SALINITY IMPACT ON LOWER MURRAY HORTICULTURE

MILESTONE 4 REPORT (DEP 15 PROJECT)

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DEP15 Project: Salinity Impacts on Lower Murray Horticulture
Milestone 4 Report

Cover page: A drip irrigated Loxton vineyard (left), installing logging tensiometer in a Riverland vineyard (centre), and a Sunraysia citrus orchard (right).

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Executive Summary

This report forms Milestone 4 deliverables of the DEP 15 project "Salinity Impacts on Lower Murray Horticulture" and contains the work carried out by the Tri-State Salinity syndicate of Government agencies from western NSW, Victoria and South Australia between May to November 2005. This report forms a part of the suite of milestone reports aimed to generate the knowledge for managing root zone salinity hazards and to assess the risk of salt accumulation under precision irrigation, with a goal to deliver strategies for minimising yield losses.

The South Australian Water Allocation Plan for the River Murray Prescribed Water Course 2004 (WAP) encourages growers to achieve a water use efficiency of at least 85%. During the past two decades efficient irrigation management and system upgrades have raised the field application efficiency (FAE) in the Lower Murray horticultural districts from about 50 to 85%. Consequently, the drainage volumes have reduced from about 50 % to 15% of the water applied. With Murray water salinity of about 0.4dS/m, and a 15% leaching fraction, one would expect an average root zone salinity of 0.6 dS/m. This algorithm assumes that the leaching water uniformly displaces the (saline) soil water as 'piston' flow, but is unlikely to occur because of the presence of macropores that allow bypass flow.

Field data from this study for conventional drip irrigated vines in the Riverland-Sunraysia region showed that less than 10% of applied water was found to leave the root zone during the irrigation season. This resulted in salt build up in root zone. Triplicate sets of porous ceramic extraction tools called 'soil water extractor (SWE)', specially developed for monitoring root zone salinity of permanent horticultural plantings were installed in vineyards and citrus orchards at 30, 60 and 90 cm depths during Nov-Dec 2004. Throughout the following year (2005), the irrigation, rainfall and reference evapotranspiration (ETo) data were collected from the field sites while monitoring the changes in soil water salinities. The soil water salinities data obtained from the SWE and presented in Fig. 1 showed a gradual increase in salt build up at all the measured depths during the irrigation season. The above average annual rainfall of 332 mm (historical average 250 mm) in the Riverland during 2005 was sufficient to leach the irrigation (631-732 mm) induced salinity from top 60cm soil layers but failed to leach the salt from the bottom portion of the rootzone (90cm). This is particularly of concern if the average leaching efficiency (LE) falls below 100%.

The project has also developed a simple methodology for rapid and in situ measurement of LE, based on the chloride concentration of captured infiltrated water in a wetting front detector (FullSTOP), and the SWE installed at the same depths. Preliminary data obtained from 30 cm soil depth indicate that the LE is variable for the same soil and crop type irrigated by different irrigation systems, eg, drip and under canopy. The high frequency, low volume application of drip irrigation gave a LE value of 0.90 (or 90%) when measured right under the dripper compared to a 57% LE measured at 25 cm away the dripper where dripper spacing was 100 cm. On the other hand, an under-canopy sprinkler irrigation in a citrus orchard delivering more water per irrigation event but applied less frequently resulted in 72% LE.

Our results indicate that LE of permanent horticulture plantings is a dynamic parameter and likely to be governed by the irrigation type, evapo-transpiration, rainfall and its distribution, cover crop and associated crop management practices. However, the average LE at 30 cm based on two different methods was found to be around 70%.

High water use efficiency results in less irrigation water draining below the crop root zone, which is referred to as deep drainage (DD). There is a compelling need to develop a set of practical tools and methods for growers to monitor and quantify deep percolation. The DEP15 project has identified the absence of a practical and reliable method for irrigators to measure or confirm deep percolation events. This has presented an opportunity for the DEP15 project to

collaborate with Rural Solutions SA Irrigated Crop Management Service (ICMS) and the SA Murray Darling Basin Natural Resources Management Board (previously the River Murray Catchment Water Management Board) in extra site establishment, data collection and interpretation to develop in-situ methods to quantify deep percolation. This project has developed a new methodology for directly assessing DD from data generated by multi-sensor capacitance probes. In modern horticultural districts there are usually large networks of capacitance probes (approx 7500 in Australia alone) used for irrigation scheduling. In this new methodology DD is estimated by using Darcy's flux equation, and a water content –suction (θ-ψ) relationship has been developed from data generated by two sensors, located just below the root zone.

This direct method has also been compared with an alternative water balance based method of measuring DD, using the Farm Level Water Management Module (FLWMM) developed by ICMS under a previous L&WA funded project in the Riverland and Sunraysia.

In 2004/05 the SA Murray Darling Basin Natural Resources Management Board initiated a project to assist irrigators adopt the FLWMM with the aim of minimising degradation of land and water resources from irrigation by improving irrigation efficiency and productivity. Software associated with FLWMM calculates a daily soil water trace by simulating changes in crop root zone soil water content throughout the growing season. It provides irrigators with a very useful management tool. The simulated soil water trace also calculates deep drainage, which is used to calculate field application efficiency.

An interim report containing the DD work done in association with ICMS and submitted to the SA Murray Darling Basin Natural Resources Management Board. The report tests a variety of deep drainage detection and measurement devices on various properties in Riverland and compares them with the DEP15 method. The goal is to develop a set of on-farm monitoring activities and devices capable of generating reliable estimates of deep drainage that will complement the use of the FLWMM.

The salinity status of grapevines and citrus at our field sites was assessed by measuring the chloride and sodium concentrations in leaf petioles and lamina sampled at flowering and harvest, and, in grapes, berries sampled at harvest. In all samples the concentrations of these two putatively toxic ions were below levels assessed as indicative of salinity damage.. Grape varieties sampled included Chardonnay and Colombard on either Ramsey rootstock or on their own roots.

Modelling work within the project looking at soil-water and salt movement associated with precision irrigation at a Loxton vineyard in Bookpurnong Lock-4 districts, has showed that during summer about 2 t of salt /ha would accumulate in the root zone if the River water salinity is 0.8 dS/m. However, even at the currently River salinity of 0.3 dS/m and 95% FAE, crop losses due to gradual salinity build up may be inevitable in the Riverland/Sunraysia districts. The modelling tool was a two-dimensional numerical flow/transport "LEACHM-TRANSMIT" model.

The additional work that has been conducted on the "Economic Assessment of Salinity Impact on Lower Murray Horticulture" project in the past nine months has involved extending the range of industries/crops included in each of the regions to include potatoes, and three types of pasture; perennial, annual and lucerne. For each of these industries/crops, the area of production, related to the three major soil types in the four regions, was tabled. From these figures, the percentage and value of lost production was calculated under the seven salinity scenarios specified in the previous report.

For the additional four industries/crops, the area of production data was sourced from the 2001 Australian Bureau of Statistics (ABS) Agricultural Census, the only consistent source of regional level industry data available at that time. Negotiations are currently proceeding to access more recent regional level data, from various industry and regional sources, to allow production area data to be updated (and thus the evaluation of lost production) for all twelve industries/crops evaluated in the project.

During this reporting period, the DEP15 team has facilitated extensive collaboration between various agencies across the country and have attracted additional funding from NAP (through SA-CNRM) to extend the work to high salinity irrigation areas in SA. In addition to providing training to three new irrigation graduates the project has produced several media articles for regional papers, and conference papers for the IAA Conference 2005, Townsville, ANCID Conference 2005, Mildura and CRC for Irrigation Futures Conference 2005, Mildura.

Outcomes and generic deliverables set for Milestone 4

Due date/ Item No	Deliverables during Milestone 4	Outcomes	Quick Reference
30/11/2005			
1.	Work plan continues with all priority stakeholders participating	Report/article /meeting	Chapter 1&2 Appendix 1
2	Sustainable Irrigation Projects receiving input as appropriate for their project (as defined in milestone 2)	CRCIF meeting	Appendix 1
3	At least one Steering Committee meeting with year 2 data and analysis reported and discussed by the Committee.	3 Nov 05 Merbein	Appendix 2
4	Review and confirmation that the economic framework to be used in the final analysis is correct	10 June 05 Adelaide	Appendix 3
5	Soil and plant sampling and analysis undertaken.	Report/paper	Chapter2
6	Field data compared to the models outputs.	Conf paper	Chapter 2

Milestone 4 Highlights in a Nutshell

i. Grower friendly ‘Root Zone Salinity WATCH Toolkit’ (using the Soil Water Extractor, SWE) has been developed, which is being used in NSW, WA, SA and Vic to monitor the risk of salt build up.

ii. Methodology has been developed for Rapid in-field assessment of ‘Leaching Efficiency” using simple soil-water capture tools.

iii. Average LE from field trials was 70% at 30 cm depth under precision irrigation, & seasonal salt build-up was noticed to 90cm.

iv. Project technology has now been transfered to additional 6 Riverland sites in collaboration with the ICMS, to estimate deep drainage.

v. Three students have started their Honours projects on Leaching Efficiency and modelling aspects.

vi. Seven articles have been published, including 3 refereed conference articles and 4 media articles in SA, Vic and NSW rural newspapers.

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Land & Water Australia (through NPSI-National Programme for Sustainable Irrigation)
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South Australia Murray-Darling Basin Natural Resource Management (previously known as RMCWMB).

1. Introduction

Irrigated horticulture in the Lower Murray (Riverland-Sunraysia) region contributes a 'gate-value' of about $ 2.5 billion a year to the national economy.

The South Australian Water Allocation Plan for the River Murray Prescribed Water Course 2004 (WAP) encourages growers to achieve a water use efficiency of at least 85%. However it is recognised that some drainage water must displace the residual salts of the irrigation water and thus avoid a salinity build up in the root zone causing crop yield losses.

During the past two decades efficient irrigation management and system upgrades have raised the field application efficiency (FAE) in the Lower Murray horticultural districts from about 50 to 85% (Biswas *et al.* 2005a; Biswas *et al.* 2005b; Biswas *et al.* 2005c; Schrale and Biswas 2004). Consequently, the drainage volumes have reduced from about 50 % to 15% of the water applied. Under steady state conditions, root zone salinity can be estimated from salinities of the irrigation water and the leachate (i.e. extra irrigation water applied which drains out of the base of the root zone). With Murray water salinity of about 0.4dS/m, a 15% leachate, one would expect an average root zone salinity of 0.6 dS/m (Biswas *et al.* 2005c; Stevens 2002). This algorithm assumes that the leaching water uniformly displaces the (saline) soil water as 'piston' flow, but is unlikely to occur because of the presence of macropores that allow bypass flow. (Bouwer 1969)) reported this by-path water and salt transport process and described the 'leaching efficiency' (LE) as a ratio of the volume of drainage flowing by piston flow to the total volume of drainage.

In order to understand and manage this salinity hazard, a 'Tri-State Salinity' syndicate of Government agencies from western NSW, Victoria and South Australia (with support from federal agencies) was formed to undertake a 3 year laboratory and field scale study popularly known as the "TriState Salinity Project" or the DEP15 project for the Lower Murray irrigated permanent horticulture.

1.1 Project objectives

The DEP 15 project has been developed to test the hypothesis that: *'a depressed leaching efficiency (LE) in the Lower Murray irrigation districts raises the root zone salinity and that improved water use efficiency (WUE) may have an upper limit determined by paddock's LE and its variance'*.

