FINAL REPORT

LWRRDC Project ref: MIL1

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Research Organisation : Murray Irrigation Ltd.

Project Title : Improving hydraulic efficiency of irrigation and drainage systems through benchmarking

Sponsors: Jointly funded by Murray Irrigation Ltd and LWRRDC.

Date Prepared: September 2001

Project Objectives

(1) To develop a practical set of hydraulic performance indicators for a gravity fed irrigation system which could be applied nationally and internationally;

(2) To evaluate the economic benefits of the hydraulic performance indicators;

(3) To evaluate different options to improve hydraulic performance;

(4) To develop incentives to encourage both water managers and irrigators to achieve optimum irrigation and drainage efficiency and minimise impacts on streams and aquifers.

Background:

The project area is supplied by one channel, Mulwala 20, which diverts water from the main supply channel the Mulwala canal. All performance indicators pertain to this channel system and do not take into account the performance of the main supply channel carrying the water to the project area.

During the initial data collection period, year 1 of the project, it was apparent that historic water use data was inaccurate and unreliable. Equipment was installed and calibrated over the following years and the early data was adjusted to ensure consistency throughout the project.

The project was initially to be completed in September 2000 but was extended for one more year because in September 1999 the allocation of water to the project area was zero. The allocation rose to 29% during the season allowing further data collection, which has been included in the project results.

Over the course of the project, weather conditions were indicative of dry seasons. Consequently, drainage from farms was non-existent throughout this period.

Methods:

The first task undertaken was to install equipment to control and measure the water in the project channel to ensure accurate data collection and be able to provide benchmarks that are accurate and realistic.

Offtake and Escape flows:

The offtake structure was modified and an automated gate fitted. Calibration of the flows through the structure took place over two seasons and previous diversions were adjusted to obtain consistency.

The escape structure was modified and an automated gate fitted. This gate not only controlled the channel level at the escape it measured and recorded the flow out the escape.

Two regulators on the channel were mechanised then remotely controlled in the first year of the project with another three regulators being automated, but not remotely controlled, in the second year. This allowed a comparison of the benefits of remote control against on-site automation for regulators

Deliveries to farms.

The project channel supplies 99.8% of the water to farms through a Dethridge wheel with the remaining 0.2% being delivered by pipe outlets for stock and domestic use.

All Dethridge wheels on the channel were scrutinised for defects before being installed to design specifications. A number of wheels had to be replaced as they were found to be slightly oval in shape and could not be installed accurately.

MIL provide a once per day service for its shareholders with staff starting and stopping Dethridge wheels as they set the flow for the day at the regulators. This process was intensified early in the project when each Dethridge wheel operating had a meter reading taken and the usage compared to the farmer's order for that day. The intensity of the readings was reduced to once a week, still compared to the weekly order, without a discernible reduction in efficiency.

Considerable time was spent checking the accuracy of the Dethridge wheels with a portable magnetic flow meter. The meter was used to measure flow before and after flowing through the wheel. Due to the size and weight of the magnetic flow meter, and lack of accessibility to the wheels, only four wheels on the channel were tested. Where testing was possible, the portable meter was left in place for three to four weeks to enable assessment of flows over the entire flow range of the wheel.
Wheels that were not accessible to the magnetic flow meter were checked using instantaneous readings from a velocity meter in the farm channel. Magnetic flow meters were set up on Dethridge wheels on other channels, where suitable sites could be found, to obtain further flow data.
It was established that Dethridge wheels in the project area were under measuring by 4% but the under measurement across the entire MIL system is more than likely to be 8%.

Leakage:
At the commencement of the project, the channel was inspected to ensure there were no leaks through banks and all Dethridge wheel doors were checked to ensure a good seal. From that time any leak noticed was repaired immediately.

Seepage:
Pondage tests were planned for the commencement, and close, of the 2000/01 season. However, these tests had to be cancelled because of farmer demand for water caused by the extremely dry conditions at the time.
During a short period of no flow, checks were sealed and water levels marked on each check. There was no measurable fall in water levels after a five day period of no flow.
In another period of zero demand from farmers, a flow of one Megalitre was on at the offtake and there was no measurable loss of that Megalitre at the escape.
MIL is involved in an MDBC funded project to identify and quantify seepage areas and volumes. The project is in the first year of a three year study.

Landholder information:
Surveys were undertaken regularly of farmers on the channel to ascertain crop water usage and farm production.

Geographical Information System (GIS)
Farm boundaries, channels, drains and infrastructure were digitised, soil type maps were obtained and a series of piezometers were installed in the vicinity of the channel to measure depth to watertable.

