Ready Reference for the Shepparton Irrigation Regional Catchment Strategy

Volume (I) Farm Scale

Draft - October 2003

Purpose

The purpose of this booklet is to provide a ready reference on natural resource management issues for individuals working on the Shepparton Irrigation Regional Catchment Strategy. The aim is for everyone to have this booklet on their bookshelves whenever they need it.

What is Inteca and other terminology?

Inteca stands for Integrated Catchment Analysis. It's a tool to assist people make decisions or analyse results about integrated catchment issues to do with natural resources. The Inteca tool is a GIS computer based program that allows you to enter in scenario data and look at results. To assist using this program, this booklet has accompanying diagrams and look-up tables. This booklet can be used as a stand-alone document also.

The term **Bayesian Network** is really only referring to the type of statistical technology used to make the Inteca logic diagrams.

The **Inteca logic diagrams** are box and arrow diagrams, which diagrammatically explain the relationships between different natural resource and biophysical reactions. It can also be called a "cause and effect" diagram.

Biophysical – the physics of biological processes and phenomena.

The Farm Scale

Within the Shepparton Irrigation Region Catchment Strategy there is a sub-program called the Farm and Environmental Program.

Farm and Environmental Program 2000-2005 Vision

The Farm Program strives to improve land management practices on private land within the Shepparton Irrigation Region to protect and enhance the environment to improve economic viability and to help rural communities make informed decisions.

Farm Program 1995 Goals

To reduce groundwater accessions, soil salinisation and waterlogging on farms.

Farm and Environmental Program 2002 Goals

To improve land management practices on private land within the Shepparton Irrigation Region to protect and enhance the environment, to improve economic viability and to help rural communities make informed decisions.

Background Information on Salinity and Water Management at the Farm Scale (Inteca – Farm)

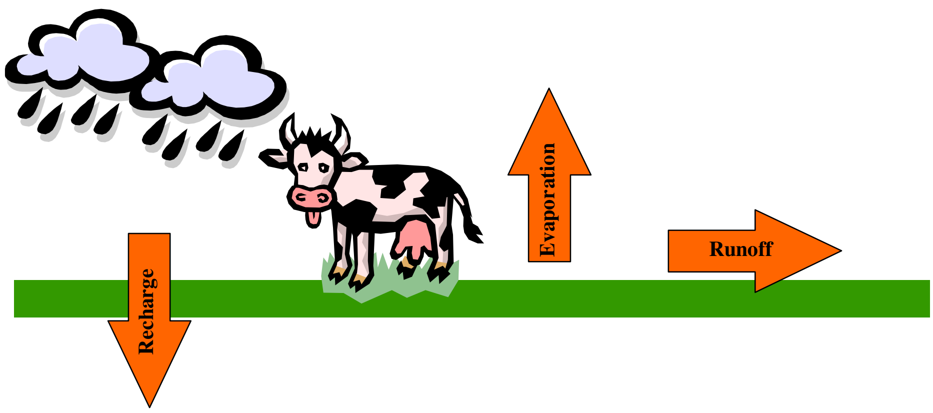
Within the Shepparton Irrigation Region, the majority of land is managed for agriculture. The fundamental agricultural management unit is a farm, however frequently a farm is comprised of separate blocks that are separated spatially. The development of this model has assumed the basic spatial unit is a farm block.

Understanding the role of salinity management activities at farm level is dependent on understanding the processes influencing the salt and water balance at that scale. An annual time step has been selected as the development of salinity occurs over long temporal scales and intra-annual variation may mask the long-term trend.

Description of the water balance logic diagrams

A typical farm can be comprised of dryland and irrigated components. The relative proportion of each is dependent on the farm type and irrigation system used. The salt and water balances within each of these components will differ due to differing seasonal processes, intensities of water application and land uses.

Once water has entered a farm, through irrigation or rainfall, there are three major water 'loss' pathways, namely evapotranspiration, recharge and runoff.



In the non-irrigated proportion of the farm block, water supply is limited by rainfall and therefore this rainfall can be separated into evapotranspiration, runoff and recharge.

The water balance benchmark is a crop that is irrigated to meet the water requirement of the crop, as determined from climatic data. Through the application of the crop water requirement, an amount of surface runoff (Point Irrigation Runoff) and recharge (Point Irrigation Recharge) will occur, which is dependent only on the Irrigation Method, Soil Type and Watertable Depth.

