

IMPROVING EFFICIENCY OF WATER STORAGES AND WATER SUPPLY SYSTEMS

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Introduction

Water for irrigation is the limiting resource for cotton production in Australia. While this has been recognised by the cotton industry for at least the last twenty years, the Australian Water Reform Agenda of the last five to ten years has heightened the importance of high water use efficiency. Cotton growers in New South Wales and Queensland have suffered a significant reduction in water allocation from both surface and groundwater resources since the mid 1990s.

Both the research and commercial sectors of the industry have increased focus on water use efficiency issues in the last five to ten years but significantly more needs to be done. Storage and conveyance of water from government and private scheme to the farm gate, storage and conveyance on-farm, application of irrigation and the return and storage of tailwater all need to minimise losses. Fortunately with defined water allocation security, improvements in efficiency should result in increased production per megalitre for the irrigator along with improved environmental performance.

Water Use Efficiency – What Does it Mean

Evaluation and benchmarking of irrigation performance is a fundamental step towards improving and maintaining that performance. To be able to evaluate and monitor performance over a range of crops and regions, it is first necessary to agree on an Australian:

- framework, terms and definitions for water use efficiency in irrigation,
- set of measurement protocols, and
- set of accepted methods for data interpretation and presentation.

This was recognised by Land and Water Australia (LWA) in early 1999 who commissioned a project “Gaining Acceptance of Water Use Efficiency Framework, Terms and Definitions”. The final report by Aquatech Consulting and Naturally Resourceful of May 2003, (Aquatech, 2003) details the adopted terms and the process of gaining national acceptance.

Water use is one of many irrigation performance indicators as shown on Figure 1 and water use performance is described as a series of water use indices as follows:

Gross Production Water Use Index	=	$\frac{\text{Total Product (kg)}}{\text{Total Water Applied (ML)}}$
Irrigation Water Use Index (Applied)	=	$\frac{\text{Total Product (kg)}}{\text{Irrigation Water Applied (ML)}}$
Marginal Irrigation Water Use Index (Applied)	=	$\frac{\text{Marginal Production due to Irrigation (kg)}}{\text{Irrigation Water Applied (ML)}}$
Crop Water Use Index	=	$\frac{\text{Total Product (kg)}}{\text{Evapotranspiration (mm)}}$
Gross Production Economic Water Use Index (Applied)	=	$\frac{\text{Gross Production (\$)}}{\text{Total Water Applied (ML)}}$
Irrigation Economic Water Use Index (Applied)	=	$\frac{\text{Gross Production (\$)}}{\text{Irrigation Water Applied (ML)}}$
Marginal Irrigation Economic Water Use Index (Applied)	=	$\frac{\text{Marginal Production due to Irrigation (\$)}}{\text{Irrigation Water Applied (ML)}}$
Crop Economic Water Use Index	=	$\frac{\text{Gross Production (\$)}}{\text{Evapotranspiration (mm)}}$
Irrigation Water Use Index (Farm Gate)	=	$\frac{\text{Total Product (kg)}}{\text{Irrigation Water Supplied to Farm Gate (ML)}}$
etc.		
etc.		
etc.		

Note – All indices should be clearly defined with units specified. “Applied” means volume of water applied to the field where “Farm Gate” means volume of water supplied to the farm gate.

