DWLBC REPORT

Volumetric Conversion in the South East of South Australia: Validating the Allocation Model

2006/30

Government of South Australia
Department of Water, Land and Biodiversity Conservation

Volumetric Conversion in the South East of South Australia: Validating the allocation model

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September 2006

Report DWLBC 2006/30

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Disclaimer

ISBN-13: 978-1-921218-31-6

Preferred way to cite this publication

Pudney, S 2006, *Volumetric Conversion in the South East of South Australia: Validating the allocation model,* DWLBC Report 2006/30, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Mount Gambier.

FOREWORD

South Australia's unique and precious natural resources are fundamental to the economic and social wellbeing of the State. It is critical that these resources are managed in a sustainable manner to safeguard them both for current users and for future generations.

The Department of Water, Land and Biodiversity Conservation (DWLBC) strives to ensure that our natural resources are managed so that they are available for all users, including the environment.

In order for us to best manage these natural resources it is imperative that we have a sound knowledge of their condition and how they are likely to respond to management changes. DWLBC scientific and technical staff continues to improve this knowledge through undertaking investigations, technical reviews and resource modelling.

The Volumetric Conversion Project was a four-year project initiated in 2002 to facilitate the process of converting the existing area based water licences in the South East of South Australia to licences with a volumetric basis for allocation. The conversion approach was developed following a comprehensive community consultation process, using the best available science and extensive field data.

The conversion approach will be implemented through the review of Water Allocation Plans for the Padthaway, Tatiara and Lower Limestone Coast Prescribed Wells Areas that is being conducted by the South East Natural Resource Management Board. The reviewed Water Allocation Plans will define the arrangements for the issue of new volumetric allocations, taking into account the recommendations of this report, the sustainability of the resource and input from the stakeholder community.

Rob Freeman
CHIEF EXECUTIVE
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ACKNOWLEDGEMENTS

The author would like to thank all FIST program participants for their cooperation and assistance with the data collection process. Much help was also received from collaborating researchers from the lucerne seed, dairy and viticulture industries.

The author would also like to acknowledge the contributions from Tony Adams and Mark Skewes (Rural Solutions SA), Gerrit Schrale (South Australian Research and Development Institute) and John Bourne, Ross Carruthers and Brian Latcham (from the Department of Water Land and Biodiversity Conservation) who provided many helpful comments when reviewing this report.

ASSOCIATED REPORTS

Carruthers, R 2006, *Volumetric Conversion in the South East of South Australia: Community Consultation Processes,* DWLBC Report 2006/33, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Mount Gambier.

Carruthers, R, Latcham, B & Pudney, S 2006, *Volumetric Conversion in the South East of South Australia: Summary of the Conversion Model and Associated Conversion Rates,* DWLBC Report 2006/29, Government of South Australia, through Department of Water, Land and Biodiversity Conservation, Mount Gambier.

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EXECUTIVE SUMMARY

A model that describes the process for converting area based water licences in the South East of South Australia to volumetric licences has been developed through an iterative process of consultation and amendment with the South East irrigation community.

The 'proposed volumetric conversion model' has been developed to enable 'reasonably efficient' irrigators to continue their current irrigation practices. Following consultation processes (with the South East community), the term 'reasonably efficient' has been defined as allowing 75% of irrigators to continue their current practice. As the proposed volumetric conversion model has been finalised, there is a need to assess whether this objective has been met. This report describes the validation process used to determine whether the proposed conversion model will allow 75% of irrigators to continue their current practice.

To determine whether 75% of irrigators will be allocated sufficient water to continue their current irrigation practices, the annual volume pumped at each of the project's Field Irrigation System Trial sites was compared to the proposed allocation for the relevant license. The percentage of flood irrigators disaffected by conversion ranged from 0% in 2002–03 to 25% in 2004–05. For spray irrigation, in two of the three seasons ~10% of growers were disaffected. It was only in 2004–05 that figure rose to greater than 25% (27%). No drip irrigators were disaffected by conversion.

Amongst the Field Irrigation System Trial data set, a small number of sites were found to be repeatedly pumping more water than will be allocated. The irrigation practices at these sites were investigated using a computer model. It was found that there was significant potential to improve irrigation practices (and reduce annual volumes pumped) at both of these sites.

The validation process described in this report provides confidence that the 75th percentile is a reliable cut-off point to define 'reasonably efficient' irrigators i.e. licensees pumping more water than what they will be allocated are likely to have the capacity to alter their irrigation practices to align with the allocated volume. In conclusion, the proposed volumetric conversion model achieves the aim of providing reasonably efficient irrigators with sufficient water to continue their current irrigation practices.

1. INTRODUCTION

1.1 GENERAL INTRODUCTION

The Volumetric Conversion Project was initiated in 2002 to facilitate the process of converting 2500 area based water licences in the South East of South Australia to licences with volumetric allocations.

The volumetric conversion process will be implemented through the review of Water Allocation Plans, due for finalisation in late 2006. Over the past four years the Project has developed a model that describes the proposed process for conversion using an iterative process of consultation and amendment with input from the stakeholder community.

The proposed conversion model is shown below (Fig. 1). All licensees will receive a Base Allocation and a Delivery Component. The base allocation provides for crop irrigation requirements (Skewes 2006). Some licensees may also be eligible for a Crop Adjustment Factor that provides additional Base Allocation for licensees where, due to initial calculation problems, the existing area based system does not provide adequate allocation.

The Delivery Component is the volume of water needed in excess of the crop irrigation requirements to account for irrigation system losses (evaporation losses, deep drainage etc.). In certain crop production systems it is necessary to use water for other activities, this water will be provided through the Specialised Production Requirements model component. The Bridging volume is an additional temporary water allocation designed to give irrigators who are currently pumping in excess of their new volumetric allocation time to adjust to the new system. The Specialised Production Requirement and Bridging Volume model components may be available on application, subject to meeting eligibility criteria.

The volumetric conversion model has been developed to enable 'reasonably efficient' irrigators to continue their current practices. Following a consultation process with the SE community 'reasonably efficient' has been defined as allowing 75% of irrigators to continue their current practices ie. the sum of these model components (allocations) should allow 75% of irrigators to continue their current practices. As the proposed volumetric conversion model has been finalised there is a need to assess whether this objective has been met. This report describes the validation process used to determine whether the proposed model will allow 75% of irrigators to continue their current practice. Other reports (listed in 'Associated Reports') detail the calculation of the base allocation, delivery component, bridging volume and specialised production requirement. A report has also been published on the community consultation processes used in this project.

1.2 INTRODUCTION TO THE VALIDATION PROCESS

Three data collection programs were initiated as part of the volumetric conversion project.

- Annual Water Use Returns (AWUR) Program – Through the AWUR program each licensee reports on their annual irrigation activities. The volume of water extracted per hectare irrigated is reported on the survey form, in some cases metered data is supplied in others the volume extracted is estimated.

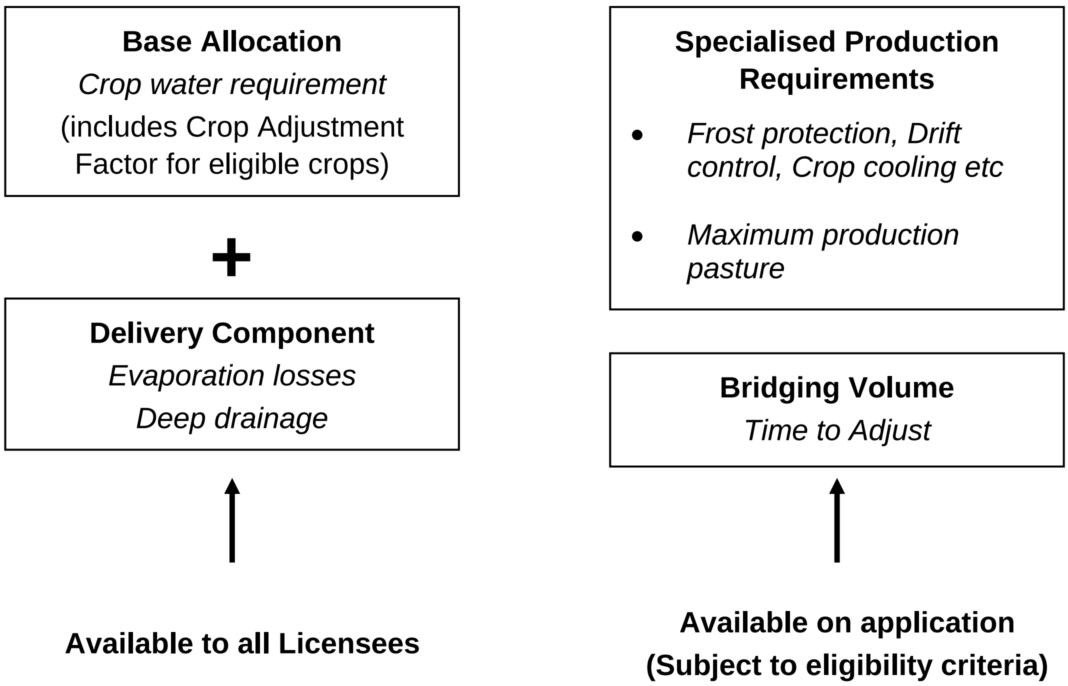


Figure 1. Proposed Conversion Model.

- Metered Extraction Trials (MET) Program – Through the MET program water meters were installed at 160 trial sites. Metered records of volumes extracted per hectare irrigated were obtained from each of these sites.
- Field Irrigation System Trials (FIST) Program – At FIST sites detailed information is collected on each of the components of the on-farm water balance. 36 sites are monitored as part of the trial. Instrumentation installed at the FIST sites includes soil moisture probes, rain gauges and water level sensors (weather stations were installed at a few select properties).

The FIST dataset has been used to assess whether the proposed volumetric conversion model will allow 75% of irrigators to continue their current practice as the data is accompanied by individual irrigation event records (metered) and soil moisture information (which makes detailed site analysis possible).

2. OBJECTIVE

To determine (using data from the Field Irrigation System Trial) whether 75% of irrigators will be able to continue their current irrigation practices under the proposed volumetric conversion model.

3. METHODOLOGY

Field Irrigation System Trial (FIST) data has been used to determine whether the model will allow at least 75% of irrigators to continue their current practice. When the volumetric conversion project commenced, a selection process was employed to ensure that the selected FIST sites were representative. The number of FIST sites allocated to each crop type compares well with the number of hectares irrigated per crop type for the whole of the South East (Table 1).

Table 1. FIST site representivity. The number of FIST sites allocated per crop versus irrigated area #

Crop Type	Number of FIST sites	Number of FIST sites (%)	Area Irrigated (ha)	Area Irrigated (%)
Pasture^	17	47	38 595	49
Lucerne Seed	7	19	10 523	13
Vines	7	19	14 146	18
Perennial Clover Seed	2	6	5 123	6
Potatoes	1	3	2 823	4
Summer Fodder	1	3	1 435	2
Other	1	3	6 397	8

Irrigated area sourced from (Kelly and MacIntyre 2006 - Unconfined).

^ Includes lucerne hay/ graze

To calculate the percentage of FIST sites that will have sufficient water to continue their current practices, the volume pumped for each season was compared to the proposed allocation for the relevant license. The proposed allocation was calculated by determining base allocation and delivery component for the location of the property and irrigation system type. A specialised production allowance was added if applicable.

Base allocation (ML) = haIE x NIR_0, where haIE is the number of irrigation equivalents being used to grow the crop monitored in the FIST program, and NIR_0 is the net irrigation requirement of the reference crop for the appropriate climatic band (for more information see Skewes, 2006). The Delivery Component is the volume of water that a reasonably efficient irrigator needs to extract in excess of crop water requirement to grow the crop. The SE has been divided into Delivery zones and an appropriate delivery volume has been determined for each irrigation system type within each zone (based on the 75th percentile methodology described in Latcham et al., 2006). The delivery component is expressed as a percent of the base allocation. The two components are added together to provided the proposed allocation (where appropriate a Specialised Production Requirement allocation was added to the proposed figure). As it has been assumed that some provision will be made for seasonal variation in the final allocation model, ten percent was then added to the proposed allocation figure. In summary any pumped volume records that fall within allocation + 10% are considered to be able to continue their current practices.

The analysis is based on three season's data (2002–03, 2003–04, and 2004–05), collected at each of the FIST trial sites. Irrigation records that include un-metered data (estimates of volume pumped) have been excluded from the analysis, as have un-representative irrigation practices, eg disposal of effluent water.