So we have the baseline water balance for a farm, but this is subsequently modified by paddock scale activities, including the irrigation layout and management. The irrigation layout includes factors such as bay design, laser grading and channel design, that improve paddock drainage and irrigation uniformity. Indicators of irrigation layout include areas laser graded and completed whole farm plans. The management factors will include irrigation scheduling, irrigation management and maintenance of channels etc. Management decisions may increase or decrease the runoff and recharge, but may only decrease the water supply to the crop.

Farm block scale activities also impact on the water balance. Surface runoff, in non-exceptional circumstances, is only possible if the farm has Access to Regional Drainage. The amount surface runoff reaching the regional drainage system is reduced by the presence of a reuse system. The total quantity of runoff may be further reduced by diversions from a community surface drain, which may be greater than the total runoff from the farm and hence net farm block runoff may be negative.

The total irrigation water requirement is the sum of the water supplied to the crop and irrigation runoff and irrigation recharge. The total irrigation water requirement can be supplied through either privately pumped groundwater or from external sources, such as licensed drainage diversions or channel supplies. The total farm-block runoff and recharge will be the weighted sum of both irrigated and non-irrigated components of the farm block.

Salt Balance

The salt balance for this farm level builds upon the water balance and predicts the final rootzone salinity given an initial value and the inflows and outflow of salt within the time-step (typically annually). The salinity of runoff and recharge are also predicted.

Relationships

The quantitative relationships within the network are currently relatively simple and based on the literature. In the development of the Shepparton Irrigation Region Land and Water Salinity Management Plan (1989), a comprehensive research program was undertaken to understand the effectiveness of various salinity management options. Many of the relationships have been developed from this work. Some relationships are more qualitative and come from discussion with various specialists within the Regional Catchment Strategy.

Assumptions underlying the Shepparton Irrigation Region Catchment Strategy

General Assumptions

Assumptions	Justifications
Total Shepparton Irrigation Region (dryland and irrigation) is about 586,000ha. The Shepparton Irrigation Region area is based on 500,000ha.	
Watertables which reach 2m below ground level indicates when salinisation occurs.	2m is where fruit tree roots reach to.
The provision of financial incentives will accelerate on-ground works and Plan activities.	
The majority of the Shepparton Irrigation Region can be considered as recharge. Only those sites, which have non-porous clays, which do not allow water to percolate into the groundwater, will not be recharged.	Due to the nature of salinity, most salt affected land in the Shepparton Irrigation Region is also subject to waterlogging.

Farm Scale

Assumption	Justifications
The weighted mean annual recharge within the Shepparton Irrigation Region is 70 mm/year.	The optimistic recharge reduction estimate for land forming and surface drainage on-farm option is 20% of that obtained on a poorly drained property, assuming an average recharge rate of 70mm/year, and channel seepage losses of 14mm/year.[x] Amount of seepage per year as calculated by the publication Hydrogeology of the Riverine Plain[i] Seepage from main channels 102,000 ML Seepage from district channels 130,000 ML On-farm seepage 140,000 ML Rain accessions 18,000 ML Total accessions for each district Shepparton 90,000 ML Rodney 96,000ML Tongala-Stanhope 54,000ML Deakin 30,000ML Rochester 84,000ML Murray Valley 138,000 TOTAL 492,000ML
Average farm has 5ML/ha irrigation and 5% average accessions.	On-farm recharge reduction has little impact on River Murray disposal requirements.[x]
There is a reduction of 17.5% of accessions to groundwater on the average farm laid out in accordance to a Whole Farm Plan (including laser grading (10%) and installation of farm drainage (7.5%)).	The absence of natural drainage will increase the duration of root zone waterlogging and provide a mechanism by which soluble salts can be mobilised from lower in the soil profile. These salts may then be transported to adjacent areas that are infrequently or never irrigated. Any areas within an irrigated paddock that are not inundated due to their elevation can become saline. Laser land forming / grading gives greater control of soil salinisation as there is a higher potential for the infiltrating water to leach accumulated salts more homogeneously from the soil in that bay. [ii] Land formed/graded bays usually require more frequent irrigation, which has the potential to increase accessions.[ii] Laser land forming/grading can not increase pasture production in isolation. Need to assist in soil structure development.[ii] Productivity of land increases following land forming and laser grading because of changes in management.[ii] The full benefit of laser land forming/grading is significantly reduced if farm and regional drainage are unsatisfactory. This emphasises the need for whole farm planning.[ii] Small capacity, shallow farm drains can lead

