central Catchment Management Authority 2012). It is bordered by the Murray river in the north, the great dividing range and the Wombat State Forest to the south and the Mt Camel range to the East (Figure 7). It contains 4 major river catchments including the Loddon, which is where most of the irrigation occurs, using 1,425,000 ML/year (North Central Catchment Management Authority 2003).

Figure 7: North Central Catchment Management Area (Source: NCCMA Website (North Central Catchment Management Authority 2012)

The Regional Catchment Strategy (RCS) is the primary integrated planning framework for natural resource management within the catchment. The targets and outcomes of the RCS are aligned with the national outcomes and targets and take into consideration those outlined in state-wide policies and strategies. The RCS identifies six regional priority issues, included is salinity in both dryland and irrigated areas (North Central Catchment Management Authority 2003). The RCS targets for salinity are that:

- Reduce the irrigated area of salt affected land (C and D classes) and increase the areas that is A and B class soils by 2023; and
- Manage salt load exported from the land to the River Murray and regional waterways within EC credits and ecological limits

These will be achieved through salt interception and improving irrigation efficiency as well as encouraging development of new irrigation practices on the appropriate soil/land and allowing for adjustment with future land use packages (North Central Catchment Management Authority 2003).

This is achieved with community involvement to ensure sustainable management practices against salinity are put into place.

The RCS focuses on an asset based-framework, with assets being the drivers behind the plans and strategies rather than problems. These include land, water, biodiversity and climate. The RCS also takes into consideration existing plans and strategies in order to manage the natural resources in the catchment effectively. This includes the Loddon Murray Land and Water Management Strategy and the Shepparton Irrigation Region Catchment Strategy which are detailed in other sections below.

Goulburn-Broken Catchment Area

The Goulburn-Broken catchment stretches from the Murray River in the North to the outskirts of Melbourne to the south and includes the Shepparton Irrigation Region (SIR). The vision of the RCS of the Goulburn-Broken Catchment is to reduce the environmental footprint of irrigated and dryland farming, to increase land available for new ecosystems and environmental flow to create new opportunities for economy and employment (Goulburn Broken Catchment Management Authority 2003). This vision is supported by the use of "triple bottom line" accounting for investment in natural resource management so that actions and management strategies will often generate not only environmental but social and economic benefits as well.

Salinity is one of the major threats to the catchment's natural assets. In irrigation areas the catchment faces major challenges in dealing with disposal of drainage water and managing areas where land protection options are limited. Twenty percent of the catchment is irrigated, most of this within the SIR (Goulburn Broken Catchment Management Authority 2003). Attempts are being made to set targets aligned with those set in the MDB Salinity Strategy and readjusting existing programs within the catchment to conform to the expectations of the MDBA.

The GBCMA have taken actions in order to improve the quality of their natural assets and to reduce the impact of salinity in particular. The transfer of water rights has presented the opportunity to better match water and land use to its appropriate capacity however further effort is needed to ensure that environmental benefits are maximized. Within the irrigation areas, salt disposal is one of the main strategies in which the GBCMA is approaching the salinity problem. This has been approached through conjunctive water use, serial biological concentration and evaporation basins (see later sections), with conjunctive water use having the most acceptance within the community (Goulburn Broken Catchment Management Authority 2003). Drainage diversions are also an important part of managing the salt exports; however, as these flows decrease, the salt concentration of the water will increase reducing the quality of the drainage water and what it can be used for.

Although the GBCMA have outlined their strategies for improving salinity, these are mainly managed and implemented through the Shepparton Irrigation Region Salinity Management Plan.

About the catchment

The Goulburn Broken Catchment Management Authority (CMA) is a statutory authority established by the Victorian government to coordinate land, water and biodiversity management in the region.

It was established as one of 10 CMAs in 1997 under the Catchment and Land Protection Act (CaLP Act) covering the State of Victoria. The Lower Goulburn Waterways Authority, Mid Goulburn Broken Waterways Authority and Upper Goulburn Waterways Authority ceased to exist and became direct operational arms of the Goulburn Broken CMA upon its creation. The move to whole of catchment management was an opportunity to incorporate other environmental degradation issues with salinity and to address these issues on a more holistic perspective (GBCMA, 2011).

The Goulburn-Broken catchment stretches from the Murray River in the North to the outskirts of Melbourne to the south and includes the Shepparton Irrigation Region (SIR) and Victoria's main water storage, Lake Eildon. Although it occupies just 2% of the Murray Darling Basin, the GBC region provides 11% of the Basin's water resources (GBCMA, 1997)

The region supports major agricultural (dryland and irrigated), food processing, forestry and tourism industries. The major commodities are dairy, horticulture, viticulture, grain and prime lambs and beef but wool, timber, thoroughbred horses, tourism and recreation are also important to the region's economy. About 270,000 hectares is irrigated agriculture, over 1.3 million hectares is dryland agriculture and 800,000 hectares is public land. In addition, 70,000 hectares of the North Central Catchment is also included in the Sustainable Irrigation Program for consistency of management (GBCMA, 2011).

Major natural resource threats are reduced water quality and quantity, dryland and irrigation salinity, native vegetation loss, biodiversity decline, pest plants and animals and emerging issues of climate change.

Catchment Management History

Broad community concern throughout Victoria about natural resource degradation, particularly from salinity in the early 1980's, resulted in a parliamentary inquiry into salinity. Because of the high level of community action within the Goulburn Broken Catchment with the commencement of Landcare, it was selected as the pilot region for a community driven program to develop a catchment-wide salinity plan (known as the Salinity Pilot Program Advisory Council, SPPAC).

The introduction of the Catchment and Land Protection (CaLP) Legislation in 1994 saw the role of the Salinity Program Advisory Committees replaced by the Goulburn Broken Catchment and Land Protection Board. Under this new legislation the Board became the lead body responsible for setting policy and direction, coordinating implementation and monitoring achievements in Natural Resource Management. The Regional Catchment Strategy (RCS) was prepared by the Goulburn Broken Catchment and Land Protection Board and was adopted by the Goulburn Broken Catchment Management Authority at its first meeting held on 1st July 1997.

Salinity is one of the major threats to the catchment's natural assets. Twenty percent of the catchment is irrigated, most of this within the SIR. Attempts are being made to set targets aligned with those set in the MDB Salinity Strategy and readjusting existing programs within the catchment to conform to the expectations of the MDBA (GBCMA, 2003).

Catchment Strategy (1997)

As already mentioned salinity is a major threat to the catchment's assets. The 1997 catchment strategy states that the Dryland is a major source of salt entering the river system. At the time the catchment was estimated to have about 4500 ha of salt discharge areas where saline water had evaporated leaving heavily saline soaks or salted ground. The catchment at the time exported an average of 180,000 tonnes of salt from the Dryland areas to either the irrigation region or the River Murray. This was predicted to double in 50 years without remedial action.

Regional Catchment Strategy summary (2003)

The 2003 RCS synthesises the key elements of a raft of sub-strategies, action plans and technical papers. It incorporates the Goulburn Broken Regional Catchment Strategy 1995; Shepparton Region Land and Water Management Plan 1990; Goulburn Broken Dryland Salinity Management Plan 1990; Goulburn Broken Water Quality Strategy 1996; Goulburn Broken Native Vegetation Management Strategy 2000; Goulburn Broken Weeds Action Plan 2000; and Goulburn Broken Rabbit Action Plan 2000.

In addition to the sub-strategies the RCS includes three year investment plans to meet the needs of funding programs, and annual regional management plans which contain more detail about work programs.

The Catchment community is almost halfway through delivering the irrigation and dryland salinity plans and progress has been excellent. In irrigation areas, actions are progressing according to plan but face major challenges over the next five years in dealing with salt disposal and addressing those areas where land protection options are limited.

Sustainable Irrigation

The Sustainable Irrigation Program oversees the delivery of on-ground works relating to sustainable irrigation in the Goulburn Broken Catchment. These on-ground works align with overarching strategies for the health of both the Goulburn Broken Catchment and the Murray Darling Basin.

The Shepparton Irrigation Region Catchment Implementation Strategy (which provided the basis for successful funding of the Farm Water Program through the recent federal "On-Farm Irrigation Efficiency Program") and the Mid Goulburn Broken & Upper Goulburn Sustainable Irrigation Action Plan direct the strategic priorities for investment across the irrigated landscape of the Goulburn Broken Catchment.

Lachlan Catchment Management Area

Case Study - Jemalong Land & Water Management Plan

An example of how a lack of funding and political processes can affect effective implementation is the Jemalong Land and Water Management Plan.

The planning process was started in 1992 due to community concerns about the high water tables resulting from the 1990 floods in the Lachlan River and the perceived threat of dryland and irrigation salinity. Water tables in the district had risen by up to 8 metres in the past 50 years and after the floods approximately 50% of the district had water tables within 2 metres of the surface. The groundwater under a large part of the district was highly saline (up to 70,000 EC).

Except for some groundwater data dating back only as far as 1967, river flow and weather data, there was very little information available. The planning process initially covered an area of some 170,000 hectares. This area was almost an enclosed system with very little external surface and groundwater influences. Because of this, provided the appropriate measures were taken, it should have been possible to reverse the trend of rising water tables within the area and actually lower the water tables to manageable levels. Extensive investigations were carried out by various consultants to establish the information database required to develop the strategies for the Plan. When the Irrigation District was corporatised in early 1995, a condition of the Licence was the establishment of the Jemalong Land and Water Management Plan. The planning process was funded through the MDBC and State Government by the provision of some 3.5 million dollars over 8 years.

Towards the end of the planning process it was decided to limit the Plan area to incorporate the irrigation area of operations only, effectively half its previous size. This decision was ostensibly made for 2 reasons:

- The refusal by Government to establish a Catchment Management Trust as the implementation entity for the Plan. This effectively left Jemalong Irrigation Limited as that entity; and
- The perceived excessive cost of implementation for the whole of the original plan area.

This effectively illustrates how a lack of long-term recurrent funds and political inflexibility have imposed a band aid solution on what could have been a long-term effective and sustainable solution.

Murray Catchment Management Area

The Murray catchment management area is 35,1750 square kilometres and is bound by the Murrumbidgee River Catchment boundary in the north, the Murray River to the south and the Australian Alps to the east (Figure 8) . The catchment plays a significant role in Australia's agricultural production with production in excess of $800 million per year (Murray Catchment Management Authority (MCMA) 2012). Around 1200GL of water is diverted for irrigation for agriculture each year within the catchment.

In agreement with the MDB Salinity Strategy, the Murray Catchment Management Area's Catchment Action Plan (CAP) identifies that salinity is the most important factor impacting on river quality and health and that salinity must be addressed at the landscape level (Murray Catchment Management Authority (MCMA) 2007). The CAP outlines the management practices currently and to be implemented in order to address the problem of salinity. The current target is:

"that by 2010, the salinity concentration in the Murray, downstream of the Wakool junction will be at or below 294EC 80% of the time with a trend to returning to year 2000 average salinity by the year 2016"

This target is to be achieved by reducing the amount of area at risk of salinity. These areas will be identified and mapped, and the level of salinity will be assessed with modeling (Murray Catchment

Management Authority (MCMA) 2007). Improving these areas will be achieved by the establishment of perennial pastures and woody vegetation in medium risk areas, establishing deep-rooted perennials in areas of high risk salinity and improving the use of water. In areas that have less than 500mm rainfall/year, halophytic vegetation will be established.

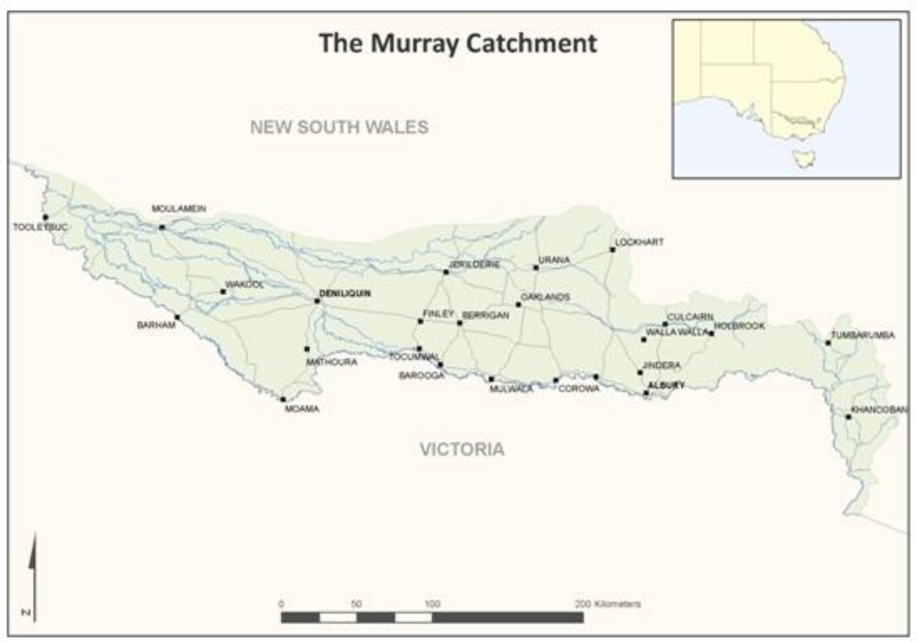

Figure 8: The Murray Catchment Management Area, source MCMA (2012).