For sites where the volume pumped repeatedly exceeded the proposed allocation a computer model was used to investigate the irrigation practices. 'IRES' (developed by Irrigated Crop Management Service, Loxton – see Meldrum et al. 2004) is a program that graphs 'real' soil moisture data (from field devices) against simulated or 'predicted' soil moisture. The program plots cumulative crop water use against irrigation and rainfall inputs and provides an estimate of the amount of water that was not retained in the rootzone (drainage from irrigation events). Inputs required by the model include: meter readings for individual irrigation events, rainfall events, reference crop evapotranspiration, crop coefficients (FAO 56), Total Available Water (TAW), Readily Available Water (RAW) and soil moisture available on the 1st July of the relevant irrigation season.

At each FIST site there are two 'Agrilink'® soil moisture probes installed; each probe is fitted with five sensors. For a direct comparison to be made between the 'field' soil moisture data and 'simulated' data, full points must be determined (for the field data). In order to estimate full points it was necessary to determine the active rootzone, only data from sensors positioned within this zone were included in the analysis. The soil moisture probes were installed towards the end of 2003 at all sites, hence it is only possible to review the 2003–04 and 2004–05 irrigation seasons in detail. The Agrilink® soil moisture data presented in this report is not calibrated.

3.1 CLIMATIC CONDITIONS DURING TRIAL PERIOD

Net Irrigation requirement (NIR) was above average in all three trial years (The NIR of pasture is given in Table 2 as an example). The drier than average irrigation seasons will have had different impacts on the NIR of different crops, the timing of rainfall events will have appreciable influence on NIR, particularly for shorter season crops.

Table 2. Net Irrigation Requirement of reference crop and pasture categories for specific irrigation seasons expressed as a percent of the historical average (for whole of SE)

Crop	2002–03	2003–04	2004–05
Reference Crop	+19%	+10%	+16%
Pasture	+15%	+8%	+9%
Maximum Production Pasture	+15%	+7%	+7%

4. RESULTS AND DISCUSSION

4.1 PROPOSED ALLOCATION VS. HISTORICAL VOLUME PUMPED

Historical water use at each of the FIST sites is shown in Figure 2 (flood irrigators), Figure 3 (spray irrigators) and Figure 4 (drip irrigators). The volume pumped in each season has been expressed as a percent of the proposed volumetric allocation for each site. Very few licensees pumped in excess of the proposed allocation; the percent of irrigators (from FIST trial pool) who pumped more water than they will receive under the proposed volumetric conversion model is given in Table 3. 'Number of records' indicates the number of sites included in the analysis. The 'Pumped data' column shows the percentage of irrigators who pumped more than the base and delivery components of the model combined. 'Pumped data allowing for SPR' shows the percentage of irrigators who pumped more than the base, delivery and Specialised Production Requirements combined. The final column 'Pumped data allowing for SPR and 10% seasonal allowance' shows the percentage of irrigators who pumped more than the base, delivery, Specialised Production Requirements (where eligible) and a 10% seasonal allowance combined. Drip irrigation data is not presented in Table 3 as all drip irrigators pumped less than their proposed allocation (see Fig. 4).

Table 3. Percentage of irrigators that will not have sufficient allocation to continue their current practices #

Year	Number of records	Pumped Data (%)	Pumped Data Allowing for SPR (%)	Pumped Data Allowing for SPR and 10% seasonal allowance (%)
Flood				
2002–03	5	0	0	0
2003–04	7	14	14	14
2004–05	8	25	25	25
Spray				
2002–03	10	20	10	10
2003–04	15	27	13	7
2004–05	15	40	33	27

Drip irrigation data has not been presented as all drip irrigators pumped less than their proposed allocation.

Despite the NIR being greater than average in all three trial years the percentage of irrigators exceeding the proposed allocation is small. In 2002–03 the NIR of reference crop (NIR_0) was 19% above average, 10% of pivot irrigators pumped more water than the proposed allocation (no flood irrigators exceeded the proposed allocation). In 2003–04 the NIR_0 was 10% above average, 14% of flood irrigators and 7% of spray irrigators pumped more water than the proposed allocation. In 2004–05 NIR_0 was 16% above average, 25% of flood irrigators and 27% of spray irrigators pumped more water than the proposed allocation. Note, these figures include SPR allocations where appropriate and include a 10% seasonal allowance.

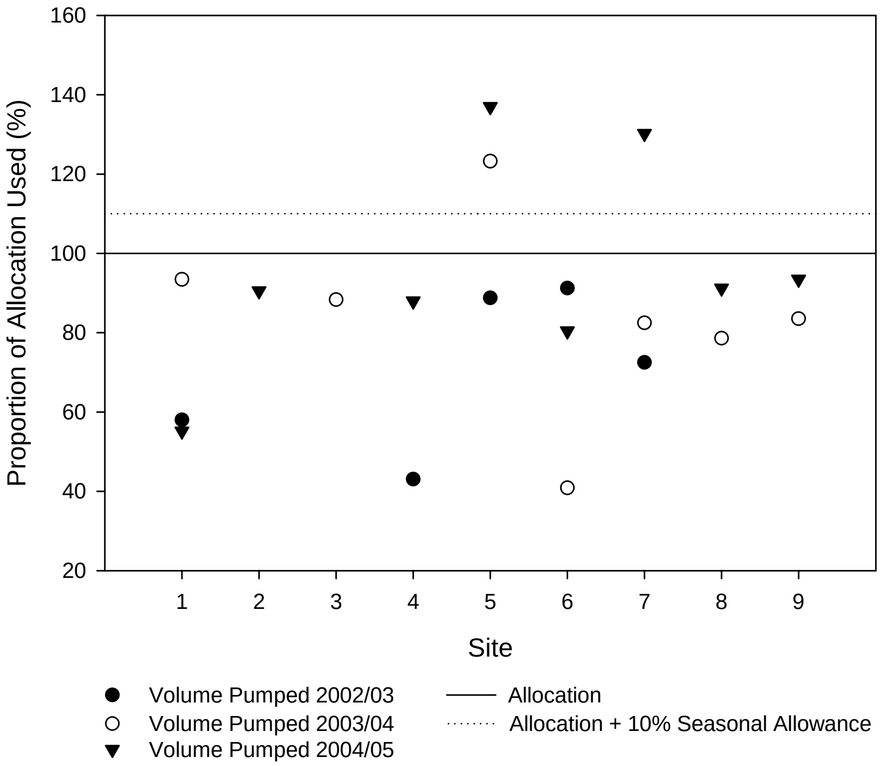


Figure 2. Proportion of allocation used to water area of crop monitored in the FIST program - Flood Irrigation sites (includes SPR component where appropriate)

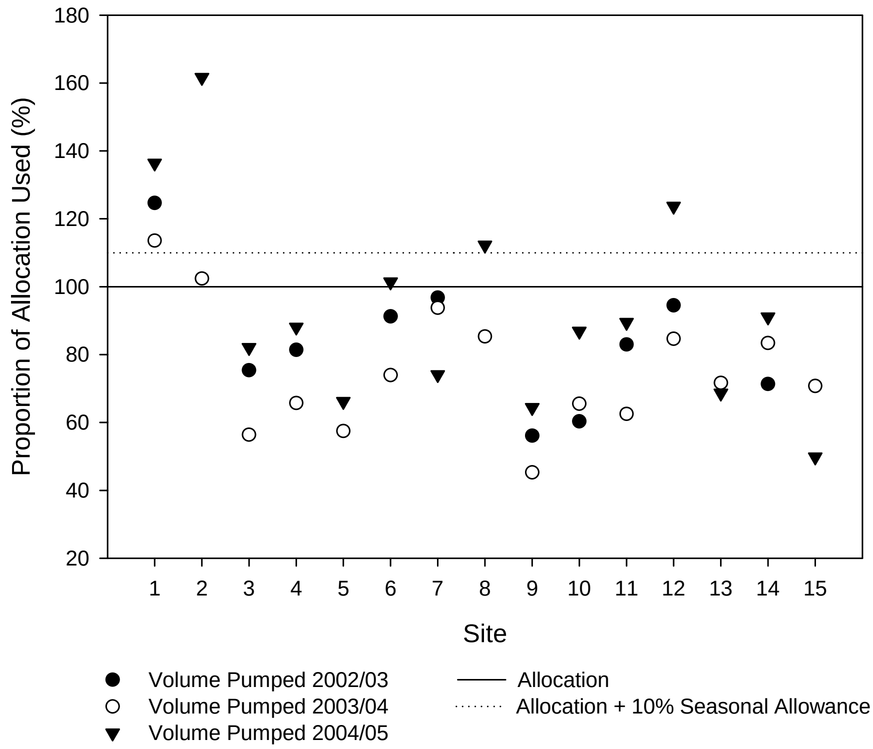


Figure 3. Proportion of allocation used to water area of crop monitored in the FIST program – Spray Irrigation sites (includes SPR component where appropriate)

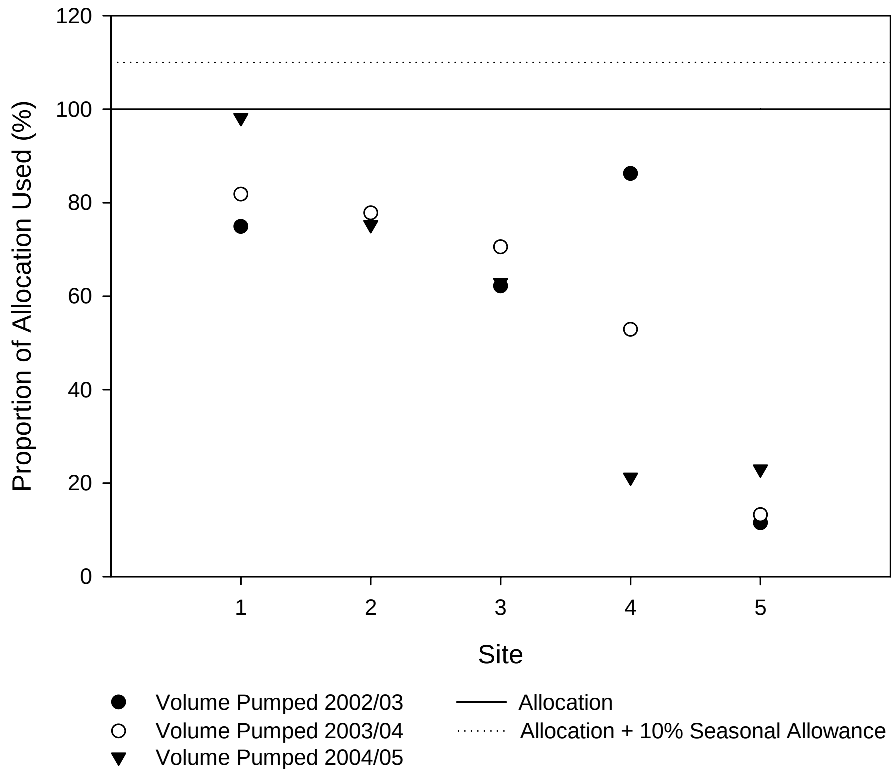


Figure 4. Proportion of allocation used to water area of crop monitored in the FIST program – Drip Irrigation sites (includes SPR component where appropriate)

It is interesting to note that a seasonal allowance of 10% reduced the number of pivot irrigators pumping in excess of the proposed allocation, however the allowance had no effect on the number of flood irrigators pumping more than the proposed allocation. This suggests that further investigation into the ‘carryover amount’ or seasonal allowance may be required.

Only one flood and one spray irrigator significantly exceeded the allocation (Base, Delivery and SPR) in more than one season (see Fig. 1, Flood site 5 and Fig. 2, Spray site 1). If the volumetric conversion model achieves the objective of allowing reasonably efficient irrigators to continue their current practices, then it should be possible to identify reasons why irrigation practices at these sites would not be considered as ‘reasonably efficient’.

4.2 FLOOD SITE INVESTIGATION

The flood site investigation (detailed in App. A) revealed that a large volume of irrigation water is passing through the profile as drainage with each irrigation event (~74 mm). In 2003–04 the annual irrigation drainage volume was estimated to be 65% of the volume pumped, in 2004–05 irrigation drainage was estimated to be 68%. Changes to bay design (smaller bays) and higher pumping rates would most likely reduce the annual volume pumped (by reducing the amount of drainage experienced with each irrigation). The modelling exercise revealed that during the 2003–04 irrigation season the profile was in the Readily Available Water zone 38% of the time, in 2004–05 this figure increased 55% (see App. A, Figs 7 and 11); these results indicate that there is considerable potential to improve irrigation practices at this property.

4.3 SPRAY SITE INVESTIGATION

The spray site investigation revealed that there is a mis-match between the pivot application depth and the soil water holding capacity, which (as per the flood site) leads to excessive drainage with each irrigation event. It is estimated that between 19% and 32% of the pumped volume passed through the soil profile as drainage during the 2003–04 and 2004–05 irrigation seasons (see App. B for more detail). Throughout the two irrigation seasons the profile was in the Readily Available Water zone for ~55% of the time (App. B, Figs 18, 23–24). The modelling exercise once again suggests that irrigation practices could be significantly improved at this property. Matching the irrigation system application depth to the soil water holding properties is likely to significantly reduce the annual volume pumped. A detailed account of the spray site investigation is given in Appendix B.