Assumption	Justifications
	irrigation and rainfall runoff to drainage reuse and/or the regional drainage system. These drains act to reduce groundwater accessions by at least 7.5% if regional drainage is available. Other benefits range from reduced waterlogging and improved farm productivity through to improve pasture/crop yields and, if drainage reuse is incorporated, increased irrigation water availability. Land forming and surface drainage will minimise frequency and duration of ponding, hence recharge during the irrigation season and also the winter/late spring period. Furthermore efficient irrigation practices will minimise late autumn soil moisture, which will in turn reduce winter recharge.
Non-irrigated land within irrigated areas accumulate salt	The absence of natural drainage will increase the duration of root zone waterlogging and provide a mechanism by which soluble salts can be mobilised from lower in the soil profile. These salts may then be transported to adjacent areas that are infrequently or never irrigated. i) Any areas within an irrigated paddock that are not inundated due to their elevation can become saline. Irrigated perennial pastures usually able to maintain a positive salt balance but adjacent less frequently irrigated areas will become progressively more saline (will occur irrespective of the accuracy of surface grading)[ii] Groundwater levels in non-irrigated areas are rising and will continue to rise independent of the implementation of salinity management plans in irrigated areas.
53% of soils in the Shepparton Irrigation Region are prone to waterlogging (RM71).	The fate of water remaining in a waterlogged root zone will depend upon the hydraulic conductivity of the soil, the height of the watertable and evaporation from the upper capillary fringe. [ii] That the combined effect of waterlogging and salinity may be far more detrimental than salinity alone. [ii] Capillary rise will occur when the watertable is closer to the surface than 60cm.[ii]
Channel seepage	Channel seepage is estimated to contribute 120,000 ML/year to the groundwater in the Murray Valley and Goulburn Valley Irrigation schemes.[iii] Nelson and Robinson (1966) estimated channel seepage losses to be between 4 and 25% of water moving in northern Victorian supply channels.
The installation of a farm drainage reuse system saves 0.67ML/ha of	The Best Management Practice (BMP) for reuse system design is to design the reuse as part of the

Assumption	Justifications
drainage and intercepts 0.4kg/ML phosphorus, 1.6kg/ML nitrogen, and 300kg salt/ML (on an average area of 60 ha).	development of a whole farm plan for the property. The BMP for reuse management is to have the storage empty at the end of each irrigation so that the maximum volume of rainfall runoff between irrigations can be collected. This emptying of the storage minimises the concentration of build up of nutrients, reducing the risk of algal blooms. The BMP for high groundwater conditions is to operate the reuse systems so that the storage is not emptied below the watertable level in order to minimise groundwater inflow. The BMP for saline water is to monitor the salinity of the water and shandy the saline water with fresh supply water to minimise productivity losses from using saline water. The BMP for using water from a reuse where a blue-green algal bloom has occurred is to irrigate recently grazed paddocks, avoiding grazing the area for as long as possible, preferably after using fresh water for the subsequent irrigation or following rain to remove toxins. The BMP for maintenance is to regularly maintain the reuse system for efficient operation.
A reduction of 8.25ML of runoff is achieved by an automatic irrigation system installed on an average property, which retain 0.003 tonnes of phosphorus and 0.13 tonnes of nitrogen on the farm. Water savings of 6,600ML equals decrease 2.6t tP, decrease 10.56 tN (NHT bid 01/02). Each year 500ha of flood irrigated pasture will be automated. This will save 150ML therefore 1ha = 0.3ML 0.3ML/ha water saving = decrease 60kg P, and decrease 240kg N	Installing auto irrigation will reduce on-farm labour requirements for irrigation, greater flexibility to commence and cease irrigation (particularly at night and weekend), and improved water use efficiency through reduced wastage of water. Auto will reduce run off from a bay from 15% to 0%.
Local Area Plans will accelerate on-ground works	
	A water budget has been used to estimate deep drainage from the basic formula; $P + I - SD = E + VD$ Where P = rainfall I = irrigation watering the area SD = surface drainage leaving the area via drains, rivers, streams E = evaporation (including plant evapotranspiration)