Results:

Table 1

The data below is the sum of water use in the 98/99, 99/00 and 00/01 seasons

			MLs	%
1	Diverted at Offtake		16,230	
2	Metered Through wheels		14,751	
3	Delivered by pipe Outlet		92	
4	Total Delivered to Farm		14,843	
5	Undelivered water (1-4)		1,387	8.55
6	**Irrigation Water Delivery Efficiency (IWDE)**			**91.45**
7	Ordered at wheels		15,621	
8	Metered at wheels		14,751	
9	Difference		870	
10				
11	Escaped		432	2.66
12				
13	Surface Area of Channel (sq meters)	68,950		
14	Evaporation (Nett mm)	4,140		
15	Loss by Evaporation		285	1.76
16	Seepage (Estimated at 0.1ML/d)		81	0.50
17	Nett Channel Filling		8	
18				
19	Adjustment for wheels (4%)		590	
20				
21	**Unaccounted for loss (MLs)**		**-9**	**-0.06**
22				
23	Cost of Original infrastructure	$448,346		
24	Cost of upgraded structures	$136,467		
25	Infrastructure depreciation & maintenance	**$8.46 / ML**		
26				
27	Megalitres Drained from farms		0	0
28				
29	Average depth to watertable	2.27		
30	Total Area of project (Hectares)	2,431		
31	Irrigation Intensity (MLs per Ha. over the 3 yrs)	6		
32				
33	Total Entitlements	7,027		
34	Total MIL Revenue from sales	$16.06 / Ml		
35	Gross Production (Farm Gate)	$4,460,999		
36	**Irrigation Water Economic Index**	**$301 / ML**		

Results against Objectives

Objective 1 : *To develop a practical set of hydraulic performance indicators for a gravity fed irrigation system that could be applied nationally and internationally;*

Due to the variable allocation levels, 29% to 78%, over the project period the Benchmarks below have been calculated from the data collected over the length of the project, ie. three irrigation seasons , 98/99, 99/00 and 00/01 to provide more consistent indicators rather than being based on one isolated season.

1 - Irrigation Water Delivery Efficiency (IWDE) Diverted Delivered Lost % of diversion delivered 16,230 14,843 1,387 91.45%	Benchmark1= 91.45%
2 - Irrigation Water Economic Index Delivered $ Value $/ML 14,843 $4,460,999 $300.55	Benchmark 2 = $301
3 - Megalitres per change in watertable Delivered 14,843 ; 6.11 MLs /Ha over three years Average depth to watertable start = 2.21 metres Average depth to watertable finish = 2.09 metres Change = rise of 0.12 metres	Benchmark 3 = 0
4 Megalitres Delivered / drained Delivered Drained 14,843 0	Benchmark 4 = 0
5 Megalitres Drained / Rainfall Rainfall (mm) Drained 984 0	Benchmark 5 = 0
6 Cost Infrastructure / Megalitres Delivered Cost of upgraded Infrastructure - Depreciation and Maintenance over 3 years $125,595 = $8.46 / Ml	Benchmark 6 = $8.46

Notes on Benchmarks:

Benchmark 1 - Irrigation Water Delivery Efficiency (IWDE) Megalitres delivered is the water metered onto each farm; loss is the difference between the water diverted into the channel at it's offtake and the water metered onto farm ie. the undelivered water. This project analysed a closed channel system only and water leaving the channel was assumed lost, although this water may have been utilised further down the system.

Analysis of losses:

Evaporation: the surface area of the channel was measured using the Global Positioning System (GPS) and Murray Irrigation's Geographical Information System (GIS). Evaporation data was from the CSIRO weather station at Finley.

Evaporation is a true loss and accounted for 285 MLs, or 1.76% of the MLs diverted to the channel.

Seepage: Ten piezometers were installed at various points along the channel and readings showed slight rise in the water depth when the system was filled and an equivalent fall when the channel was drained. This indicates that in some sections of the channel the soil profile around the channel wetted up but the volume lost from the channel was negligible. Extensive Electro Magnetic 31 (EM31) surveys were done along the channel to locate possible seepage points. It was clear that in the case of this channel, seepage control works would not amount to significant water savings but may be required to protect the surrounding environment.

Seepage is true loss and was estimated to account for 81 MLs, or 0.5% of the MLs diverted to the channel. This estimate was by the volume of water lost in the one Megalitre flow test that indicated approximately 0.1 ML/d being lost. The channel system operated for a total 807 days over the three seasons.

Escape water: Escaped water was the largest volume of water lost from the system. The volume of escaped water was directly related to the amount of water ordered per farm but not taken at the Dethridge wheel. Inaccurate offtake diversions also contribute to escaped water.

Water released from escapes was minimised by the installation of an automated gate that controlled the level so it only released water when the level of the channel became dangerously high.