5. SUMMARY

One of the principles of conversion was to ensure that reasonably efficient irrigators were able to continue their current practices. Through community workshops the term 'reasonably efficient' was defined as allowing 75% of irrigators to continue their current practice, i.e. 25% of irrigators would need to make changes to their current irrigation system to comply with volumetric allocation. If it is accepted that the FIST sites are a fair representation of irrigation practices in the SE, then Table 3 indicates that this objective has been met. The percentage of flood irrigators disaffected by conversion ranged from 0% in 2002–03 to 25% in 2004–05. For spray irrigation, in two of the three seasons ~10% of growers were disaffected. It was only in 2004–05 that figure rose to greater than 25% (27%). No drip irrigators were disaffected by conversion. These results were achieved even though the net irrigation requirement in all three trial seasons was greater than average (Table 2).

Two licensees in the FIST program (one flood irrigator and one spray irrigator) repeatedly pumped more water than will be allocated under the proposed conversion model. If the 75th percentile is a robust method for determining 'reasonably efficient' irrigators, then the detailed site investigations should reveal that irrigation practices at the two aforementioned sites could be significantly improved; this was certainly the case. Poor system design, which ultimately compromises irrigation management, has significantly contributed to the 'above average' water use at both sites. Significant improvement could be made at both sites by matching the irrigation application depth to the soil water holding capacity. This could be achieved at the flood site by increasing the pumping rate and or reducing the size of the bays. At the spray site, the pivot specifications would need to be modified to reduce the amount of water applied with each pass.

5.1 CONCLUSION

The results of the site analysis provide confidence that the 75th percentile is a reliable cut-off point to define 'reasonably efficient' irrigators i.e. licensees pumping more water than what they will be allocated are likely to have the capacity to alter their irrigation practices to align with the allocated volume. In conclusion the proposed volumetric conversion model achieves the aim of providing reasonably efficient irrigators with sufficient water to continue their current irrigation practices.

APPENDICES

A. FLOOD SITE INVESTIGATION

The flood site is an irrigation bay (~30 m x 525 m) located in the Biscuit Flat region. Artesian well pressure supplies the head for delivering irrigation water to the bays. The soil is a shallow dark loam (~20 cm) over limestone. Sheep are grazed on the pasture grown at the site.

In two of the three irrigation seasons the average volume pumped across the flood property was greater than the volume that will be allocated under the proposed volumetric conversion model. In 2003–04 23% more water than what will be allocated was pumped, and in 2004–05 37%, however if a 10% seasonal allowance is included in the calculations the figures are reduced to 12% and 24%. Detailed irrigation records (meter readings) were received from this site.

The following information has been used in the flood site investigation. Wrattonbully weather data (SILO Data Drill – Queensland Department of Natural Resources and Mines) has been used as the source for rainfall data. Reference crop Evapotranspiration has been estimated from SILO Class A Pan data for Wrattonbully. The Readily Available Water holding capacity of the soil was estimated to be 16 mm (20 cm dark clay loam over limestone pers comm. D. Maschmedt 2004). Below the clay loam is a layer of calcrete-capped limestone of unknown depth. It has been assumed that the pasture does not utilise any of the water stored in the limestone. The Total Available Water was estimated to be 32 mm. The soil water balance on 1st July was estimated to be 24 mm (there was 24 mm of available water in the soil). FAO 56 crop coefficients for Pasture were used to calculate crop water requirement (see Skewes 2006 for more information). The Full Point estimations for the soil moisture data are given in Appendix C. Only data from the 10 cm and 20 cm sensors (active rootzone) were included in the analysis.

Before irrigation data was entered into IRES it was adjusted for application losses. Pondage test results show that 1% of the pumped volume is lost through channel seepage, hence 1% was deducted from the metered volumes. Evaporation from the channel and bay was estimated by multiplying the number of hours water was present (in the channel or bay), by the wetted area and the Evaporation rate (SILO Data Drill – Queensland Department of Natural Resources and Mines) during the relevant period. The irrigated hours supplied by the licensee was used to calculate channel evaporation. In estimating evaporation from the bay it was assumed that surface water is present in the bay for two days. These estimates of evaporation losses were also deducted from the metered volumes.

FLOOD SITE RESULTS AND DISCUSSION

Irrigation Season 2003–04

Twelve irrigations were applied during the 2003–04 irrigation season, a total of 13.2 ML/ha was applied. All irrigations were detected at 50 cm (pink trace), but not at 100 cm (black trace) (Fig. 5). The square shape of the irrigation peaks indicates that water remained above

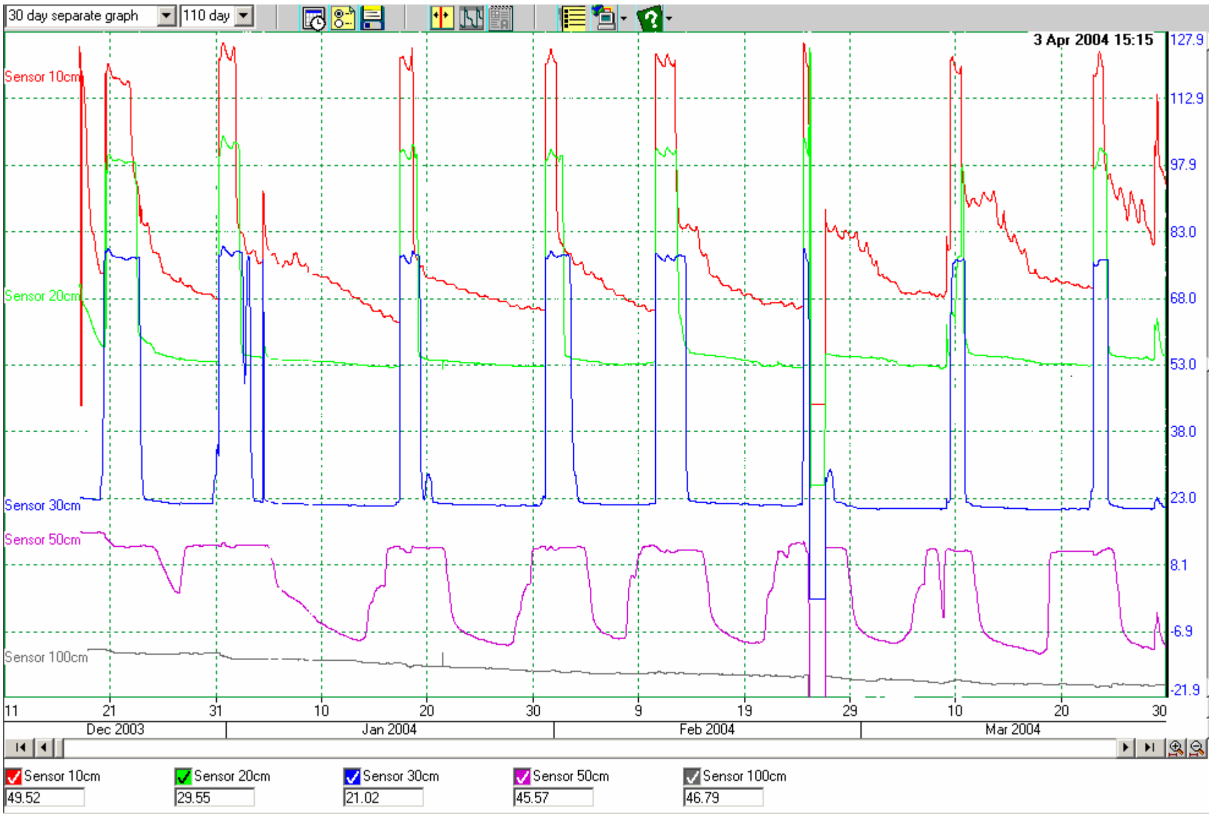


Figure 5. Field soil moisture (10, 20, 30, 50 and 100 cm sensors) data recorded on site during the 2003–04 Irrigation Season

field capacity for some time following the irrigation events. It appears that soil moisture was elevated in the upper soil layers for three days, and at depth (50 cm) for approximately five days following each irrigation event. Closer inspection of the traces reveals that the soil moisture becomes elevated at 50 cm prior to the commencement of the irrigation. It is most likely that lateral flow from an irrigation event in an adjacent bay has caused the rise in moisture. Unfortunately the water level sensor installed at this site was not operational during this period.

The predicted and ‘field’ soil moisture traces follow each other very closely (Fig. 6). Rainfall (green) and irrigation events (blue) are represented by vertical bars. The ‘field’ soil moisture data is represented by the blue trace, and the predicted soil moisture by the pink trace. If the relative rootzone soil water content is above zero, the soil is above field capacity, less than zero indicates the soil profile is drying. The soil moisture probe was not operating from July to mid-December and from April to June hence the field trace reads zero during these periods. The close match between the predicted and field soil moisture trace confirms that the FAO coefficients for pasture are appropriate for the South East of South Australia. It also indicates that the parameters used in the IRES simulation are representative of site conditions.

The simulated trace indicates that irrigations should have commenced at the end of September, according to IRES the soil was in deficit for 45 days prior to the first irrigation Throughout the irrigation season the soil profile is in deficit for approximately six days before each irrigation (the actual number of days varied from 1–10). The total number of days the

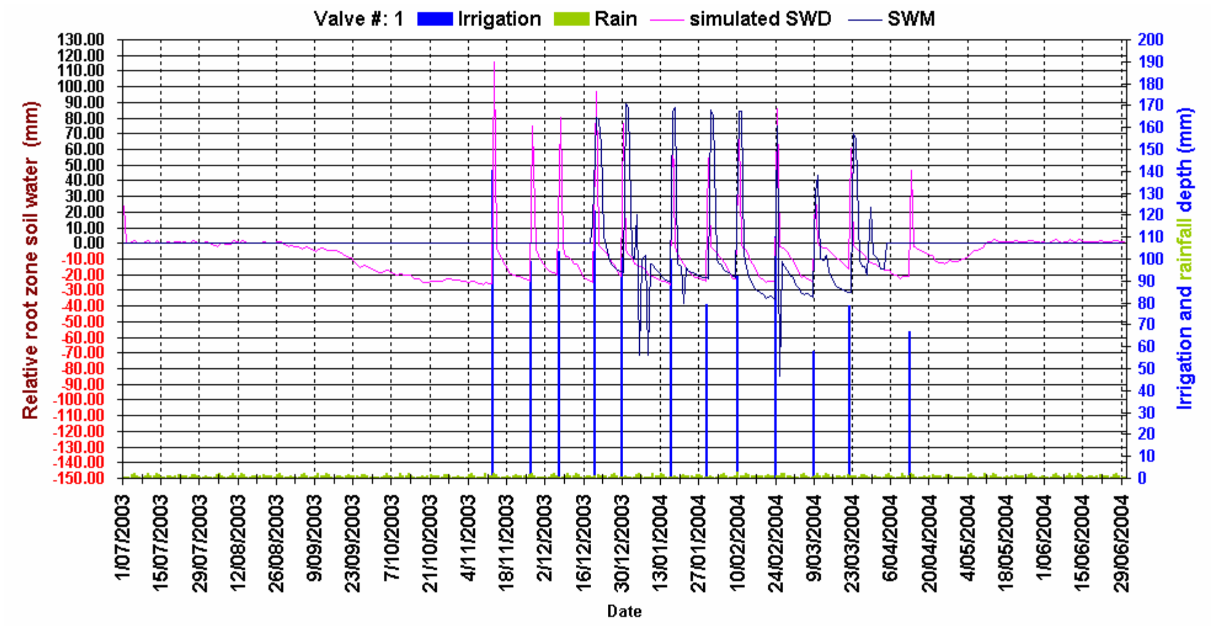


Figure 6. **Predicted soil moisture (pink trace) vs. field soil moisture (blue trace) recorded during 2003–04**

profile was in deficit for the season was 108. The soil profile is in the RAW range for ~75 days and above field capacity for 13 days throughout the irrigation season (Fig. 7). The days above field capacity may have been underestimated as the IRES model does not take account the effect of irrigating adjacent bays. Nevertheless it is probable that the total volume pumped could be reduced if the irrigation frequency was increased and the irrigation depth reduced. As this site relies on flow rates from an artesian well to water the bays, it is likely that the installation of a pump and or a reduction in bay size would make it possible to apply smaller amounts more frequently.

Drainage from irrigation is estimated to be 8.55 ML/ha, this equates to 65% of the volume pumped (13.2 Ml/ha). This in turn means that ~35% of the water pumped is available for the plant to use. At this efficiency level a delivery component of 186% would be required to ensure enough water reaches the target zone. In this area a reasonably efficient flood irrigator was deemed to require a delivery component of 132%.