The project activities were grouped into two distinctive stages that spread over 6 milestone activities, to deliver an outcome that could assess the risk of irrigation water-induced salinity on Lower Murray horticulture. The specific objectives were to:

1. Determine/update the salinity relationships for irrigated horticulture along the Lower Murray: Riverland, Sunraysia and western NSW;
2. Determine the variability of EC (soil water) and leaching efficiency in the field under known soil conditions and irrigation management;
3. Simulate the performance of horticultural crops under different scenarios of River Murray salinity at Morgan; and
4. Provide input to the implementation of the Salinity Strategy and Integrated Catchment Management Plan of the Murray-Darling Basin.

This report forms Milestone 4 deliverables of the DEP 15 project and contains the work carried out between May to November 2005. This report also forms a part of the suit of milestone reports aimed to generate the knowledge for managing root zone salinity hazards and to assess the risk of salt accumulation under precision irrigation, with a goal to deliver strategies for minimising yield losses. Three previous reports submitted to the funding agencies contained the outputs of Milestone 1,2[#] and 3[#] activities respectively. These reports can be accessed from the reference sources (Biswas *et al.* 2005a; Biswas *et al.* 2005c; Schrale and Biswas 2004). The executive summaries of these reports are presented in Appendix 4.

Deliverables of Milestone 4 activities are listed below.

Outcomes and generic deliverables set for Milestone 4 Task

Due date/ Item No	Deliverables during Milestone 4	Outcomes	Quick Reference
30/11/2005			
1.	Workplan continues with all priority stakeholders participating	Report/article /meeting	Chapter 1&2 Appendix 1
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3	At least one Steering Committee meeting with year 2 data and analysis reported and discussed by the Committee.	3 Nov 05 Merbein	Appendix 2
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6	Field data compared to the models outputs.	Conf paper	Chapter 2

[#] Elaborate description of work plan and associated reviews were presented in Milestone 2 and 3 reports.

2. Outcomes♣ from the Milestone 4 reporting period

2.1 Papers on Root Zone Salinity and Deep Drainage

(1) Biswas, T., Stevens, R. and Schrale, G . (2005). Root zone salinity in the lower Murray districts. ANCID Conf 2005. 23-26 Oct, Mildura. Firestarter Pty Ltd. PO Box 692, North Melbourne VIC 3051. www.lmw.vic.gov.au/ancid2005

(2) Biswas TK, Schrale G, Dore D (2005) Measuring the effects of improving water use efficiency on root zone salinity. *NPSI Research Bulletin.* **1,** 1-4.

(3) Biswas, T.K., Adams, A.C. and Schrale, G. (2005). Deep percolation assessment by capacitance probe data ANCID Conf 2005. 23-26 Oct, Mildura. Firestarter Pty Ltd. PO Box 692, North Melbourne VIC 3051. www.lmw.vic.gov.au/ancid2005

(4) Biswas, T.K., Edraki, M. Adams, A.C. and Schrale, G. (2005). Real -Time Drainage Fluxes From The Root Zone By Using Capacitance Probe Data . pp1-4. In proc Irrigation 2005 Conf, Townsville, Qld 18-20 May. IAA, North Queensland Region, PO Box 978,Townsville QLD 4810. www.irrigation.org.au/Irrig2005

Root Zone Salinity Risks in the Lower Murray Districts (Paper # 1)

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Abstract

Due to improved irrigation management and system upgrades, the field application efficiency (FAE) in the Lower Murray horticultural districts has risen from about 50 to 85% during the past 2 decades. Consequently, the drainage volumes have reduced from about 50 % to 15% of water applied. Under steady state conditions, the salinity in the root zone can be estimated from salinities of the irrigation water and the leachate (i.e. extra irrigation water applied which drains out of the base of the root zone). For this estimate it is assumed that the leaching water uniformly displaces the (saline) soil water in a 'piston' flow manner.

Despite the relatively low salinity of the River Murray flows in the past five years, growers practicing 'precision' irrigation expressed concern about the gradual, but visual accumulation of salinity in the root zone of drip irrigated vineyards in particular. A 'Tri-State Salinity' syndicate of Government agencies from western NSW, Victoria and South Australia (with support from federal agencies) was formed to generate new knowledge for managing root zone salinity hazards by undertaking a 3 year laboratory and field scale studies. Besides assessing the risk of salinity accumulation under precision irrigation, the project team is working on strategies for minimising production losses.

Field data from conventional drip in the Riverland and Sunraysia regions showed that only less than 10% of applied water was found to leave the root zone during the grape growing season, which resulted in salt build up in root zone. This is particularly of concern when the average

♣Detailed summary of DEP15 communication activities is presented in Appendix 1.

leaching efficiency at the 14 surveyed properties was 63% and where only <5% of total applied water is flushing the root zone during the irrigation season.

Using the data from a drip irrigation vineyard at Loxton in Bookpurnong Lock-4 district, the output of a two-dimensional numerical flow/transport model (LEACHM-TRANSMIT) showed that during summer about 2 t of salt /ha would accumulate in the root zone if the River water salinity is 0.8 dS/m. However, even at the currently River salinity of 0.3 dS/m and 95% FAE, crop losses due to gradual salinity build up may be inevitable in the Riverland/Sunraysia districts.

Introduction

As a result of improved irrigation management and systems, growers in the Lower Murray (Riverland-Sunraysia) horticultural region have improved their water use efficiency (WUE) over the past two decades from about 50% to about 80%. However a negative consequence of this achievement is the emerging risk of salinity build-up in the root zone, threatening the sustainability of the region (Biswas *et al.* 2005a; Biswas *et al.* 2005c; Biswas *et al.* 2005c; Biswas *et al.* 2005c; Biswas *et al.* 2005c; Biswas *et al.* 2005b). The amount of irrigation applied must account for both the crop water use and some extra water (the leaching fraction) to flush periodically the residual salt out of the root zone. For example, when the average river water salinity is about 0.4 dS/m, a 15% leaching fraction (15% more than the crop needs) should give root zone salinity around 0.6 dS/m. However field surveys indicate that the root zone salinity, though very variable, is often greater than 1.3 dS/m. The discrepancy between observed and expected soil salinity may be due to a portion of the leaching water moving rapidly through the larger soil pores without displacing soil soluble salts from the root zone. As a result, the leachate is a mixture of irrigation water that has passed unchanged and of displaced soil solution. Van der Molen (1956) described this by-path water and salt transport process and used the term 'leaching efficiency' to describe the ratio of the volume of drainage flowing by piston flow to the total volume of drainage (Bouwer, 1969).

The River Murray Catchment Water Management Board has sought to manage the impact of return flows of irrigation drainage water on river water quality and health of the floodplains by introducing a target of WUE of 85% in the current Water Allocation Plan. Insufficient leaching at this target may result in high levels of root zone salinity and subsequent yield losses for the local horticultural crops (Stevens 2002).

Since the end of 2003 a tri-state syndicate of government agencies from western NSW, Victoria and South Australia has been working on a strategy to manage this salinity hazard. This paper reports some of the findings to date, focusing on results of monitoring root zone salinity and deep drainage in sprinkler and drip-irrigated citrus orchards and vineyards.

Measuring root zone salinity

Measurement of the electrical conductivity (EC) of soil began in 2002/03 irrigation seasons at 3 properties in the Lower Murray and during 2003/04 another 11 properties were added to this measurement regime. The seasonal depth of water applied for the citrus crops ranged from 588 to 1646 mm; the associated total rainfall ranged from 235-284 mm. The vines had seasonal irrigation depths ranging from 440 to 1133 mm and total rainfall from 153 to 303 mm. This survey indicates that the mean measured value of soil salinity (Cl_{sw}) was at least 2-fold higher than the values estimated by application of a range of irrigation water to soil salinity conversion formulae (GHD, 1999, Hoffman and van Genuchten, 1983, and Ayers and Westcot, 1985). As presented in Table 1, the mean leaching efficiency of 63% at these sites was significantly less than unity ($P < 0.01$) and had a large coefficient of variation (77%). Leaching efficiency is the efficiency with which the drainage water mixes with the soil solution and is accepted as 100% when every mm of water passing below the root zone carries its full quota of salt.

Table 1. Volume weighted Cl concentration in water (Clw) applied in 12 months preceding soil sampling, Cl concentrations in the soil solution at base of root zone (Clswb), leaching fraction and leaching efficiency.

No of farms surveyed	Years under irrigation	Clw mmol/L	Clsw mmol/L	Leaching Fraction =1-FAE or Clw/Clswb	Predicted Clsw mmol/L	Leaching Efficiency
14	>45	1.2	12	0.2	4.1 –5.1**	63%

*estimated as twice the Cl concentration in the saturated paste extracts **P=0.01 paired t-test between Clsw and predicted Clsw

The leaching in-efficiency and its large variation are likely due to local characteristics and their spatial variability. In order to gain temporal variation of both leaching fraction and leaching efficiency four representative vineyard and citrus farms across the Riverland and Sunraysia irrigation areas were selected. The major criteria were that the sites should have had at least 12 years of irrigation and the water table should be more that 3 meters below the surface depths (Schrale and Biswas, 2004; (Biswas *et al.* 2005a; Biswas *et al.* 2005c).

At each of these sites an EM38 survey was undertaken, which uses electromagnetic resonance imaging, to map the paddocks into units of greater or lesser salinity (Figure 1). The results showed great variation between core samples and between farms, but generally salinity increased with depth (Figure 2). This is expected because evaporation and absorption by the plant roots reduces the amount of free water and therefore concentrates the salt in the substrata.

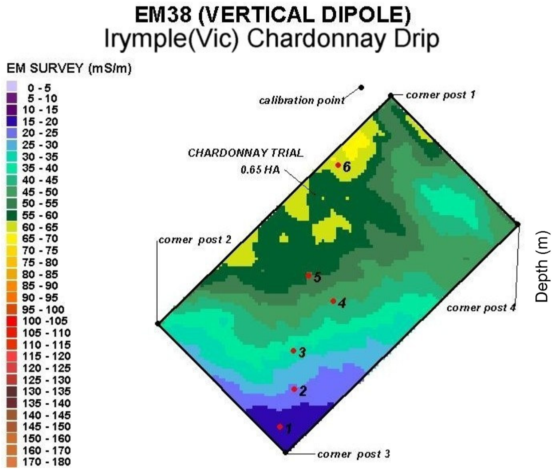

Figure 1. Map of apparent salinity (ECa for the drip irrigated Chardonnay block, and location of core samples. The colours show the variability in salinity across the paddock, ranging from 0.2 to 0.75 dS/m. 1 mS/m = 0.01 dS/m.

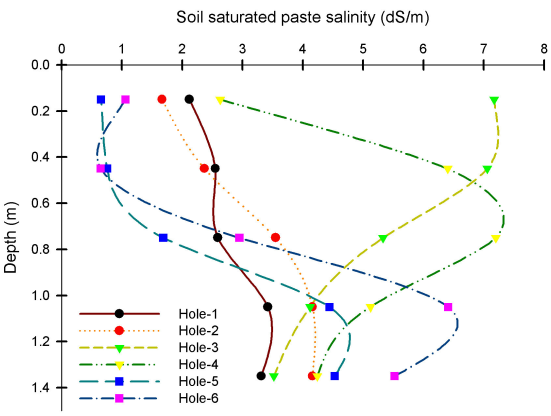

Figure 2. Variation in salinity (x axis dS/m) with soil depth (y axis in m) for each of the core samples in Fig 1

Soil solution salinity was monitored at each sites at depths of 0.3m, 0.6m and 0.9m. Following each irrigation or rainfall event, solutions were extracted under a suction of 70 kPa. ECsw measurement was used as surrogate measure for Cle.