River Murray Water Allocation Plan

The River Murray Water Allocation Plan (WAP) establishes specific principles regarding river salinity management, which have been developed into salinity zone policy to manage the salinity impacts of any new irrigation developments. The River Murray Water Allocation Plan contains a specific water use efficiency (WUE) target for irrigators of 85 percent. Achieving this level of WUE decreases the likelihood of deep drainage events which are a major contributor to salinity increases in the long term.

District Level

Four case studies considering salinity management are presented in the following section. All four are irrigation based.

Introduction

The original district plans for managing important environmental issues within the Murray Darling Basin were called Salinity Management Plans in Victoria and Land & Water Management Plans in New South Wales. All plans were developed by community working groups and involved extensive community consultation. The Victorian salinity management plan process commenced in the early 1980s under the Victorian salinity program; in New South Wales the development of plans did not occur until the early 90s (McClintock & Young, 1996).

The extent and severity of soil salinisation and water-logging varies within and between irrigation areas. As part of the planning process for developing district Land & Water Management Plans the nature and extent of the problems particular to each area were assessed. It is difficult to make direct comparisons between plans for different districts because the methods, assumptions, constraints and objectives for each plan reflect different problems and approaches. The options evaluated for programs within the plan also differ for the same reasons. For instance the options proposed within the farm program of the Victorian plans tended to focus on broader management options such as the concentration of resources on A and B class soils and whole farm plans whereas the New South Wales plans assessed more specific farm management options such as irrigated woodlots and the earlier application of irrigation to certain crops. The extent to which structural adjustment issues, particularly land retirement options, have been assessed in the various plans varies considerably (McClintock & Young, 1996).

All of the plans include assessments of the likely effectiveness of ameliorative actions and a ranking of the viable options according to the expected benefits and costs (McClintock & Young, 1996).

All of the district plans include a 'no plan scenario' as this was a requirement for a land and water management plan as outlined in the guidelines for developing a plan as supplied by the regional bodies.

Some of the plans acknowledged that local landholders would adjust to changing environments over time without assistance. However it was usually assumed that the rate of adoption of the preferred options for improving local land and water management would proceed at a greater rate with a plan in place. Incentives and education are an integral part of most plans. In determining the cost-sharing arrangements for implementation of plan recommendations the ability of farmers to pay was taken into consideration by all plans.

According to McClintock & Young (1996) some information has been collected on the cost and time taken to develop management plans. The Kerang-Swan Hill plan was developed over six years and cost $3.4 million. Planning for the Shepparton region was completed in four years and cost $3.3 million. The cost of developing plans for some regions was found to be high, relative to the expected net benefits.

An important component of each district management plan was the provision for monitoring and review during the implementation phase. Some plans developed sets of performance indicators that monitor such things as change in area affected by water-logging and soil salinisation, drainage water quality, farmer contributions to plan implementation and so on. For the state of Victoria, the working groups responsible for the plans were required to submit annual progress reports and more detailed reports at five year intervals covering key indicators for progress, assessments of the plan's effectiveness and future monitoring requirements (McClintock & Young, 1996).

Shepparton Irrigation Region

The Shepparton Irrigation Region (SIR) covers an area of around 500,000 ha of northern Victoria and of this about 280,000 ha is irrigated. The region does not suffer as much from salinity as from shallow groundwater levels; in the year 2000 over 35% of the region was underlain by shallow water tables (<2m from the land surface) although a combination of dry seasons and progress with salinity works has reduced this. The rise in watertable level was very rapid until 1995, when the distribution of shallow watertables peaked at 47 % of the total area. Shallow water tables were predicted to increase to around 65% by the year 2020 without active management (GBCMA, 2003). Gravity surface water is the main source of irrigation although groundwater is also extracted from shallow (Upper Shepparton Formation) and deep (Calivil Formation and Renmark Group Deep Leads) groundwater systems (Hunter, 2008).

Regional catchment management plans have been successful in addressing salinity issues through implementation of the SIR Land and Water Salinity Management Plan (L&WSMP). A partnership between community agencies, Local Government, State Government and Federal government, the SIR L&WSMP is one of the earliest and most successful plans in the Murray-Darling Basin (DSE/DPI, 2005). Operational since 1990 the plan has implemented on-ground works, changed the behavior of land managers and increased community understanding of environmental issues (Sampson et al. 2000).

The plan consists of four main action program areas; Farm and Environment, Surface Drainage, Sub-Surface Drainage and Waterways. The main focus of the Farm and Environment program was to improve the efficiency of water use by reducing groundwater accessions, soil salinisation and waterlogging. This was done through the introduction and implementation of farm plans. Salinisation would be severe, resulting in significant loss to the region's economic assets and irreversible degradation of most major wetlands. At the farm scale, irrigation can cause wetlands and remnant vegetation to undergo changed wetting and drying cycles that significantly degrade them. Algal blooms in some wetlands are increasing as a result of increased nutrient levels. The adoption of improved water use efficiency practices have led to over 2,500 reuse systems being constructed; these trap around 50% of the water used in irrigated areas which reuse over 200,000 ML/year of farm run-off, therefore reducing irrigation salinity.

The construction of new drainage works combined with environmental awareness from surveys under the environmental program have reduced the amount of water being put back into the river system, improving water quality for those downstream.

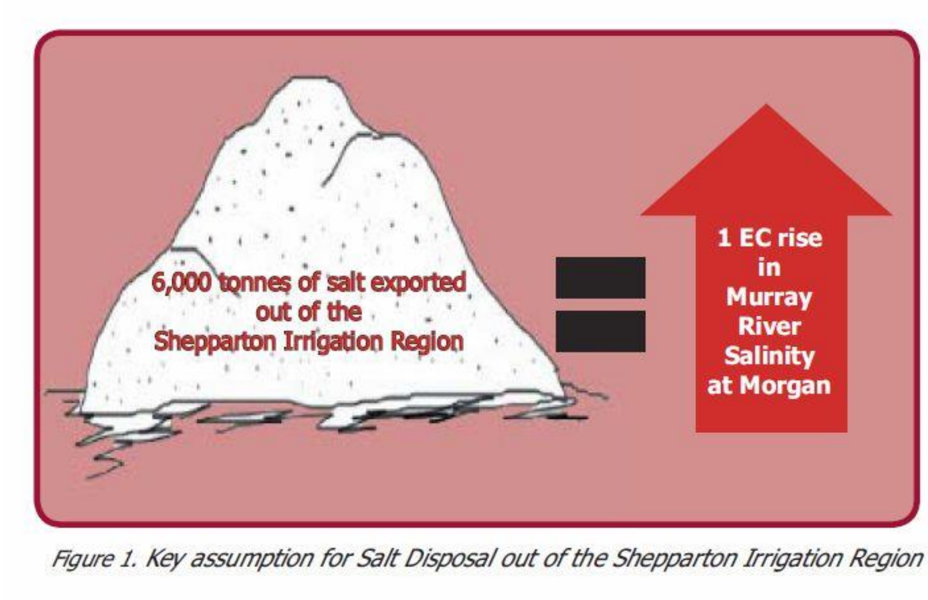

Figure 9: Shepparton Irrigation region community awareness message (Source: DSE/DPI (2005) “Balancing the salt budget for the SIR”)

Until very recently the plan has been overseen by a community implementation committee which reports to the regional catchment authority (GBCMA).

The Shepparton Irrigation Region is dominated by horticulture, which until recently provided high value crops.

The area is underlain by usable groundwater resources and salinity management relies on the inter-relationship between shallow groundwater and the surface water system. Shallow groundwater is pumped to reduce locally high watertables, this water is pumped back into the irrigation delivery system (thus reducing flow into the Murray). Groundwater is also pumped from sand strings, prior stream beds and other shallow high permeability layers into the irrigation delivery system where salinity allows. To encourage groundwater pumping as a measure to manage shallow watertables, large entitlements were given out to users. Where saline groundwater is pumped, it is disposed of to a regional evaporation basin.

The salinity "cost" at Morgan from the Shepparton Irrigation Area was estimated to be 3-4 EC. This can be compared to a salinity "cost" from the Kerang-Swan Hill area of 10-20 EC. This highlights the utility of re-use in this area as the overall salinity was low.

After increased groundwater pumping, reusing and recycling water, return flow to the Murray River decreased, reducing salt load into the Murray.

The Challenge

From the Shepparton Irrigation Region perspective, the challenge has been to balance the amount of salt that comes into the region in irrigation water, with the amount of salt leaving the region in the drainage network. Before the Catchment Strategy was implemented, it was estimated that about 100,000 tonnes of salt entered the region every year in irrigation water, but only 60,000 tonnes could be accounted for as leaving the region via the drainage network (drains, rivers and streams). This implies that 40,000 tonnes of salt was being added to the region's soil, every year. These figures were based on a number of "best guess" assumptions but the message was clear - with the development of high watertables across the region, there is no room for storage of salt within the catchment, therefore there needs to be a discharge of salt to reduce the potential effects of salinisation (DSE, DPI, 2005, p9)

Issues:

The opportunity (and need) for recycling irrigation drainage water by extraction from the Upper Shepparton Formation is likely to decrease. Accordingly groundwater allocation policy, extraction arrangements and management should reflect the uncertainty and risk associated with extracting water from the Upper Shepparton Formation as a resource.

The Shepparton Irrigation Region Water Supply Protection Area Groundwater Management Plan (established in 1999 to manage extraction from the Upper Shepparton Formation) may be of limited value for groundwater resource management because it does not have a Permissible Consumptive Volume (PCV) or mechanisms to control water usage on a seasonal basis. Also the variability of the Upper Shepparton Formation and lack of contiguous aquifers means it is not feasible to manage groundwater as a transferable and tradable resource in most areas of the SIR.

The current licensing arrangements under the Water Act do not reflect the "opportunistic" nature of water in the Upper Shepparton Formation. Unbundling of groundwater entitlements (and incorporation of these entitlements into Water Use Licenses) may provide an opportunity to implement more suitable management arrangements. Care will need to be taken to ensure any new management framework recognises that water in the Upper Shepparton Formation is principally irrigation drainage water and that reduced infiltration to groundwater is likely to have some impact on Deep Lead groundwater system recharge volumes.

The SIR Catchment Implementation Strategy programs for management of risk from high groundwater levels will need to be reviewed in light of changing climate, infiltration and groundwater extraction conditions (Hunter, 2008).

The Solution

The Shepparton Irrigation Region Catchment Strategy component of the Goulburn-Broken Regional Catchment Strategy has five key programs to address the salinity problem. The Farm Program focuses on private land use: improving water use efficiency, irrigation layout and adoption of sustainable irrigation practices. The Environmental Program provides the framework for protection and enhancement of natural features in the Region on private land, including wetland management and biodiversity.

The Waterways Program oversees the River Health Strategy for the Goulburn Broken Catchment Management Authority and addresses issues associated with riparian zone protection, nutrient and sediment reduction, river flow and in-stream habitat. However, the two programs which have the most direct impact on regional salt loads are the Surface Water Management Program and the Sub-surface Water Management Program.

Underpinning these programs are a number of assumptions that describe the relationship between works and impact on river salinity. One of the main assumptions is that for every 6,000 tonne of salt discharged from the Shepparton Irrigation Region, there is a 1 EC increase in the river salinity at Morgan (DSE, DPI, 2005, p9)

The SIR L&WSMP

A community-based Salinity Management Plan was developed to address the issue of rising groundwater levels in the SIR. Operational since 1990 the plan has since been widely recognised for the successful implementation of best management practices at the catchment scale. Developed and refined over the years with community input and involvement at all stages the plan has changed the behaviour of landholders, increased community understanding of environmental issues and achieved direct change on the ground. Targets set by the community for on-ground works such as whole farm planning, groundwater pump installation, surface drainage construction, wetland protection, fencing of remnant vegetation, waterways rehabilitation, and revegetation had all been met or exceeded 10 years after the plans initial implementation (Sampson et el. 2000).

Community input into the SIR L&WSMP development has been facilitated and encouraged in many ways. This included assisting the formation of landholder groups, close interaction with municipalities, regular information meetings with special interest groups, and a community issues paper prepared for major policy issues. These were distributed widely throughout the SIR and requested feedback from the broader community. The local media, particularly the press, were also widely utilised during this stage (Sampson et al. 2000)

A major community education program was mounted to raise awareness of salinity issues. A significant increase in community awareness was specifically linked to the "Underground flood' campaign – a series of coloured maps of the region showing the inexorable rise of watertables on an annual basis (Sampson et al. 2000).

The responsibility for implementing the SIR L&WSMP and other components of the RCS in the SIR was until recently that of the SIR implementation committee of the GBCMA. This committee developed a number of programs designed to improve irrigation management and efficiency. Working groups were established for each of these programs. These were made up of community representatives from various GMW water service committees, the Victorian Farmers Federation, local government, environmental groups and agency representatives. The groups managed in detail all aspects of the particular program including budget allocation, works programs, monitoring, policy development and research. The groups had real power to influence a budget of over $16 million a year (Sampson et al. 2000).