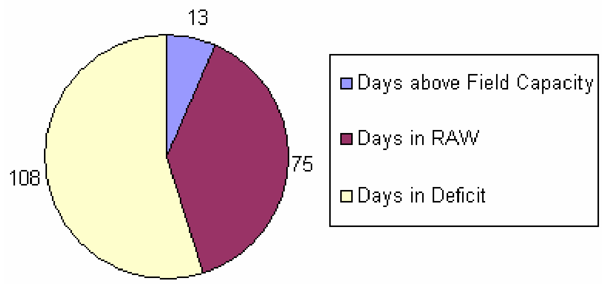


Figure 7. **Modelled soil moisture conditions. Number of days that the soil profile is above field capacity, in the RAW range and in deficit during the 2003–04 irrigation season – Flood site**

When the total amount of water added to the bay is plotted against the total amount of water used by the crop (cumulative rainfall and irrigation is plotted against cumulative crop water use - ETC) it is evident that the amount of water applied far exceeds the crop water requirement (Fig. 8). The delayed start to the irrigation season is also highlighted in Figure 8.

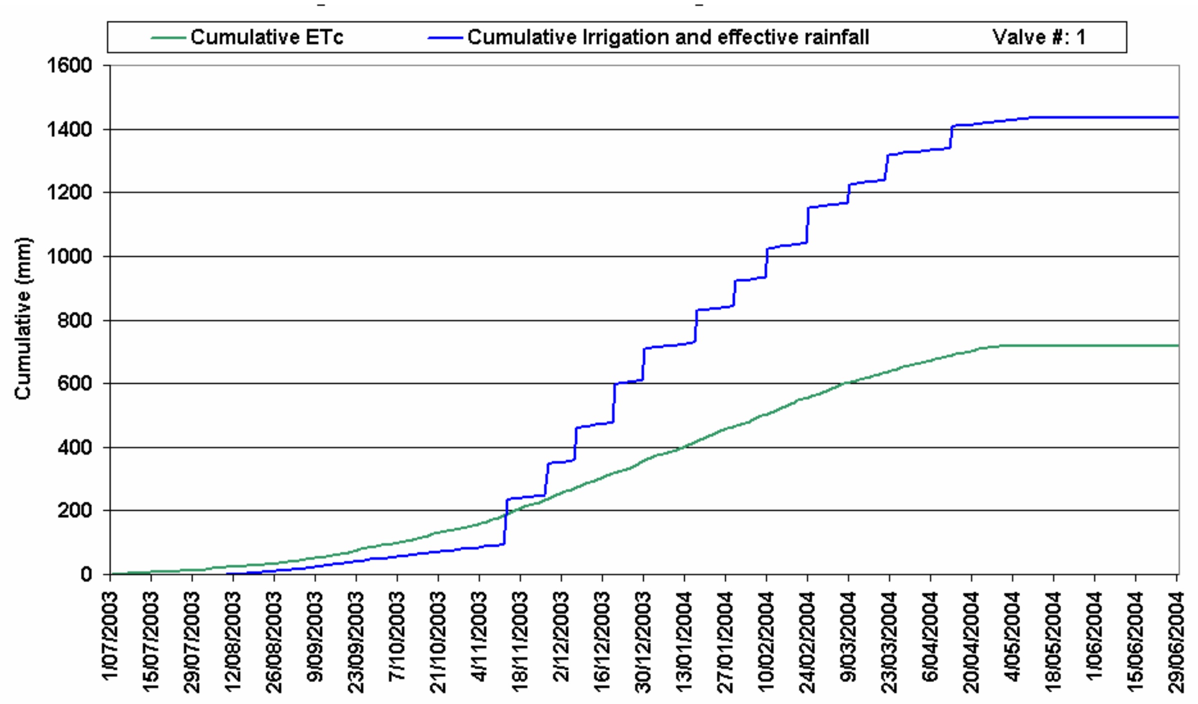


Figure 8. **Cumulative crop water use vs. cumulative rainfall and irrigation (2003–04 irrigation season - Flood site)**

Irrigation Season 2004–05

The 2004–05 irrigation season was similar in many ways to the 2003–04 irrigation season. Two extra irrigations were applied during the 2004–05 season (14 compared to 12); the total amount of water applied was 15.7 ML/ha. All irrigations were detected at 50 cm, with some detected at 100 cm (Fig. 9). As per 2003–04, the soil remained above field capacity for some time following the irrigation events (square shape of the irrigation peaks). In 2004–05 the soil moisture was elevated in the upper soil layers for 2–3 days, and at depth (50 cm) for approximately five days following each irrigation event. Once again a rise in soil moisture was evident at 50 cm prior to the surface soil layers.

As per 2003–04 the predicted and ‘field’ soil moisture traces follow each other very closely (Fig. 10). The close match between the predicted and field soil moisture trace once again confirms that the FAO coefficients for pasture are appropriate for the South East of South Australia. It also indicates that the parameters used in the IRES simulation are representative of the site conditions.

The simulated trace indicates that a higher level of production would have been achieved if the first irrigation was applied at the beginning of October; according to IRES the soil was in deficit for 20 days prior to the first irrigation (Fig. 10). Throughout the irrigation season the soil profile is in deficit for approximately four days before each irrigation event (the actual number of days varied from 0–8). The total number of days in deficit for the season was 81.

Figure 9. Field soil moisture (20, 50 and 100 cm sensors) data recorded on site during the 2004–05 Irrigation Season

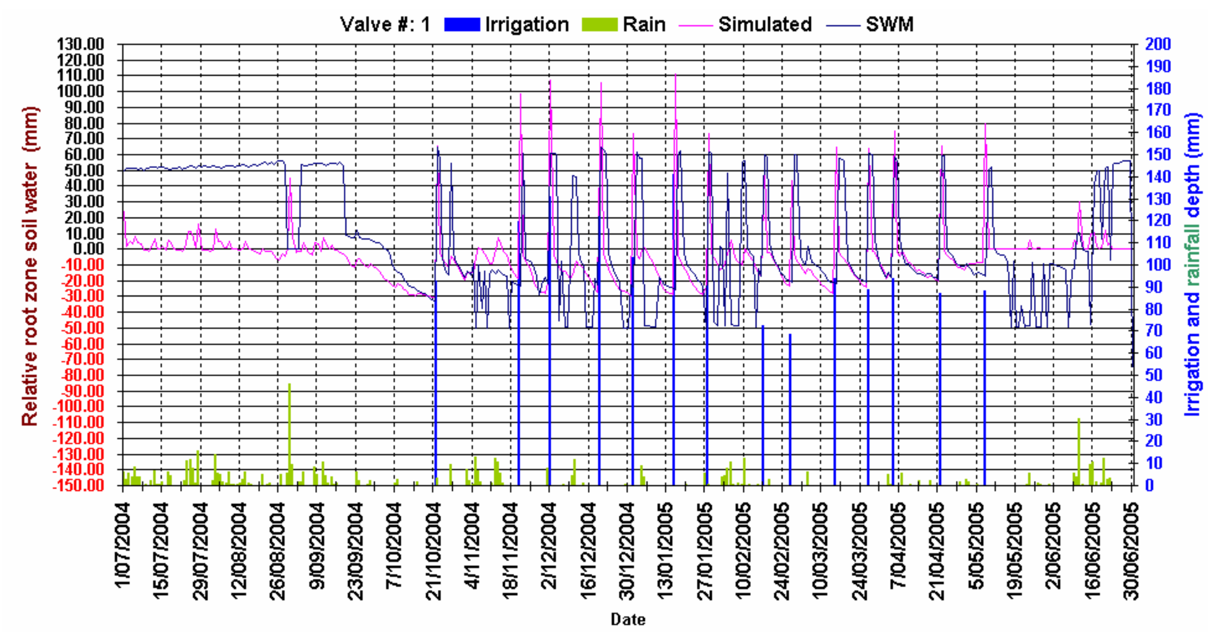


Figure 10. Predicted soil moisture (pink trace) vs. field soil moisture (blue trace) recorded during 2004–05

The soil profile is in the RAW range for ~125 days and above field capacity for 21 days throughout the irrigation season (Fig. 11). The days above field capacity may have been underestimated as the IRES model does not take account the effect of irrigating adjacent bays. Although the pasture experienced fewer days of soil moisture deficit in the 2004–05 season, the simulation and field soil moisture data both indicate considerable potential to improve irrigation scheduling and to reduce deep drainage. Smaller more frequent irrigations are likely to reduce the total volume of water pumped over the season and produce a higher quality, more consistent pasture.

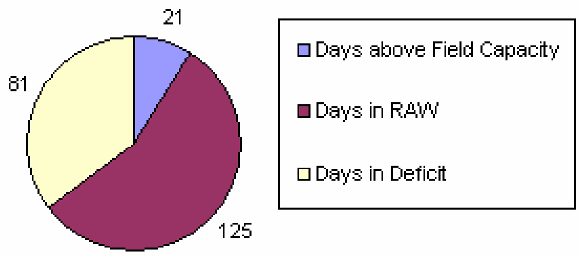


Figure 11. Modelled soil moisture conditions. Number of days that the soil profile is above field capacity, in the RAW range and in deficit during the 2004–05 irrigation season – Flood site

Drainage from irrigation during the 2004–05 season is estimated to be 10.76 ML/ha, this equates to 68% of the volume pumped (15.7 ML/ha). This in turn means that ~32% of the water pumped is available for the plant to use. At this efficiency level a delivery component of 213% would be required to ensure enough water reaches the target zone.

When the total amount of water added to the bay is plotted against the total amount of water used by the crop (cumulative rainfall and irrigation is plotted against cumulative crop water use - ETC) the amount of water applied once again far exceeds the crop water requirement (Fig. 12). The delayed start to the irrigation season is also highlighted in Figure 12.

Flood Site Summary

This modelling exercise suggests that the irrigation start date at this site should be brought forward and the irrigation interval reduced to obtain better pasture growth. Due to the large volume of water passing through the profile as drainage with each irrigation event (~74 mm) it is also recommended that the irrigation application depth is reduced. Changes to irrigation bay design and flow rates may be required to achieve this. The profile was in the optimal moisture range (RAW zone) for 38% of the season in 2003–04 and 55% in 2004–05, this could certainly be improved by smaller more frequent irrigations.

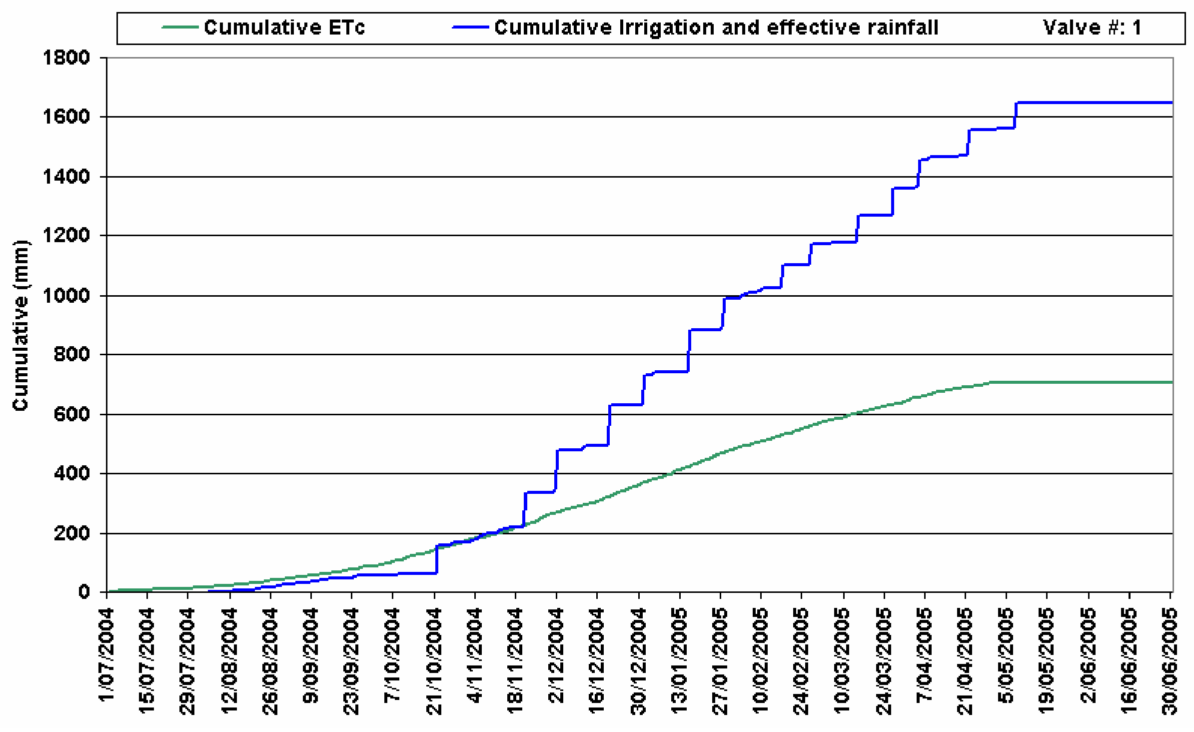


Figure 12. Cumulative crop water use vs. cumulative rainfall and irrigation (2004–05 irrigation season - Flood site)

B. SPRAY SITE INVESTIGATION

The spray site is a 65 ha pivot located near Mount Gambier on shallow soil overlying limestone. The pivot is used to produce pasture for dairy cows; the pasture is rotationally grazed.