The salinity of soil water (ECsw) peaked at 20 dS/m at 90 cm root zone depth under drip irrigated vineyard, but was rarely more than 1.5 dS/m in an undercover sprinkler citrus orchard (Figure 3). According to (Maas and Hoffman 1977) and (Ayers and Westcot 1976) the threshold ECsw for yield reduction is 4.2 dS/m for grape and 2 dS/m for citrus respectively. Although the salinity of the entire root zone at the citrus farm (irrigated by under-cover sprinklers) is kept well below the threshold salinity, the salinity of the lower root zone strata in the drip irrigated vineyard was above the threshold for most of the season.

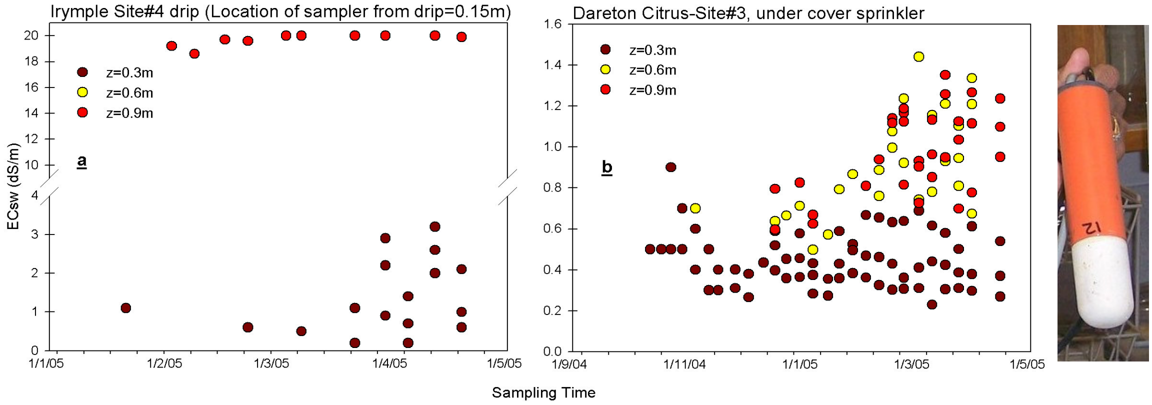

Figure 3. *Electrical conductivity of soil water (ECsw) under (**a**) a drip irrigated vine and (**b**) an under-cover sprinkler citrus tree. On the right: solution extractor.*

Deep drainage estimation

Four methods were used to try to determine the amount of water draining from the root zone. These were:

1. estimation of water balance throughout the season;
2. using chloride as a tracer;
3. seasonal water balance, validated by capacitance probe logs;
4. capacitance probe method using Darcy equation.

Method 1 involves estimating changes in soil water storage from soil texture, irrigation records, crop types, climatic data and crop coefficients. Water applied in excess of water holding capacity of the root zone is attributed to deep drainage.

Method 2 assumes that the ratio of deep drainage to the amount of water applied is equivalent to the ratio of the chloride (Cl) concentration in irrigation water to the Cl concentration Cl in drainage water. By monitoring these concentrations in the field, a seasonal picture of deep drainage can be built up. If a Soil Solution Extractor is used, soil water can be extracted from the root zone at a standard suction pressure similar to that applied by the plant roots.

Method 3 uses capacitance probe logs for measuring total root zone water content, estimates of the field capacity of the soil, and rainfall and irrigation data to determine deep drainage (Edraki *et al.* 2004). Whereas Method 1 uses crop coefficients to predict the crop's average water use at various stages of development, Method 3 makes no such assumptions, but simply derives the amount of water leaving the profile.

Method 4 uses the van-Genuchten function to smooth hourly capacitance probe soil water content data into soil matric potentials. Using Darcy function these results along with the soil hydraulic functions are converted into the deep drainage volume. Detailed methodology is presented in Biswas *et al.* (2005b).

Using Method 1, it is estimated that 4-10% deep drainage is occurring under drip irrigated vines and citrus compared to 24% and 35% respectively for citrus and grapes irrigated by undercover sprinkler. This means that the WUE under drip is 90-95% with consequently high risk of long-term salt accumulation in the root zone and associated yield losses.

Using Method 2, drip irrigation would not have produced any leachate at one site, and produced only 1% of applied water at the other. With undercover sprinklers the estimates were 21 ± 3 % and 17 ± 4 % of deep drainage. The results are summarised in Table 2.

Table 2. Estimated Deep Drainage (Sep 04-Apr 05) from soil Cl tracing technique (Method 2)

Site	Irrigation (mm)	Rainfall (mm)	Deep Drainage (%)
Loxton vine drip	510	177	ND[a]
Irymple vine drip	343	116	1 (±0.02; n=10)[b]
Loxton vine uc sprinkler	735	177	21 (±3; n=53)
Dareton citrus uc sprinkler	912	102	17 (±4; n=31)

[a]ND=Not detected
[b]value in parenthesis indicates standard deviation (SD) and n = sample size

Using Method 3 estimates of deep drainage ranged from 7-16% and 13-17% for drip irrigation and for undercover sprinkler irrigation respectively. The results are presented in Table 3. This confirms the method 1 result that the WUE under precision drip is often more than 90%.

Table 3. Deep Drainage estimated from field capacity and capacitance probe data (Method 3)*

Site	Period	Apparent Field Capacity (%)	Deep Drainage (%)
Loxton vine drip	10 Dec 04-23 Jun 05	31	7
Irymple vine drip	22 Dec 04-23 Jun 05	30	16
Loxton vine uc sprinkler	6 Jan -23 Jun 05	20	13
Dareton citrus uc sprinkler	30 Jan-1 Aug 05	19	17

* based on non-calibrated enviroscan data

Using Method 4 during summer irrigation, under a drip irrigated vine the drainage estimates resulted in negligible deep drainage (1%) whereas under sprinkler irrigated citrus deep drainage was 17%, which confirm the Method 2 findings.

What do the results mean?

Although the results from the 4 methods vary considerably, they suggest that, in summer, negligible leaching is occurring under drip irrigation compared to the uniform under canopy sprinkler irrigation, regardless of the crops grown. Consequently, the general concern for precision drip irrigation is that if winter rainfall does not provide effective leaching, accumulation of residual salt in the root zone is going to be a major concern.

To develop a strategy for root zone salinity management, a two dimensional solute transport model (LEACHM-TRANSMIT) (Hutson and Wagenet, 1995) simulation was run for 278 days to estimate the salt accumulation in the root zone for irrigation salinities of 0.3 dS/m (current river water salinity at Loxton) and 0.8 dS/m (the Morgan benchmark). The scenarios are shown in Figure 4. Under the scenario of drip irrigation with 10% root zone drainage and 0.3 dS/m water, about 130 kg/ha of salt (is this chloride or salt – if salt then 0.3 dS/m ~ 165 mg/L and if 8 ML/ha then cumulative salt in equates to 1.320 Mg/ha equates to 132g/m2) would accumulate in the root zone during first irrigation season. Under the 0.8 dS/m water scenario, 2000 kg/ha of salt would accumulate in a 1 m root zone during a normal grape growing season.

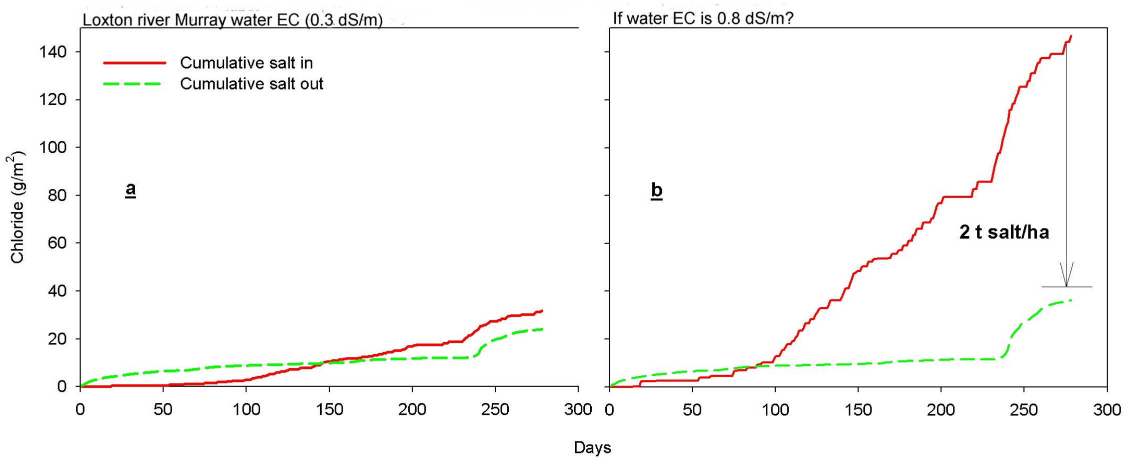

Figure 4*. Results of a two dimensional salt transport model that predicts salt build up in the root zone with two different salinities of River water, the 0.3 dS/m (current level), and 0.8 dS/m the Morgan benchmark*

It is important to note that the fruit and leaf analysis for the 0.3 dS/m scenario showed no significant salt problem for either grapes or citrus except at one site.

Future direction

With more field data and calibration of capacitance probes, the team plans to further investigate the variations in deep drainage estimates that the different methods have shown. The detailed monitoring of daily and hourly changes in unsaturated hydraulic conductivity is proving critical to the estimation of deep drainage, as wetting periods are not homogeneous events. However the results to date suggest that deep drainage may have been over-estimated by the traditional water balance methods (Methods 1 and 3).

We plan to measure leaching efficiency and model the scenarios of different levels of River Murray salinities on root zone salinity accumulation for the current irrigation system and management practices. The aim is to develop a user-friendly root zone monitoring toolkit for growers and a modelling tool and field validation system for water managers to assess the risk of excessive root zone salinity for the Lower Murray irrigation districts.

We also plan to undertake an economic assessment of grower losses across the region under different River salinity scenarios by using previously developed salinity-yield relationships for different horticultural crops. This information is keenly sought by State government agencies who, through the Murray-Darling Basin Ministerial Council, are investing multi-million dollars in salinity mitigation works to reduce salinity in both the drinking and irrigation water in the Lower Murray region.

The outcomes of the 3 year project will be compiled in Salinity Management Guidelines with salinity triggers that will assist the different investors to identify their temporal and spatial options for salinity management from the perspective of irrigation water salinity management for the Lower Murray region. This information, combined with the environmental and socio-economic requirements, will lead to the best 'triple bottom line' outcomes for this important horticultural region of Australia.