This arrangement has changed somewhat in recent years. The implementation committee structure was reviewed in 2010/11 in recognition of the changing environment in which CMAs were then operating. As an outcome of this review a new community engagement approach was adopted by the CMA board in 2011 (GBCMA, 2009). Implementation committees have become advisory groups supporting the delivery of three Goulburn Broken CMA programs; Sustainable Irrigation, Land & Biodiversity and River and Wetland Health and Floodplain Management. The advisory groups do not have the same power to decide how money is spent; the funding has become more prescriptive and so there is less flexibility to tailor the programs to local needs.

The five programs developed by the SIR implementation committee (now part of the Sustainable Irrigation Program within the Regional Catchment Strategy) were specifically designed to improve the efficiency of water use on farms; reduce the amount of water lost to the watertable or into the drainage network; protect land and water resources from rising water tables; and protect the catchment and it's downstream rivers from any adverse impact of irrigation (Hunter, 2008).

The farm program focuses on private land use and improving water use efficiency, irrigation layout and the adoption of sustainable irrigation practices. Encouraging whole farm planning to achieve these goals resulted in 1, 595 whole farms plans for 116, 850 ha by the year 2000 (Sampson et al. 2005). Whole farm plans were also made a prerequisite for other incentives available to individual landholders under the Environment and Sub-Surface drainage programs.

Salt Disposal Entitlements

The sub-surface drainage and surface water management programs of the Shepparton Irrigation Region Catchment Strategy have the greatest impact on River Murray salinity levels.

Most of the activities in the region's catchment strategy either have an EC saving or require an EC credit also known as a Salt Disposal Allocation (SDA). The continued delivery and provision of activities through the SIRCS is dependent upon the availability and sharing of EC credits with other irrigation regions in the state of Victoria that also have an impact on salinity levels in the Murray.

The salt levels in the Murray River can be managed in part, by the salt interception schemes along the lower Murray. These intercept very saline groundwater that would otherwise seep into the river. This water is pumped to evaporation basins located 'inland' from the river. The EC units by which the river salinity is reduced become the EC credits that can be shared by upstream communities that wish to drain irrigation areas.

Operating and maintaining the salt interception pumps and evaporation basin is expensive. The communities discharging salt pay charges for salt disposal equivalent to their proportional share of operating the salt interception schemes. The SIR region contributes to the operation and maintenance of these pumps at a cost of $90-140K per EC unit that the region can discharge to the river.

Solutions – Groundwater control in the Shepparton Irrigation Region

Altering the type of agriculture to include more salt tolerant plants is one way of dealing with the problem but is not always the most attractive option. In most of the Region this is the last resort because of the high value of agricultural production. This means there is scope to invest more money in other methods of managing the high watertable.

Physical lowering of the watertable can be achieved by installing and managing groundwater pumps or bores (large diameter single bores, or small diameter multiple well-point systems) or tile drainage. These systems drain the water away from the vicinity of plant roots, reducing water logging and allowing the leaching of accumulated salts from the surface. However, this drained water has to be managed either by transferring it to the surface drainage system or via some other disposal method. Conjunctive reuse (mixing of pumped groundwater with surface water supplies) is the most common method of managing disposal of saline groundwater. The other option is to export the salt out of the region. The other key methods include surface drainage and irrigation system management and improvement.

One of the main mitigation strategies for high groundwater levels has been promotion of groundwater extraction from the Upper Shepparton Formation. This groundwater extraction is a form of water recycling because water in the Upper Shepparton Formation is principally irrigation drainage water (Hunter, 2008).

In the SIR more than 1000 bores are licensed to pump over 45, 000 ML a year (GB RCS, 2003).

Groundwater & Salt Management Plan (2009)

The sub-surface drainage program was formulated in 2003. In late 2008 the program underwent a significant mid-term review which resulted in changes to the program name, vision, mission and objectives. The main change to the vision was to provide an improved focus on social assets and limiting the region's impacts beyond the SIR. The main changes to the mission were an increased focus on the uniting of community with government agencies, and highlighted the emphasis on an adaptive approach and the need to foster viable communities. The main changes to the objectives of the new groundwater and salt management plan (GSMP) were an increased emphasis on adaptive management, management of risk related to salt storage and mobilisation and water balance changes, optimising institutional arrangements, with an emphasis on the community and the environment.

The program is delivered through partnerships between GMW, DPI and the GBCMA. The GSMP is funded as part of the Shepparton Irrigation Region Catchment Implementation Strategy (SIRCIS) with support and funding from the Victorian Government through State Salinity Infrastructure funds.

Tragowel Plains

The Tragowel Plains Salinity Management Plan is one of four plans that were implemented in the Loddon Murray Region, which has more recently become the Loddon Campaspe Irrigation Region. Kerang-Swan Hill, Torrumbarry East of Loddon and Boort West of Loddon are the other plan areas. More recently the four plans have been integrated into a single Loddon Murray Land & Water Management Strategy, part of the revised North Central (CMA) Regional Catchment Strategy

The Tragowel Plains Irrigation District is located in the Lower Loddon Catchment of northern Victoria, south east of the Kerang Swan Hill area (Figure 10). Prior to the development of a salinity management plan (SMP) for the area, the Tragowel Plains were generally associated with poor surface drainage leading to prolonged periods of surface water ponding.

Ninety nine percent of the area is used for agriculture. Remnant natural areas are small and scattered and generally highly modified. Remaining woodlands and wetlands have been affected by salinity and water-logging.

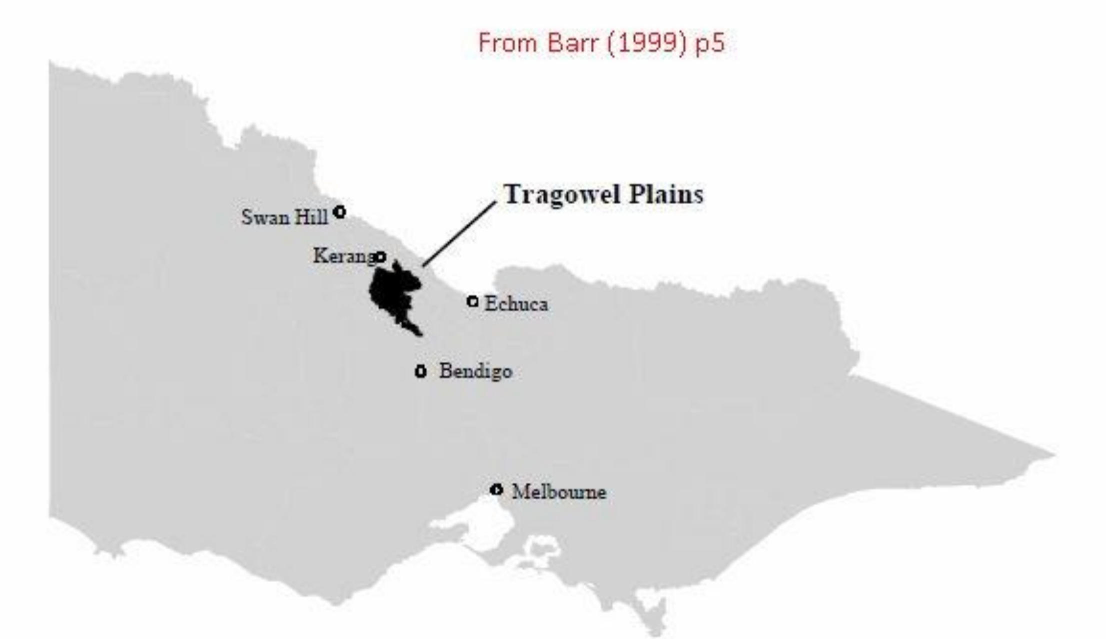

Figure 10: Location of the Tragowel Plains

The Tragowel Plains are a natural flood plain. When irrigation first began farmers were able to dig a series of holes in the branch channel, a practice known as 'wild flood irrigation'. Water would flood the plain, which, although flat, was riddled with 'crabholes', small circular depressions from five to fifty metres in diameter. Water would collect in the crabholes leaving higher areas of the paddock dry (Barr, 1999: 10). This practice was highly inefficient. Higher areas were not leached and remained salty despite irrigation, whereas the lower areas were waterlogged.

To ensure regular leaching of salts a strategy advocating a change in farm layout was devised. Farms would be divided into regular watering bays with the supply channel at one end, a drainage channel at the other and raised banks called checkbanks running down each side. The surface of each bay was levelled with horse drawn implements. Bays had to be built to fit in with the contours of the farm. The process was expensive and time consuming and often the end result was many small bays, pointing in different directions, that had to be watered, one by one, by digging and then filling a hole in the supply channel (Barr, 1999:13)

The border check style of irrigation had mixed success. Not all farmers were willing or financially able to re-layout their farms. Watering of one paddock could produce rising salt in a neighbouring paddock. Layout improved leaching but contributed to rising water tables and/or drainage of salty water. "The greatest contradiction was that 'irrigation was required to undo the damage done by irrigation' but Tragowel farmers did not, in any case, have access to enough water to irrigate all of their land (Barr,1999: 15). Improved water in later times only aggravated the problem of rising water tables and poor drainage.

In the late 80's the Victorian State Government sponsored the development of a community managed Salinity Management Plan (SMP). A Tragowel Plains Sub Regional working group composed of community representatives was provided with technical support from government scientists, planners and policy advisors. Government guidelines for the preparation of salinity management plans required the group to evaluate proposals from economic, environmental and social perspectives. Over a two year period the working group received eleven formal reports on the following topics: the social impact of salinity, soil salinity surveys, hydrogeology, sub-surface drainage, environmental conditions, stream management, surface drainage, flood management, farm situation, water supply, and salt loads and drainage (Barr, 1999). These reports were then integrated to form a set of recommendations that would form the basis for a salinity management plan (Barr, 1999; TP Draft SMP, 1989).

From the outset it was clear the external impacts of draining the plains area were going to be high so the plan had to look at ways of internalising the impact (Ray Evans pers. comm.) Significant internal adjustment through the movement of water within and between properties was necessary to achieve this. If the Plains area was to survive as an irrigation district, farmers needed to live with salinity by increasing the productivity of non-saline soils.

Detailed investigations of the Tragowel Plains study area as part of the salinity management planning process revealed the following:

- Large areas of land were salinised and the community was generally unaware of salinity levels on individual properties and the extent and impact of salinity on production;
- A large percentage of farms were too small (at existing productivity levels) to be viable without off-farm income;
- Irrigation intensity was low and spread over high and low salinity soils. Some properties did not have enough water to irrigate all low salinity soils while others did not have enough soil of low salinity on which to use their water allocation; and
- Groundwater in the area was (and still is) generally highly saline, which limits disposal options.

A key component of the plan was the use of whole farm planning to facilitate the plan objective of concentrating resources on lower salinity soils. This required that both a salinity survey and a topographic survey be undertaken to ensure that irrigation layout and farm drainage could account for soil salinity levels on the farm.

EM-38 soil surveys were a cheap way of classifying land as either appropriate for development or inappropriate for reclamation, and identifying farms that were non-viable due to a combination of soil salinity and farm size (Barr, 1999: 32). Soil surveying was costed into the SMP with government paying 90% and landholders contributing 10% (labour). The surveys classified land into four classes. Class A was non-salinised land capable of growing white clover. Class B was land with moderate salinity, capable of growing rye grass and sub-clover (conventional annual pasture). C and D class land were deemed unsuitable for conventional agriculture.

Different recommendations were put forward for the management of the different soil types (Figure 11). Farmers were encouraged to reduce, or preferably cease, irrigation of saline soils and to find an alternative use for the saved water which would provide a higher return. Class C and D soils should be fenced and sown with salt tolerant vegetation. Grazing on these areas should be for short periods only and strictly controlled. Higher value use of water on Class A and B soils would include re-allocation to perennial pasture or the sale of water to other landholders in the newly created water entitlement market (Barr, 1999)

Another key component of the Tragowel Plains SMP was a restructuring package. According to Barr (1999: 34) the inclusion of a structural adjustment component in a community salinity plan was a brave step that was firmly resisted by other salinity management planning groups. The plan's restructuring component aimed to improve the viability of existing farms by increasing the productivity of Class A soils and the Class A size of existing farms. Changing the nature of property turnover in the district would favour existing owners with salt free land and developed drainage systems.

A key objective was to increase the number of viable farms by encouraging property amalgamation; this would increase the likelihood of there being sufficient financially viable farm businesses to ensure the continued maintenance of district irrigation infrastructure (Barr, 1999: 37). It was also hoped that shifting irrigation water from saline to non-saline soils within the Tragowel Plains would prevent irrigation water from leaving the district through transfer of water entitlements.

To further slow the expansion of large low-input farms and 'cannibalisation' by neighbouring irrigation districts the salinity working group proposed that a stamp duty rebate be available to existing businesses which purchased additional land; but only if additional irrigation would be on A and B class soils within specified intensity limits (Barr, 1999: 37).