In all three irrigation seasons, metered records show that the spray site pumped more water than will be received under the proposed volumetric conversion model. In 2002–03 53% more water was pumped than will be allocated, 2003–04 40% and in 2004–05 68%. However, if a SPR allocation and 10% seasonal allowance is included in the calculations, the figures are reduced to 13%, 3%, 24% respectively. Irrigation records (meter readings) were received from this site, however not all events were documented. It is also not known what area of crop was watered during each irrigation event (the variation in volumes pumped suggests that the area irrigated is variable as the pivot is operated at the same speed throughout the season). For these reasons it is necessary to make several assumptions about the irrigation practices at this site to complete the site investigation.

It has been necessary to assume an irrigation application depth. The application depth has been determined by analysing data from irrigation events for which meter readings have been provided. It was assumed that a full circle was completed during each irrigation event. When metered records are analysed (in the manner described above) the application depth is equivalent to 15.7 mm per pass. 15.7 mm corresponds to the volume of water pumped with each event, it does not allow for any evaporative losses or drift. It is widely accepted that ~15% of the water pumped by a pivot does not reach the target zone (River Murray Catchment water Management Board, 2002); an application efficiency of 85% has therefore been assumed. For simplicity an on ground application depth of 12.75 mm (85% of 15 mm) per pass has been assumed for all irrigation events. This figure compares well with the results from a catch can test performed at the site.

The frequency of irrigation events was determined by combining the supplied records with the soil moisture traces. Where there was a substantial increase in soil moisture levels and no rainfall recorded, it was assumed that a 12.75 mm irrigation event took place. There were some instances where details of an irrigation event were supplied, but there was no corresponding increase in soil moisture levels, these events have been ignored. It is necessary to ignore these events as IRES graphs ‘field’ soil moisture data against a theoretical or ‘predicted’ trace. If irrigation events are included that did not pass over the soil moisture probe then the predicted trace will not reflect what was happening at the soil moisture sensor installation site. Two soil moisture probes were installed at the site. Where a probe was not operating it was assumed that the same amount of water was applied to both probes.

The following information has been used in the spray site investigation. Mt Gambier weather data (SILO DataDrill, Queensland Department of Natural Resources and Mines) has been used as the source for rainfall data. Reference crop Evapotranspiration has been estimated from SILO Class A Pan data for Mount Gambier. The Readily Available Water holding capacity of the soil was estimated to be 9.75 mm (15 cm of Clay Loam with Readily Available Water Holding Capacity of 0.65 mm cm-1, -8 to 60 kPa, Wetherby 2003). Below the clay loam is a layer of limestone of unknown depth. It has been assumed that the pasture does not utilise any of the water stored in the limestone. Piezometer results suggest that the limestone is highly permeable, irrigation water has reached the water table within one hour of water application. The Total Available Water was estimated to be 20 mm (double RAW). The soil water balance on 1st July was conservatively estimated to be 5 mm (i.e. there was 5 mm of available water present in the soil). FAO crop coefficients for Maximum Production Pasture were used to calculate crop water requirement (see Skewes 2006 for more information). The Full Point estimations are given in Appendix C. Only data from the 10 cm sensor (active rootzone) was included in the analysis.

SPRAY SITE RESULTS AND DISCUSSION

Irrigation season 2003–04

When an application depth of 12.75 mm (per pass) is assumed, and the frequency of irrigations is inferred from records, the inferred seasonal volume pumped is within allocation i.e. inferred volume pumped = 7.07 ML/Ha (5.99 ML/ha + 18% Delivery Component to allow for drift and evaporative losses), volume allocated = 7.65 ML/ha. This contradicts the seasonal metered pumped records (8.69 ML/ha). The most likely explanation for this discrepancy is that the pasture on elevated ground is watered more frequently than that on lower lying ground. During the 2003–04 season both probes were located on low lying ground.

The data recorded ‘in field’ by the C-Probes during the 2003–04 season is shown in Figures 13–14. The red line represents the 10 cm sensor and the pink line the 50 cm sensor. In 2003–04 both probes were installed in lower lying ground. The trace from the water table level sensor (blue) is also included in Figure 13. On average irrigations were applied every 3–4 days. All irrigations were detected at 50 cm and caused a slight rise in the water table. The water table became elevated during January and February, peaking at 50 cm below the soil surface.

Predicted soil moisture is plotted against the field soil moisture trace in Figures 15–16. The simulated trace is in deficit (values less than -10 mm) more often than the ‘field’ trace. There are a few possible explanations for this mis-match. The size of each irrigation event may have been under-estimated; if the application depth was higher then the profile will have reached saturation more frequently. It is also possible that inappropriate Full Points have been applied to the ‘field’ soil moisture data. If these have been underestimated then the trace will show that the soil moisture is in surplus more often that it really is. One way to ascertain which is the case would be to look at production statistics, however under and over-watering will both have negative impacts on crop growth. Aside from this discrepancy the traces follow each other quite well. The greatest departure of the predicted soil moisture trace from the field trace occurs during the period when the water table is elevated.

The water table reaches its maximum height (is closest to the soil surface) during January and February. The rising water table is most evident in the soil moisture traces from probe 2 (Fig. 14). As the water table rises, the soil moisture content at 50 cm reaches saturation (square shape), the 10 cm appears to be saturated for a short time directly after each irrigation event. Interestingly, it appears that full point increases during January/ February. One possible explanation is that the rising water table (as a result of irrigation) increases the RAW of the soil by making water available from the limestone layer (through capillary rise). Probe 1 (Fig. 13) does not show the same response; it appears that the soil surrounding the probe is waterlogged during this period. This is consistent with on site observations. The

Figure 13. Field soil moisture (10 and 50 cm sensors) and water level data recorded on site during the 2003–04 Irrigation Season – Probe 1

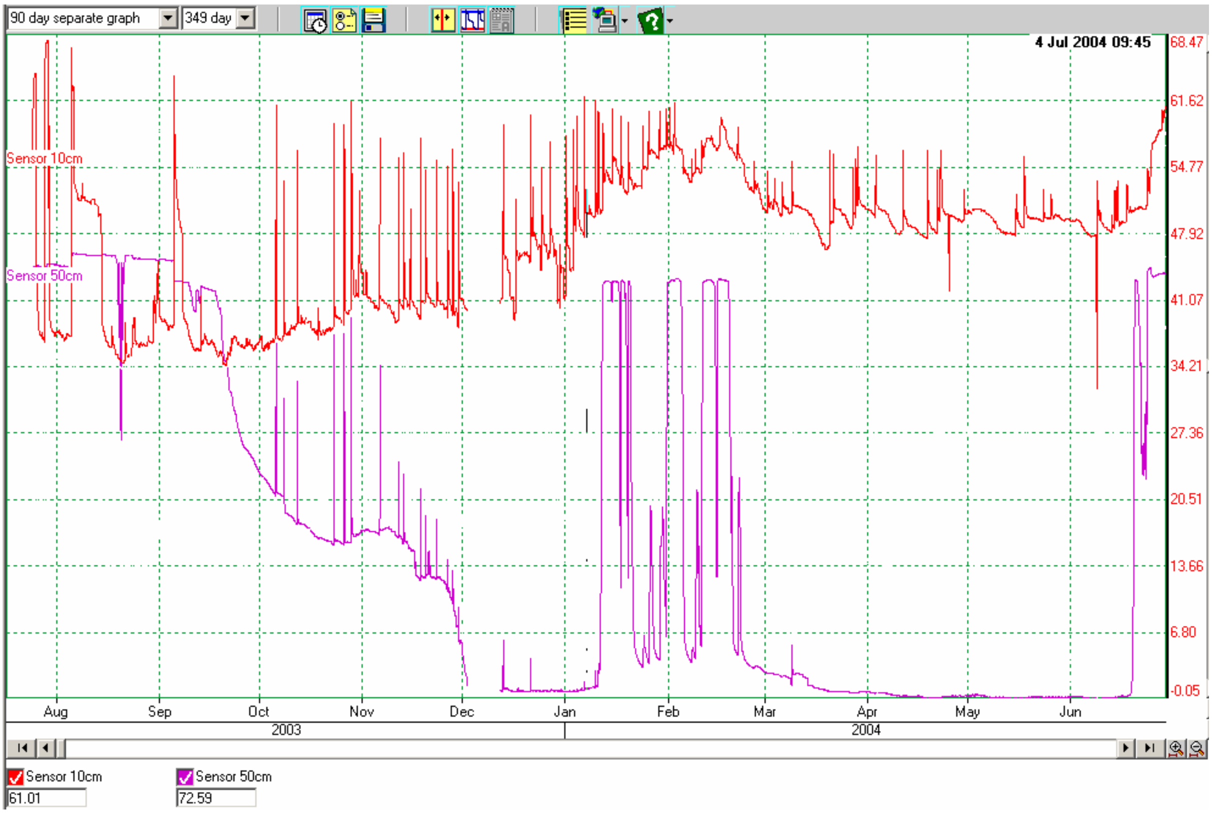


Figure 14. Field soil moisture (10 and 50 cm sensors) data recorded on site during the 2003–04 Irrigation Season – Probe 2

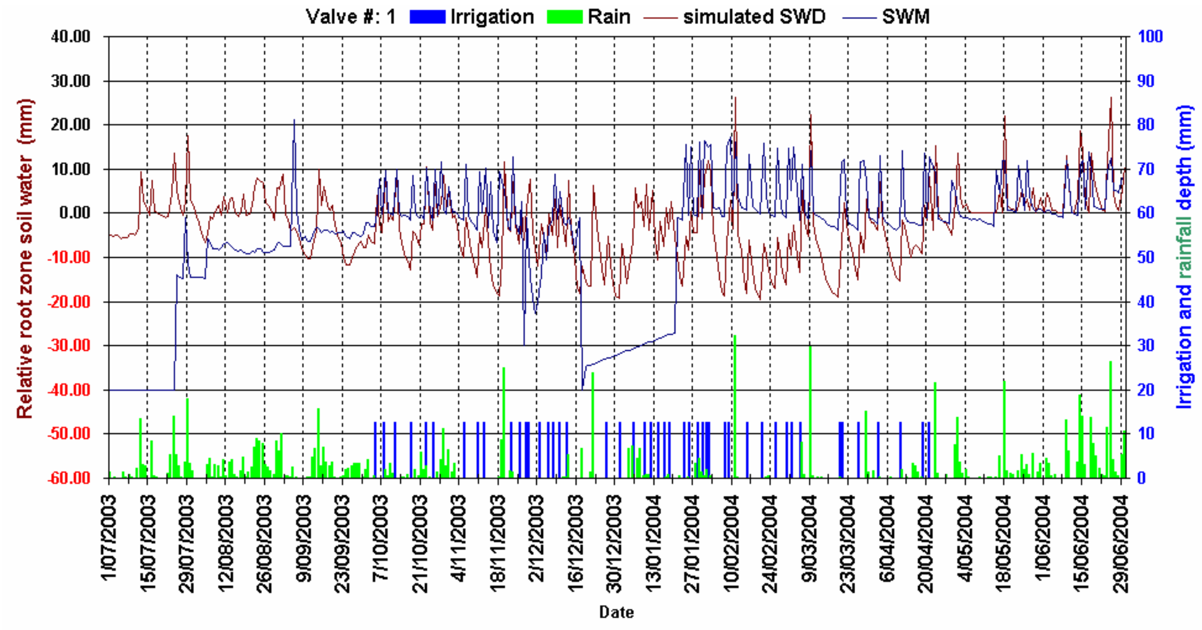


Figure 15. Predicted soil moisture (brown trace) vs. field soil moisture (blue trace) recorded by Probe 1 during 2003–04