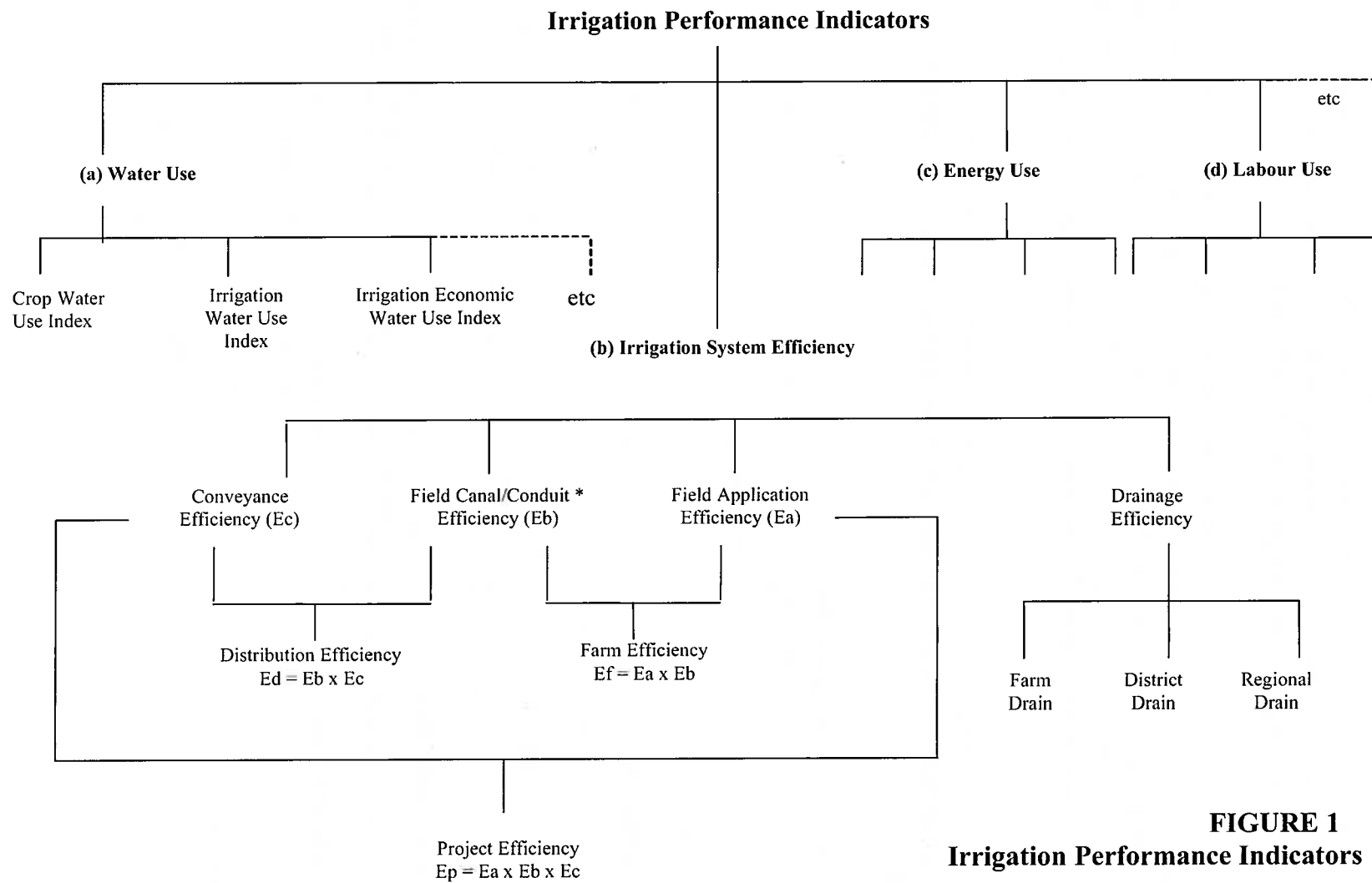


FIGURE 1
Irrigation Performance Indicators

The term Water Use Efficiency (WUE) no longer has a specific meaning but should be used as a generic label for any performance indicators used to describe water use in crop production. The label, WUE need not be defined but should be considered like a label on a toolbox. Inside the toolbox are many specific performance indicators called Water Use Indices.

Another irrigation performance indicator is Irrigation System Efficiency which is a defined volumetric efficiency. Unfortunately there is an overabundance of “recognised” definitions. LWA adopted the definitions shown in **Table 1** which are based on the definitions used by the Food and Agricultural Organisation of the United Nations (FAO 1977). **Figure 2** details a generalised irrigation scheme layout which shows the use of the various elements of the irrigation efficiency terms.

To avoid unnecessary confusion even when using the adopted terms and definitions, it is essential to clearly define all water use indices with units and the elements described in irrigation efficiency definitions.

Table 1 Adopted Irrigation Efficiency Definitions

Term	Definition
⁽¹⁾ Overall Project Efficiency (E_p)	<u>Irrigation water available to the crop</u> Water released at project headworks
⁽²⁾ Conveyance Efficiency (E_c)	<u>Water received at the inlet to a block of fields (Farm)</u> Water released at project headworks
⁽³⁾ Field Canal/Conduit Efficiency (E_b)	<u>Water received at field inlet</u> Water received at the inlet to a block of fields (Farm)
Field Application Efficiency (E_a)	<u>Irrigation water available to the crop</u> Water received at field inlet
⁽⁴⁾ Drain Efficiency	<u>Water leaving drain</u> Water entering drain

⁽¹⁾ These definitions allow a “nested” approach for a particular irrigation event (assuming no rainfall or unregulated flow into the supply system) as follows:

$$\begin{array}{cccc} \text{Conveyance} & \times & \text{Field Canal/Conduit} & \times & \text{Field Application} & = & \text{Overall Project} \\ \text{Efficiency} & & \text{Efficiency} & & \text{Efficiency} & & \text{Efficiency} \\ (E_c) & & (E_b) & & (E_a) & & (E_p) \end{array}$$

Similarly, the product of Conveyance Efficiency and Field Canal/Conduit Efficiency is called **Distribution Efficiency (E_d)**

$$E_c \times E_b = E_d,$$

and the product of the Field Canal/Conduit Efficiency and Application Efficiency is called **Farm Efficiency (E_f)**

$$E_b \times E_a = E_f \quad (\text{see Figure 1}).$$

⁽²⁾ Conveyance efficiency can be broken up into a number of sub-sets depending on the system involved eg headworks conveyance efficiency, district main supply canal conveyance efficiency, district sub-branch canal conveyance efficiency, etc (see **Figure 2**).