The costing of the Tragowel Plains SMP took into consideration the local community and landholders' ability to pay. Because productivity and disposable farm incomes in the plains area were low it was assumed that a large proportion of landholders would not be able to participate in the plan without financial assistance in the early implementation phase. For this reason the proposed cost-sharing arrangements for certain components had to overlook the beneficiary pays principle. It was decided that vital activities such as soil salinity surveys, topographic surveys and irrigation design, along with groundwater investigations would receive a high percentage of government assistance based on each farmer's ability to pay (TP draft SMP, 1989)

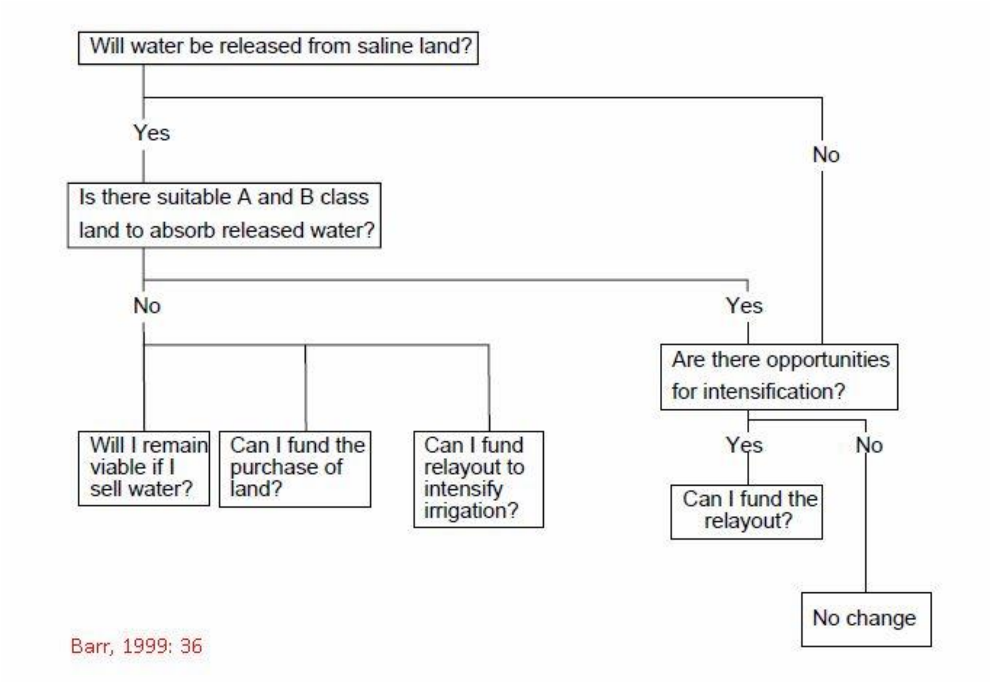

Figure 11: Decision tree based upon provision of EM-38 results

The proposed salinity management plan was strongly supported by most local farmers and the government. It commenced operation in 1990 with funding for all of the proposed initiatives for a five year period. Funding also included extension support for plan implementation and the purchase of a property to act as a demonstration farm for the plan's recommended management strategies were also funded.

Tragowel Plains SMP outcomes

Neil Barr (1999) wrote the following in his concluding chapter:

Five years of salinity plan management resulted in 27% of saline soils irrigated in the 1989-90 season being retired from irrigation. A further 17% were subject to significant reduction in irrigation intensity. Water equivalent to almost 7% of the district water right had been saved by ceasing irrigation of saline soils; equivalent to twice the volume of water sold permanently out of the area during the same five year period. The use of whole farm planning (see Figure 12) significantly increased as a result of salinity plan implementation and the provision of soil salinity data to farmers reduced the uncertainties associated with land development through laser grading.

The Basin Salinity Management Strategy (2001-02) summarises the total benefits of the Tragowel Plains SMP since the start of implementation:

The plan has been very successful in improving surface water management, retiring salinised land from irrigation, and concentrating inputs onto the most productive soils. It is considered that the plan implementation has been a major factor in the reduction of depth to watertable across the region. Prior to implementation 83% of the Tragowel Plains had a depth to watertable of less than 1m. In 1999 this percentage had dropped to 31% (SKM, 2000).

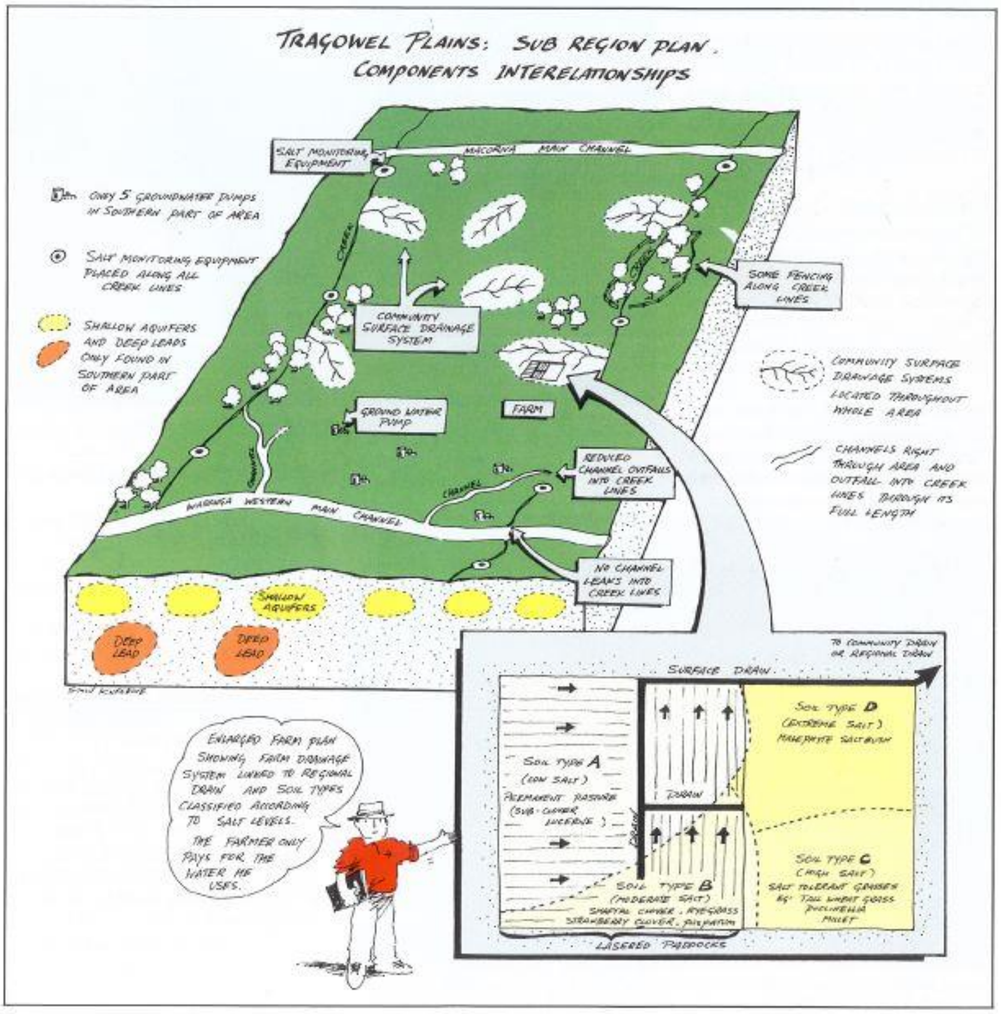

Figure 12: Tragowel plain community awareness information

Kerang-Swan Hill

Shallow saline groundwater developed under predominantly flood irrigated pasture within the Kerang-Swan Hill area. In 1968-69 a total of 179,000 acres was irrigated, 141,000 acres was irrigated pasture and 102,000 acres was low-profitability annual pasture. To overcome the problems posed by saline shallow groundwater, the Kerang region would need to drain, and this would ultimately end up in the Murray River. To implement options to lower the water table, subsidies were requested from the government, but these were refused. It was economically not possibly to drawdown the water table sufficiently to prevent further salinization given the costs on downstream users of disposing of the water to the River.

Table 5: Extent of salinity on surveyed agricultural land in the Murray Valley, 1995

	Soil Salinity Class			
Plan Region	**A (low)**	**B (moderate)**	**C (high)**	**D (extreme)**
	ha	ha	ha	ha
Shepparton	7 256	1 495	1	0
Kerang-Swan Hill	8 338	2 829	1 191	2 531
Tragowel Plains	48 711	22 345	8 044	10 278

Source: McClintock & Young, 1996

The Kerang-Swan Hill area sits within the Loddon Catchment and covers all of the irrigated land west of the Loddon River. The major part of this area sits on the western edge of the Riverine Plain with the dominant soil types being heavy grey and brown cracking clays used for cropping and pasture. In the north west, are the Tresco and Woorinen areas, characterised by Mallee dune fields. The lighter Mallee soils support most of the horticultural development. The major natural features of the district are the numerous lake and lunette systems dotted across the flat plain.

The area is supplied with irrigation water from the Murray River via the Torrumbarry Irrigation System which is an extensive, interlinked system of channels, lakes, weirs and streams. Over a distance of 160km irrigation water is supplied to districts from Kerang to Woorinen. Irrigation flows are augmented by pumps at Pental Island and by natural flows of the Loddon River and Bullock and Wandella Creeks (KLA, 1992b).

Salinity has been a serious problem since the 1930s on much of the irrigated land around Kerang. Farmers in the upstream areas of the system use water to grow pasture. Saline water is not so much of a problem as soil salinity. Irrigated horticulture, which is more sensitive to salt than pasture, is located towards the bottom end of the Torrumbarry system. However, horticultural demand for high quality water had to be balanced with the need to manage flooding along the Loddon River, downstream of Kerang Weir. For environmentalists the impact of irrigation on important wetlands was of concern. The Kerang Lakes area straddles the junction of three major flood plains and is home to a large number of wetlands, swamps, lakes and waterways of environmental significance.

The Kerang Lakes management plan needed to reduce water salinity, control soil salinity, mitigate the affects of flooding and protect the wetland environment. A draft salinity management plan was released in 1992. The plan foreword states that to some extent the area was a victim of circumstance with little control over water entering from three river systems and a number of anabranches. Salt was being imported at a rate of 294,300 tonnes per year, with 64,600 tonnes staying in the area. This posed a serious challenge for the working group overseeing the development of the salinity management plan. Solutions which may have addressed problems in earlier times, and which might still be an option in other areas, were not an option within the framework laid down by the Murray Darling Basin:

> *And so we are left with many ironies:*
>
> > *-at times we see irrigation water entering our area with salinity already above the threshold for optimum production*
> >
> > *-our crystal salt export industry was severely curtailed when our unique salt harvesting lakes were commandeered for the evaporation of drainage from outside areas – drainage too often at salinity less than supply water we can deliver to some irrigators*
> >
> > *-meanwhile we have areas to which we can offer little because we have no sustainable sub-surface drainage disposal (Simms, KLA 1992, pii)*

The draft Salinity Management Plan proposed eight programs to resolve environmental issues and ensure the future viability of the Kerang/Swan Hill region. The main aim was to reverse the accumulation of salt on farms and to further concentrate salt in the Tutchewop Disposal basins from where it could be harvested or otherwise disposed of.

The Lake Tutchewop scheme is perhaps one of the most distinctive features of this particular irrigation district. Once a high value wetland and flood buffer the lake was isolated from the flood plain during the 1960s by the Rural Water Commission. Barr Creek is the main outfall drain for much of the irrigated land around Cohuna, draining salty water from this area throughout the year. Water from Barr Creek (via the Loddon River) was the largest single point source of salt entering the Murray River from Victoria. To tackle this problem the Water Commission built a pumping station and a channel to carry salty water from Barr Creek to Lake Tutchewop which was meant to be the first of a series of planned evaporation basins. According to the 1992 draft SMP:

> *Taking Lake Tutchewop out of the lakes system is a sore point with local landowners. The lake no longer fills in floods so the flood peaks on surrounding land are higher. There is no advantage to local farmers as the salt water diverted to the Lake does not come from their own area. They are concerned it may be leaking salt into the watertables beneath their land. Environmentalists see its destruction as vandalism… (KLA, 1992: 6)*

The next stage of the Tutchewop Scheme was to have been the utilisation of the Mineral Reserves Basins in a dryland Mallee area adjacent to one of the horticultural areas. Landholder opposition led to a class action against the Rural Water Commission and the project was eventually cancelled 'for economic reasons' (KLA, 1992). In 1987 the Victorian government established a working group of local people to look at other ways of balancing the competing demands upon the lakes system. The 1992 draft SMP was the outcome of that process.

Each implementation program as documented in a summary of the draft salinity management plan consisted of a number of proposals which aimed to address key problems at the regional level (supply system and regional drainage) and the local level (on farms and specific wetlands). The eight salinity action implementation programs proposed by the draft plan were:

- On-farm program
- Environmental Program
- Water Quality Program
- Salt Disposal Program
- Surface Drainage Program
- Channel Seepage Reduction Program
- Flood Plain Management Program
- Implementation, Education and Extension Program

On-farm program: This component aimed to encourage farmers to concentrate farm inputs on the least saline soils and to cease irrigation and minimise stocking on more saline areas. As with the Tragowel Plains SMP soil salinity surveys were to be the first step in the development of on-farm management plans. The plan proposed that government would contribute 90% of the survey cost. Whole farm plans would include new irrigation layouts, drainage works, revegetation of saline soils and tree planting; and would be a pre-requisite for other on-farm assistance measures.

The on-farm program also included a structural adjustment package for existing farms that might be too saline to be viable in the long term. The package would assist non-viable farmers to sell to local buyers who could demonstrate that the purchase would improve the viability of their own enterprise. Assistance would include stamp duty rebates and access to low interest loans; a draft plan amendment later recommended that the implementation group consider the Tragowel Plains experience with their stamp duty rebate scheme.