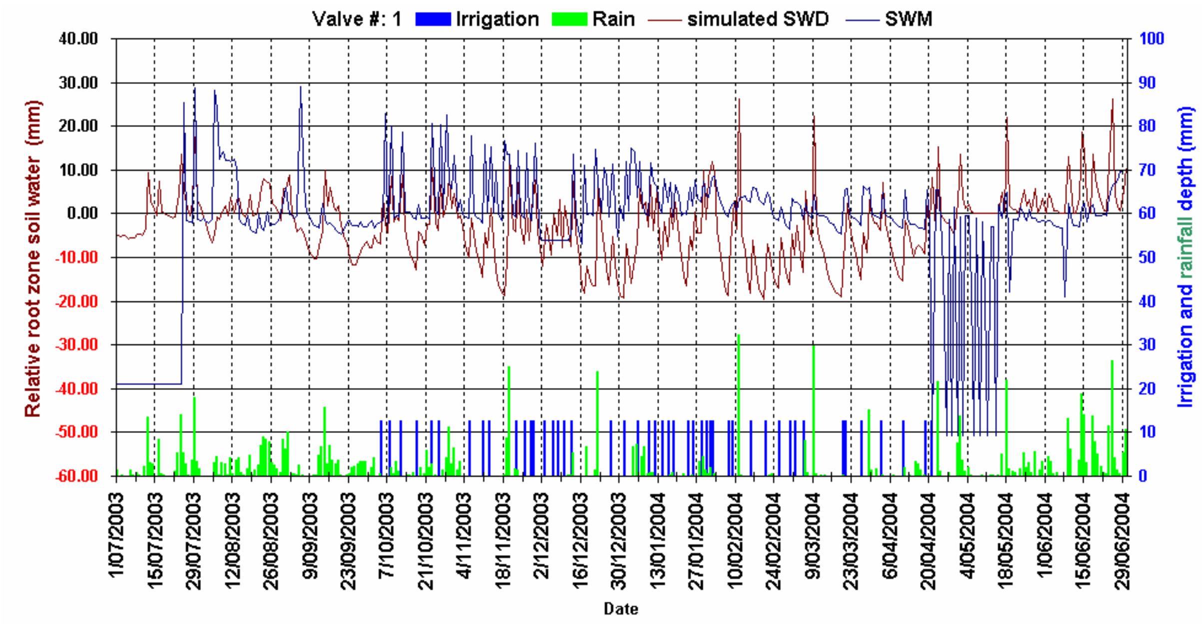


Figure 16. Predicted soil moisture (brown trace) vs. field soil moisture (blue trace) recorded by Probe 2 during 2003–04

theoretical trace suggests that the most severe plant stress occurs when the water level is at its highest, if the pasture is accessing water in the limestone layer then it may not be stressed at all.

If the total amount of water used by the system is plotted against the total amount of water added to the system (cumulative crop water use - ETC is plotted against cumulative rainfall and irrigation) a perfect match is almost achieved (Fig. 17). This indicates that enough water is being applied to meet crop water requirements, however the periods of soil moisture deficit

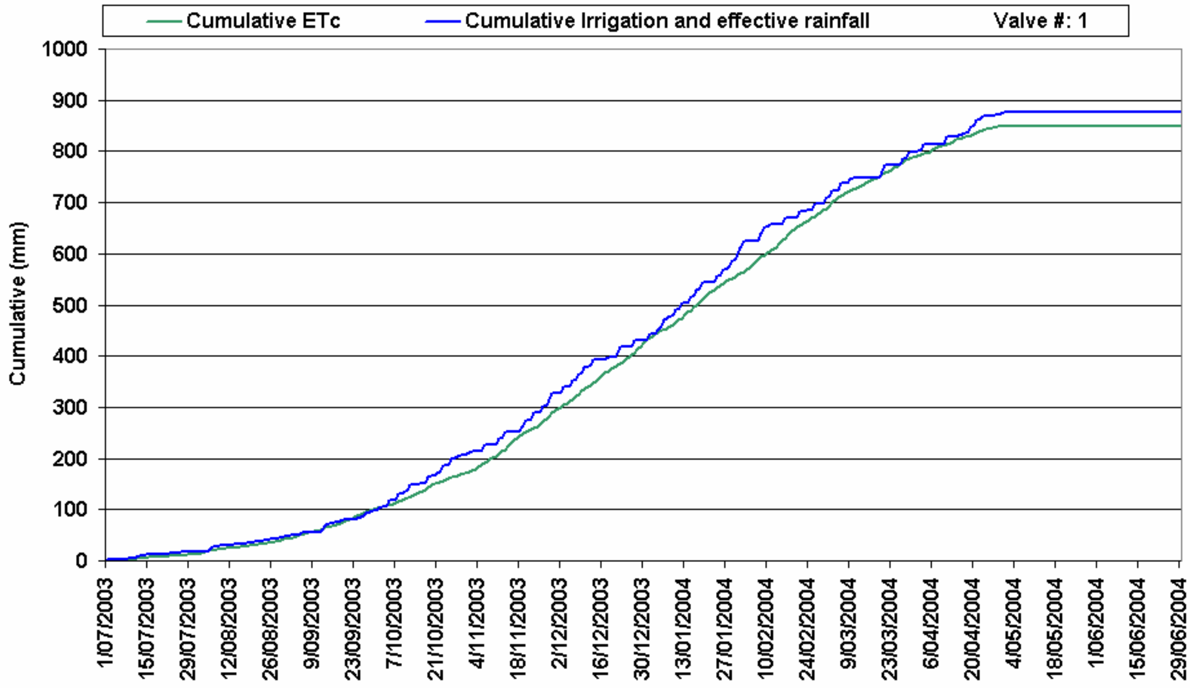


Figure 17. Cumulative crop water use vs. cumulative rainfall and irrigation (2003–04 irrigation season - Spray site)

and waterlogging (Figs 15–16) suggest that the pasture would benefit from reduced application depth for the whole of the season with the frequency of irrigation events increased during months of highest water use. The RAW holding capacity of the soil was generously estimated to be 9.75 mm, in some areas the water holding capacity would be significantly less than this. The application depth was estimated to be 12.75 mm, thus with each irrigation event at least 3 mm will pass through as drainage. In 2003–04 IRES estimates that the drainage from this spray system equates to 1.32 ML/ha (19% of the water pumped).

According to the predicted soil moisture trace, soil moisture was within the Readily Available Water range for a total of 101 days throughout the irrigation season, the profile was in deficit for 59 days and above field capacity for 40 days (see Fig. 18). In reality the crop may have spent fewer days in deficit due to the effect of the rising water table.

Irrigation season 2004–05

Prior to the commencement of the 2004–05 irrigation season, Probe 2 was relocated to slightly elevated ground beneath the same pivot.

When an application depth of 12.75 mm (per pass) is assumed, and the frequency of irrigations is inferred from records, the volume pumped equates to 8.54 ML/ha (Probe 1) and 9.31 ML/ha (Probe 2). When an additional 18% is added to these figures to allow for system losses, the inferred volume pumped exceeds the allocated volume by 32% (10.1 ML/ha) and 44% (11.0 ML/ha). These percentages are reduced to 20% and 31% when a 10% allowance is made for seasonal variation. This compares well with the metered data supplied by the irrigator which indicates that in the 2004–05 season the allocation was exceeded by 24% (including seasonal allowance) which is equivalent to a pumped volume of 10.44 ML/ha.

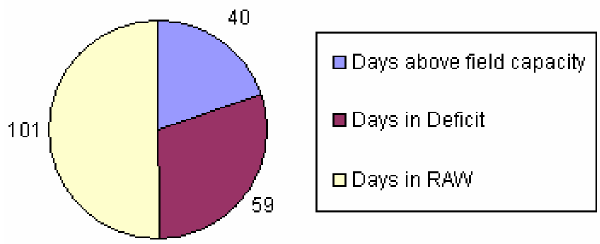


Figure 17. Modelled soil moisture conditions. Number of days that the soil profile is above field capacity, in the RAW range and in deficit during the 2003–04 irrigation season – Spray site

The 'field' soil moisture and water table level traces are shown in Figures 19–20. Once again the water table rose during the irrigation season, the table peaked at 50 cm towards the end of March. Irrigations were applied approximately every four days throughout the season. The 50 cm trace has been excluded in Figure 19 due to large spikes in the data, nevertheless the trends are consistent with the previous irrigation season. The full point of Probe 1 increases as the water table moves upwards and the soil 50 cm and below becomes saturated. The sensors on Probe 2 remain relatively wet for the whole season.

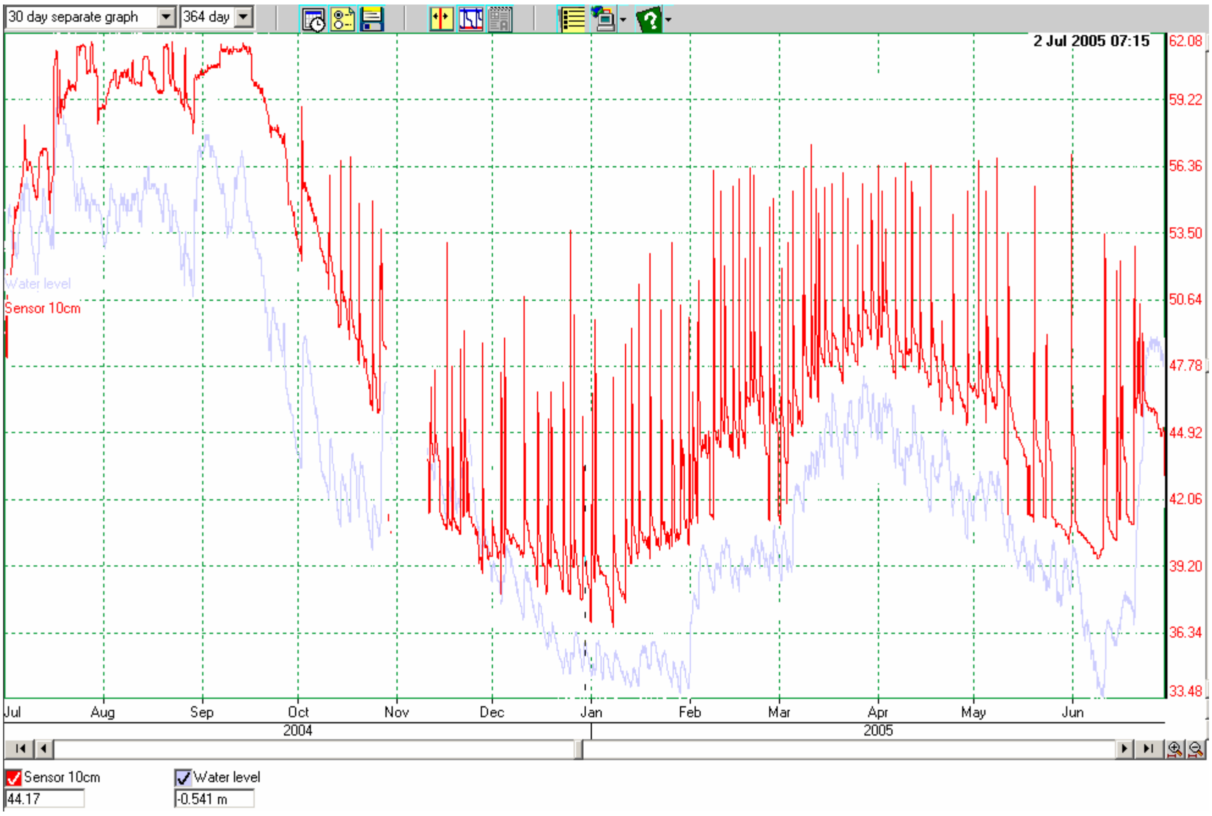


Figure 19. Field soil moisture (10 cm sensor) and water level data recorded on site during the 2004–05 Irrigation Season – Probe 1