Assumption	Justifications
	VD = drainage below the root zone (groundwater accessions)[iv]
In an average flood event the average annual area flooded is approximately 10% of total farm area.[xiii]	In the River Murray Commission Report [v] it was assumed that 50% of rain falling on irrigated pasture seeps to the groundwater in winter, whilst only 10% seeps during the growing season. Rainfall accessions over the Riverine Plains area totalled 31,300 ML/year using these figures. If no remedial action is forthcoming, they estimate 50% or 786,000 ha of irrigated land will be affected by shallow watertables within 3 metres of surface by 2020.[v] Large potential watertable accessions occurring under the lighter prior stream soil types.[vi] Waterlogging losses are due to more than one cause; (a) waterlogging due to irrigation, and (b) waterlogging due to rainfall.[xiii] In the evaluation of the Economics of Drainage Projects in was assumed that all soils classed as Active Floodplain and Far Floodplain soils, together with 30% of Near Floodplain soils, were prone to micro-waterlogging. [xiii] Proportional losses in gross income due to long-term flooding were as follows: Perennial pasture 100% Annual pasture 82% Winter crop 56% Rice 8% Dryland 0[xiii]
Recharge to the watertable is increased as a result of an increase in electrolyte content, which causes an increase in the hydraulic conductivity.[vii]	
A low watertable will reduce the opportunity of crops and pasture to extract water from the capillary fringe, hence it will increase net accessions.[vii]	In a low watertable environment, evapotranspiration from watertable capillary rise is negligible, therefore net accessions are equivalent to recharge.
Farm channel seepage assumptions[viii]	Summer pasture (Group 1), old layout Seepage rate = 1.35ML/ha/year Summer pasture, old layout Seepage rate = 0.45ML/ha/year Summer pasture, modern layout Seepage rate = 0.04ML/ha/year Annual pasture, old layout Seepage rate = 0.07ML/ha/year

Estimates of recharge in the summer seasons were found to be significantly affected by;

i) Decreasing aquifer piezometer levels from 100cm to 50cm tends to double recharge.

ii) Increasing residual depth from 1cm to 2cm increases recharge by 2cm per season.
iii) A change in soil type; for the top 2cm profile, a Lemnos loam has less than half the recharge of the Shepparton fine sandy loam.
iv) Raising residual depth from 1cm to 2cm increases run off. [ii]

The DESM assumes that each measure or combination of drainage measures reduces losses to the same degree for all crops.[xiii]

- On-farm works reduces salinity losses by 15%.
- Sub-surface and on-farm works reduces salinity losses by 90%.
- Surface drainage and on-farm works reduces salinity losses by 30%.
- Sub-surface drainage, surface drainage and on-farm works reduces salinity losses by 90%.
- On-farm works reduces waterlogging losses by 40%.
- Sub-surface drainage and on-farm works reduces waterlogging losses by 40%.
- Surface drainage and on-farm works reduces waterlogging losses by 60%.
- Sub-surface drainage, surface drainage and on-farm works reduces waterlogging losses by 60%.
- On-farm works reduces flooding losses by 10%.
- Sub-surface drainage and on-farm works reduces flooding losses by 10%.
- Surface drainage and on-farm works reduces flooding losses by 70% .
- Sub-surface drainage, surface drainage and on-farm works reduces flooding losses by 70%.

According to G-MW census information – the following table gives the assumption for each property size range, the "typical" proportion of the following land use categories; perennial pasture, annual pasture, dryland pasture, and area under non agricultural use were estimated, as was the average water use (ML/ha). [xii]

Representative Range (ha)	**30-60**	**60-110**	**110-140**	**140-200**	**200-280**	**>280**
Nominal farm size (median) (ha)	40	80	120	160	240	320
Perennial pasture %	73.8	61.4	48.7	45.8	39.8	32.8
Annual Pasture %	18.5	22.8	27.6	26.6	24.4	20.4
Dryland pasture %	7.8	12	16.3	17.1	19.6	17.4
Area under non agricultural use %	0	3.9	7.4	10.4	16.2	29.4
Average water use (ML/ha)	4.9	4.1	3.3	3.3	2.8	2.6
Perennial pasture equivalent (ha)	33.5	59.2	76.9	97.3	129.6	143.2

Groundwater Scale

Assumption	Justifications
Groundwater flow processes do not materially alter the net storage of salt in the region.	
1 ML of water pumped protects 1 ha of land	The RWC at the start of the Plan estimated there were 850 private licensed groundwater pumps in the Shepparton Irrigation Region. Private groundwater pumps extract water from all levels of the Shepparton formation and from the Calivil/Renmark aquifer, but most groundwater is extracted from the top 20cm of the profile.[ix] The estimated daily yield of a potential pump site is based on a 3-day pump test of 2 trial well points and field measurements. There is a high level of confidence in the estimated daily yield, however, the annual yield estimate is less reliable. Theoretical pumping rates range from 12.5-87 mm/year depending on soil types, irrigation application, groundwater salinities and incoming channel salinities, for estimating the amount of private pumping required to provide a reasonable degree of farm groundwater control. Theoretical pumping requirement to provide leaching for high B3 and B2 type management areas was estimated to be approximately 21mm/year for low salinity irrigation water.
There will be minimal interference between bores	
Installation of low capacity groundwater pumps to protect existing horticultural area (mainly Shep East) – 1 pump protects 25 ha.	
Each new public pump protects 200 ha.	The area receiving salinity control from a Groundwater Control Pump which operates for less than 6 months/year is assumed to be the same as would be achieved if it operated as a Salinity Control Pump. If the pump operates for more than 6 months/year it is assumed to provide Salinity Control to a larger area than it would if operated as a Salinity Control Pump. Average operating schedule of 2 * 60 day periods (1 in winter and 1 in summer) and an extraction rate of 50mm/ha/year.
Volume of groundwater reused on the area irrigated by the pump will not exceed 3ML/ha/year.	New private pump grants have a reduced ceiling which is based on the estimated 'salinity share' of the benefits, after excluding the costs and waterlogging benefits to the