⁽³⁾ The **conduit** term has been added to the original FAO definition in recognition that irrigation water can be supplied by either canals or pipes.

⁽⁴⁾ Drainage efficiency has been added to the original FAO definitions.

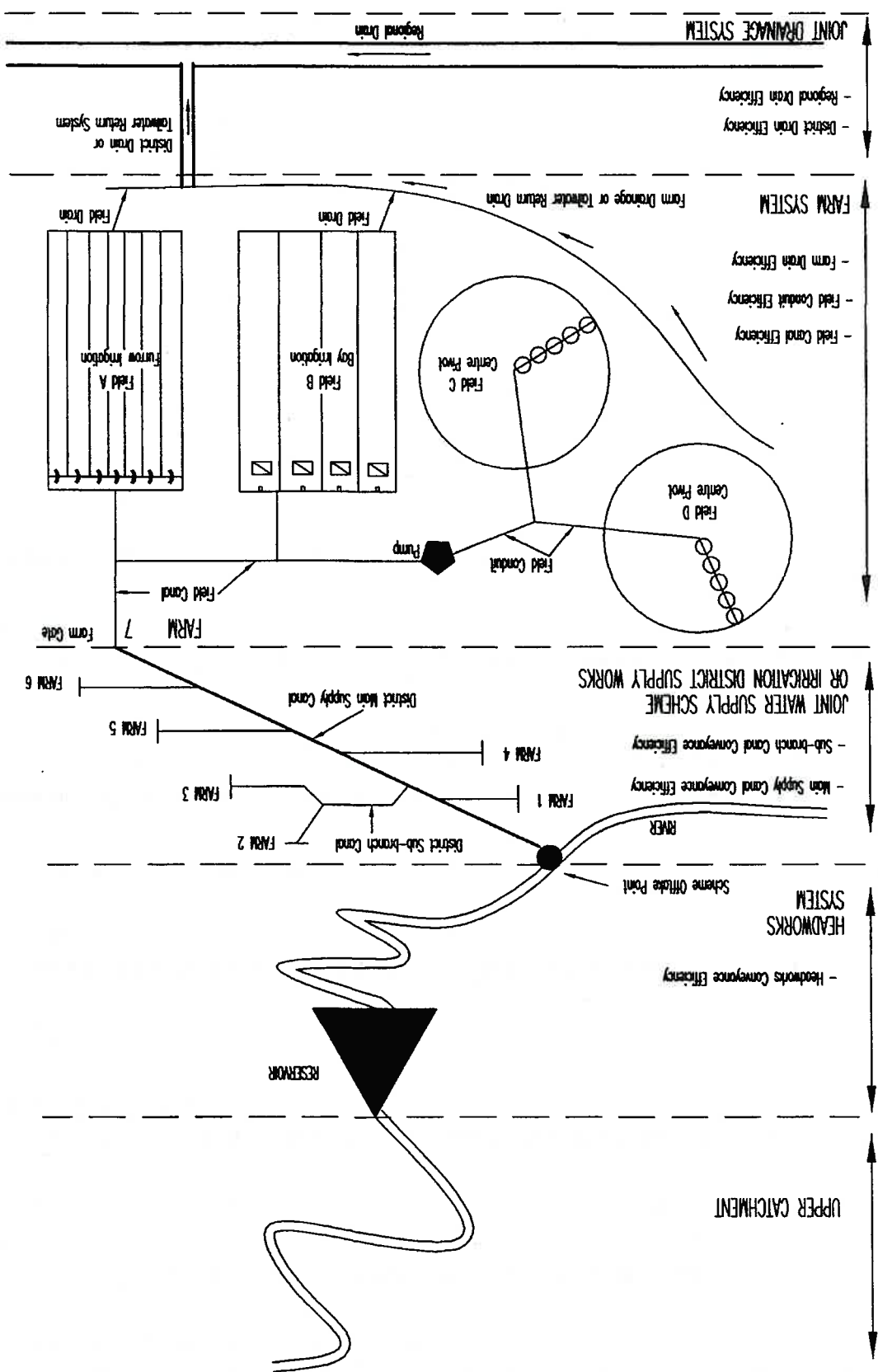


Figure 2 Generalised Irrigation Scheme Layout

It is also very important to define spatial and temporal boundaries when describing a water use index or an irrigation efficiency.