Environmental program: This part of the plan would concentrate on rehabilitating valuable wetlands, as well as streamside and wetland vegetation. One of the draft proposals was that over 10 years, 100km of stream or wetland frontage be fenced and revegetated to intercept seepage and overland flow, provide habitat and reduce erosion. Other proposals included the preparation of management plans for selected wetlands and the removal of saline water from a number of semi-permanent and permanent wetlands. Flushing would largely utilise existing irrigation infrastructure during the winter non-irrigation period. Semi-permanent wetlands would be managed to include a drying cycle every five years. One lake would be managed for natural 'through flushing' of saline water into the groundwater system, thereby avoiding the need for costly pumps and channel works.

Water quality program: This program acknowledged the conflict inherent in attempting to use one system to meet water supply, flood plain management and drainage needs. It consisted of four complementary projects that would separate irrigation supplies from saline flows at key points:

- A groundwater interception scheme for Pyramid Creek, a major point source of concentrated salt inflow into the River Murray. Prior investigations revealed that approx. 25,000 tonnes of salt were entering the creek annually, with 80% of the inflow occurring in the upper 12.3 km. Intercepted groundwater would be relocated to salt harvesting ponds and salt processing facilities.

- A Wandella Creek bypass channel of 300 ML/day capacity to divert the low (but saline) Wandella Creek flows, and district drainage. This would improve the quality of irrigation water in the lakes system.
- An upgrade of the 17/2 channel west of Kerang. The channel would be enlarged to supply 150 ML/day of water to Reedy Lake, especially in spring, to replace existing saline flows from the Loddon River.
- A flushing channel for Lake Charm; this would link the north end of the lake to the lower sheep wash creek.

The Salt Disposal program: The net accumulation of salt in the Kerang-Swan Hill area would be reduced from 64,600 to 47,900 tonnes per year with the implementation of the SMP. However accumulation in the Tutchewop disposal basins would increase from 41,300 to 60,300 tonnes per year, most of it in Lake Tutchewop. Without active management the lake would in future have no environmental value with salinities predicted to reach 244,000 EC by the year 2050. It was proposed that back flushing to the historically saline Lake William would enable a target salinity of 60,000 EC to be reached (KLA, 1992b). Additional research into the feasibility of enhancing the evaporative capacity of existing disposal sites was also proposed.

The surface drainage program: Broad application of sub-surface drainage was not an option due to the cost of construction and problems of disposal. Surface drainage was judged a more affordable salinity control measure. This scheme would provide grants of 90% for the planning, and 50% of construction costs, to groups of landholders, provided there was an acceptable drainage outfall (KLA, 1992b). It allowed for a further 26,000 ha to be drained by shallow community drains in irrigated areas, enabling the full benefits of the on-farm program to be achieved. Improved surface drainage would also prevent extensive ponding of rainfall runoff and the consequent accessions to the watertable.

Channel Seepage Reduction Program: It was estimated that channel seepage accounted for 8.5% of the irrigation water entering the Kerang-Swan Hill area with 70% of the seepage occurring in the lighter soils of the north. Concrete lined channels in the Woorinen area were in an advanced state of disrepair. The program proposed remedial treatment in those areas with higher than average seepage loss in earthen channels. Incentives would encourage landholder to plant trees to intercept seepage. A study would examine alternatives for reconstructing the concrete channels, how they might be financed and other options for water supply to Woorinen horticultural area (KLA, 1992, KLA, 1992b).

The Flood Plain Management Program: This program proposed a series of works to minimise flooding using available river and lake capacities and to provide a flood path separate to the irrigation supply system so that irrigation water quality would not be affected. For instance the capacity of the main inlet to the Lakes system (Washpen Creek) would be doubled, providing better protection for the Lower Loddon River. Changes to the operating guidelines of the Kerang Weir would be upgraded to allow for increased flow to the lakes without significantly affecting irrigation water quality. Avoca River floods would be better managed by upgrading the outfall system including the rebuilding of banks and levees to reduce the risk of failure under flood conditions (KLA, 1992, KLA, 1992b)

Implementation, Education & Extension: This last component of the plan would ensure that the community (rural and urban) was made aware of the problems, the proposed solutions, and the assistance available under the plan. It would also keep the community involved in the implementation and further development of the plan.

The draft SMP proposal included the flushing of Lake Charm and a surface drainage program servicing an area of 26,420 ha with around 135 km of community drains (MDBC, 2003). The government allocated a total Salinity Disposal Entitlement (SDE) of 1.41 EC to the Kerang Swan-Hill SMP. An initial SDE of 0.44 EC was assigned when this SMP was added to the MDBC Salinity and Drainage Strategy Register in August 1993. The credit enabled the commencement of the proposed surface drainage program. An additional SDE of 0.47 EC was added in 1995 to allow Lake Charm flushing. This figure was estimated using salt load impact studies and REALM modelling of the Kerang Lakes System, based on data from 1975 to 1985 (MDBC, 2003).

The summary of the draft salinity plan for this area was quite good in that each proposal clearly illustrated the costs involved for the overall plan and the cost-sharing arrangements for each program and for proposals within the programs. Whilst this information was included in other plans it wasn't always so clearly set out. The total cost of this plan over its lifetime was estimated to be $41M with benefits of $57M being generated. Farmers would receive 60% of the total regional benefits from the boost to agriculture, with the balance of the regional economy receiving 40%. The State and Federal government would fund most of the capital costs and the community would contribute annually to the operation, maintenance and replacements costs. Farmers would contribute substantially as and when they decided to undertake on-farm development works and community drainage schemes. All users of irrigation water would contribute increasing amounts as the water quality program was implemented. All residents would contribute to the annual cost of the environmental program.

Murrumbidgee Irrigation Area

MIA has never had a large salt input into the MDB system, due to the small overland return flows. The use of Barren Box as a regional evaporation basin, the use of localized evaporation ponds, and the use of recycling return flows both on field and at district level emphasizes MIA's relative isolation from the river system (other than extraction).

The following is an abridged version of two documents: The MIA Land & Water Management Plan Summary (July 1998) and the MIA L&WMP (complete document)

The Murrumbidgee Irrigation Area (MIA) is located on the northern fringe of the Riverine Plain, north of the Murrumbidgee River. It is one of the most diverse and productive regions in Australia contributing over A$5 billion annually to the Australian economy. It is managed by Murrumbidgee Irrigation, one of the largest private irrigation companies in Australia, which currently services an area of 660,000 ha with over 3,500 km of supply channels and 2,160 km of drainage channels.

The MIA & Districts Community Land & Water Plan (LWMP) includes the Yanco and Mirrool Irrigation Areas (Leeton & Griffith the major towns respectively) and the associated irrigation districts of Benerembah, Lake Wyangan and Wah Wah. Agriculture is the basis of the local economy with the primary industries being irrigated agriculture and horticulture. In 1998 when the plan was approved there were about 2000 farm businesses, half being large area farms, the other half horticulture. The major irrigated enterprises were rice, wheat, citrus, wine grapes, peaches, vegetables, prime lamb, wool and beef cattle.

Irrigation on a large scale began in Yanco in 1912 following the construction of Burrinjuck Dam on the Murrumbidgee River. Irrigation water was initially used for horticulture, dairy, and pasture production. Rice was first grown experimentally in 1924 but has since become the MIAs major large area farm commodity. The Wah Wah and Benerembah districts were developed in the 1930s to make use of the drainage water from Yanco and Mirrool. These were developed as stock and domestic supply schemes with some supplementary pasture irrigation although rice growing later became the major enterprise. Further expansion occurred in the 1970s with the completion of the Snowy Mountains Scheme and the construction of Blowering Dam.

The MIA area was originally chosen for its good soil and gently sloping land, allowing the water to be delivered to farms by gravity. It is a completely recycled system as it incorporates a combined supply and drainage function with all drainage re-used. The five irrigation districts are supplied with water via two off-takes from the Murrumbidgee river at the start of the system near the town of Narrandera. Irrigation was managed by the state government until 1997 prior to Murrumbidgee Irrigation Ltd taking over 1999.

According to the LWMP it started out as an “Integrated Drainage Scheme for the MIA & Districts”, the catalyst being widespread damage due to flooding in 1989. At that time, however, excess surface drainage was only a symptom of inefficient water supply and unsustainable irrigation practices. The area is also highly modified by urban and agricultural development and more prone to flooding as a result.

The main surface drainage feature of the MIA & Districts is Mirrool Creek and its tributaries. The creek has its headwaters near the town of Temora and drains a large catchment before it reaches the irrigation areas. Within the MIA Mirrool Creek acts as an integral part of the supply and drainage system, ensuring continual supply for the Wah Wah Irrigation District via Barren Box Swamp. Around 90% of all drainage leaving the MIA is collected in Barren Box Swamp and then re-used in the Wah Wah Irrigation district. Only about 10% drains back to the Murrumbidgee River from the Yanco and Gogeldrie areas south of the township of Leeton. Several parts of the MIA have no off-farm drainage disposal arrangements at all.

Areas east of Barren Box are ‘upstream’, with ‘downstream’ areas to the west. Many of the environmental problems occurring downstream were the result of excess drainage from the upstream areas. The January 1997 draft plan therefore dealt principally with those issues associated with the areas east of Barren Box Swamp with the greatest priority given to programs which would reduce surface drainage flows and seepage. The local areas of Wah Wah, Lake Wyangan and Benerembah differ in their physical environment and water management, and detailed investigations were carried out for each of these areas during the plan preparation.

As in other areas the MIA L&WMP was developed within a regional context, overseen by the Murrumbidgee Catchment Management Committee (now known as the Murrumbidgee Catchment

Management Authority)(MCMA). The MIA plan had to implement broader regional objectives at the sub-regional scale, taking into account both up-stream and down-stream impacts.

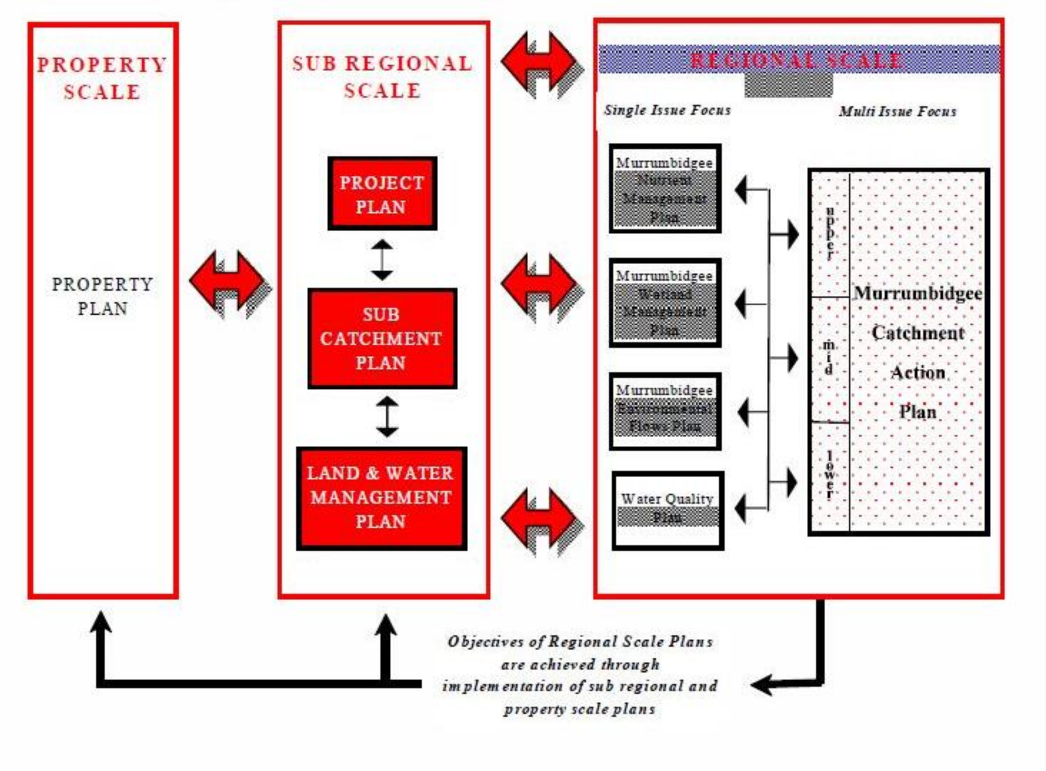

Figure 13: The planning framework for the Murrumbidgee catchment

Seven years in the making, the MIA & Districts LWMP was underpinned by two key assumptions:

1) That the NSW state government will provide a financial grant to refurbish the existing water supply and drainage infrastructure. Assessments of various components of the plan have also been based on the assumption their costs and activities are additional to those being financed by the proposed grant; and
2) That existing resources would not be counted towards LWMP funding. Existing work already being funded through a range of government, industry and community sources was bringing about change, but not at a rate that would guarantee the future sustainability of the MIA. The plan would accelerate the pace of on-farm work and initiate new programs to address particular problems, provided that funding for the plan was additional to existing funds.