Assumption	Justifications
	farmer of pumping in the winter. It has been suggested that total pumping and disposal of groundwater might be limited to that required to satisfy the minimum leaching requirement for irrigation with incoming channel water. In an area of perennial pastures on Lemnos loam receiving an average of 400 mm/year of water at about 100 EC this significantly reduces the requirement for disposal to the Murray and avoid the use of channels and drains in season. This limit is NOT applied to bores installed before 1 July 1999.
On-farm accessions from irrigation and rainfall contribute approx 80% of the total recharge within the Shepparton Irrigation Region. The remaining 20% is channel seepage loss.[x]	The Shepparton Irrigation Region water balance model estimates the aggregation of both components of recharge (on-farm accessions and channel seepage) to range between 30 mm/year and 170 mm/year. The high level of spatial variability is a function of the non-uniformity of both irrigation intensity and soil type.[x] The Shepparton Irrigation Region channel seepage loss is 100,000 ML/year, which is equivalent to an average of 20 mm/year. 30% of this are losses through surface evaporation, therefore the effective channel seepage loss is 14 mm/year.
Maximum salinity of irrigated on any property would be 500EC on average.	This assumes reuse salinities up to 800 EC on about 65% of property and channel water only on the remainder.
To estimate potential groundwater usage these assumptions were made; ▪ No pumping where total area is less than 25ha ▪ Minimum pumping rate of 40ML/year ▪ Maximum pumping rate of 150ML/year ▪ Maximum average irrigation salinity of 500EC.	
Energy consumption and pumping costs assumptions for groundwater pumps can be found in.[xi]	
Cost benefit ratio for groundwater pumping was 1.7 for pasture program and 1.3 for the horticultural component (from 93/94 review)	
The hydraulic connection between the deep regional aquifer and the shallow systems is generally poor beneath the Irrigation region.	
Phase A program terminated in 1985, with 79 pumps installed protecting 3400ha of horticulture and 14600ha of adjoining pasture.	Shepparton East is excluded from the construction of public pumps as the hydrogeology generally restricts works to small-scale pumps or tile drains. Continued operation of the existing Phase A

Assumption	Justifications
	Groundwater Control Pumps where technically appropriate was an assumed ongoing action.
The average overall summer reuse of 75% is assumed for any public pump.	Studies undertaken during the development of the Plan indicated groundwater reuse from the channel system averaged 93% and ranged from 40-80% from the drainage system. This 75% average summer reuse assumption is appropriate for planning purposes, however, for the SDA estimate should be refined.
800 EC	The 800 EC is based on zero productivity loss for perennial pasture. The upper limit of 1700 EC (estimated 15% productivity loss) is the current irrigation salinity limit guideline for private groundwater pumps installed without Plan assistance. Information on salinity thresholds for wetland, rivers can be found in the Sub-surface Review 99/00. EC levels for zero productivity losses are; ▪ Flood irrigated perennial pasture on medium soil is 800EC ▪ Lucerne (flood) 1200EC ▪ Fruit trees (deciduous) 500EC ▪ Eucalytus (1st year) 3000EC ▪ Eucalytus (subsequent years) 5000EC
It is assumed that the full benefits of salinity control from sub-surface drainage would be achieved in the third year after pump installation.	33% benefits achieved in the first year and 67% in the second year[xii]
Areas with low salinity groundwater, a long-term productivity decline of 12% is assumed where the overall water-use intensity is 2ML/ha, rising to about 30% with a water use intensity of 5ML/ha[xiii] Where groundwater is highly saline the assumed long-term productivity decline is taken at about 20% with an overall water-use intensity of 2ML/ha and 35% with an intensity of 5ML/ha.[iii]	

In applying the Drainage Evaluation Model (DESM) it was necessary to quantify a range of input parameters relating to the Plan. An appendix details the assumptions that were made during the application of the model and can be found in the Sub-surface drainage review 99/00 document, page 89.