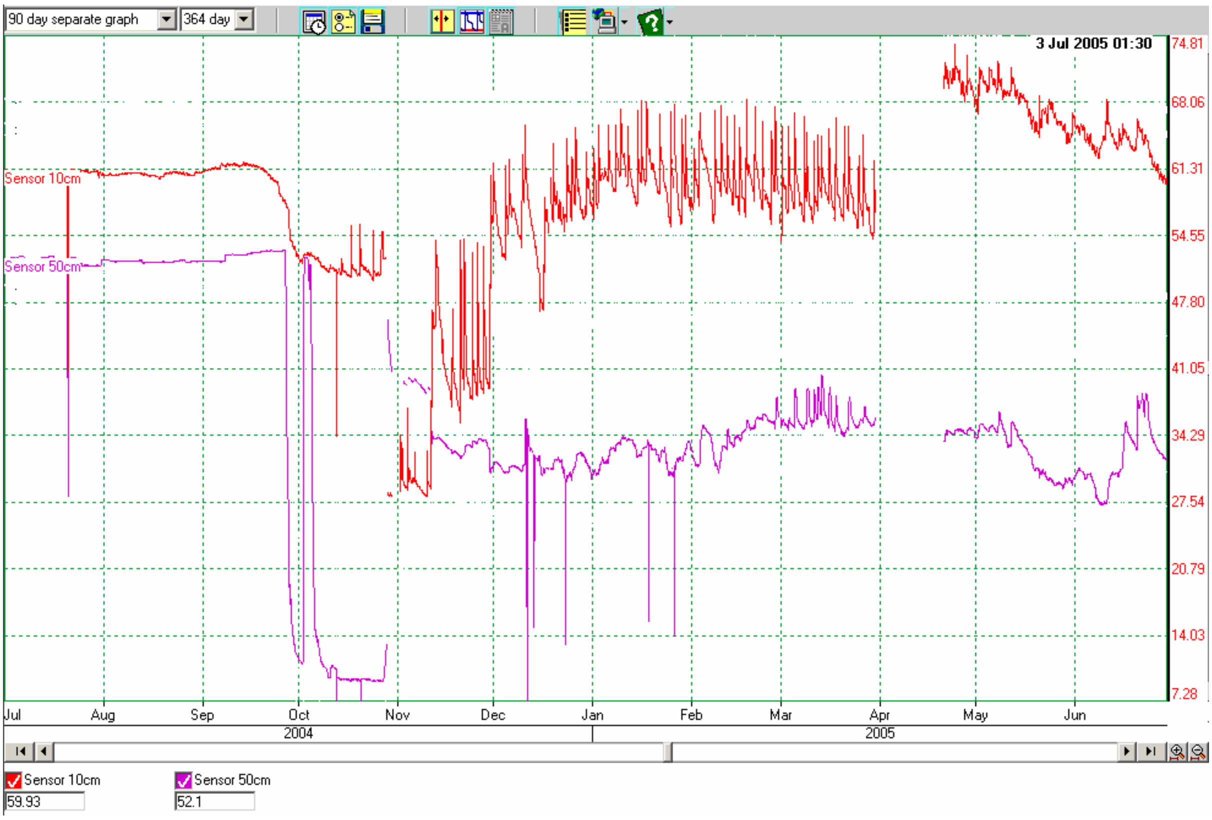


Figure 20. Field soil moisture (10 and 50 cm sensors) data recorded on site during the 2004–05 Irrigation Season – Probe 2

In 2004–05 there was a very good match between the predicted and field soil moisture levels for both Probe 1 and 2 (Figs 21–22). The improved match is most likely due to the 'bedding in' of the probes. The close match suggests the FAO crop coefficients for Maximum Production Pasture are appropriate for the climatic conditions in the SE of South Australia. Furthermore it is a good indicator that the parameters used in the IRES simulation are representative of the site conditions. Lower values observed on the trace from Probe 2 are due to spiking in the field soil moisture data, they do not reflect true soil moisture deficits. The traces (predicted and field) suggest that the pasture experienced almost no water stress due to dry soil conditions throughout the irrigation season. The number of days the profile was in deficit in the 2004–05 season was 30 and 20, Probe 1 and 2 respectively, compared to 59 days in 2003–04 (Figs 18, 23–24). It is estimated that soil moisture levels were optimal (within RAW) for ~125 days (126 Probe 1 and 124 Probe 2). Soil moisture was above field capacity for ~70 days (66 Probe 1 and 78 Probe 2). Again it must be noted that the influence of the rising water table is not accounted for in these estimates.

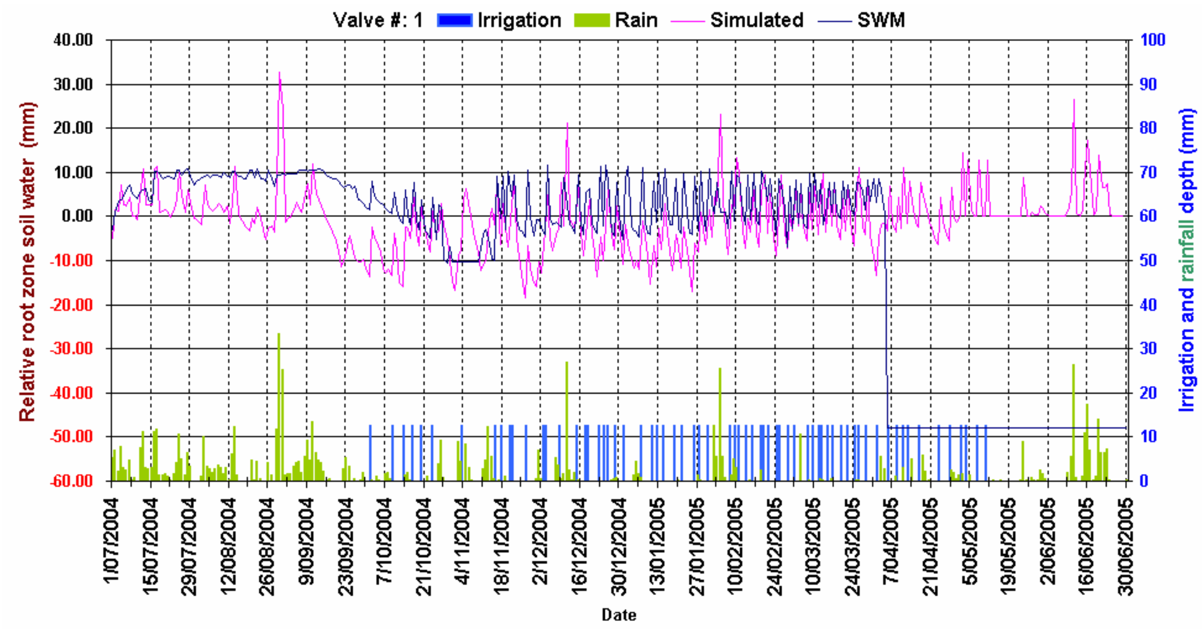
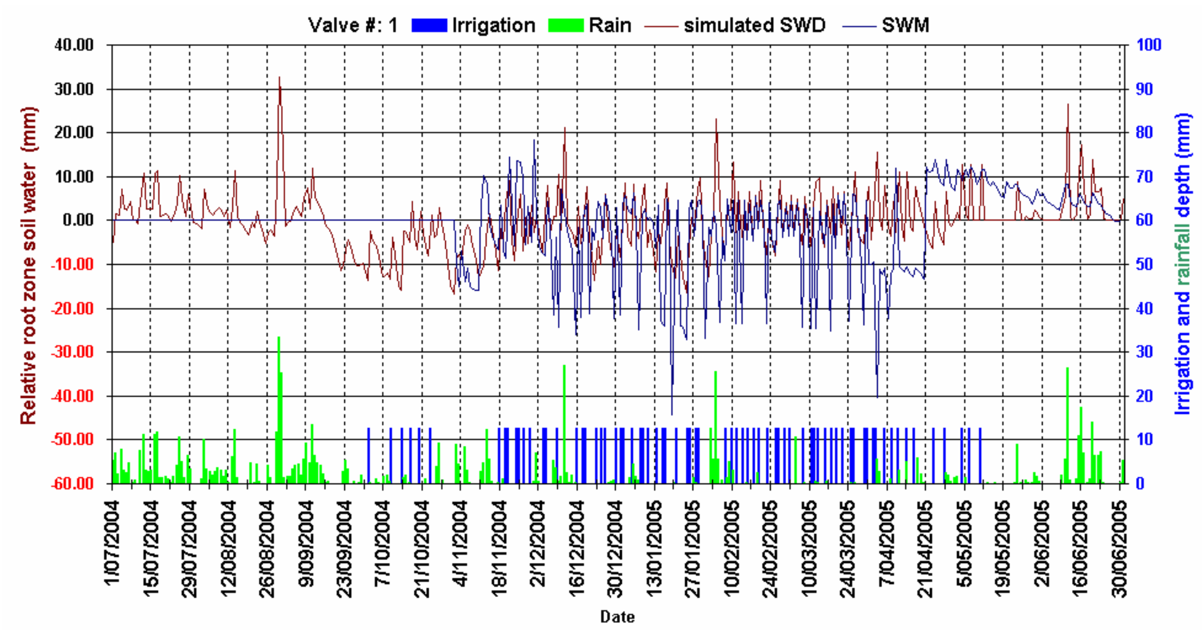


Figure 21. Predicted soil moisture (pink trace) vs. field soil moisture (blue trace) recorded by Probe 1 during 2004–05



Lower values observed on the ‘field’ trace are due to sensor spiking, they do not reflect true soil moisture deficits.

Figure 22. Predicted soil moisture (brown trace) vs. field soil moisture (blue trace) recorded by Probe 2 during 2004–05#

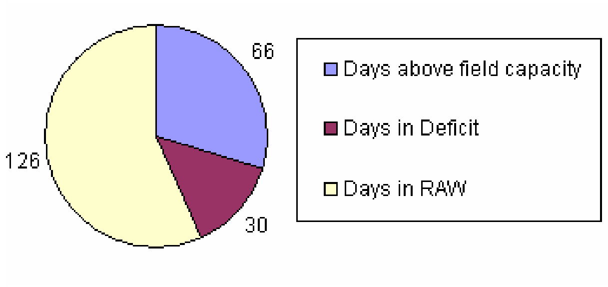


Figure 23. Modelled soil moisture conditions. Number of days that the soil profile is above field capacity, in the RAW range and in deficit during the 2004–05 irrigation season – Spray site Probe 1

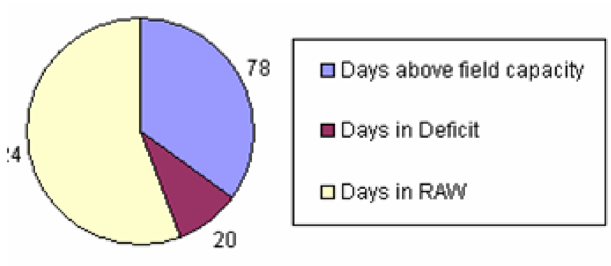


Figure 24. Modelled soil moisture conditions. Number of days that the soil profile is above field capacity, in the RAW range and in deficit during the 2004–05 irrigation season – Spray site Probe 2

If the total amount of water used by the system is plotted against the total amount of water added to the system (cumulative crop water use - ETC, is plotted against cumulative rainfall and irrigation) it becomes evident that surplus water is being supplied to the crop as of December (Probe 2) and February (Probe 1), Figures 25–26. The IRES program estimates that the drainage from irrigation events ranged from 2.95 Mlha-1 Probe 1 (29% of inferred volume pumped) to 3.54 MLha-1 for Probe 2 (32% of inferred volume pumped). The average for the pivot circle is likely to be somewhere in between. Interestingly, if drainage from irrigation events is subtracted from the inferred volume of water applied to the crop, the amount of water applied to Probe 2 is reduced to 7.46 ML/ha (11–3.54) and Probe 1 to 7.1 ML/ha (10.1–2.95). The allocation for Maximum Production Pasture for the location of the spray site is 7.65 ML/ha (8.4 ML/ha with 10% seasonal allocation).

Spray Site Summary

Incomplete irrigation records were received from the spray site, this required several assumptions to be made about the irrigation practices. As a result, some of the parameters used in the simulation may have been over-estimated, others may have been under-estimated; nevertheless, the results of this analysis strongly suggest that irrigation practices could be significantly improved at this site. Matching the irrigation system application depth to the soil water holding properties is likely to significantly reduce the volume of water pumped.