Improvement of water use efficiency is an integrated process requiring:

- (i.) reduction in system losses in the irrigation system at all levels,
- (ii.) conservation of soil moisture,
- (iii.) optimisation of crop yield,
- (iv.) reduction in crop growing costs, and
- (v.) maximum beneficial use of rainfall.

Water Losses on an Irrigation Farm

An understanding of the location and process of water losses on an irrigation farm is essential to the reduction of those losses and the improvement of WUE. While this discussion is confined to the irrigation farm, losses from headworks storages, scheme supply canals and drains follow the same principles.

Each element of a typical irrigation farm can be studied in isolation to discuss the process and reduction of losses. In the bigger picture, however, often one man's loss is another's gain. For example, seepage losses from a canal and storage could find its way into a stream or drain and become supply water to a downstream user.

Canal and Drains

Earthen canals provide cheap and efficient conveyance if the natural clay soils are available which have very low saturated permeability. For instance, an earthen canal capable of running 150 megalitres per day (ML/day) would consist of a 1.0 metre (m) water depth with a 3.0m wide bed and bed slope of 1 in 5,000. The canal would cost around \$8 - \$10/metre length to construct. To convey the same flow in a pipe would require a pressure pipe of around 1200 millimetre (mm) diameter costing around \$1,400/m length installed.

Open earthen canals, however, lose water by evaporation and seepage. Dalton (2000) detailed results of several authors on seepage losses including Worstell (1976), Withers and Vipond (1980), Burt (1995) and McLeod et al (1994). A useful summary of typical seepage losses in canals is provided by Withers and Vipond (1980) and is shown in **Table 2**. McLeod et al (1994) measured seepage losses of between 14 and 34 mm/day in the large Tatura East Channel and between 5 and 9 mm/day in the Dhurringle Channel. Dalton (2000) measured losses from supply canals and drains on seven farms in the Macintyre Valley between 1998 and 2000. Seepage losses ranged from 1 to 20 mm/day representing losses of between 9 and 14%.

Table 2 Typical Canal Seepage Losses.

Soil Type	Seepage Losses (m ³ /m ² /day)
Impervious clay loam	0.07 – 0.10
Medium clay loam, impervious layer below channel bottom not exceeding 900 mm in depth	0.10 – 0.15
Clay loam, silty soil	0.15 – 0.23
Clay loam with gravel, sandy clay loam, gravel cemented with clay particles	0.23 - .030
Sandy loam	0.30 – 0.45
Sandy soil	0.45 – 0.55
Sandy soil with gravel	0.55 – 0.75
Pervious gravelly soil	0.75 – 0.90
Gravel with some earth	0.90 – 1.80

(Taken from Withers and Vipond)

Typically seepage losses from canals in clay and silty clays are low at less than 0.3 m³/m²/day. Most often isolated sections of canals can have high seepage losses where the canal passes through or over a permeable section of material like a prior streambed or sandy gravel layer. Repair of these isolated sections, once identified, offer large water savings.

Evaporation losses from canals is difficult to measure directly and total losses include seepage which can vary significantly. Estimates of evaporation from a free water surface was established by Penman (1948) as approximately 80% of the evaporation from a US Class A Evaporation Pan. Fortunately Class A evaporation information is available for many official weather stations but unfortunately evaporation pans are subject to significant errors if not maintained well and the Penman relationship does not appear to be recently validated.

Even very accurate measurement of total losses from canals and storages cannot provide delineation between evaporation and seepage. Often seepage losses are less than the error in estimating evaporation. Relative losses between different reaches of the same canal which have the same evaporation is a practical method of comparing seepage. New decision support tools discussed later can also be used.

Storage

Losses from on-farm storages (ring tank and gully dams) can be very substantial and difficult to reduce. Like open earthen canals and drains storages will lose water from seepage and evaporation. Because of the scale of large ring tanks the potential losses are significantly higher. For example, a 2,600 ML ring tank with a square shape storing 4 m of water offers an area of around 800 x 800 m or 64 ha of storage area. If that storage had some water in it for nine months (270 days) and was

constructed in reasonable clay soils, it would be likely that seepage losses ($0.25 \text{ m}^3/\text{m}^2/\text{day}$) could be around 160 ML and evaporation losses around 1,100 ML or a total loss of 1,260 ML. These losses are irrespective of whether 2,000 ML or 8,000 ML were run through the storage over that time.

Losses from storages can therefore be very significant. Attention to shape, depth, available soils and management can provide significant savings. For instance, the same ring tank with 8 m of water depth would cover an area of 570 x 570 m or 32.5 ha and losses from evaporation would halve and seepage losses nearly halve assuming slightly higher seepage from the higher head on the soil. Savings of around 620 ML might be expected.