Acknowledgements

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2.2 New Tool and Methodologies for In-situ Monitoring of Root Zone Salinity and Leaching Efficiency under Precision Irrigation

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Keywords: precision irrigation, rootzone salinity, soil water extractor, leaching efficiency

Introduction

The South Australian Water Allocation Plan for the River Murray Prescribed Water Course 2004 (WAP) encourages growers to achieve a water use efficiency of at least 85%. During the past two decades efficient irrigation management and system upgrades have raised the field application efficiency (FAE) in the Lower Murray horticultural districts from about 50 to 85% (Biswas *et al.* 2005a; Biswas *et al.* 2005b). Consequently, the drainage volumes have reduced from about 50 % to 15% of the water applied. Under steady state conditions, root zone salinity can be estimated from salinities of the irrigation water and the leachate (i.e. extra irrigation water applied which drains out of the base of the root zone). With Murray water salinity of about 0.4dS/m, a 15% leachate, one would expect an average root zone salinity of 0.6 dS/m (Stevens, 2002). This algorithm assumed that the leaching water uniformly displaces the (saline) soil water as 'piston' flow, but is unlikely to occur because of the presence of macropores that allow bypass flow. (Bouwer 1969) reported this by-path water and salt transport process and described the 'leaching efficiency' (LE) as a ratio of the volume of drainage flowing by piston flow to the total volume of drainage.

Despite the relatively low average salinity (0.4 dS/m) of the River Murray flows in the past five years, Riverland growers practicing 'precision' irrigation have become concerned about the gradual, but visual accumulation of salinity in the root zone, particularly in drip irrigated vineyards. Although there are various complex in-situ salinity measuring tools available in the market, growers are particularly interested in a simple toolkit for monitoring root zone salinity hazards.

This paper discusses new methodologies for in-situ monitoring of root zone salinity and measurement of leaching efficiency under precision irrigation

In situ monitoring of root zone salinity risk

Field data from this study for conventional drip irrigated vines in the Riverland-Sunraysia region showed that less than 10% of applied water was found to leave the root zone during the irrigation season. This resulted in salt build up in root zone. Triplicate sets of porous ceramic extraction tools called 'soil water extractor (SWE)', specially developed for monitoring root zone salinity of permanent horticultural plantings were installed in vineyards and citrus orchards at 30, 60 and 90 cm depths during Nov-Dec 2004. Throughout the following year (2005), the irrigation, rainfall and reference evapotranspiration (ETo) data were collected from the field sites while monitoring the changes in soil water salinities. The soil water salinities data obtained from the SWE and presented in Fig. 1 showed a gradual increase in salt build up at all the measured depths during the irrigation season. The above average annual rainfall of 332 mm (historical average 250 mm) in the Riverland during 2005 was sufficient to leach the irrigation (631-732 mm) induced salinity from top 60cm soil layers but failed to leach the salt from the bottom portion of the rootzone (90cm). This is particularly of concern if the average leaching efficiency (LE) falls below 100%.

The average salinity tolerance threshold of grapevine is 2.1 dS/m (Walker and Stevens, 2004) when the EC is measured in saturated paste extract (ECe). Preliminary data indicates the EC of soil water extracted by the SWE is 1.5 times higher than ECe in a Riverland vineyard which is irrigated at 60 kPa. Hence, the threshold salinity showed in Fig. 1 is 1.5 x 2.1 = 3.2 dS/m. During drought years river water EC often tends to go up. A high water demand coupled with poor quality irrigation water is most likely to add more salts in the root zone than a normal year.

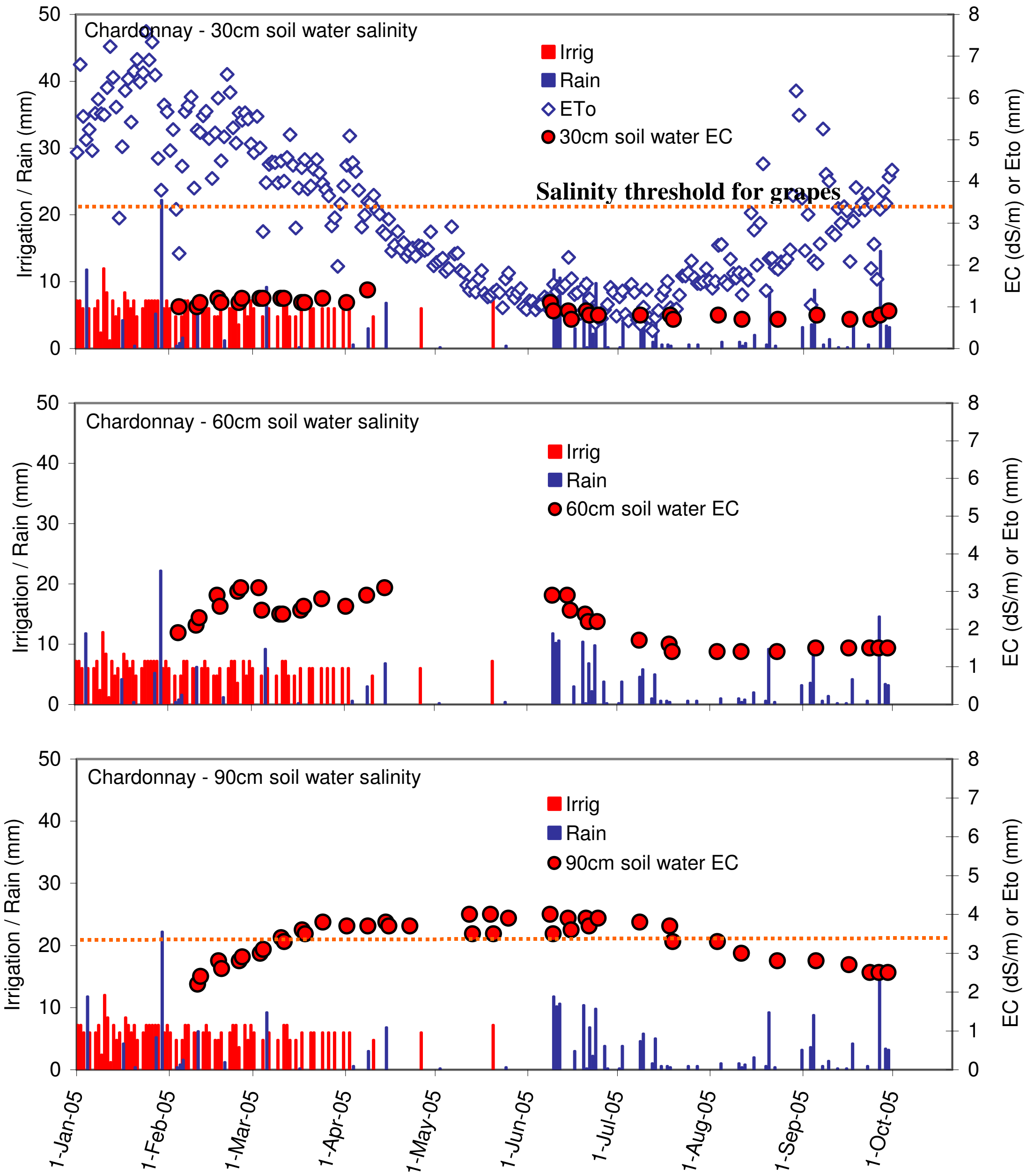

Figure 1. Seasonal changes in salinity profiles (30 cm-top, 60cm middle & 90 cm-bottom) under a drip irrigated Chardonnay vineyard in the Riverland. Irrigation/rainfall events are in left x axis and soil water EC measured by SWE is in right x axis.

New methodology for in-situ field estimation of Leaching Efficiency (LE)

This concept of LE is not new. In 1969, Bouwer explained LE thus "Some of the irrigation water will move rapidly through the larger pores and reach the lower boundary of the root zone with little increase in salt content. On the other hand, water moving through the finer pores may displace soil water essentially as a piston flow, so that the drainage water from the smaller pores will have about the same salt concentration as that of the soil water in the root zone. Thus, the water draining from the lower boundary of the root zone can be considered as a mixture of irrigation water that has passed unchanged through the root zone, and soil solution that has been directly displaced by irrigation water. The hypothetical fraction of the drainage water consisting of displaced soil solution has been called the leaching efficiency, symbol E_l". In this paper, E_l is synonym to LE. He goes on to speculate that, "an important reason for the lower values of E_l, for field conditions may well be the presence of macropores."

A simple methodology for rapid and in situ measurement of LE is proposed by the authors using chloride concentrations of captured infiltrated water from wetting front detectors (FullSTOP as in (Stirzaker 2003) and the SWE installed at the same depths. In a simple term leaching efficiency can be written as:

$$LE = \frac{\text{volume of soil solution displaced}}{\text{volume of drainage water}}$$

$$= 1 - Bypass\ Flow\ (BF)$$

$$BF = \frac{Cl_{SWE} - Cl_{FS}}{Cl_{SWE}}$$

$$LE = 1 - \left[\frac{Cl_{SWE} - Cl_{FS}}{Cl_{SWE}}\right]$$

where;
Cl_{SWE} = Chloride concentration in soil water extracted by SWE
Cl_{FS} = Chloride concentration in soil water captured by wetting front detector, FullStop

Preliminary data obtained from 30 cm depth indicate that the LE is a variable property of the same soil and crop type irrigated by different irrigation systems, eg, drip and under canopy sprinkler. The high frequency, low volume application of drip irrigation gave a LE value of 0.90 (or 90%) when measured right under the dripper compared to a 57% LE measured at 25 cm away the dripper where dripper spacing was 100 cm (see Fig. 2). On the other hand, an under-canopy sprinkler irrigation in a citrus orchard as shown in Fig. 3, delivering more water per irrigation event but applied less frequently resulted in 72% LE. Results indicate that LE of permanent horticulture plantings is a dynamic parameter and likely to be governed by the irrigation type, evapo-transpiration, rainfall and its distribution, cover crop and associated crop management practices.

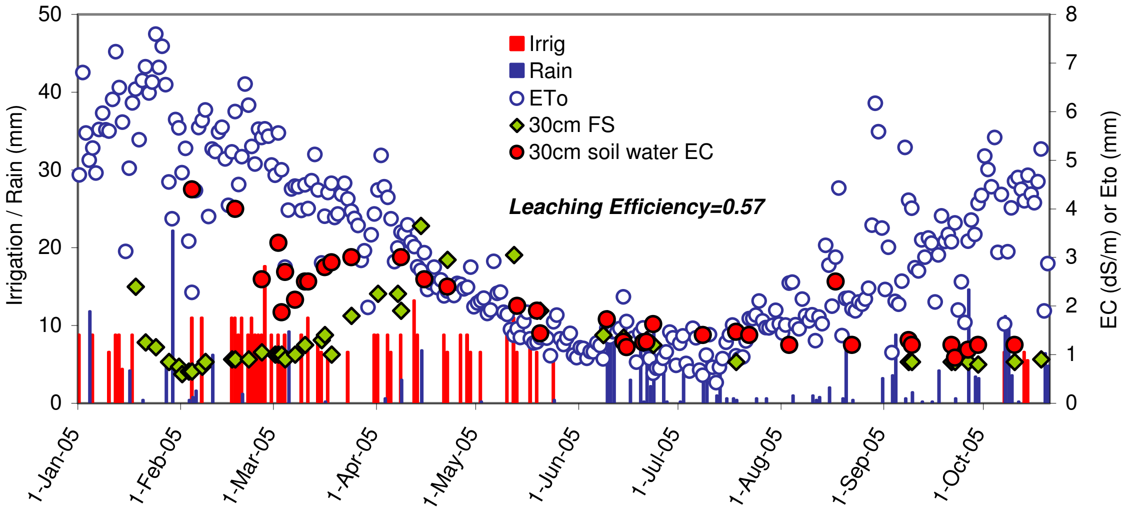

Figure 2. Leaching efficiency of a drip irrigated Colombard vineyard in Riverland estimated from the irrigation/rainfall (left y axis) and soil water EC measured by wetting front detector and SWE (right y axis) between Jan-Oct 2005 (x axis). SWE was installed at 25 cm away the dripper (dripper spacing = 100 cm).