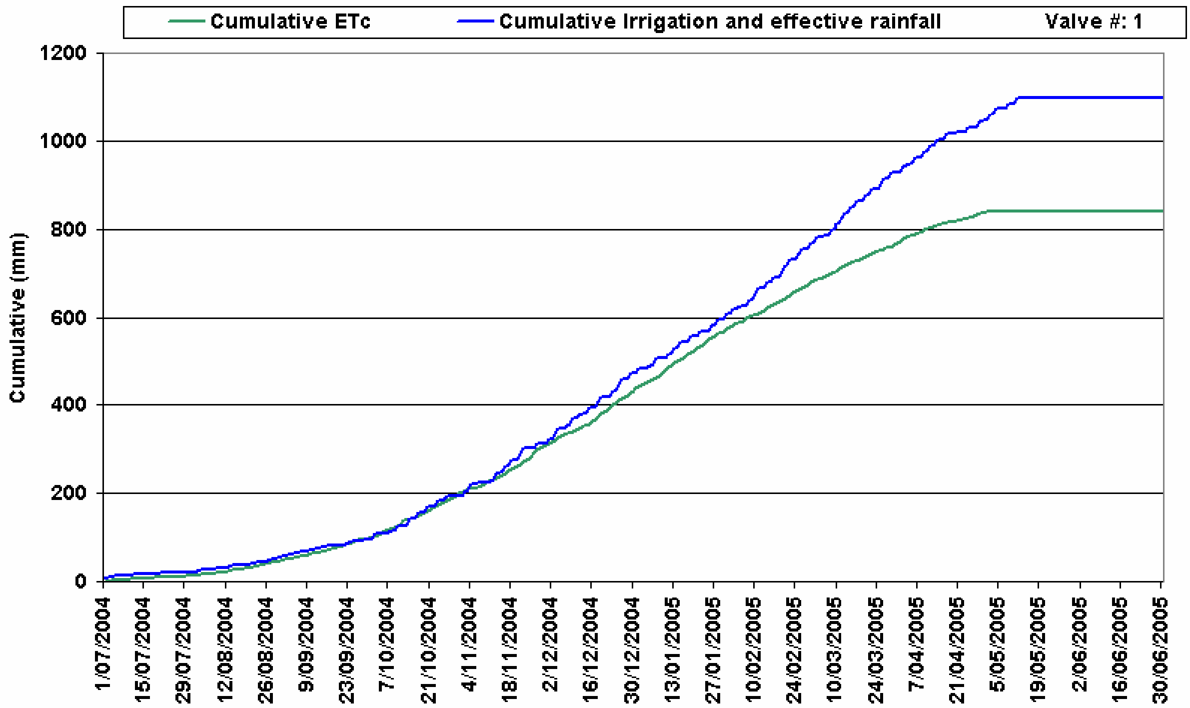


Figure 25. Cumulative crop water use vs. cumulative rainfall and irrigation (2004–05 irrigation season - Spray site Probe 1)

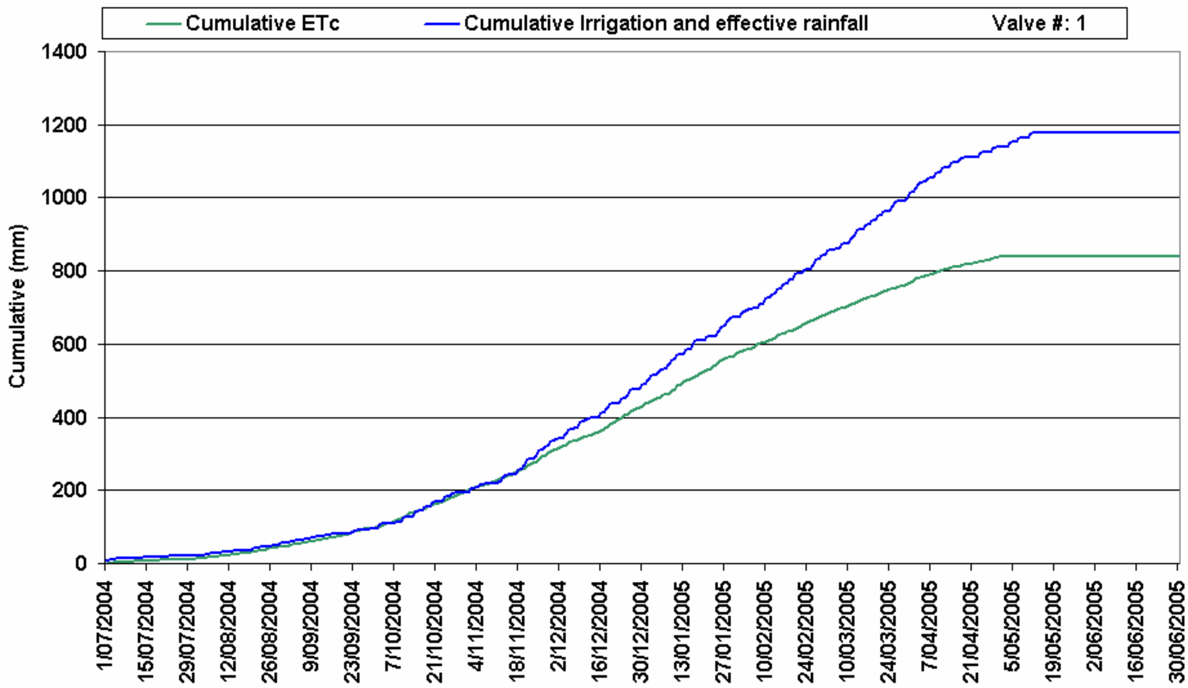


Figure 26. Cumulative crop water use vs. cumulative rainfall and irrigation (2004–05 irrigation season - Spray site Probe 2)

C. FIELD SOIL MOISTURE DATA FULL POINTS

Flood Site Full Points

Irrigation Season 2003–04

Date Start	Date End	Full Point
01/12/03	11/02/04	71
12/02/04	03/04/04	85

Irrigation Season 2004–05

Date Start	Date End	Full Point
01/07/03	30/06/04	75

Spray Site Full Points

Irrigation Season 2003–04 – Probe 1

Date Start	Date End	Full Point
01/07/03	30/06/04	40

Irrigation Season 2003–04 – Probe 2

Date Start	Date End	Full Point
01/07/03	31/10/03	39
01/11/03	30/11/03	41
1/12/03	05/01/04	46
06/01/04	10/01/04	50
11/01/04	05/02/04	53
06/02/04	29/02/04	54
01/03/04	30/06/04	51

Irrigation Season 2004–05 – Probe 1

Date Start	Date End	Full Point
01/07/04	15/11/04	51
16/11/04	29/12/04	44
30/12/04	18/01/05	42
19/01/05	07/02/05	44
08/02/05	19/02/05	46
20/02/05	30/06/05	48

Irrigation Season 2004–05 – Probe 2

Date Start	Date End	Full Point
#02/11/04	29/11/04	44
30/11/04	05/01/05	60
06/01/05	07/02/05	65
08/02/05	19/03/05	63
20/03/05	30/06/05	60

#Probe was relocated on 28/10/04

UNITS OF MEASUREMENT

Units of measurement commonly used (SI and non-SI Australian legal)

Name of unit	Symbol	Definition in terms of other metric units	Quantity
Centimetre	cm	mm x 10	length
day	d	24 h	time interval
hectare	ha	10^4 m^2	area
Irrigation rate / requirement	ML/ha	mm depth	rate
megalitre	ML	10^3 m^3	volume
metre	m	base unit	length
millimetre	mm	10^{-3} m	length
percent	%	fractions, decimal	proportion
year	y	356 or 366 days	time interval

Hectare Irrigation Equivalent haIE, Area based water entitlement

GLOSSARY

Annual Water Use Returns (AWUR's). End of season reporting process whereby water license holders detail their water use activities for the given season. The details required include areas of crop types grown and assessments of volumes pumped.

Application Depth. The depth of water applied (mm) with each irrigation.

Application Losses. Water delivered to the border of the field, which is lost during application to the field and therefore not made available to the crop. Includes evaporation, run-off, deep drainage and drift.

Area-Based Licensing System (haIE). Existing water access entitlements to irrigate a given area of crop per annum, with no restrictions on the volume of water applied to the crop. Measured in terms of hectares of irrigation equivalents (haIE).

Base Allocation (BA). The crop water requirement component of the proposed volumetric licenses. Base Allocation (ML) = haIE x NIRo

Bridging Volume (BV). The Bridging volume is an additional temporary water allocation that may be granted on application subject to eligibility criteria. The bridging volume is designed to give irrigators who are pumping in excess of their new volumetric allocation time to adjust to the new system.

Catch Can Test. Test performed to quantify application losses (drift and evaporation) from spray irrigation systems (eg. Centre pivot).

Class A Evaporation Pan. Rate of water loss by evaporation from an open surface of a pan (Doorenbos and Pruitt, 1977). The Australian Bureau of Meteorology uses the Class A Pan as the standard for measuring evaporation.

Climatic Bands. 10 Climatic Bands across the South East that were developed to better represent the range of evapotranspiration and rainfall rates across the SE of SA. It is proposed that these Climatic Bands form the basis for determination of each irrigator's volumetric allocation.

Crop Adjustment Factor (CAF). The Crop Adjustment Factor provides additional base allocation for licensees where, due to initial calculations problems, the existing area-based licensing system does not provide adequate allocation.

Crop Coefficient (Kc). Ratio between crop evapotranspiration (ETC) and the reference crop evapotranspiration (ET0) when crop is grown in large fields under optimum growing conditions, or ETC = Kc x ET0 (Doorenbos and Pruitt, 1977).

Crop Water Requirement. Depth of water required by a crop for evapotranspiration during a given period (Doorenbos and Pruitt, 1977).

Cumulative. Increasing by continuous additions

Deep Drainage. Water that percolates past the crop root zone and is no longer available to the crop for transpiration.

Delivery Component (DC). The volume of water that a reasonably efficient irrigator needs to extract in excess of the crop water requirement to irrigate and grow the crop to account for application and distribution losses.

Delivery Zones (DZ). Areas of like characteristics within the SE. They were used to calculate delivery components and have been developed using soil mapping data, volume pumped data and other hydrogeological information sources (ie depth to water table, salinity).

Drip Irrigation. High precision irrigation where water is delivered via emitters (drip, trickle, micro-spray) spaced evenly along a supply line, usually located along each crop row.

Evapotranspiration (ET). Rate of water loss through transpiration from vegetation plus evaporation from the soil (Doorenbos and Pruitt, 1977).

FAO 56. Food and Agriculture Organization of the United Nations. FAO Irrigation and Drainage Paper, 56 (1998) - Crop Evapotranspiration; Guidelines for Computing Crop Water Requirements.

Field Irrigation System Trials (FIST Program). Field trial sites equipped with monitoring equipment to collect detailed information on the on-farm irrigation water balance.

Flood / Surface Irrigation. Non-pressurised gravity feed irrigation, whereby water is delivered from the pump via channels to fields constructed to form rectangular bays using parallel check banks. Water flows down the bay's slope as a sheet guided by the check banks.

Full Point. Also known as field capacity, is the wettest drained condition of the soil

haIE. The number of hectares of irrigation equivalents endorsed on an existing area-based water licence.

IRES. A computer program that simulates on-farm water balances.

Irrigation Equivalents (IE's). The current area-based water licensing system shown in hectares, where 1 haIE is equivalent to the evapotranspiration minus contribution by effective precipitation from one hectare of reference crop under the average climatic conditions for that region.

Irrigation Rate (ML/ha). The annual volume pumped for irrigation expressed in Megalitres (ML) divided by the area irrigated in hectares (ha).

Maximum Production Pasture (MPP). A category of pasture that has been recognised as having increased NIRc due to significant changes in pasture management systems.

Megalitre (ML). One ML equal one million litres or one thousand Kilolitres.

Metered Extraction Trials (MET Program). A field trial program aimed at generating accurate 'real-life' volume pumped data representative of irrigation practices in the region.

Net Irrigation Requirement – Crop (NIRC). Net irrigation requirement for a specific crop, grown according to a defined crop calendar, calculated according to the FAO 56 method (Allen et al., 1998).

Net Irrigation Requirement – Reference Crop (NIR_0). Net irrigation requirement for the reference crop, reflecting the evapotranspiration demand at a certain location, according to climatic conditions in that location, calculated according to the FAO 56 method (Allen et al., 1998).

Net Irrigation Requirement (NIR). Depth of water required for meeting evapotranspiration minus contribution by effective precipitation, ground water, stored soil water; does not include operational losses and leaching requirements (Doorenbos and Pruitt, 1977).

Pondage Test. Test performed to quantify seepage losses from irrigation delivery channels.

Readily Available Water (RAW). Amount of water in the soil that can be easily be obtained and used by plants.

Reference Crop Evapotranspiration (ET_0). Rate of evapotranspiration from an extended surface of 8–15 cm tall, green grass cover of uniform height, actively growing, completely shading the ground and not short of water (Doorenbos and Pruitt, 1977).

SILO DataDrill. Continuous interpolated daily climatic data. Queensland Department of Natural Resources and Mines.

Specialised Production Requirements (SPR). (1) Water that is necessarily applied as a part of the crop production process that does not contribute to crop water use and is not included in the delivery component (e.g. to prevent soil drift or to protect against frost damage). (2) Water that is required in addition to base allocation due to significant changes in the crop production system (as recognised by FAO 56). For example Maximum Production Pasture.

Spray Irrigation. Pressurised irrigation systems with water applied through some form of sprinkler/s. Water is delivered from the pump to the sprinkler through pipe works. Includes centre pivots, fixed sprinklers and travelling irrigators.

Transpiration. Rate of water loss through the plant which is regulated by physical and physiological processes (Doorenbos and Pruitt, 1977).

Volumetric Conversion Model. Describes the components and methodologies for the conversion of existing area-based allocations to volumetric allocations.

Volumetric Licensing System. Licensees are entitled to pump a certain volume of water per annum, but are not restricted by the area of crop/s grown.

Water Allocation Plan (WAP). A plan prepared by a Natural Resource Management Board or water resource planning committee and adopted by the Minister in accordance with Division 3 Part 7 of the Water Resources Act 1997.

Total Available Water (TAW). Also know as plant available water, is the amount of water that may be taken up by plants from field capacity (wettest drained condition of the soil) to the permanent wilting point (driest soil condition that plants can tolerate).

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