- Sub-surface drainage reduces salinity losses by 90%[xiv].
- Sub-surface drainage and surface drainage reduces salinity losses by 90%
- Sub-surface drainage and on-farm works reduces salinity losses by 90%
- Sub-surface drainage, surface drainage and on-farm works reduces salinity losses by 90%
- Sub-surface drainage does not reduce waterlogging losses
- Sub-surface drainage and surface drainage reduce waterlogging losses by 10%
- Sub-surface drainage and on-farm works reduce waterlogging losses by 40%
- Sub-surface drainage, surface drainage and on-farm works reduce waterlogging losses by 60%
- Sub-surface drainage reduces flooding losses by 10%
- Sub-surface drainage and surface drainage reduce flooding losses by 50%
- Sub-surface drainage and on-farm works reduce flooding losses by 10%
- Subsurface drainage, surface drainage and on-farm works reduce flooding losses by 70%.

Salt Disposal

Assumptions	Justifications
There will be enough SDA's given to the Shepparton Irrigation Region to fully implement the sub-surface drainage strategy.	Salt Disposal Allocations (SDA's) are required for works implemented after 1st January 1988.
60,000 tonnes/year of salt is assumed to enter the Goulburn River between Seymour and Nagambie[xv]	This is allowing for monitored and unmonitored tributaries.
Van Weel's assumptions in calculating salt load to the River Murray in 2020 [xvi]	Salt inputs from private diversions from the Goulburn and Broken Rivers and Broken Creek were considered not significant and therefore not included in the Shepparton Irrigation Region salt lead input. Surface runoff from undrained areas that have high watertables and salt problems will only reach the River Murray in water after high rainfall events. Runoff from areas with low watertables will not contribute a significant salt load and have been neglected. The summer salt load to the Broken creek; the Goulburn, Broken and Campaspe Rivers is reused by diversions from those systems, as the demand on these systems is high. The summer period is equal in length to the effective irrigation season (ie. 200 days on average). There will be no change in the salinity of input water as a result of dryland processes The major source of salt load removal is by the diversion of water from the drainage system. The diverted salt load will remain reasonably constant to the year 2020 because the increase in drain water quality will be matched by decreases in the volume of water diverted.
Assumptions in determining the salt load export from new drains [xvi]	The implementation of surface and subsurface drains work under the Preferred plan will lead to a decline in baseflow. Any surface salt wash-off during irrigation is intercepted or reused and recycled within the Region. For areas that do not have a high watertable problem or areas that have a high watertable but have active groundwater control schemes the salt wash-off is proportional to the quantity of incoming salt resulting from irrigation.

Assumptions	Justifications
	Groundwater salinities will not change over the planning period. For areas with a high watertable and minimal control the salt wash-off will be higher due to the build up of salt in the upper soil profile. Data for the study was obtained from existing drains of 2.5m depth and applied to 1.5m depth drains as proposed in Plan. Water use efficiency will increase leading to a decline in the quantity and quality of drainage waters, and a decline in the interception of salt through drainage diversions. The baseflow salt load remains constant throughout the year.
The estimated salt input to the Region (excluding the Campaspe Irrigation District) is 90,000 tonnes/year over the period of 1977 to 1988.	
Draft Shepparton Irrigation Region Salinity Plan 1990 for disposal to achieve protection of assets with the Shepparton Irrigation Region was 31.92 EC. Since then changes in approach in the form of reuse of groundwater within the Shepparton Irrigation Region and redesigning surface water management systems (shallower) has reduced this need by 13.2 EC and 1.7 EC respectively to 17.0 EC. The indicative allocation from the Victorian Government is 10.8 EC. Agreement has yet to be reached. Confirmed allocations to 2002 is 4.9 EC.	
6,000 tonnes salt / EC; depends on timing and salinity of water; derived from MDBC flow model.	
0.0022 EC / km Primary drains. 0.00024 EC / km Community drains.	In regional plan regional surface water management will add 1.3 EC. (Primary drains using 0.7964 EC and Community drains using 0.50488 EC)
Each Farm reuse system is on average 10 ML and is used 10 times during the season which uses 100 ML	Aim is to have 5,600 systems x 10ML x 10 uses = 566,600 ML/year @ 250 EC = 84,920 t/year = 14.1 EC saved.

