Appendix 1: Surface Irrigation Project Report (2008)

Project objectives

In 2003, the South East Natural Resources Management Board (SENRMB) initiated the *Irrigation Efficiency Project* for the improvement of irrigation efficiency and management in the South East of SA.

The surface irrigation component of the Irrigation Efficiency Project was tasked with the following objectives **(numbered points indicated those with links to SE NWI Project)**

1) Identify technical and management issues limiting production, profitability and irrigation efficiency associated with surface irrigation on broad area pasture and field crops in the South east of South Australia.

2) Identify those limiting issues that are likely to provide greatest improvement or financial return.

3) Compile known solutions, technologies and management practices to address the limitations.

4) Identify the issues requiring new research.

5) Work with project partners and selected irrigators to develop best practice case study field sites, with a view in subsequent years to utilise information from the sites for training programs and promoting best practice to the broader irrigation community.

- Provide support to the Steering Committee for the SENRMB's Irrigation Efficiency Project.

- Develop a comprehensive irrigation curriculum, manuals and workshops that incorporate findings from field investigations, issues identified during the introductory workshop series, soils, optimum system design and scheduling strategies for the main irrigation systems used in the SE.

Executive Summary

- Evaluations conducted at nine case study sites suggest that surface irrigation systems in the South East operate below desired performance levels and often with great variation from property to property and between individual applications.

- The application efficiency of individual irrigations ranges from approximately 15% to 65%, with site averages ranging from approximately 20% to 55%. These figures are based on 37 field evaluations conducted across all sites and normal operating conditions are believed to be represented.

- A review of literature suggests that for many situations it is possible to design and operate surface irrigation systems that will deliver at least 70% application efficiency. Although it is difficult to develop site specific recommendations without at least some in-field experimentation, such findings provide a useful target for systems in the South East.

- Surface irrigation systems in the South East have primarily been designed to suit labour and cost constraints, with bay dimensions often fitting within established field boundaries. As is common in other regions, system operation has been based around a desired 'shift' time (i.e. 12 or 24 hours). In order to achieve better performance, it is necessary to place greater emphasis on crop water requirements and soil characteristics.

- The primary disadvantage common to all sites is the volume of water 'lost' as deep percolation below the rootzone – tail-water losses are insignificant in comparison. Such losses may have a negative impact on groundwater and are likely to limit productivity and flexibility when operating within the confines of a volumetric allocation. Deep percolation is a result of excessive intake opportunity time, which in itself is related to the time required for water to advance from the upper end to the lower end of a bay.

- The primary factors that determine surface irrigation performance are soil infiltration characteristics, inflow rate, bay length and initial soil moisture content. With the possible exception of bay length, these factors are multidimensional and interrelated (altering one causes change in others) and it is for this reason that predicting the effect of alternative strategies can be difficult. Furthermore, unique site characteristics promote the need to perform in-field experimentation in order to find an optimum combination. In circumstances where soil infiltration characteristics are not conducive to higher efficiencies under surface irrigation, conversion to another irrigation system must be considered

- Water delivery and control structures vary in specification, quality of design and standard of maintenance. Pipe and riser delivery systems appear to be best practice but have not been adopted widely.

- Simulation of irrigations using the model SIRMOD II indicates that reducing bay length is the simplest method for reducing variability and improving application efficiency. For example, decreasing bay length from 535m to 250m at site #5 would decrease the average volume of irrigation water applied from 1.061 to 0.633 ML/ha/irrigation and increase average application efficiency from 38.5% to 64.2%. Higher distribution uniformity is also likely to improve pasture productivity.

- Field measurements revealed that at six of the nine sites monitored slope in the advance direction changes two or three times along the bay. Although levelling has been conducted at all sites the capacity to alter gradient is often limited by shallow soils. Other factors that might influence the quality of the finished surface are cost and earthmoving technique. Previous research into surface irrigation shows that although the degree of slope in the advance direction has only a minor effect on the rate of advance, a uniform surface gradient is important for irrigation recession, uniformity and surface drainage. However, significant improvements to system performance following earthworks (increasing gradient from 0.12% to 0.17%) at site #7a suggests that gradient may be of increasing influence under certain field conditions. Further investigation is required to better understand such interactions and how these gains have been achieved.

- Evidence suggests that, whilst not necessarily reducing the volume of water pumped, increasing inflow can improve system productivity and flexibility. The installation of a second pump at site #1b reduced the time required to complete an irrigation cycle, thus enabling the operator to apply irrigation at closer-to-optimal intervals. This has resulted in higher Lucerne seed yield and less labour demand.

- Inflow, expressed as the volume of water delivered per unit width of bay, may be altered by delivering a different volume of water or changing bay width. Increasing inflow to reduce advance time therefore requires increased delivery, reduced bay width or a combination of both. The extent to which these factors can be modified may be limited by the practical requirements of the production system (i.e. operation of machinery), supply capacity (size or number of bores) and risk of soil erosion. Another important consideration is that of irrigation management; optimum efficiency requires accurate cut-off and this may be more difficult to achieve at higher inflow.

- At present, automated irrigation management appears to have only limited benefit to system performance. Timer-controlled bay gates are used at two properties in this project and, although of different designs, both require the operator to estimate likely start and cut-off times – the accuracy of which may vary considerably. As such, these are considered semi-automatic irrigation controls. Completely automated systems require real-time measurement of soil moisture, irrigation advance and control of outlets (gate or riser) via telemetry. Furthermore, to achieve greater benefits from automation these components must be integrated into a well designed field.