Dalton (2000) determined the performance of four ring tank storages in the Macintyre Valley by monitoring storage water level, evaporation pans and rainfall on a continuous basis with results logged at 15 minute intervals. Reliable seepage estimates from a water balance approach were made during the non irrigation season when no water was taken in or out of the storage. Efficiency estimates for these storages are detailed in **Table 3**. The three main factors affecting the storage efficiency shown in **Table 3** are storage period, surface area and total water stored. The surface area (shape and depth) is the only variable which can be controlled. Inflow volumes and timing are controlled by nature.

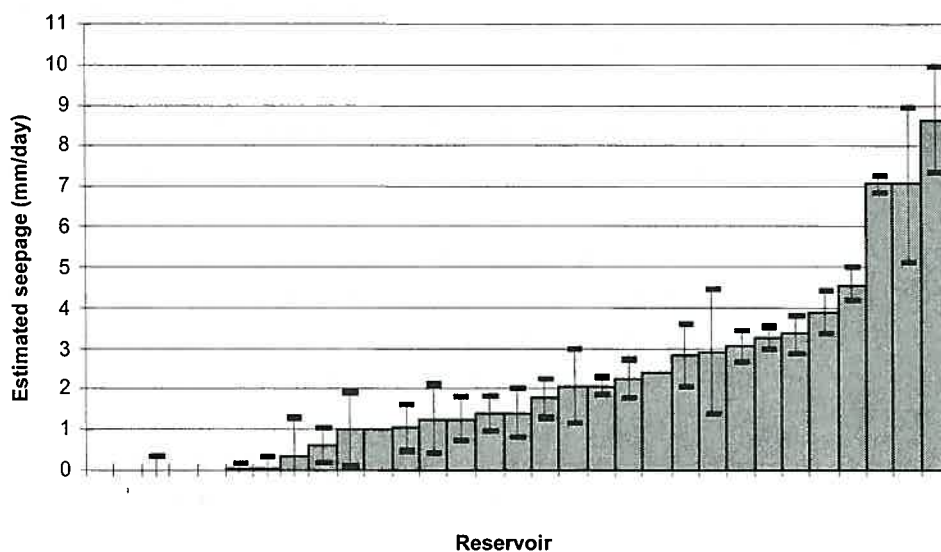
Table 3 Storage Volume Balance, Efficiency and Losses by Volume and Percentage.

Storage Description	Storage Period	Stored Water	Used	Seepage	Evaporation	Storage Efficiency
Farm A 4m max depth 1800 ML	27/11/98 to 28/12/98 (31 days)	1272 ML	1082 ML (85%)	14 ML (1.1%)	177 ML (13.9%)	85%
Farm A 4m max depth 2500 ML	27/11/98 to 5/7/99 (222 days)	2388 ML	1313 ML (55%)	255 ML (10.6%)	930 ML (39%)	55%
Farm B 3m max depth 500 ML	2/12/98 to 5/5/99 (154 days)	729 ML	581 ML (79.7%)	34 ML (4.7%)	121 ML (16.6%)	79.7%
Farm E 4m max depth 1800 ML	13/8/99 to 16/2/2000 (187 days)	3649 ML	2776 ML (76.1%)	180 ML (4.9%)	701 ML (19.2%)	76.1%

Taken from Dalton (2002)

The results of an independent evaluation of seepage in 26 storages in the Macquarie Valley by Pat Hulme, Sustainable Soils Management, Warren NSW, in the mid 1990s (pers com) is presented in **Figure 3**. All but four of the storages had seepage less than 4 mm/day and 18 had less than 3 mm/day. The worst 2 – 3 storages are now out of service and others have had significant reconstruction and lining works completed.

Figure 3 Estimated Seepage from Storages in the Macquarie Valley



Provided by Pat Hulme

Accurate water loss measurements are required on existing storages to establish whether seepage is a problem.

Irrigation application

Efficient irrigation by any means: surface, sprinkler or drip, requires an understanding of:

- the soil moisture deficit of the root zone,
- the infiltration characteristics of the soil profile, and
- careful management of the irrigation application.

Measurement of the amount of water applied to a field with sprinkler or drip irrigation through pipes is a relatively straight forward task. Measurement of the depth and distribution of water applied by surface irrigation is a much more challenging task.

Work by Raine (1995) in the Burdekin, Qld, Swann et al (2002) in the Macquarie Valley and the development of the Irrimate™ surface irrigation evaluation package by the National Centre for Engineering in Agriculture, Toowoomba has now meant that commercial measurement of surface irrigation application can be made. Measurement of total water on and off a field will provide an average depth of application and measurement of flows on to selected 8 m wide sections of a field along with field slope and lengths and water advance rates allow calculation of detailed depths of application down the field. If the soil moisture deficit is known, a comparison between the depth of application and soil moisture deficit can be made. It is therefore now possible to determine commercially the irrigation field application efficiency and the uniformity of distribution of the application.