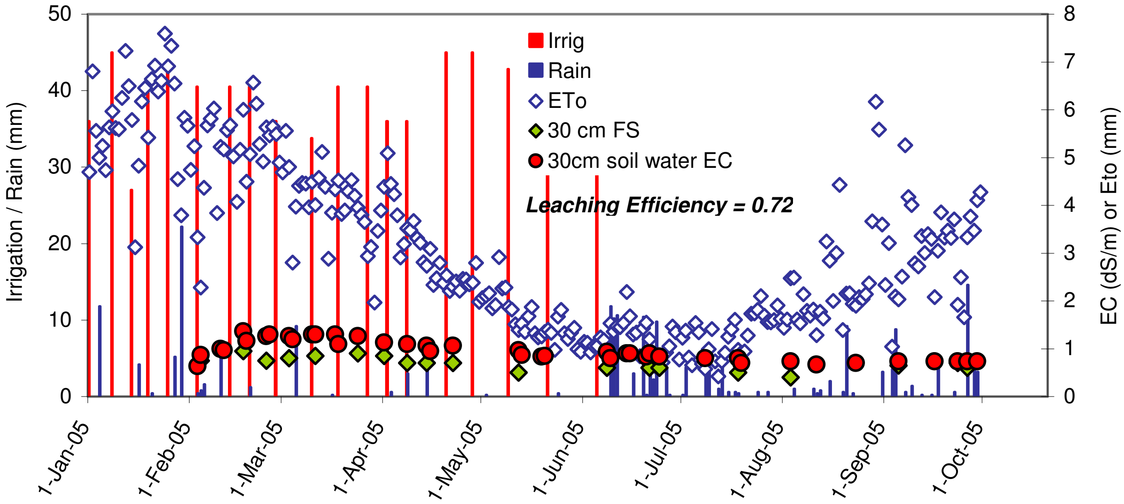

Figure 3. Leaching efficiency of an under canopy sprinkler irrigated Navel citrus in the Riverland estimated from the irrigation/rainfall (left y axis) and soil water EC measured by wetting front detector and SWE (right y axis) between Jan-Oct 2005 (x axis).

Conclusion

Conventional methods of estimating leaching efficiency are laborious and expensive processes, which need specialised skills and equipments. Often the measurement does not represent the actual field and growing conditions. The proposed method of LE is an inexpensive and simple process that involves cheap soil water monitoring tools such as FullStop ($150/pair) and SWE ($150/pair).

In Riverland and Sunraysia plantings with a poor LE, crop losses under precision irrigation may be inevitable due to gradual salinity build up, even at the currently average River salinity of 0.4 dS/m. This suggests that growers should undertake a 'rootzone salinity watch' and keep the salt out of the plant environment. Management option should include strategic leaching of the rootzone at times when extra water of preferably low salinity is available in order to provide a buffer to accommodate high salt input during droughts with reduced allocations and/or higher salinity irrigation water.

Acknowledgements

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2.3. Grower's Tool for Monitoring Root Zone Salinity Risk

DRAFT COPY

SARDI Soil Water Extractor For Monitoring Root Zone Salinity Risk - An Instruction Manual

Changes in soil water salinity and chemistry under irrigated plantings can be monitored in-situ with a new extractor made of inexpensive materials. The extractor is called "soil water extractor (SWE)'. This device is expected to give excellent results because:

(i) The inert ceramic cup will not alter the soil solution composition;
(ii) They can continuously deliver relatively small volume samples unlike others;
(iii) The extractor can be permanently installed and be sampled at any time with minimal disturbance, and
(iv) They enable to extract samples over a wider range of unsaturated conditions.

Soil water extractor

A specially designed ceramic cup is attached to a specific length of 40 mm PVC conduit. The outside surface of the ceramic tip is smoothed and inserted into the bottom of the PVC conduit. The joint is glued together to make it airtight. A hole is drilled through the top of the PVC conduit to house the vacuum cum extraction tube. A two-way medical stopcock (luer lock) is attached to the top of extraction tube (see Figure 1a).

Figure 1. (a) SARDI soil water extractor & (b) sterilisation

Pre-installation

Soak the extractors for 1 day in 3% sodium hypochlorite detergent (bleach) in tap water/rainwater (see Figure 1b). Take the extractor out and draw up the rest of the bleach water from the extractor and dispose the extract. The extractor, now sterile and free of air bubbles, is ready for insertion into the ground.

Field installation and operation of extractor

Before proceeding to the field, make sure you have the following material with you:

a) 40 mm auger
b) Hand shovel/Trowel
c) Bucket & water
d) Builders dry sand or fine riversand: Active Gel Bentonite in the ratio of 2:1
e) 60mL disposable plastic syringe
f) Kitchen sieve
g) Wooden stake/dowel (40 cm)
h) Plastic twine (15 cm)
i) Long nose pliers
j) Tape measure
k) Cattle tag (optional)
l) Permanent marker pen

Figure 2. Field installation of the extractor in a vineyard

Correct field location and installation procedure

(i) It is essential that the selected plant, dripper or sprinklers are representative of the whole paddock. The extractor must be placed in the plant root zone. For general purpose and to capture the root zone comprehensively, place a duplicate nest of extractors at 30, 60 and 90cm depths. For practical purpose, place a duplicate sets of extractors at 30 and 60 cm depths.

(ii) Clear trash away from site and place 3 holes markers in a radius of 10-15 cm around the dripper as illustrated in Figure 3 and within 75cm of sprinkler radius. With sprinklers, place within the sprinkling range and not at the edge.

(iii) Using a 40 mm auger dig hole to the depth of interest plus 30mm. Clearly mark the auger with correct depths. This ensures that the middle of the 60mm length ceramic cup will be at the desired depth.

(iv) While digging, keep the 15 cm soil increments in separate heaps to ensure back filli. ng with respective depths.

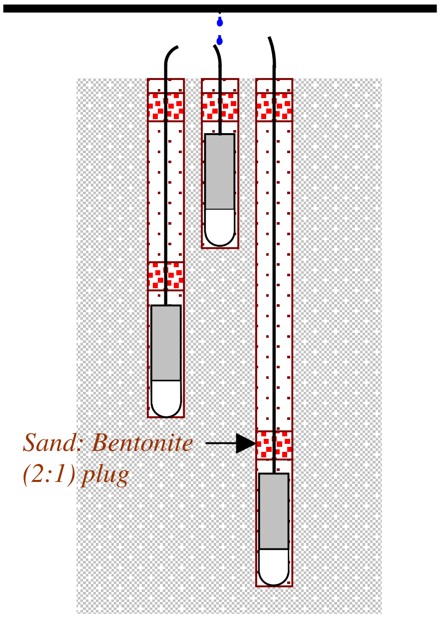

Figure 3. Layout of SWE around a dripper

(v) Sieve about 80g soil collected from the bottom of the hole into a plastic mug. Add water to the mug to make slurry; decant extra water and pour the slurry into the hole to soften the wall and ensure good contact between soil and extractors. *If the soil is a clay soil, use diatomaceous earth as it is instead of soil slurry.*

(vi) Lower down the soil water extractor into the hole tying with an insertion tool (see Figure 4a). The insertion tool is placed on the top of the extractor and the extraction tube positioned through the hole of insertion tool's cap.

(vii) Before inserting, seal tube with electrical tape to prevent bedding material entering during installation.

(viii) Insertion tool and extractor is lowered into the hole and pushed gently to make strong contact between the tip of ceramic cup and bottom of the hole.

(ix) Add dug soil and make sure the side of tube is sealed until the top of tube.

(x) Add 60 mL sand:bentonite plug. Add soil to the top for 30cm extractor. For 60 and 90 cm extractors, add two sets of plugs and top up with dug soil in between as illustrated in Figure 3.

(xi) After installation of all extractios, tie the individual tube with a wooden peg (see Figure 4b) using a 15 cm plastic twine and encase the peg and extraction tube with a 50 mm PVC pipe cut to a foot length. This is to protect the tube from damage by farm animals and machinery (see Figure 4c).

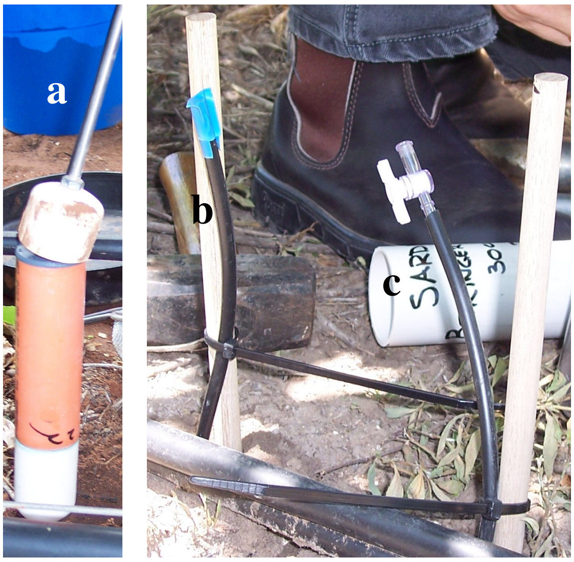

Figure 4. (a) Insertion tool (b) wooden pegs and (c) PVC encasing

Operating the extractor

(i) Allow a day after the irrigation event before commencing the sample extraction. ***The selected time interval must always be constant.***

Never operate the extractor before irrigation water reaches the depth of the ceramic tip, because suction can never be achieved while ceramic tip is dry.

(ii) Connect the 60 mL syringe to the luer lock and open the valve.
(iii) Put one hand below the syringe wings and with your other hand draw the syringe piston all the way back (60 ml).
(iv) Keep holding the piston tightly and close the lur lock valve with your other hand (90^o).
(v) Disconnect the syringe from the luer lock.
(vi) Repeat the whole exercise for each extractor.

Collecting soil water sample from the extractor

Generally it requires a fortnight before the extractor will yield a representative soil water sample. During this fortnight, discard 2 extracted samples to avoid distortion of samples, if any.

Allow 4 hours or more after the suction had been applied before drawing soil water sample.

(i) Open the luer lock valve and connect the syringe to the luer lock and pull the syringe piston all the way back (60 ml) as shown in Figure 5.
(ii) Within a few seconds the syringe will be filled with soil solution. Disconnect the syringe from the transparant nozzle and leave the valve open.
(iii) Immediately measure the salinity by using a portable electrical conductivity meter (EC) or salinity meter.

Figure 5. Drawing soil water

Maintenance

After drawing out the solution, the extractor should not remain at vacuum conditions till the next time of operation.

The ceramic tip must be sterilized in-situ against fungi every three months. Fill the syringe with the sterilizing 30 mL bleach solution as described above. Open the luer lock and inject it into the extractor slowly for 1 minute. Allow 2-3 minutes before drawing up the rest of the solution from the extractor and dispose of it. Discard couple of soil water samples following the sterilization process.

Soil water salinity tolerance of permanent horticultural crops

Salt tolerance levels shown in the Table below should be used as a guide. They may require adjustment depending on management, irrigation water salinity, soil salinity and leaching efficiency.