The plan had five main objectives:

- To reduce seepage to the groundwater system [from 117,000 ML without a plan to 94,000 with a plan];
- To reduce surface drainage volumes to acceptable levels [from 236,300 ML without a plan to 194,400 with a plan];
- To keep drainage water quality within agreed standards [as outlined in the EPA license requirements, with salinity levels at Barren Box to be subjected to continuous improvement];

- To manage drainage disposal to meet agreed standards [by reducing flood volumes and flood frequency in Lower Mirrool Creek to environmentally acceptable limits]; and
- To protect natural resources within the area commensurate with the fundamental changes that irrigation in the MIA has already brought about

Salt Balance

The salt balance for the MIA was calculated prior to the drafting of the LWMP. Estimates based on the amount of salt coming in through the irrigation system and leaving via the surface drainage system suggested a net salt accumulation of some 40,000 tonnes/year. However, salt also enters and leaves the area via the groundwater system through processes of leaching and capillary rise. The MIA contains about 200 tonnes/hectare of salt in the soil profile above bedrock which is in the order of 30 million tonnes across the area. More relevant to agricultural production however is the salt balance within the root zone. Examination of the increase in soil salinity distributions since the start of high water table conditions indicated that soil salinity within the irrigated area had increased by 290,000 tonnes. Further calculations led to an estimated increase in the topsoil of about 20,000 tonnes per year. It was concluded that a significant proportion of the arriving salt load was passed on to the groundwater system where watertables were deeper; and by leakage between shallow and deep aquifers.

Coleambally Irrigation Area

A series of booklets was produced by the Open Learning Institute, CSU Albury as part of the Education Program associated with the Coleambally Land & Water Management Plan. The program was jointly funded by NHT and Coleambally Irrigation. Landholders were encouraged to participate in the education program, and access to some of the L&WMP incentives was conditional upon completing core units. In the acknowledgement at the front of each booklet is the following statement:

The Coleambally L& WMP Committee believes that the booklets will assist landholders to use irrigation management to ensure a more sustainable future for the Coleambally Irrigation Area

The booklets of most relevance to this document are:

McCaffrey, A (1998) Unit 2: Coleambally Landscape: Past, Present… Future

McCaffrey, A (1998) Unit 5 – Living with Water Tables and Salinity

The Coleambally Land & Water Management Plan was drafted in 1996 and is still in operation.

Introduction

The Coleambally Irrigation District (CID) is located 60km south of the city of Griffith on the southern side of the Murrumbidgee River. The area was developed during the 1960’s when approximately

79,000 ha was gazetted an irrigation area with 311 large area mixed farms and 22 small horticultural farms. Currently the area is made up of 495 irrigation farms totalling 79,000 ha of irrigated land. The four main farm enterprises are rice, sheep and annual pastures, winter crops (mainly wheat) and soybeans. On a smaller scale there are horticultural products such as grapes, prunes and vegetables. The CIA is the most intensively cropped non-horticultural irrigation area in southern NSW.

The area has an average rainfall of 400mm/year. Rainfall is variable both in quantity and distribution throughout the year. Summers are generally long and hot, winters are wetter with low evaporation and periods of frost.

Irrigation water is diverted from the Murrumbidgee River into the Coleambally Main Canal upstream of Gogeldrie Weir near Darlington Point. The Irrigation District consists of 41km of Main Canal, 477 km of supply channels, and a further 734km of drainage channels. Open earthen channels supply irrigation water via a gravity fed, solar powered system which incorporates state of the art metering and flow regulation technologies for automated water ordering and accounting. Over $40 million has been invested over the previous 10 years in system automation (CICL, ACR, 2011).

Beneath the CIA the Calivil Formation aquifer contains large reserves of low salinity (600EC) water which is accessed by licensed pumpers to the north, west and east and within the CIA. It also supplies town water to Coleambally and Darlington Point. Various crops are grown along the Murrumbidgee River north and west of the CIA using about 90,000 ML/year of groundwater (Draft L&WMP, 1996).

The Coleambally Irrigation District irrigation water license is held by the Coleambally Irrigation Co-operative Limited (CICL), a private co-operative that commenced trading in the year 2000. All customers of CICL are members of the co-operative which oversees water delivery and associated services to district landholders. Three L&WMPs cover CICL's operational area; the Coleambally L&WMP, the Kerarbury Channel L&WMP and the Coleambally Outfall District (COD) L&WMP. Co-operative members have spent upwards of $100m since 2000 improving land and water management practices and enhancing local biodiversity. The co-operative also manages 1700 ha of Crown land that has been set aside for biodiversity purposes.

History

Prior to irrigated agriculture, watertables were about 20m below the surface. Over the 10 year period from 1981 – 1991, watertables in the CIA rose dramatically. By 1983/84 1,000 ha were underlain by shallow water tables (<2m from the surface). By the end of 1990, after two unusually wet years and larger areas under rice, there were 40 000 ha (50% of total farmed area) with the watertable a metre or less from the surface. Drier conditions and the operation of a deep bore resulted in a temporary decrease in the area underlain by high watertables (approx. 27,000 ha in 1993).

Table 6: Summary of the outcomes of the no action scenario (Source: McCaffery, 1998)

Issue	Current Area affected	Extent in 30 years
Soil Salinity	Approx. 2% of the area greater than 2dS/m ECe	About 25% greater than 2dS/m ECe directly related to groundwater levels
Groundwater	About 27,000 ha in 1994	About 60,000 ha in 2023 caused by groundwater accessions
Soil acidity	85% CIA with pH < 5.5 in CaCl	Acidity expected to increase further causing reduced cropping flexibility
Natural vegetation	500 ha left – loss due to clearing and rising water tables.	Further decline
Farm profitability	Current levels	$5.48 m loss from waterlogging over 30 years. $4.39 m loss from salinity over 30 years

The total salt load leaving the CIA in farm runoff and escapes historically was been in the order of 21,000 tonnes and the corresponding salinity about 237 uS/cm. A 'no plan' scenario (Table 6) estimated that farm runoff and seepage into drains would increase the salt load leaving the CIA. A likely increase in salt load of about 5,500 tonnes of farm runoff over the next 30 years due to increasing soil salinity was predicted in 1996 when the draft L&WMP was released.

Coleambally L&WMP

The Coleambally L&WMP is based on the "Guidelines for Land & Water Management Plans" (1992) prepared by the Murray and Murrumbidgee Catchment Management Committees. Components developed from the guidelines include:

- District summary
- 'No Action' Scenario
- Option development & evaluation
- Strategy development

- Implementation Program, including cost sharing arrangements and monitoring and review programs

This plan was designed to be implemented over a period of thirty years with government contributions limited to the first 15 years. It was recognised that the key to managing high water tables and soil salinity is early recognition of the problem with on-farm monitoring the most effective way of identifying areas at risk. A target of no more than 15% of the CIA to have a soil salinity reading of greater than 2dS/m ECe was considered necessary for long term sustainability.

A Community Environmental Committee (CEC) is responsible for providing community input to CICL for the implementation of the L&WMP. A L&WMP committee co-ordinates information for the implementation of the plan along with the formal review process.

A key implementation component of the management plan (MP) was Net Recharge Management (NRM) whereby the recharge from irrigated crops on each farm was assessed and evaluated. This part of the plan was to be implemented over a period of 10-15 years and aimed to involve all landholders in decision making processes. Implementation began in 2000 when the Swagman Farm model software was demonstrated for 42 farms. Subsequent to this, individual landholders entered into an agreement with CICL with an agreed allowable net recharge for their property. The aim was that landholders use NRM models and techniques to plan cropping rotations and to manage their farms; the range of available options in lieu of previous practices would be considered during the planning process.

The second major implementation component of the plan was Drainage Water Control, which aimed to improve water quality for downstream users, manage salinity in drains and improve the natural environment affected by CIA drainage. The initial focus was on the recycling and reuse of drainage to avoid downstream pollution. Table 7 lists a range of on-farm and regional options for managing drainage water.

Table 7: Control of Drainage Water Quality Strategy

Options	Target (years)	Comments
ON-FARM OPTIONS		
Farm Management: 1.On-farm drainage reuse with/without water storage.	80% in 10 yrs	Control quantity and quality of drainage. Improve farm layouts and designs for efficient irrigation and to reduce waterlogging.
2.Reuse of fresh groundwater from spearpoint pumping, 3.Irrigation scheduling, 4.Bed and row cropping, 5.Horticultural irrigation systems.	Life of Plan	
6.Management of Saline Lands	Life of Plan	Control spread of salinity. Rehabilitate saline areas where possible. Reduce salt loads in drainage by excluding run-off.
7.Management of Pesticides and Nutrient Levels in Drainage	80% in 10 yrs	Undertake accredited "Farm Chemical Users Course" to reduce the entry of pesticides and nutrients into off farm drainage systems.
REGIONAL OPTIONS		
1.Saline Water Management	At high river flows	Drain numerous sand and gravel pits and natural depressions of saline groundwater to control the groundwater rise.
2.Escape Loss Control	2	Minimise loss of good quality irrigation water.
3.Shallow Groundwater Pumping (as per Net Recharge Management Strategy).	15-30	Extract groundwater from high watertable areas to lower the watertable.

Regional water table maps are produced every year by Coleambally Irrigation; these are used to identify areas where high watertables might be a problem. The maps are based on the data from a network of piezometers that are installed directly into aquifers. Local or perched watertables can be quite different to that of the regional water table and vary according to soil type, topography and on-farm management. Local water tables are monitored by test wells and landholders are required/ encouraged to develop and implement a basic monitoring program for their farms. The "Living with Water Tables and Salinity" unit that was part of the Education Program associated with the Coleambally L & WMP contained information on how to identify high risk areas on farms, how to develop a monitoring program and how to manage high risk areas appropriately (McCaffery, 1998b).

A third key component of the L&WMP was an education strategy to link and facilitate the implementation components. This was based on the assumption that if landowners are unaware of their responsibilities toward the environment then they may unknowingly do the wrong thing. To encourage participation landholders were required to complete the core units of the education program in order to fully access L&WMP incentives. Core units included Landscapes past and present, Soils of Coleambally, Whole Farm Plans, Understanding watertables and salinity, Net recharge management, Irrigation practices, Water quality, Managing remnant vegetation and Farm business decision making. Over a period of five years over 70% of landholders took part in the program (AER, 2003). A Property Management Program that complemented the Education Program was subsequently developed and offered to landholders.

More recently the education program has been phased out although community educational activities are ongoing and include field days, farm walks, workshops and seminars.

Plan Implementation

Table 8 shows the timetable of implementation of the Kerarbury Cahnnel L&WMP (CICL AER 2001), which is a subset of the Coleambally MP with many of the same options. The table gives an overview of the main options for adoption over different time frames.

Table 8: Timetable for implementation of the Kerarbury Channel LWMP

KERARBURY CHANNEL LWMP OPTIONS			
1 year (2001-2002)	5 years (2001-2006)	10 years (2001-2011)	30 years (2001-2031)
Monitoring of Bores	Whole Farm Plans	Drainage System	Landforming
Dethridge Long Meters	EM-31 surveys		Biodiversity
	Recycling/Storage		Remnant Vegetation
	Education Program		Water Quality
	Net Recharge Management		Groundwater Monitoring
			Education
			Deep Groundwater Management
			LWMP Survey

Not all areas are suitable for rice production and so there is a classification system that allows unrestricted rice growing in some areas and marginal production (1 rice crop in 4 years) in others. Other areas are deemed unsuitable for rice. These limitations have led to the development of farm rotation systems throughout the CIA, with a typical rotation (40-50% of farms) being rice (1-3 years) – fallow – winter cereal (1-2 years) – annual pasture (2-4 years).

Physical lowering of the water table can be achieved by installing and managing groundwater pumps or bores or tile drainage. These systems drain the water away from the vicinity of plant roots, reducing water logging and allowing the leaching of accumulated salts from the surface. However this drained water has to be managed, either by transferring it to the surface drainage system or via some other disposal method. Conjunctive re-use (mixing of pumped groundwater with surface water supplies) is the most common method of managing disposal of saline groundwater. The other option is to export the salt out of the region. The other key methods include surface drainage and irrigation system management and improvement ("Balancing the salt budget for the SIR", 2005).

Current situation

20 years on the 2011 Coleambally Irrigation Annual Compliance Report (ACR) reported a small rise in groundwater levels as a result of the second highest rainfall total since records commenced in 1920. Even so the water table was within 2m of ground level for only 495 ha and well below the LWMP remediation trigger point of 10,000 ha.

Loxton SIS

The Loxton Salt Interception Scheme was approved for construction by the MDBA as a joint works scheme under the Basin Salinity Management Strategy (BSMS) in 2003. The scheme has been constructed in two stages, a Floodplain and a Highland Scheme.

The Scheme is designed to intercept salt inflows to the Murray River that are being driven by high rates of irrigation water accession in the adjacent Loxton irrigation area. The Scheme is being complemented by on farm water use efficiency improvements including improved water use and rehabilitation of old and leaking water delivery infrastructure.

The Loxton Floodplain SIS, which has been operational since 2009, has 27 production wells, and a 285m Cliff Toe Drain. The scheme disposes the intercepted saline groundwater to the Noora Basin, located approximately 20km east of Loxton. In 2009-10 the Floodplain Scheme intercepted approximately 98 tonnes of salt per day. Over a 30 year average the scheme will have a salinity benefit of 8.2EC at Morgan.