Losses during surface irrigation application can occur from:

- evaporation from the soil surface during irrigation,
- deep drainage through the soil profile past the root zone, and
- irrigation tailwater either directly off-farm (rare now) or from seepage and evaporation of tailwater during re-circulation and storage.

Evaporation directly from the free water surface during furrow irrigation can be calculated knowing the water surface width and rate of advance down the furrow. Similar to the estimation of evaporation from a free water surface like a storage, a factor times the US Class A Evaporation Pan reading can be made. In the absence of detailed research, a figure of 1.1 x Class A pan for a shallow furrow stream on hot soil would seem appropriate. On this basis evaporation from the furrow stream during a typical irrigation event represents around 2% of the infiltrated volume or 2 to 3 mm of the infiltrated depth. While the basis of this calculation requires validation the magnitude of the loss appears small and would be even less when full crop canopy was established.

Deep drainage from over irrigation represents a larger potential loss. Humphreys and Edraki (2003) presented a review of field investigations of components of the water balance of irrigated pastures and broadacre crops in Australia. **Table 4** details a summary of studies for cotton. These results indicate a range of deep drainage from nil to 236 mm per season.

Commercial measurement of 55 irrigation applications on 17 farms in the Narrabri / Moree area by Aquatech Consulting from the 2000/01 to 2003/04 seasons indicate irrigation applications, on average, of around 0.15 ML/ha/irrigation greater than the measured soil moisture deficit. Ignoring deep drainage from heavy rain and assuming six irrigations per season, this totals a deep drainage potential of around 90 mm per season. Most of the over irrigation measured occurred in the top one third to half of the field. In nearly all cases this over irrigation was almost eliminated by increasing furrow flow rates and decreasing irrigation set times from 12 – 14 hours to 6 – 8 hours.

The biggest potential for reducing losses in irrigation field application appears to be the reduction of over watering by changing irrigation practices. Reductions of the order of 100 mm per season over six irrigations may be possible.

Table 4 Results of Determinations of Components of the water Balance – Field Studies - COTTON

REFIRR ID	Location (nearest town)	Soil		Layout	Watertable		Irrigation		Rain R (mm)	Surface Drainage SD (mm)	Net deep drainage (-ve = upflow)			ET		Source
		Local Name	Type		Depth (m)	Salinity (dS/m)	Method	Amount (mm)			Method	Amount (mm)	Depth (m)	Method	Amount (mm)	
224	Narrabri NSW		Cracking grey clay	1m x 1000m beds			Furrow – 1975/6 1976/7	No. 1 154 ^A 2 247 ^A 3 302 ^A 1 132 ^A 2 298 ^A 2 277 ^A 3 389 ^A 4 443 ^A infiltration	550 550 550 502 502 502 502 502	5 138 190 27 120 90 158 170	Hydraulic conductivity soil water relationship	Negligible upflow in all treatments		R+change in SWC-SD	704 659 662 607 680 689 743 775	Cull et al. 1981
147	Moree NSW		Cracking grey clay (Gwydir) Red loam (Gwydir) Cracking grey clay (Namoi)	1m x 1000m beds			Furrow	397 342 176	161 19 0	139 34 9	Water balance DD=I+R-ET-SD -change in SWC (for 3-6 days during & after irrig)	158 53 3	1	Change in SWC		Silburn and Montgomery 2001
149	Lower Macquarie Valley NSW	Mullah Wilga	Cracking grey clay Red brown earth	2m x 859 m beds 2m x 576 m beds	-2 m		Furrow Furrow	378 ^A infiltration 502 ^A infiltration	328 ^B 335 ^C		Water bal Cl mass bal Darcy Water bal Cl mass bal	236 214 67 145 104	2 2 1.05,2 2 2	Kc x Modified Penman	542 585	Willis et al 1997
151	Narrabri NSW		Cracking grey clay	16 rows x 200 m 4 years			Furrow Surface drip Subsurt drip	89-485 ^A 122-616 149-585								Chan and Hodgson 1981
138	Griffith NSW	Wunnamurra clay Hanwood loam	Cracking grey clay Red brown earth	8 m x 35 m plots beds >8 m x 35 m plots beds	-1.5? 1.8		Furrow Furrow				ET-change in SWC	32-42% crop water use from upflow 5-11% crop water use from upflow	1 1	Kc x modified Penman		Mason et al 1983
222	Dubbo NSW	Mullah clay Mitchell Poorly Drained Wilga Non Calcic Macquarie	Uniform heavy clay Duplex, heavy B Duplex, light B Uniform silty loam	Point samples in paired sites with history of cleared dryland use or irrigated cotton			Furrow-farmer records of number of irrigations, and assumed 100 mm/irrigation				Chloride mass balance	17 45 131 202				Willis and Black 1996
225	Meralh Nth NSW		Grey self mulching clay -67% clay & sodic	Cotton-cotton Cotton-wheat Cotton-dolichos							Cl mass bal	98 76 19				Weaver et al 2002