Surface Water Management Assumptions

Assumptions	Justifications
The area of land protected by a community drain is 104 ha for every kilometre of drain constructed.	Average number of landowners in an active community surface water management group is 15 (1995 review).
Surface water management systems reduce groundwater accessions by 11.5%	Surface drainage will reduce groundwater accessions by up to 19% (from 1989 Plan) Any initial short term effects on downstream users from shallow surface drainage should be minor and should be offset by the long term benefits of reduced accessions to groundwater if there was no immediate downstream impact on the receiving stream.
The average area that landowners protect through fencing in a drainage project is 2 ha.	
Nutrient removal schemes (turkey nest dams) intercept 600ML/year equivalent to the removal of 0.24 tP/year and 0.96 tN/year	From Chris Norman's assumptions Also found – nutrient removal schemes intercept 5,185 ML/year, equivalent to the removal of 11 tP/year and 0.96 tN/year.
Surface water management schemes are designed to provide drainage for a 1 in 2 year rainfall event.	
When regional drainage goes through a catchment, on-farm infrastructure is improved to take advantage of the drainage service	Documented in Whole Farm Plan surveys.
When it rains in a catchment (during the irrigation season), 25% of catchment all the rain turns to runoff, 25% has little runoff, 25% has a lot of runoff, and 25% has no runoff.	
Drainage Course Declarations (DCDs) will provide little quantifiable benefit. However, for the Shepparton region as a whole an average benefit of 30% of the maximum achievable benefit has been assumed on the basis that at least a 300m wide section of depression will benefit to some degree by the declaration works[xvii]	
Much of the direct salt inflow to the Murray is from surface drainage hence the assumption that the Shepparton Irrigation Region contribution greatly outweighs that from Deniliquin as the later has no surface drainage xiv	
Surface drainage reduces salinity losses by 10%. Sub-surface drainage and surface drainage reduces salinity losses by 90%. Surface drainage and on-farm works reduces salinity losses by 90%. Sub-surface drainage, surface drainage and on-farm works reduces salinity losses by 90%.	

Assumptions	Justifications
Surface drainage reduces waterlogging losses by 10%. Sub-surface drainage and surface drainage reduces waterlogging losses by 10%. Surface drainage and on-farm works reduces waterlogging losses by 60%. Surface drainage, sub-surface drainage and on-farm works reduces waterlogging losses by 60%. Surface drainage reduces flooding losses by 50%. Sub-surface drainage and surface drainage reduces flooding losses by 50%. Surface drainage and on-farm works reduces flooding losses by 70%. Surface drainage, sub-surface drainage and on-farm works reduces flooding losses by 70%. Benefits of surface drainage on dairy farms $80/km^3/year. Benefits of surface drainage on mixed farms $10/km^3/year xiv.	
Roads benefit from the construction of surface drainage[xviii]	-Ability to adopt lower pavement standards when re-constructing roads, with consequent lower costs. -Longer lives for existing roads. -Lower road maintenance costs. -Variations in design standards (1 in 2 compared with 1 in 10) of drains have little effect on the magnitude of road benefits. This is because the wetting up of pavements is a long term process and the main benefits are obtained by the reduction of elimination. -For main roads (defined as roads with traffic counts of over 500 vehicles per day), there will be a delay of 5 years from the time of construction of drainage before the benefits would be obtained, while with other roads, there would be no delay. -The main effect of saline groundwater on roads costs is that of seal detachment as a result of salts being deposited as capillary water evaporates, depositing salt just below the seal. -March/April is the worst time for road flooding except following a heavy rainfall event.

Assumptions	Justifications

Surface Water Management Program Economics – Original Plan

Pasture Production benefits only gained on:
12% of Lemnos loams
90% of Goulburn loams
100% of Congupna clays
Anything lighter than a Lemnos loam is adequately drained.

Crops are only grown on better-drained soils
Congupna clay → Dryland AP only
Goulburn loam → Irrigated AP and PP and Dryland AP
Lemnos loam → Irrigated AP and PP

Maximum Pasture Production (if ample superphosphate, 10ML/ha irrigation, have good soil drainage, 7 day or less irrigation cycle, grazing interval of over 20 days)

Shep. f. sandy loam	PP 21 t DM/ha	AP 13 t DM/ha
Lemnos loam	PP 18 t DM/ha	AP 11 t DM/ha
Goulburn loam (85% LI)	PP 15.3 t DM/ha	AP 9.35 t DM/ha
	Dryland AP 2 t DM/ha	

To achieve Maximum Pasture Production
- apply 10 ML/ha at 7 day irrigation cycle
- Graze pasture every 20 days (Surface Water Management Program Economics – 1995 Plan)

Reuse water benefit (Surface Water Management Program Economics – 1995 Plan)

An additional 5% of catchments will be irrigated due to reuse water, and irrigated at an average 5ML/ha, if drains are installed now.
Over a period of 25 years the benefit will decline to 1% of area using drainage diversion water as water quantity and quality decline.