- Designed to intercept a total of 70 tonnes of salt per day from entering the River Murray with a 19 EC benefit at Morgan.
- Being constructed in two stages – floodplain and highland.
- The Floodplain section of the scheme became operational at the start of 2009 and is currently intercepting a total of 50 tonnes of salt per day.
- The Highland component is currently under construction.
- Currently only the Floodplain component has been put on the BSMS Salinity Registers, the highland component will be added once the scheme is commissioned in 2010-11.

The Loxton Highland SIS comprises 33 production bores and a horizontal well with 250m of production zone. By the end of 2009-10 a total of $19.7 million of the allocated $20.0 million had been spent on the construction of Loxton SIS with the remaining $311,000 to be spent in 2010-11.

Lower Murray Salt Interception Schemes

The Lower Murray River is deeply incised into its flood plain and as such areas that are irrigated lie at a higher elevation than the river and its floodplain. Inefficient irrigation causes watertables to rise and this in turn increases the hydraulic gradient between the irrigated area and the river. The regional groundwater is highly saline, and so any of this groundwater that is driven into the river by the higher gradients causes a noticeable impact in salinity levels of the River.

In these areas, salt interception schemes have been developed at a number of places to intercept the saline groundwater inflow. The schemes are comprised of a series of bores along the river tapping the most productive aquifer (Figure 14). Groundwater is extracted to manage the head difference between the groundwater below the river and the river level itself. Extracted saline groundwater is disposed of in evaporation basins located away from the floodplain environment.

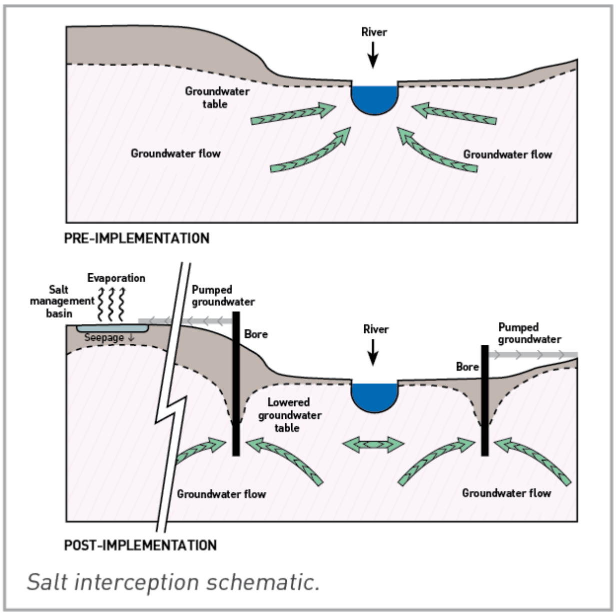

Figure 14: Salt Interception Scheme schematic (Source: MDBA, 2011)

Field Level

This section discusses field level strategies for the reuse of saline drainage water and the disposal of saline water using evaporation basins. The Australian experience has shown that saline drainage water can be successfully reused on a wide range of crops, from pastures to maize and trees. These re-use schemes have been successful because they have paid attention to providing adequate subsurface drainage and as such soil salinisation has been avoided.

Where reuse is not feasible due to the salinity of the drainage water, location or economics, Australia has successfully used evaporation basins to safely dispose of saline drainage waters given that the disposal of saline waters to rivers systems is no longer acceptable, uneconomic, and governed by the Salinity Management Strategy for the Murray-Darling Basin.

A further major constraint to the reuse of drainage water is soil salinisation resulting in soil structural decline due to sodification. This is because drainage waters are often high in Sodium and low in Calcium. Special care is needed to maintain soil structure so that water can infiltrate and leaching through the profile can occur. Specific problems have occurred in trying to get good crop establishment when annual crops have been cultivated, especially when fresh water comes into contact with saline/sodic soil, leading to dispersion and surface waterlogging. This together with the need to retain high levels of organic matter lead to the conclusion that forage crops that are grown as perennials are most suited for use with drainage waters.

Another issue that has arisen in some areas is associated with Boron. High levels of Boron can be expected in subsurface drainage water in some geological locations. This has dual problems in that Boron is reported as requiring 2 or 3 times more water to leach from soil than other salts and also plants are more sensitive to high Boron levels than other salts.

In terms of irrigation systems assessment of reuse systems for poor quality waters in terms of sustainability and environmental management leads to the conclusion that drip or sprinkler irrigation would be preferable. Sprinkler irrigation has the drawback of possible foliar injury, careful management required, and drip has a potential disadvantage in providing uniform leaching of soils. There is the likelihood of salt accumulating at the edge of the wetting pattern.

Thus in assessing the success of saline drainage water reuse there are five main issues:

1) Ensuring adequate subsurface drainage, either natural or artificial;
2) Avoiding Boron toxicity;
3) Maintaining soil structure – drainage water sodicity, organic matter, reduced cultivation;
4) Avoiding foliar injury due to salt burn; and
5) Ensuring that the drainage from the reuse site is suitably managed.

Conjunctive water use (CWU) in northern Victoria

Level: Field

Objective: To demonstrate an approach to drainage water recycling

Method: Conjunctive Water Use

The Land and Water Salinity Management Plan for the Shepparton Irrigation Region (SIR) promotes groundwater pumping and re-use for irrigation where groundwater quality and availability allow dilution with channel water to levels that produce minimal production losses from annual and perennial pastures used widely for dairying; this is termed 'Conjunctive Water Use' (CWU),.

An upper limit to irrigation water salinity of 0.8 dS/m is currently recommended in the Plan. This recommendation is based on empirical data from experiments on unstocked, perennial pasture collected over 2 decades on red-brown earths in the region.

In a field assessment of the impact of this CWU strategy on the irrigation region, Surapaneni and Olsson (2001)reached the following conclusions in their review paper.

Although the strategy has so far achieved acceptable control of soil salinity levels in the crop root zones, while generally maintaining pasture yields, a concern that 'conjunctive water use' may not be sustainable in the long term arises from the sodicity of the groundwater and wastewaters. The continual addition of sodium to clay soils, initially low in both sodium and electrolytes (upper 0.5 m depth), risks the soils becoming sodified, with attendant soil physical problems should salts be leached to below threshold electrolyte concentrations, as in winter for example.

Clay soils supporting pastures in the Shepparton Irrigation Region sodify with time under 'conjunctive water use'. The evidence for adverse effects of such sodification on soil physical properties affecting plant productivity and hydrologic processes undermine the long-term sustainability of the strategy.

In order for conjunctive water use to be sustainable physically and economically, salt concentrations in the soil solution must be limited to those that support high pasture yields and minimise any adverse effects of added sodium on soil physical properties influencing hydrology and pasture yield. Aquifer quality must also be maintained (both as sodium and salinity). Any ongoing sodification under conjunctive water use would lead inevitably to salinization since the EC requirement for TEC will eventually increase to beyond the salt tolerance of pastures and crops. Unless gypsum is applied strategically in autumn the EC in winter is unlikely to be maintained above the threshold electrolyte concentration (TEC) (Surapaneni and Olsson 2001). Any retention of salts due to incomplete leaching may, to varying degrees, suppress the manifestation of soil sodicity so that it may be difficult to measure any adverse effects of salt leaching on soil properties such as hydraulic conductivity (HC).

Management of conjunctive water use must aim to slow sodification by limiting the amounts of sodium added in the irrigation water. An upper limit to the SAR of the applied water needs to be defined. Adverse effects on soil properties and pasture productivity should be minimized by keeping ESP low with the strategic use of gypsum and maintain high levels of organic matter (Surapaneni and Olsson 2001).

A concern, however, is that both groundwater salinity and sodicity will increase with time with continued conjunctive water use, resulting in high ESP soils. Any reclamation of such soils using gypsum, for example, may lead to further problems at depth and in the groundwater, due to sodium displaced from the upper layers. The need to adopt strategies to obtain a salt balance in the SIR protected by the pumps, which could involve some periodic salt export through the surface drainage system of the area and salt containment in the rootzone of salt tolerant crops have been suggested as options in integrated salt management. However, Mann *et al.* (2003) expressed concerns on the observed slow and steady rises in groundwater salinity in hot-spots within SIR under CWU operations. This indicates that the long term operation of CWU may well be unsustainable in many areas.

Serial Biological Concentration in Northern Victoria

Level: Field

Objective: To demonstrate an approach to water reuse

Method: Serial Biological Concentration

The sequential biological concentration technique has been suggested as an alternative approach to conjunctive water use. A Serial Biological Concentration (SBC) project has been carried out to reuse the drainage water pumped from a shallow saline aquifer on a 3-ha tile-drained forestry cropping area, to reduce the volume of water for disposal in an evaporation pond. An effective salt balance was achieved in the forestry area of the SBC trial over the 4-year observation period (Figure 15). In the evaporation basins, out of 524 tonnes of salt discharged into the ponds, only 125 tonnes could be accounted for in the water stored in the ponds after 4 years of operation, indicating considerable leakage.

Figure 15: Three year old SBC site at Undera with salt-affected land in the foreground (Source: FAO, Photo 9; http://www.fao.org/DOCREP/005/Y3796E/y3796e09.htm)

Reclaimed water (RCW) reuse in the Northern Adelaide Plains (NAP) horticultural districts

Level: Field

Objective: To demonstrate an approach to water reuse

Method: Reclaimed Water Reuse

Reclaimed water (RCW) reuse has been practiced on the Northern Adelaide Plains (NAP) horticultural districts for more than 28 years. The RCW has had approximately 1.7 times the salinity and twice the sodium absorption ratio (SAR) of bore water commonly used for irrigation in the district. Recently, a large-scale reclamation scheme has been commissioned which could eventually supply approximately 30 GL of RCW to over 250 growers on the NAP.

Stevens *et al.* (2003) studied the effects of reclaimed water reuse on the NAP. Their study compared historical water quality and time of use data with physio-chemical properties of soil cores taken from sites where reclaimed (RCW-irrigated) or bore water had been used for irrigation, or sites that had not been irrigated. The aim was to determine if current farming practices irrigating with RCW could, now or in the future, lead to a decrease in yields through detrimental increases in soil salinity, sodicity, and boron (B) concentrations, and to determine if these changes were significantly different between bore-irrigated and non-irrigated sites. Stevens et al. (2003) summarised the results of a study as follows. *Data suggested that changes in soil salinity and B concentration from RCW use would not decrease yields. However, changes in soil SAR had the potential to restrict drainage and consequently increase salinity; although a more functional critical SAR value for the NAP soils needs to be defined to assess this potential. These findings suggest that farming methods, in the 1967-95 period, did not address the physico-chemical changes associated with the use of more sodic RCW. Considering the future scale of RCW use, the SAR of the irrigation water may need to be decreased* *and/or appropriate farming methods developed and practised with the use of RCW to protect these soils for future horticultural activities.*

Their data also showed that although the soil salinity in the shallow rooting depths of vegetable crops was below critical limits, salt accumulation was observed at depth which could affect cropping with deeper rooted crops. There was insufficient winter rainfall to leach the salt from these deeper soil layers.

The Land FILTER system in Griffith, NSW.

Level: Field

Objective: To demonstrate water reuse approaches

Method: Land FILTER

Studies on use of saline and sodic wastewaters on soils with restricted drainage have indicated development of salinity and sodicity problems. Falkiner and Smith (1997) found that four years of irrigation with slight to moderately saline and sodic effluent resulted in marked increases in soil salinity and increase in soil sodicity to around 20-25%. Smith *et al.* (1996) showed that excess water needed to be applied at this effluent irrigated plantation to promote the leaching of excess salt accumulating in the rootzone of the soil profile.

The FILTER (Filtration and Irrigated Cropping for Land Treatment and Effluent Reuse) technique was developed as a controlled flow system for sustainable land treatment and reuse of poor-quality polluted and saline wastewaters, on soils with restricted drainage (Jayawardane 1995; Jayawardane, Blackwell et al. 1997a; Jayawardane, Cook et al. 1997b; Jayawardane, Blackwell et al. 2002; Jayawardane, Biswas et al. 2004). The FILTER technique combines the use of nutrient-rich wastewater for intensive cropping, with filtration through the soil to a subsurface drainage system (Figure 16). Wastewater application and subsurface drainage in the FILTER system are regulated to ensure adequate removal of pollutants, thereby producing minimum-pollutant drainage water which can meet the stringent Environmental Protection Authority (EPA) criteria for discharge to sensitive inland surface waterbodies. The use of the subsurface drainage system to remove the excess water during the periods of low cropping activity or periods of high rainfall allows the use of this technique throughout the year.