^A amount infiltrated based on measured change in soil water content using neutron counts

^B rain during Oct-Dec (after first irrigation) was 272 mm, approx double the long term average of 121 mm

^C rain during Oct-Dec (after first irrigation was 236 mm, approx double the long term average of 121 mm

Taken from Humphries and Edraki (2003)

Decision Support Tools for Improving Water Use Efficiency

Canal and Drains

Accurate measurement of total water loss in a ponded canal or drain during no flow and very low evaporation offers the most reliable method of estimating seepage losses. Very accurate pressure sensors with sub-millimetre accuracy linked to data loggers on real time is one method which holds promise.

By comparing the total losses during the middle of the night with those during daylight, an estimate of seepage, evaporation and total losses can be made. Work currently being completed by the National Centre for Engineering in Agriculture (NCEA), Toowoomba, "Controlling Evaporation From Water Storages" funded by the Queensland Department of Natural Resources and Mines (Craig & Hancock 2004) should result in commercial equipment and measurement protocols for this purpose.

Often seepage losses in canals will occur in isolated areas of high permeability. Recent work with electromagnetic (EM) survey of soils has resulted in the identification of areas of high permeability. An EM31 instrument measures average conductivity of the soil to a depth of 6 m. Changes in apparent conductivity from an EM Survey of the soil can result from:

- (i.) the porosity of the soil,
- (ii.) soil moisture,
- (iii.) the salinity of the soil and / or soil moisture,
- (iv.) temperature,
- (v.) the clay content of the soil, and
- (vi.) the type and amount of organic matter in the soil.

An EM survey that shows an area of significantly different conductivity can indicate areas of high permeability. A pondage test of total water lost in that area compared to other sections of the canal can quickly confirm if seepage is occurring.

Once an area of high permeability has been identified, backhoe pits offer the best method of determining the cause of the seepage. Over-excavation and lining with compacted natural clays close to the area still offers the most economic solution to reduce seepage.

Storages

The same tools and measurement procedures apply to identifying seepage from storages as canals. Again seepage from storages often occur in isolated areas of high permeability. Aerial photos, EM surveys and backhoe pit investigation still offer the best means of locating and investigating potential

seepage areas. Like leaking canals, clay lining with compacted moist natural clays generally offers the most economic solution to leaking areas.

Reducing evaporation from storages offers the largest potential saving in water on an irrigated cotton farm. Current research by NCEA is evaluating:

- floating bubble wrap covers,
- webbed shade structures supported by cables and wooden poles,
- monolayers spread onto the water surface, and
- individual small weighted floats.

Each method is being evaluated for effectiveness in reducing evaporation and the construction / installation and maintenance costs are being determined. The result should be an economic assessment of the cost / benefit.

Regardless of the outcome of this project, a number of established criteria can be employed to reduce evaporation and seepage losses from storages:

- reduce the storage area by building square or circular ring tanks and using larger water depths (8 m high banks are possible in good soils with proper construction),
- complete a full soils investigation of the site before construction starts including EM surveys and backhoe pits (use only qualified and experienced engineers or soil scientists),
- compact the central core of the embankment and consider compaction of the floor in some cases to reduce infiltration and seepage,
- do not store water in several storages partially full (pumping costs are small compared to loss of water and therefore production),
- consider a small deep section of the storage for storage of water between seasons,
- consider treelines and windbreaks around the storage (but not on or within one tree height of the embankment) to reduce evaporation,
- do not position the storage on the worst soils on the farm because that area does not grow much anyway,
- complete a water balance of the farm over the last 50 – 100 years based on modified historical water availability, green area, delivery rate onto the farm, stormwater harvesting capability, rainfall and evaporation (only build a storage as large as can be economically used).

Finally, measurement of the water levels in the storage regularly if not continuously allows calculation of the losses. This information will allow the determination of the cost / benefit of changes to the storage or management of it.

Irrigation Application

The cotton industry was very quick to adopt soil moisture monitoring to determine the optimum timing of irrigation. The next step for most is to determine the correct amount of irrigation to apply and how to adjust traditional irrigation practices to apply only that amount.

This process has adopted the name of “precision irrigation” and will become routine if water losses in field application are to be reduced. Work by Raine (1995), Dalton (2000), Swann (2002) and commercial work by Aquatech Consulting and others with the Irrimate™ surface evaluation system over the last four cotton seasons have shown that around 0.15ML/ha/irrigation can be saved by modifying irrigation practices.