Irrigation frequency (Surface Water Management Program Economics – 1995 Plan)
The base production is achieved from irrigating every seven days in mid summer. If this frequency is greater, then production is lost.
- 7 day irrigation interval = 100% production
- 8 day irrigation interval = 90% production
- 9 day irrigation interval = 85% production
- 10 day irrigation interval = 80% production
- 11/12 day irrigation interval = 75% production

Water Quality Assumptions

Assumptions	Justifications
Reducing nutrient concentrations into the River Murray will reduce the risk of nutrients from the Shepparton Irrigation Region causing or contributing to algal blooms downstream	Algal blooms result from high Phosphorus levels in the water. Large nutrient loads are often associated with high stream flow periods, naturally occurring over August, September and October. However, large nutrient loads are evident in irrigation drains over the summer months as

Assumptions	Justifications
	this is the period of high flows for irrigation use. The Goulburn River contributes some 37% of the flow and 58% of the sediment relative to all streams entering the Murray upstream of the Murrumbidgee junction. The Broken Creek contributes 2% of the flow and 8% of the sediment.
New strategy benefit cost ratio is 1.4 (discounted at 80% over 30 years)[xix]	
The implementation of Best Management Practices will lead to a reduction in blue-green algal blooms.	There are best management practices for; Irrigation drainage Diffuse sources Sewage treatment plants Urban stormwater Intensive animal industries Local water quality issues Other water quality issues Program coordination
pH has lowered by one unit over a ten-year period.	
If we did nothing to combat rising nutrient pollution[xx], then; Irrigation – increase by 34 tP Dryland – increase by 1.65 tP Urban stormwater increase – increase by 1.8 tP Sewage treatment – no change Intensive animal industries – increase of 64.5 tP Total – increase in 6.5 tP	If we maintained the status quo, then; Keeps Phosphorus loads and concentrations steady over next 30 years. A net reduction in 64.5 tP is required to achieve this. Cost of option is $10.7M (capital) and $0.12M (operation and maintenance) (In 1996 dollars – not discounted). If we achieved maximum nutrient reduction in order to return Phosphorus loads to their natural state and involves adopting as many nutrient management options as possible. Cost of option estimated to be $708M (capital) and $22M/year (O&M) to achieve a reduction of P loads of approximately 90%. If we reduce P loads from "hotspots" in the catchment to achieve substantial reduction in loads exported. Two ways of achieving this is; a) installing reuse systems on farm – reducing P loads by 55% at a cost of $217M b) diverting water from drains reducing P loads by 31% at a cost of $78M. If we target hotspots and areas with high blue green algae risk/impact, then we reduce P loads by 48% at a cost of $93M.
Reducing Phosphorus reduces other critical nutrients including Nitrogen.	Estimated that the Goulburn Broken Water Quality Strategy will reduce total Phosphorous loads by 45% over a 16-year period and that this reduction in total P would reduce the incidence of potentially toxic algal blooms by 80%.

Assumptions	Justifications
Implementation of the Water Quality Strategy will result in multiple benefits to other strategies and Plans.	
The implementation of Best Management Practices will achieve nutrient management and strategy objectives.	
Every megalitre of water removed from a drain removes 0.6kg P.	
To achieve a 50% reduction in TP loads outfalling from irrigation drains	- all irrigation farms will have an approved whole farm plan - 100% of irrigation farms will have functioning reuse systems - all reuse systems will be used effectively (encouraged to install electric power to more easily manage automation of pumping) - all dairy effluent systems managed in accord with best management practice, including no farm directly discharging dairy effluent to drains. - An extension and enforcement program be implemented to achieve management of dairy effluent systems in accordance with BMPs. - Farmers will implement fertiliser BMPs - New drainage diverters will achieve a reduction of annual drain flows by 64,000 ML, especially in the Deakin drain, Broken creek and Murray Valley drain 6. - The current incentive to encourage storage construction of diverted water in order to reduce the impact of short duration high drain flows in summer will continue. - Use Waterwatch to identify catchment hotspots and raise awareness of water quality issues.
Incorporating filter strips along streams will minimise Phosphorus by 2.5 kg/km in the upper to mid part of the catchment and by 6.5 kg/km in the mid to lower part of the catchment.	
The annual potential nutrient generation rate for irrigated perennial pasture is 8.66 kg/ha TP and 13.9 kg/ha of TN. For irrigated annual pasture the generation rates are 1.37 kg/ha TP and 3.4 kg/ha TN.	

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