Average root zone salinity threshold of soil water (ECsw)**

Tree crops	**Varieties**	**Threshold EC of soil water** at which yield decline starts
Almond	All	**3**
Apricot	All	**3.2**
Grape[$$]-own rootstocks (Sensitive)	Sultana, Shiraz, Chardonnay, Pinot Noir, Riesling, Semillon, Merlot, Cabernet Franc, Cabernet Sauvignon, Grenache. Rootstocks: 3309, 1202C, K51-40	**3.6**
Grape- Moderately sensitive)	Colombard on own roots. Rootstocks: 5BB, 5C Teleki, Richter 110, Richter 99, K51-32	**5**
Grape- Moderately tolerant	Rootstocks: Rupestris St. George, Ruggeri 140, Schwarzmann, 101-14, Ramsey	**6.6**
Grape- Tolerant	Rootstocks: 1103 Paulsen	**11**
Orange	All	**3.4**
Peach	All	**3.4**
Plum	All	**3.0**
Pear	All	**2.0**

[**]Soil water salinity is assumed as twice the EC of saturated soil paste extract (ECse) as in Ayars RS, Westcott DW (1985) 'Water Quality for Agriculture.' FAO, paper No 29, Rome.
[$$]Grape data from Walker, R and Stevens, R. (2004). *In* 'Salinity Impacts on Lower Murray Horticulture' - Stage 1 Report. SARDI, GPO Box 397, Adelaide 5001

2.4 Economic Assessment of Salinity Impact on Lower Murray Horticulture.

The additional work that has been conducted on the "Economic Assessment of Salinity Impact on Lower Murray Horticulture" project in the past nine months has involved extending the range of industries/crops included in each of the regions to include potatoes, and three types of pasture; perennial, annual and lucerne. For each of these industries/crops, the area of production, related to the three major soil types in the four regions, was tabled. From these figures, the percentage and value of lost production was calculated under the seven salinity scenarios specified in the previous report.

For the additional four industries/crops, the area of production data was sourced from the 2001 Australian Bureau of Statistics (ABS) Agricultural Census, the only consistent source of regional level industry data available at that time. Negotiations are currently proceeding to access more recent regional level data, from various industry and regional sources, to allow production area data to be updated (and thus the evaluation of lost production) for all twelve industries/crops evaluated in the project.

Appendix 1. Summary of DEP15 Communication Activities

The communication strategy was reviewed by the project steering committee at their meeting on Nov 3rd 2005 at Merbein.

It was recognised that activities to date had largely been focussed on project awareness, but now were able to report some field data. Results from the first year of field trials have been well summarised in the Research Bulletin 1, September 2005, by the National Program for Sustainable Irrigation (NPSI). This Bulletin has been circulated by NPSI at the recent ANCID Conference for 2005. Presentations to the NPSI Investors Forum and the ANCID Conference have highlighted the first year results.

The project steering committee discussed the potential for presenting the first year results at an irrigator's field day in the Riverland and Sunraysia. It was recognised however that a more strategic approach, based on a longer-term educational process for irrigators, was considered to be of greater value. Current river salinity levels are low and salinity problems have not been observed in plant measurements or crop losses, consequently a single field day summarising results so far was considered to have minimal impact on irrigators at this time.

Previous irrigator training programs in the region over many years have been successful in changing irrigator practices in relation to crop selection for appropriate soil types, system design and evaluation, and crop scheduling. The issue of salinity in the rootzone has not been addressed in any detail so far, and it is appropriate to now include this aspect into future programs for the Riverland and Sunraysia, based on the work being done in this project.

It is proposed that the project team prepare a scoping paper for an education program in early 2006, in consultation with regional project partners.

A summary of project communication activities is presented in the table below, with activities since the Milestone 3 report in italics.

Target Audience	Strategy	Activity
Project partners and funding organizations	Communication within the project	a) Bi-monthly project team meetings held at the Sunraysia Horticultural Centre Mildura, Loxton Research Centre, and Dareton Research Station NSW. b) Project team members attended Environmental Risk Assessment workshop at Mildura, hosted by NPSI, to assess a methodology for estimating environmental impact of the project. c) Five project steering committee meetings, held at Mildura, and an additional meeting by telephone hook-up. d) Fachou Zhou a Chinese PhD student from Wuhan University has completed work to assist the modeling approach within the project in a collaborative arrangement between SARDI and Wuhan University, July 2005.
	Technical presentations and publications	a) Presentations to: -2003 NPSI Investors Forum, Shepparton, Sep 2003. -NPSI Management Committee Meeting, Mildura, Sep 2004. -CRC –IF Conference, Sydney, Sep 2004 -2004 NPSI Investors Forum, Barossa Valley, Oct 2004. -ANCID 2004 Conference, Barossa Valley, Oct 2004. *- CRC-IF Winter Zone Advisory Group, Melbourne, April 2005.* *-IAA Conference, Townsville, May 2005.* *- Regional forum of the Institute of Public Administration, Berri, May05*

		-River Murray Catchment Water Management Board, Berri, June 2005. *-CRC-IF Annual Research Forum, Mildura, Sept 2005* *-NPSI Investors Seminar, Mildura Oct 2005* *-ANCID Conference, Mildura Oct 2005* b) Posters prepared for - 2003, 2004 and 2005 ANCID Conference c) Stage 1 Report (2003-2004) distributed to partners and funders, Aug 2004. d) Milestone 2 report distributed to partners and funders, Dec 2004. e) Milestone 3 report distributed to partners and funders, May 2005. f*) Milestone 4 report forwarded to L&W Australia Dec 2005.*
Additional key technologists and policy makers	Technical presentations and publications	a) Above list of presentations to Project Partners and Funding organisations would have included additional key technologists group. *b) Specific presentations to additional key technologists;* *-CRC-IF Program 3, Practice and Technology of Irrigation, Brisbane June 2005 – presentation of site instrumentation and modeling approach used in the project. T Biswas.* *c) Modelling rootzone salinity an experience with 2D models. CRC-IF Workshop Sydney July 2005. T Biswas.* *d) "Salinity extractors in Lower Murray Study", Irrigation and Water Resources Journal, Spring 2005, p23.*
	Media program	a) Tri-state salinity project coloured flyer distributed, 2004. b) *NPSI Irrigation Update Volume 4, May 2005. Article on "Addressing the silent time bomb".* *c) NPSI Research Bulletin 2005. Measuring the effects of improving water use efficiency on root zone salinity.* *d) Measuring the salty cost of efficiency. Focus on salt, national newsletter of salinity R&D, Sept 2005* *e) Managing root zone salinity. CRC-IF InFlow Newsletter, Nov 2005*
Key local irrigator, community and industry groups	Technical presentations and publications	a) AGM of the SA Murray Irrigators Inc at Mypolonga, in November 2004, on "Irrigation Performance and Rootzone Salinity Management". *b) Suction cup lysimeters used at project trial sites promoted to vegetable growers on the Northern Adelaide Plains.* *c) Presentation to SA Minister for the River Murray and local growers, Bamera, June 2005.* *d) Solution extractors purchased by Vic DPI (24) for dairy phosphate movement study, and by Rural Solutions SA (110) for a deep percolation study in the Riverland.* *e) Presentation to Renmark Agricultural Bureau, "Rootzone salinity build-up", R Stevens, September 2005.*
	Media program	a) SA Stock Journal 23/9/04. "Tackling the silent time bomb". b) Murray Pioneer 1/10/04. "Tackling the salt time bomb". c) Loxton News 20/10/04. "Tackling the silent time bomb". d) RMCWMB In the Basin newsletter, Issue 4 Dec 2004. "Tackling rootzone salinity in the Riverland and Sunraysia". e) Sunraysia Daily 12 Jan 2005, "Tackling salinity in Sunraysia and the Riverland". f) WIN TV – Riverland . Interview about the project, Jan 2005. *g) ABC Radio Country Hour. Interview on Salinity Impact on Lower Murray Horticulture, May 2005.* *h) The Land (regional NSW), and NSW DPI website - Ag Today 24/11/05 ".Tackling the salt time bomb".*

Communication update is compiled by John Bourne, Land Management and Revegetation Group, Department of Water Land and Biodiversity Conservation, GPO Box 2834, Adelaide SA 5001.

Appendix 2. Minutes of DEP 15 Project Steering Committee Meeting

CSIRO Merbein, 3rd November 2005.

Present;
John Johnson – chair; Rob Thomas, Gerrit Schrale, Rob Stevens, Tapas Biswas, Brian Caddy, Jim Grant, Graeme Sanderson, Eddie Parr, Stephen Falivene, Maxine Schache, Masoud Edraki, Kate Cunnew, Murray Chapman, John Bourne.

Apologies;
Phil Cole, Tony Meissner, Rob Walker.

Minutes of previous meeting;
Accepted.

Actions arising as per the minutes;

- Rob Stevens reported that he had obtained river chloride concentrations for NSW and Vic, but still needed to obtain SA information.
- Tapas reported briefly on the measurement of water potential and water flux in the rootzone. Short discussion held on the existence of up-ward flow. We currently assume there is none.
- Tony Meissner convened a meeting in June by to progress obtaining of crop data required by Geoff McLean for economic analysis component of the project. Problem is that data is at different scales in the 3 states. Sunrise 21 wish to charge for Vic data. Matter to be pursued by Matt Miles, DEH.
- Claim forwarded following completion of milestone 3 to LWA and payment has been received.

Interim Progress;

- Milestone 3 report completed and CD distributed.
- Generic deliverables and achievement criteria presented for milestones 4 and 5, by Tapas Biswas. A list of milestone 4 and 5 tasks was also presented for comment by the Steering Committee.
- Murray Chapman requested that field soil sampling be continued twice /year and be included in the milestone 4 report, as growers related well to this.

Milestone 4 Presentations;

Rob Stevens

- Citrus salinity data contract of $15K with Lynda Prior (biometrician). Field data set, valued at about $ 1million, was collected at Dareton from 1982 –1991 but was never written up. This data would indicate a direct salinity response for citrus, and included yield, leaf Na and Cl, soil EC, Na and Cl . Will be using VINELOGIC for the response in grapes. Mike Treeby, Graeme Sanderson and Rob Stevens to assist as technical referees.
- Calculations of LE from current research sites. Summary presented by Rob suggesting that LE was well below 50%.
- Ion Chromatograph recently purchased by SARDI and has been installed at Loxton Centre. This equipment will measure Cl accurately from very small sample sizes e.g. collected by suction cup devices installed at the field sites.

Tapas Biswas

- Summarised the 5 methods being used to measure deep drainage;
  - ✓ Conventional water balance over the season
  - ✓ Cl tracer, as per Rob Stevens
  - ✓ Water balance validated by capacitance probe log
  - ✓ Capacitance probe using Darcy's equation
  - ✓ Long stops – didn't yield any data as the wetting front didn't get far enough

- Tapas suggested another method for estimating LE, by using a combination EC data from full-stop and suction cup devices. Comparing the values from each should help estimate by-pass flow.

- Summarised results of LEACHM modelling for the past irrigation season, and estimates of salt load assuming 800EC river water and 100% LE.
- Future field sites now being added with additional CNRM $ being approved for phase 3 of the DEP 15 project. There will now a total of 14 sites that are looking at both water and nutrient movement at McLaren Vale, Langhorne Creek, Loxton, Bookpurning-Lock4, Irymple and Dareton..
- Logable tensiometers just received from Germany. Will be used to calibrate capacitance probes.

Gerrit Schrale

- Summarised the DEP 15 paper given at the ANCID Conference.

Graeme Sanderson

- Summarised the team's effort of calibrating Tri-Scan probes with assistance of Sentek.