By measuring:

- the soil moisture deficit before irrigation,
- flows on and off the field,
- or flow onto the field and furrow advance rates and field details (slope lengths and furrow shape),

it is possible to optimise furrow flow rates and irrigation set times to apply very close to the soil moisture deficit. In some isolated cases with very long fields or very flat fields some infrastructure changes may be required. Some irrigators using this service have also enlarged headditches to gain more head on siphons and some have gone to larger siphons or “doubled-up” to two siphons per furrow.

Irrigation System Losses and Water Quality

Impacts of Losses

Evaporation losses from an irrigation system are a loss to production and must be minimised. Evaporation, however, does not have significant direct environmental impacts. Seepage from canals, drains and storages and deep drainage below the root zone in irrigation fields are not only a loss to production but also can have environmental impacts at farm, catchment and regional levels.

The nature and severity of potential environmental impacts depends not only on the magnitude of the losses but the landscape and soil profile. A shallow watertable will mean impacts will be noticed quickly. A shallow watertable with poor water quality or a sub-soil with a high concentration of dissolved minerals means the impacts will be relatively quick and relatively severe. An understanding of the landscape and soil profile is essential to predicting likely impacts and how severe they may be.

A deep soil profile with good quality groundwater is a desirable situation and so is a well drained sub-soil that allows seepage and deep drainage to drain to a river or groundwater system. Regardless

of the landscape, seepage and deep drainage must be minimised and any impacts monitored and managed as early as possible.

The cotton industry is very fortunate to be concentrated in areas generally with good quality deep soils with deep good quality watertables. There are, however, isolated areas where seepage from storages and canals has already caused loss in production from water logged and saline soils. Of particular concern are areas on the Darling and Macquarie where the soils are lighter, watertables are shallower and sub-soils have higher concentrations of minerals and salts from the formation of the landscape.

Water Quality

Increasing the level of the watertable by seepage or deep drainage and reactivating previously leached minerals and salts is a well documented problem in both irrigation and dryland areas in Australia.

Irrigating with poor quality water or allowing nutrients and chemicals to percolate into the soil profile is also a well known problem which at the least can provide a store of minerals etc in the sub-soil with future problems or at worst can directly impact on groundwater and surface water and soil quality.

The potential impacts of seepage and deep drainage are significant but can be managed if the processes are understood and impacts monitored. Minimising the losses is vital to managing the impacts and maximising production.

It should also be noted that some deep drainage is necessary in the crop root zone to leach through minerals to prevent a build up within the root zone. The most effective and least cost leaching can occur from rainfall and flooding.

References:

- Aquatech Consulting Pty Ltd in conjunction with Naturally Resourceful (2003). *Gaining Acceptance of Water Use Efficiency Framework, Terms and Definitions* Final Project Report – Stage II, May 2003. Land and Water Australia
- Burt CM (1995). *The Surface Irrigation Manual*. Waterman Industries, Exeter, California.
- Craig I and Hancock N (2004). *Methods for Assessing Dam Evaporation – Introductory Paper*. Proceedings Irrigation Association of Australia National Conference, Adelaide 2004
- Dalton P (2000). *Water Tight: Whole Farm Water Use Efficiency – Determining your own Water Security*. Proceeding 10th Australian Cotton Conference. ACGRA, Brisbane, pp 395 – 413
- Doorenbos J and Pruitt WO (1977). *Crop and Water Requirements*. Food and Agricultural Organisation of the United Nations – Irrigation and Drainage Paper 24: 79 – 82
- McLeod AJ, Earl GC, McMahan TA and Moore PJ (1994a). *Measurement of Irrigation Channel Seepage in Northern Victoria*. Proceedings of Water Down Under Conference. November, Adelaide.
- Penman HL (1948). *Natural Evaporation from Open Water, Bare Soil and Grass*. Proceedings of Royal Society. Ser A, Vol 193. London.
- Raine SR (1995). *Increasing the Efficiency of Furrow Irrigation for Sugar Cane Production in the Burdekin*. Proceedings of the 12th Irrigation Association of Australia National Conference 15 – 17 May, Tamworth.
- Swann B, et al (2002). *Furrow Irrigation Evaluation in the Lower Macquarie Valley*. Proceedings of the Australian Conference on Engineering in Agriculture September, 2002. Wagga Wagga.
- Withers B and Vipond S (1980). *Irrigation: Design and Practice*. Batsford Academic and Educational Limited. London.
- Worstell RV (1976). *Estimating Seepage Losses from Canal Systems*. Journal of Irrigation and Drainage. Div. ASCE 102 : 137 – 147