- Amongst site managers irrigation scheduling is largely based on operator experience with little to no application of soil water monitoring tools. Furthermore the opportunity for irrigation scheduling is often limited by the time required to irrigate. This is common across many irrigation districts in Australia. Evidence from field sites in the South East (DWLBC) shows that surface irrigators tend to run crops and pasture (unintentionally) into moisture deficit for significant periods of time. There are many reasons as to why this might occur; however the result is increased plant stress and reduced productivity.

- Adoption of soil water monitoring tools and improved scheduling is also likely to yield more consistent irrigation application. Soil moisture status prior to irrigation influences infiltration during irrigation and therefore attention to antecedent moisture content is required. It has been shown that higher antecedent moisture levels generally result in lower initial infiltration rates (Furman et al, 2006). No system can deliver acceptable application efficiency if soils (cracking soils in particular) are allowed to become too dry.

- Greater emphasis on purpose of irrigation and strategy is required for most production systems, for productivity will suffer if: scheduling is ad-hoc, the target area is not determined prior to the irrigation season or is beyond the capacity of the system and production goals are not defined.

Table 2: Summary of simulations for evaluations performed at case study sites giving averages (and ranges in brackets) for three performance measures

	Application Efficiency (%)	Distribution Uniformity (%)	Application Rate (ML/ha)
Site #1a	**30.8** (26.9 - 39.4)	**57.7** (38.8 - 77.5)	**2.556** (2.031 - 2.873)
Site #1b	**22.1** (16.9 - 24.9)	**42.2** (37.7 - 47.9)	**3.380** (2.715 - 4.271)
Site #3	**54.2** (53.3 - 55.2)	**96.5** (93.6 - 99.3)	**1.108** (1.088 - 1.127)
Site #4	**24.9** (11.8 - 48.9)	**76.5** (64.5 - 90.6)	**2.639** (1.022 - 4.253)
Site #5	**38.5** (30.3 - 46.3)	**79.9** (58.2 - 93)	**1.061** (0.864 - 1.301)
Site #6	**19.9** (15.45 - 23.6)	**66.5** (59.1 - 74)	**3.105** (2.547 - 3.885)
Site #7a	**54.3** (38.6 - 62.5)	**93.9** (87.9 - 99.5)	**1.148** (0.961 - 1.554)
Site #7b	**31.5** (25.2 - 34.8)	**85.5** (79.6 - 92.2)	**1.912** (1.725 - 2.382)

Areas for Further Study

- Due to case study sites operating as businesses there has been limited scope to study significant system modification without risking some productive loss. Further in-field experimentation is required with allowance for a trial and error approach to define best practice, for:

    - A relationship between antecedent moisture content and irrigation performance has been identified; now techniques and tools for the determination of optimum irrigation scheduling strategies need to be developed. This may assist the implementation of automatic irrigation control components.

    - Whilst INFILT has been shown to be the most accurate and reliable method for determining infiltration parameters (Khatri and Smith, 2005) and SIRMOD has been shown to accurately simulate a wide variety of irrigation events, when investigating alternative management strategies it is important to consider the relationship between these models. Parameters derived in INFILT refer to site and event specific field conditions (Furman et al, 2006) and may not be appropriate for use in SIRMOD when making large modifications to other factors – particularly inflow.

    - The development of specific rules for the management of surface irrigation is compromised by the substantial variation in the infiltration characteristics of soils across field and throughout the irrigation season. The multidimensional effect of field and management parameters on performance requires a design approach that demonstrates these interactions and includes the effect of infiltration variability (Raine et al, 1997).

    - Raine and Smith (1996) observed that “a major obstacle to the adoption of new technologies is recognition by the farmer of the benefits associated with implementation. It requires that the full impact of adopting alternative practices is assessed prior to large scale implementation.” This implies that in addition to field experimentation, cost-benefit analyses need to be conducted to evaluate any proposed alternative irrigation strategies.

- More sophisticated irrigation management regimes should be trialled to determine suitability to soils in the South East. Surge flow irrigation in particular is thought to offer better irrigation performance and increased flexibility for existing systems on a range of soils. Advocates of surge irrigation identify advantages in three broad categories:

    - For a given inflow, the irrigation advance rate under surge flow is comparable to, if not faster than, the rate achieved for continuous flow. However uniformity during the advance phase is improved as a smaller volume of water is required to achieve the same rate of advance.

    - Deep percolation and tail-water losses can be reduced and application efficiencies improved using proper automated management.

    - Surge irrigation provides an inexpensive means of automating, managing and accurately controlling irrigation whilst reducing demands on labour.

    Essentially a method of applying water to the field in a series of intermittent surges, rather than a continuous stream, surge flow management comprises an *advance* phase and a *cutback* phase. The purpose of alternate filling and emptying of the field is to quickly lower soil infiltration, reduce percolation depth and smooth the soil surface. These changes in soil condition enable more efficient water use in the cutback phase. Following is an example of how surge flow might work in the field.

1) Cycle time, the time for one complete on/off cycle, in the advance phase is relatively long – typically more than 30 minutes. As such water is in the field for 30 minutes, out for 30 minutes and then returned for 30 minutes. This process is repeated until water reaches the end of the bay. During this phase inflow must not return until all of the water from the previous surge has disappeared, otherwise the full benefits will not be realised.

2) Cycle time in the cutback phase is shortened and water will be in the bay at all times until the end of irrigation. The cutback phase ensures that the average flow rate is approximately half that of a conventional continuous application.

The intensive inflow management required for surface irrigation is the reason for recommending system automation and therefore in-field trials of automated management tools should be pursued.