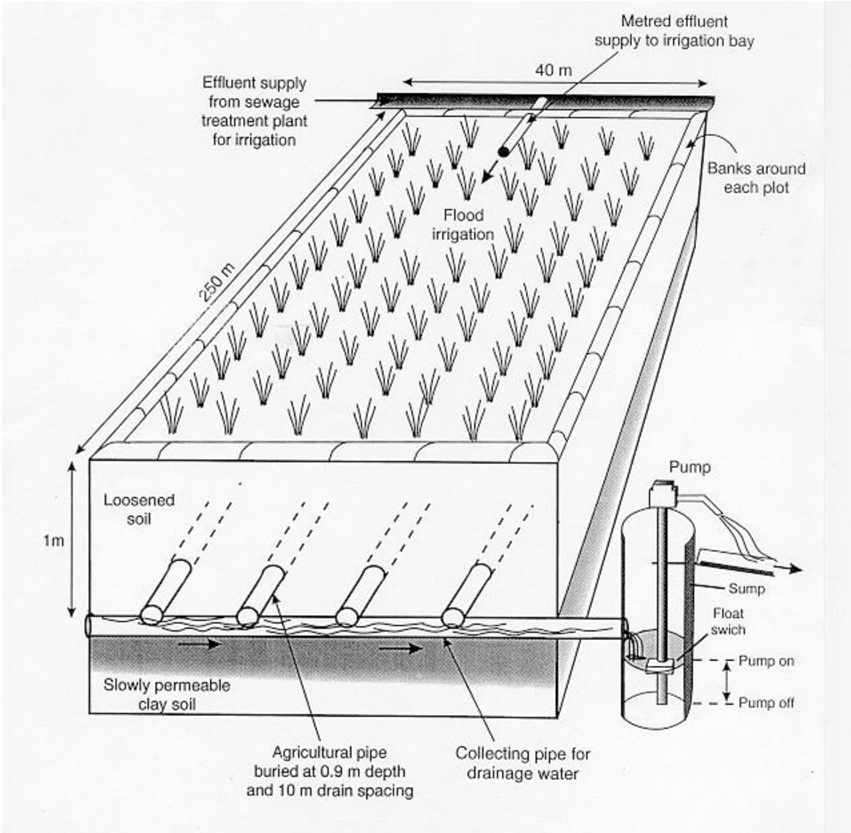

Figure 16: Diagram showing the land FILTER system

Preliminary testing of the FILTER technique was carried out on a heavy clay soil with impeded drainage. This was followed by field evaluation of a 15-hectare pilot FILTER system. The field data showed that the FILTER system met its objectives of reducing nutrients and other pollutants in the drainage waters below EPA limits for sensitive waters, while maintaining adequate drainage flow rates. Significant crop yields and nutrient removal were obtained, which would help to maintain nutrient balance required for a sustainable system, and to offset costs in a commercial system. The other beneficial effects were reduced suspended solids, E.coli, and increased N: P ratio in the drainage waters.

The use of the FILTER system on the highly saline-sodic soil resulted in a progressive decline in salinity and sodicity. The concentration of salt increased in the drainage waters, mainly due to leaching of salts that had accumulated in the soil through previous effluent application without sub-surface drainage, as well as salt concentration by evapotranspiration. After salt equilibration is reached through leaching of these accumulated salts, the salt load in the drainage water will be the same as in the effluent, while the salt concentration changes will depend on the balance between concentration through evapotranspiration and dilution through rainfall.

Provision of a sub-surface drainage system in FILTER plots at the Griffith land application site with impeded drainage reversed the pre-FILTER accumulation of salinity and sodicity (Jayawardane, Blackwell et al. 2002; Jayawardane, Biswas et al. 2004). The threshold electrolyte concentrations for spontaneous dispersion calculated using the method proposed by Rengasamy *et al.* (1984) was much lower than the $EC_{1:5}$ measured in the soil before filtration and after the three cropping seasons of the trial, indicating that subsurface soil structural stability is likely to be maintained during effluent flow through the soil to the subsurface drains. The relatively small shift in the relationship between the subsurface drainage rate and the watertable height midway between drains during the three cropping seasons indicates maintenance of subsurface soil structural stability. Modelling of sodicity and salinity changes in FILTER soils can be used to predict the longer term soil stability effects, and the needs for any remedial measures such as periodic application of gypsum to the soil surface.

The threshold electrolyte concentrations for mechanical dispersion were higher than the EC measured in the soil before filtration and after three cropping seasons of the trial, indicating that soil structural deterioration could potentially occur in these soils, if subjected to application of mechanical forces. However careful long-term planning of FILTER plot management and routine operations could minimize the risks of surface soil structural breakdown, and their adverse effects on effluent infiltration and crop growth.

The efficacy of the FILTER system to remove pesticides from wastewaters was evaluated in a spiking study on the one-hectare plots. The pesticide load reductions exceeding 98% were observed with chlorpyrifos, molinate, malathion, bensulfuron, diuron, bromacil, atrazine, metalochlor and endosulfan.

Thus, FILTER technique can provide a potentially sustainable system to manage saline waters and treat different polluted wastewaters, with suitable design and management to meet the specific wastewater site conditions and requirements.

Sequential biological concentration in the Murrumbidgee Irrigation Area, NSW

Level: Field

Objective: To demonstrate approaches to water reuse

Method: Sequential Biological Concentration

The use of the sequential biological concentration (SBC) technique was proposed (Blackwell, Biswas et al. 1999) as a community based solution to the problems of managing drainage wastewater from the Murrumbidgee Irrigation area (MIA), which contains a cocktail of pollutants and salts. The SBC technique is based on using a modified FILTER system. Previous field studies on the FILTER system indicated that it was able to remove all pollutants in MIA drainage waters, except the salts, which pass through unabsorbed by the soil in the FILTER plots. Therefore, in conceptually developing the SBC system, the FILTER system had to be modified to economically manage these salts, through a process of water re-utilisation, salt concentration and eventual salt removal (Figure 16). The results of the field trials on the SBC system are summarised by Blackwell *et al.* (1999).

As the FILTER system reduces the volume of water drained, and concentrates the salts, in proportion to the reduction in drainage volumes it can be used to grow sequentially more salt tolerant crops to achieve both a reduction of drainage volumes and maximise the financial returns from the crops produced. This sequential process is terminated when the drainage water is too salty to sustain economic crop production. The remaining components of the SBC system consists of non-vegetative biological and physical systems to further concentrate the salt, or provide a financial benefit. These systems could include production of salt-water aquatic species in ponds, salt gradient solar ponds to produce energy and evaporation basins to produce pure salts for industrial uses and for stock piling for disposal. The SBC trial was designed as a scaled down version of a commercial system required to treat saline drainage wastewater from the Murrumbidgee Irrigation Area (MIA).

The field site already had a high soil salinity due to application of saline drainage water to a soil with impeded drainage, without provision of subsurface drainage. The field studies showed that leaching with the saline waters appropriate to the three stages of the SBC system, resulted in shifting of the soil salinity profile towards the predicted equilibrium relating to each leaching regime. In stage1, it required around 35 irrigation events at high loading rate at a 10-day interval to reduce the soil salinity towards the equilibrium salinity profile. The net salt balance during each irrigation/drainage event was closely related to the drainage percentage, defined as the ratio of drainage volume to the combined irrigation and rainfall. A drainage percentage of around 10% was required to provide sufficient drainage volume to maintain a net salt removal during any irrigation event.

The high drainage percentages observed in all plots during the trial indicated that the soil hydraulic properties were adequate to maintain the desired through flow rates. Measurement of whole soil hydraulic characteristics in Stage 1 plots indicated that there was only a slight shift in this relationship during the eight consecutive irrigated cropping seasons. The difference in the whole plot soil characteristics between the plots of different SBC stages was small.

The soil sodicity measured using exchangeable sodium percentage and sodium absorption ratio of the soil solution decreased during successive cropping seasons in Stage 1 plots. Although there was a decrease in soil salinity in successive cropping seasons, the calculated threshold electrolyte concentration required to prevent spontaneous soil dispersion also decreased due to reduction in soil sodicity. The measured soil salinity values were greater than the threshold electrolyte concentration values for spontaneous dispersion, indicating that the soils will be structurally stable during flow of effluent through the soil to the subsurface drains. However as the salinity of the soil sampled before cropping and after several cropping seasons is less than the threshold electrolyte concentration for mechanical dispersion, care is necessary to prevent structural breakdown due to factors such as rainfall impact on bare soil, mechanical disturbance and trafficking damage when the soil is wet. Management practices that could be used to assist maintenance of long-term stability of FILTER/SBC plots are discussed in Jayawardane *et al*. (2002) and Blackwell *et al.* (1999). In plots of Stages 2 and 3 too, both the soil salinity and sodicity decreased during successive irrigated cropping seasons.

Crop harvests showed that yield levels were maintained up to stage 2, which was irrigated with 3.6 dS/m water, but declined to about half in stage 3 when irrigated with 10.8 dS/m water except for sunflower which performed well even at highest EC water.

References

Blackwell, J., T. K. Biswas, et al. (1999). A novel method for treating effluent from rural industries for use in integrated aquaculture system. In Proc. Wastewater Treatment and Intergrated Aquaculture Production, SARDI, PO Box 120, Henley Beach SA 5022, Australia.

Department of Environment and Resource Management QLD (2011). Salinity Management Handbook. 2nd Edition.

Department of Environment and Resource Management QLD (2012). "Salinity; Department of Environment and Resource Management." from www.derm.qld.gov.au.

Falkiner, R. A. and C. J. Smith (1997). "Changes in soil chemistry effluent in irrigated Pinus radiata and Eucalyptus grandis plantations." Australian Journal of Soil Research **35**: 131-147.

Goulburn Broken Catchment Management Authority (2003). Goulburn Broken Regional Catchment Strategy Summary, Goulburn Broken Catchment Management Authority.

Jayawardane, N. S. (1995). Wastewater treatment and reuse through irrigation, with special reference to the Murray Darling Basin and adjacent coastal areas. Divisional Report 95.1. Griffith NSW, CSIRO Division of Water Resources.

Jayawardane, N. S., T. K. Biswas, et al. (2004). A review of the land FILTER technique for treatment and reuse of sewage effluent and other wastewaters. Waste Management. A. L. Juhasz, G. Magesan and R. Naidu. Emfield, New Hampshire, USA, Science Publishing Inc.**:** 249-275.

Jayawardane, N. S., J. Blackwell, et al. (2002). Management of salinity at the FILTER site and the discharge of salt during reclamation and subsequent operation of the FILTER site - Report 11, Consultancy report prepared for GCC.

Jayawardane, N. S., J. Blackwell, et al. (1997a). The research project on land treatment of effluent from Griffith City Council sewage work - Report 7. Final report on pollutant removal by the FILTER system during the period of work from November 1994 to November 1996 for GCC, DLWC and DPIE. , CSIRO, Division of Water Resources, Consultancy Report no 97-40.

Jayawardane, N. S., F. J. Cook, et al. (1997b). The research project on land treatment of effluent from the Griffith City Council sewage work - Report 8. Final report on the hydraulic properties of the FILTER system during the period November 1994 to November 1996. Report for GCC, DLWC, DPIE, CSIRO Division of Water Resources - Consultancy Report No. 97-42.

Mann, L., A. Heuperman, et al. (2003). Piloting farm scale serial biological concentration. Final Report, Volume 1. Project No. D115, Department of Primary Industries, Victoria.

Murray Catchment Management Authority (MCMA) (2007). Murray Catchment Management Authority Catchment Action Plan, Murray Catchment Management Authority, Deniliquin.

Murray Catchment Management Authority (MCMA) (2012). "Murray Catchment Management Authority." Retrieved 13th March, 2012, from http://www.murray.cma.nsw.gov.au/.

Murray Darling Basin Authority (2012). "Murray Darling Basin Authority." from http://www.mdba.gov.au/.

Murray Darling Basin Commission (2001). Basin Salinity Management Stategy 2001-2015. Canberra.

North Central Catchment Management Authority (2003). North Central Regional Catchment Strategy 2003-2007, North Central Catchment Management Authority, Huntly, Victoria.

North Central Catchment Management Authority (2012). "North Central Catchment Management Authority website." from www.nccma.vic.gov.au.

NSW Department of Land and Water Conservation (2000). Taking on the Challenge: The NSW Salinity Strategy, NSW Department of Land and Water Conservation.

NSW Government Environment Website (2012).

Peck, A. J. and T. Hatton (2003). "Salinity and the discharge of salts from catchments in Australia." Journal of Hydrology **272**(1–4): 191-202.

Podmore, C. (2009b). Irrigation Salinity - causes and impacts. http://www.dpi.nsw.gov.au/agriculture/resources/soils/salinity/general/irrigation. N. I. a. Investment.

Rengasamy, P., R. S. B. Greene, et al. (1984). "Identification of dispersive behaviour and management of red-brown earths." Australian Journal of Soil Research **22**: 413-431.

Smith, C. J., V. O. Snow, et al. (1996). Salt dynamics in effluent irrigated soil. Land application of wastes in Australia and New Zealand: Research and Practise. In New Zealand land treatment collective - Proceedings of technical session 14., Australia Conference, Canberra.

South Australia. Dept. for Water, R. (2001). South Australian River Murray salinity strategy 2001-2015 / Department for Water Resources, Government of South Australia. [Adelaide, S. Aust.] :, The Dept.

Stevens, D. P., M. J. McLaughlin, et al. (2003). "Effect of long term irrigation with reclaimed water on soils of the Northern Adelaide Plains, South Australia." Australian Journal of Soil Research **41**: 933-948.

Surapaneni, A. and K. A. Olsson (2001). "Sodification issues under conjunctive water use in the Shepparton Irrigation Region of Northern Victoria." Australian Journal of Experimental Agriculture **42**: 249-264.

The Department of Natural Resources and Environment VIC (2000). Victoria's Salinity Management Framework: Restoring our catchments, The Department of Natural Resources and Environment, State of Victoria.