Kate Cunnew

- Summarised deep drainage measurements using Darcy's equation at the field sites in summer and winter.

Geoff McLean

- Not present but it was reported that he had completed an excel spreadsheets, which now also include potatoes and pasture. He now needs crop data as per Actions Arising above.

Tapas Biswas

- Tabled 05/06 data collection plan and task sharing sheet

- CRC-IF Summer Student work planned.
- Shaun Keys: Calibration of LEACHM with field data, leading to guidelines of how to maximise LE under different conditions.
- Adam Sluggett: LE estimations from a comparison of suction cups and full stops, see Tapas new method above.
- Virginia Rees: Determination of soil moisture release curves for the test sites; comparison with Tony Meissner's predictions.

Communication Plan Update;
John Bourne

- Update of project communication activities (mostly project awareness) to Nov 2005 tabled.
- First year field data well summarised in NPSI Research Bulletin 1, Sept 2005, and at recent CRC-IF and ANCID Conferences. While the current low river salinity has not impacted much this year on rootzone problems leading to crop losses, there is a need to prepare the community now for the future when high salinities are bound to happen.
- A discussion was led with the Steering Committee as to what approaches should now be taken in relation to communication. Issues raised included;
  - ✓ The need for an educational risk management approach with the community, not necessarily just a field day to present some results.
  - ✓ Riverlink could be a good sponsor to prepare courses to key water project officers and organisations in the first instance.
  - ✓ There is a need to link the science in the project with policy makers responsible for water.
  - ✓ There is a case for a specific project position to carry out this role, and not just to be left to scientists, as is currently the case.

Milestone 5;

- Generic deliverables and tasks previously presented by Tapas, see above.

Endorsement of Milestone 4;

- The Project Steering Committee endorsed the progress towards milestone 4.

Staff issues and other business;

- Gerrit Schrale summarised proposed new staff for phase 3 of the project, following approval of additional CNRM $.
- Murray Chapman advised of phase 2 NPSI initiatives, which could include a knowledge management project to support research in the areas of solute transport and soil structure. This may be an opportunity to access funding for communication activities in the project.
- Other;
  - ✓ Horticulture Australia Ltd is interested in supporting a technical and economic project in the performance of Open Hydroponics Systems for the citrus industry, which is proposed to be a bolt-on project for the DEP15 project.
  - ✓ Invite Richard Stirzacker on the Project steering Committee because of his role as solute signature coordinator with the CRC-IF.

Next Meeting;

May 4th 2006 at SHC, Irymple Vic.

Summary of Action Items:

Item	**Actions before next meeting**	**Person Responsible**
1	Clarify what crop data Geoff McLean actually needs for his spreadsheet. Follow-up Vic DPI for data rather than Sunrise 21.	Gerrit S.
2	Report back to PSC any evidence of up-ward flow from field data.	Tapas B.
3	Check with CRC-IF to see if they could assist with incorporating up-ward flow into the project modelling.	Gerrit S.
4	Include 2 sets of soil samples in Milestone 4 report, for the previous year.	Tapas B.
5	Invite Richard Stirzaker to join the Project Steering Group	Gerrit S.

Appendix 3. Minutes of the DEP 15 Project Economic model Meeting

Friday, 10 June 2005, Seminar Room 1.27, Plant Genomic Centre, Waite Campus

Present:
Gerrit Schrale (chair), Rob Stevens (Phone hook up), Dan Maldrum, Tapas Biswas, Tony Meissner, Geoff McLean, Andrew, Matthew Miles

Apologies:
Rob Stevens (due to problem in phone hook up)

Gerrit Schrale welcomed and highlighted the purpose of the meeting to find the best crop type data for economic assessment of the salinity impact on Lower Murray horticulture (DEP15 Project). He also delineated the progress of the project and its significance to State and National issue of salinity impacts of irrigated horticulture. Geoff McLean who is responsible for the economic analysis model briefly described his preliminary model report.

Crop data and salinity conversion:

a) Data requirement

- Crops, area and production (yield) for citrus, vines (wine and table grapes), apricot, peach, almond, carrot and onion for Riverland, Sunraysia, Blanchetown and Lower Murray regions (Geoff)
- Pasture and potatoes were also included (Andrew, Mathew, Dan, Geoff, Tony)
- For Riverland – data is available till 2003-04 however; some data structures need to be modified such as Renmark area. For Sunraysia – contact Sunrise 21 (Dan, Mathew)
- Soil type is important (Tony). Negotiations are on with DWLBC to get the recent survey digitised data (Dan, Gerrit and Tapas)

b) Gerrit and Tapas presented the leaching efficiency and its influence on salinity conversion to be used in the economic model.

c) Panel agreed that DEP 15 project would provide salinity conversion factor for the economic model.

d) MDBC (Tony) and catchment board (Dan) would look for such economic framework to estimate yield loss due to river/irrigation water salinity.

Actions

Item	Action before next meeting	Person responsible
1	Riverland database	Mathew Miles
2	Contact Sunraysia person (Sue) and send an email covering the outcome to Mathew	Tony Meissner
3	Include Pasture and potato in to the existing list of crops for the economic assessment model	Geoff McLean
4	Send econ analysis report of DEP15 project to Dan Meldrum and Mathew Miles	Tapas Biswas

Appendix 4. Previous Milestone Reports 1, 2 & 3 Summaries

Milestone 1 -Executive Summary

Background

Irrigated horticulture in the Lower Murray (Riverland-Sunraysia) region contributes a 'gate-value' of about $ 2.5 billion a year to the national economy. As a consequence of improved irrigation practices over the years, there is a risk emerging of a salinity build-up in the root zone, threatening the sustainability of this region.

Irrigation of virgin land results in leaching antecedent salts from the upper soil strata, while irrigation water itself also contains some salt. Ultimately the salinity of the root zone will be in equilibrium with the salinity of the irrigation water. In the Lower Murray region irrigation water contains a significant amount of salt. This implies that saline drainage must occur for irrigation to be sustainable.

During the early years of irrigation in the Riverland average annual applications were of the order of 10 to 20 ML/ha. Field application efficiencies were very low which meant that large amounts went to drainage and no build-up of salinity in the root zone occurred. To prevent water-logging in the soil profile, especially where low permeable Blanchetown clay was present, tile drainage was installed during the 1950's and 1960's.

During the past two decades the water use efficiency (WUE) of irrigated horticulture in this region has gradually increased from about 50 to 80% as a consequence of improved irrigation systems and management. Under steady state conditions, the salinity of the root zone can be predicted from irrigation water salinity and the leaching fraction (portion of water applied at the surface which flows out of the base of the root zone).

In the Lower Murray Region the irrigation water salinity is typically about 0.4 dS m^{-1} and with 15-20% leaching the average salinity (ECe) in the root zone should be around 0.6 dS m^{-1}. Field surveys however indicate that the root zone salinity is often greater than 1.3 dS m^{-1} with considerable variance. This value is well above the threshold for salinity damage to vines and citrus. Stevens (2002)[1] states that this discrepancy between observed and expected soil salinity may be due to a portion of the extra water applied for leaching moving rapidly through the larger soil pores without removing any salt from the root zone. On the other hand, the portion of water moving through the finer pores displaces effectively the (saline) soil water as a piston flow. As a result, the leachate is a mixture of irrigation water that has passed unchanged and of displaced soil solution. Van der Molen (1973)[2] described this salt transport process with the term 'leaching efficiency' ie the portion of irrigation water that completely mixes with the soil solution.

With the objective of managing the impact of irrigation on river water quality and health of the floodplains, the River Murray Catchment Water Management Board introduced an 85% target of WUE in the current Water Allocation Plan. Insufficient leaching at that target may result in high levels of root zone salinity and subsequent yield losses for the local horticultural crops.

In order to understand and manage this salinity hazard, a 'Tri-State Salinity' syndicate of Government agencies from western NSW, Victoria and South Australia (with support from federal agencies) was formed to undertake laboratory and field scale studies for irrigated horticulture in this region for three years starting at the end of 2003.

Objectives

This project has been developed to test the hypothesis that: *'a depressed leaching efficiency (LE) in the Lower Murray irrigation districts has been raising the root zone salinity and that any improved water use efficiency (WUE) may have an upper limit determined by paddock's LE and its variance'*.

[1] Stevens, R.M. (2002). Australian Grapegrower & Winemaker. 466:71-76

[2] Van der Molen, W.H. (1973) Salt Balance and Leaching Requirement. pp 59-100. In: Drainage Principles and Applications. Publication 16 Vol 2. International Institute for Land Reclamation and Improvement. Wageningen, Netherlands.

The project objectives are:

i. Determine/update the salinity relationships for irrigated horticulture along the Lower Murray: Riverland, Sunraysia and western NSW;
ii. Determine the variability of EC (soil water) and leaching efficiency in the field under known soil conditions and irrigation management;
iii. Simulate the performance of horticultural crops under different scenarios of River Murray salinity at Morgan; and
iv. Provide input to the implementation of the Salinity Strategy and Integrated Catchment Management Plan of the Murray-Darling Basin.

Meanwhile MDBC (subject to funds being available) has requested an economic assessment of the significance of leaching efficiency on modern (& efficient) irrigated horticulture in the Lower Murray region. An economic framework has been developed and an initial assessment using data available for irrigated areas, crop types and soil conditions has been carried out.

The project activities are spread over two distinctive stages to deliver a series of outcomes that could assess the risk of irrigation water-induced salinity on Lower Murray horticulture.

Stage 1 outputs

1. Five literature reviews on the salinity relationships for the commonly grown crops in the Lower Murray region: grape, citrus, stone fruit, vegetables (asparagus, carrot, tomato) and melon (Appendix 1)
2. A review on the need for leaching efficiency for a sustainable irrigation (Appendix 2)
3. A detailed methodology for interpretation of capacitance sensor data for estimating the leaching fraction and soil water extraction patterns in Sunraysia-Riverland (Appendix 3)
4. Field estimation of the leaching efficiency and its variance based on irrigation and soil chloride data from 23 properties in the region (Appendix 4)
5. Gap analysis of the irrigation and salinity relationships used in GHD's report estimating economic losses due to changing River Murray salinity (Appendix 5)
6. Economic assessment of salinity impact on lower Murray horticulture based on variation in River Murray salinity scenarios (Appendix 6)
7. A detailed field experimental plan for scientific measurement of water and salt flux in the lower Murray region (Appendix 7)
8. Communication plan for the project including a summary on the SARDI website (Appendix 8) (http://www.sardi.sa.gov.au/pages/horticulture/viti/sustainable/salinity.htm)

Stage 1 Finding

The literature reviews of major crop responses to root zone salinities showed that since the work on crop salinity tolerances by Maas and Hoffman (1977)[3], no significant changes been reported except for vines grown on grafted rootstocks (Walker and Stevens, 2004)[4].

The leaching review highlights that the inefficient leaching of salts from the root zone may be occurring due to preferential flow (i.e., bypass of soil matrix through soil macro-pores). In soils with a low leaching efficiency, less than the expected amount of salt is displaced from the root zone. This risk salt accumulation in the root zone is inherently greater under current irrigation practices with a high WUE.

[3] Maas,EV. & Hoffman, GJ (1977). Crop salt tolerance-current assessment. ASCE J. Irrig & Drainage Div. 103 (IR2):115-134
[4] Walker, R. & Stevens, R. (2004). Recent developments in the understanding of the effects of salinity on grapevines.

The leaching review identified that the rate of salt removal from the root zone was found to vary for the different leaching strategies, and, where possible, leaching should be only practiced in winter when plant water use and soil evaporation is low and higher leaching efficiencies can be achieved.

The Stage 1 field studies at 23 sites showed that the upper range of average soil ECe in both Sunraysia and the Riverland were well above the threshold for salinity damage to vines and citrus. The average leaching efficiency was 0.65 with a large range in the values measured. Root zone leaching according to the piston flow concept, as often anticipated to occur, has a leaching efficiency of unity.

The stage 1 findings clearly show the need for further investigations into leaching processes.

Milestone 2 -Executive Summary

During the past two decades improvements in horticultural irrigation systems and their management have raised water use efficiency (WUE)[5] from about 50 to 85% in this region. As a consequence the drainage volumes have been reduced from about 50 % of water applied to 15%. Under steady state conditions, the salinity in the root zone can be predicted from irrigation water salinity and the leaching fraction (portion of water applied at the surface which drains out of the base of the root zone). This prediction assumes that the extra water applied for leaching uniformly displaces the (saline) soil water as a 'piston' flow.

In the middle of the Lower Murray Region irrigation water salinity is typically about 0.4 dS m-1. With 15-20% leaching, the average salinity (ECe) in the root zone should be around 0.6 dS m-1. Field surveys however, indicate that the root zone salinity is often greater than 1.3 dS m-1 with considerable variance. The discrepancy between observed and expected soil salinity may be due to a portion of the leaching water moving rapidly through the larger soil pores without displacing soil soluble salts from the root zone. As a result, the leachate is a mixture of irrigation water that has passed unchanged and of displaced soil solution. Van der Molen (1956)6 described this bi-pathway water and salt transport process and used the term 'leaching efficiency' to describe the ratio of the volume of drainage flowing by piston flow to the total volume of drainage.

A 'Tri-State Salinity' syndicate of Government agencies from western NSW, Victoria and South Australia (with support from federal agencies) was formed to generate the knowledge on managing this salinity hazard by undertaking a 3 year laboratory and field scale studies for irrigated horticulture in this region.

From the Stage 1 investigations, summarised in Milestone 1 report, it was found that the extra irrigation water applied for leaching the residual salt from the root zone of vineyards and orchards in the Sunraysia and Riverland area did not remove the anticipated quota of salt. For the reader's convenience, the executive summary of the Milestone 1 report is reproduced in Appendix 1. Besides the preliminary communication plan and a framework for economic loss analysis, Stage 1 outcomes included development of Stage 2 work plan and identification of possible "bolt on" projects for the Murray Mallee region to jointly combat the challenges of root zone salinity issues in permanent horticulture. Appendix 2 incorporates the minutes from the Steering Committee meeting held on 28th Oct 2004, which complemented the DEP15 project team for heading in the right direction.

This Milestone 2 report summarises the interim progress against outcomes & deliverables set for Milestone 2 of the Tri-State Salinity project, presented in Table 1 below. This mainly includes:

i. Independent reviews of the Stage 2 work plan and the team's response to the suggestions made;
ii. Identification of representative sites for the study area across three States for instrumentations and telemetry;
iii. Draft methodology and protocol for water, soil, soil solution, hydraulic parameters and plant tissue sampling and monitoring;
iv. Interim observations and future direction;
v. Communication through various avenues to different audiences (Appendix 3); and
vi. A revised draft of root zone salinity related economic loss analysis of Lower Murray Horticulture (Appendix 4).

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5 Water use efficiency is a broad term and in this paper it is used specifically to indicate field application efficiency

6 Van der Molen, W.H. (1973) Salt Balance and Leaching Requirement. pp 59-100. In: Drainage Principles and Applications. Publication 16 Vol 2. International Institute for Land Reclamation and Improvement. Wageningen, Netherlands.

Milestone 2 Highlights in a Nutshell

i. Developed and manufactured a new device: a soil solution extractor for determining the chemical composition of soil water available for plant uptake.

ii. Installed forty eight extractors in root zones at our four vine and citrus calibration sites in SA, NSW and Vic

iii. Trained DPI-Vic and NSW-DPI and PIRSA-ICMS staff in the use of soil solution extractors; these devices are now also used in the NPSI/HAL funded project on Open Hydroponic Systems.

iv. Our preliminary survey of 14 properties indicates that salt displacement from root zone by leaching is less than expected leaching, however our results have a considerable variance (75% cv).

v. Our actually measured Leaching Fraction at a citrus property near Dareton is about 20%; this is twice the value used by MDBC for water balance modelling of irrigation districts.

vi. Project staff discovered an unpublished database on soil water release curves for nearly 300 Mallee soils from PIRSA lab work undertaken in the 1980s.

vii. Project won a CRC-IF funded, summer internship for a Flinders University student: Nicolas Kruger

viii. Our method for deep drainage assessment (See Milestone 1 report) has been adopted by RMCWMB for the Bookpurnong-Lock 4 project.

ix. Assisted the GWRRDC-funded 'Clean & Green Viticulture' project for monitoring nutrient and pesticide leaching from vineyards.

x. Seven articles on our project published including 3 media articles in SA, Vic and NSW rural newspapers.

Milestone 3 -Executive Summary

Improved irrigation management in the Lower Murray horticultural districts has raised field application efficiency (FAE) from about 50 to 85% during the past 2 decades. Consequently the drainage volumes have reduced from about 50 % to 15% of applied water. Under steady state conditions, the salinity in the root zone can be predicted from irrigation water salinity and the leachate (the extra irrigation water applied which drains out of the base of the root zone). This prediction assumes that the extra water applied for leaching uniformly displaces the (saline) soil water as 'piston' flows. However, there is anecdotal evidence that the root zone salinity is often greater than expected. The discrepancy between observed and expected soil salinity may be due to a portion of the leaching water moving rapidly through the larger soil pores without displacing soil soluble salts from the root zone.

A 'Tri-State Salinity' syndicate of Government agencies from western NSW, Victoria and South Australia (with support from federal agencies) was formed to generate the knowledge for managing root zone salinity hazards by undertaking a 3 year laboratory and field scale study. In addition to assessing the risk of salinity accumulation under precision irrigation, the project team is working on strategies for minimising production losses.

First year field data (Milestone 1 & 2 investigations) a from vineyards and citrus orchards in the Riverland and Sunraysia regions showed that the average leaching fraction is often less than 15% and salt is accumulating in the root zone. This is particularly of concern when the average leaching efficiency at 14 surveyed properties was 65% and where only <5% of total applied water is flushing the root zone during the irrigation season. For the reader's convenience, the executive summary of the Milestone 1 & 2 reports is reproduced in Appendix 1.

One of the spin-offs of the project has been the assessment of deep percolation in the Bookpurnong Lock 4 district. Deep drainage (DD) is the prime important factor influencing off-site impact of irrigation on the local landscape. In the Riverland DD becomes recharge to the underlying highly saline aquifers and accelerates the natural saline seepage into the Murray River. A 'curtain' of salinity interception wells protects the River water quality by intercepting the enhanced saline groundwater discharge into the River. To design efficient salinity mitigation works we need to quantify the deep drainage component on a property scale, which can then be integrated to district scale.

Several attempts have been made to quantify deep drainage with a varying degree of success and failure. Indirect measurements such as water balance, natural tracer and salt balance are point measurements and hence do not allow for spatial and temporal variability. On the other hand, direct measurements including drainage capture by disturbed soil profile and drainage meter are often expensive and demand excessive time from growers busy during the irrigation season.

In modern horticultural districts there are usually large networks of capacitance probes used for irrigation scheduling. In this paper we present a new method for assessing DD from data generated by these multi-sensor capacitance probes. In this method DD is estimated by using Darcy's flux equation. A water content –suction (θ-ψ) relationship was developed from data generated by two sensors, located just below the root zone.

The DD estimates were compared with results from two other (independent) methods for vineyards in Loxton (SA) and Irymple (Vic), and citrus in Dareton (NSW):

- chloride tracer technique which involves extracting soil water solution from the bottom of the root zone, and
- seasonal water tracing technique (I2003 method) which involves real time soil water storage derived from irrigation records, crop types, climatic data and crop coefficients.

The DD estimate shows considerable daily and seasonal variations of drainage rate for an under cover sprinkler irrigated citrus property in Dareton, NSW. The cumulative drainage from irrigation and rainfall was 250 mm (2.5 ML/ha) during the entire year.

In general, DD was much less under the drip system. Less than 10% of applied water was found to leave the root zone during the grape growing season, which resulted in salt build up in root zone even at the current river water salinity of 300 EC.

Using the data from a drip irrigation vineyard at Loxton in the Bookpurnong Lock-4 district, the output of a two-dimensional numerical flow/transport model (LEACHM-TRANSMIT) simulation run at 800 EC irrigation showed that 2t salt/ha could accumulate in 1 m root zone during a normal grape growing season under drip irrigation. If irrigated with 800EC during a drought year, this could increase soil EC to 5 dS/m, at which up to 60% yield loss may occur.

Chloride and sodium content of petioles and leaves at flowering and harvest, and berries at harvest were measured to assess the salt injury to the plants. Grape varieties sampled included Chardonnay and Colombard on either Ramsey rootstock or vines on their own roots. For citrus, only the leaf was analysed for chloride and sodium content. When compared against the acceptable limit, no significant salt problem was identified from the chloride and sodium analysis of either grape or citrus material from this survey.

Outcomes and generic deliverables set for Milestone 3

Due date/ Item No	Deliverables during Milestone 3	Outcomes	Quick Reference
30/05/2005			
1	Collection of second seasons data and samples	√	Chapter 2 &3
2	Simulations run and analysed	√	Chapter 2 &3
3	Sustainable Irrigation Projects receiving input as appropriate for their project (as defined in milestone 3)	√	Chapter 4
4	At least one Steering Committee meeting with year1 data analysis reported and discussed by the Committee	√	5th May 2005 Mildura
5	Work plan continues with all priority stakeholders participating.	√	Chapter 4

Milestone 3 Highlights in a Nutshell

(i) Under the drip system, less than 10% of applied water is leaving the root zone during the grape growing season.

(ii) Less than 10% root zone drainage under precision irrigation resulted in salt build up in root zone even at the current river water salinity of 300 EC.

(iii) Model simulation run at 800 EC irrigation showed that 2t salt/ha could accumulate in 1 m root zone during a normal grape growing season under drip irrigation.

(iv) If irrigated with 800EC in a drought year, this could increase soil EC to 5 dS/m, at which up to 60% yield loss may occur.

(v) Fruit and leaf analysis showed no significant salt problem for either grape or citrus during 2004-2005 except for Irymple drip site which recorded very high amount of sodium in both the leaf petiole and berry juice.

(vi) Solution extractors, developed by this project, are being adopted by the PIRSA-ICMS/RMCWMB to estimate deep percolation in the Bookpurnong Lock 4 irrigation district.

(vii) DPI-Vic's dairy project and vegetable growers from the Adelaide hill expressed keen interest in the solution extractor to monitor salts and nutrients in the root zone.

(viii) Submitted a summer studentship completion report on deep drainage work to CRC-IF.

(ix) A Chinese PhD student from Wuhan University has begun work to assist the modelling approach within the project in a collaborative arrangement.

(x) Eight articles have been published including 2 refereed conference articles and 4 media articles in SA, Vic and NSW rural newspapers.