Escape water is not necessarily a true loss because it may be utilised further downstream but it accounted for 432 MLs or 2.66% of the MLs diverted to the channel.

Dethridge wheel measurement. Most farms in the MIL area are supplied via a Dethridge wheel; pipe outlets are used for stock and domestic supplies and for small farms. Investigation into the accuracy of the Dethridge wheel under differing operating conditions was undertaken with results indicating that there was an under measurement of approximately 4% on average in the project area. This is not a true loss of water; it is water being used for agriculture that is just not being measured accurately.

Benchmark 2 - Irrigation Water Economic Index. $ value is the gross production value at farm gate; Gross production figures were obtained from the farms in the project area. Rice production indicators were from the NSW farm budget handbook, Vegetables return from the grower and dairy revenue from the Dookie dairy weekly report.

Benchmark 3 - Water table depth is the average depth to water table averaged over the 10 piezometers installed in the project area.

Benchmark 4 - The seasons covering the project were very dry and drainage from farms was non existent. This may not be the case in wet seasons.

Benchmark 5 - Rainfall data was sourced from the CSIRO.

Benchmark 6 - Infrastructure costs were calculated as below to obtain an annual cost.

Replacement cost of original Infrastructure	$448,346		
Depreciated at 2% P.A.		$8,967	
Plus maintenance at 1.25% PA		$5,604	
Total cost per annum.			$14,571
Capital cost of improved structures	$136,467		
Depreciated at 15% P.A.		$20,470	
Plus maintenance at 5% PA		$6,823	
Total cost per annum.			$27,293
Total cost P.A. of Upgraded Infrastructure			$41,865

Objective 2 : *To evaluate the economic benefits of the hydraulic performance indicators;*

In the project area, each Megalitre delivered to farm provided a return in production of $301 and income to MIL of $ 16.06.

A similar channel system nearby has been assessed over the last irrigation season to provide a comparison and the results show that losses were nearly 2% higher than in the project channel. Further 3% loss savings could be made by installing controlled supply points to farms to eliminate escape water.

The 5% gain in efficiency on this channel would save 2,250 MLs of water that if delivered to farm, would provide a return in production of $677,250.
This saving would provide increased income to MIL of $36,135 at an estimated capital cost of $ 2 million. Annual maintenance costs would be approximately $40,000 plus a provision for depreciation.

Objective 3 : *To evaluate different options to improve hydraulic performance;*

This project analysed the losses in a single channel system. The volume and percentage of water associated with each type of loss was established. Losses were attributed to escape flows, evaporation, seepage, detheridge wheel measurement and channel filling.

For each loss factor the cause and potential rectification methods available were identified. Costs estimates for each of the rectification methods were established based on Murray Irrigation's applied experience with channel seepage control and the installation of remote control and automation equipment, in particular SCADA technology. Specialist industry service providers/consultants were also involved in establishing the cost of automation.

The following table describes the losses, quantities involved, causes and potential rectification methods. Estimates of the potential megalitres saved and capital cost of infrastructure changes is also included.

The breakdown of water escaped is an indicative figure only because accurate measurement devices are yet to be established on all escapes.

Loss	Cause	Rectification Method	Estimated Megalitre benefit	Estimated capital cost
Escape water = 72,500 MLs or 4.65 % of diversion	Water ordered to farm not delivered.	**1** Read meters weekly, compare to orders, analyse results, educate irrigators to take ordered flow.	20,000	$150,000 (Operational cost.)
	Inaccurate offtake diversions.	**2** Install automated offtakes to ensure correct flow.	5,000	$2million
	Unnecessary releases from escapes	**3** Install automated escape gates including measurement of flow.	5,000	$2million
	Delivery to farms inconsistent and not as ordered.	**4** Install automated metering devices to deliver constant flow to farm.	20,000	$27million
	Inefficient channel regulation; manually once per day	**5** Install remotely controlled regulating structures.	10,000	$43milllion
		Totals if all actions are taken:	**60,000 Mls**	**$74.15 mil.**
		Ongoing per annum cost	**60,000**	**$1.85mil.**
Evaporation =39,176 MLs Or 2.51 %	Open channel system	**6** Cover channels. **7** Replace open channels with pipes	18,000 MLs 39,176 MLs	Unknown Not feasible
Seepage = 15,578 MLs Or 1%	Earthen channels	**8** Seal channels where seeping. **9** Replace channels with pipes.	7,000 MLs 15,578 MLs	 Not feasible
Dethridge wheels = 103,634 MLs (estimated 8% over entire MIL system.)	Excessive clearance between wheel and emplacement, wheels out of shape, operating outside design criteria.	**10** Improve operating conditions, replace wheels that have gone out of shape.	Zero. Not a true loss. Water going on to farms but not measured accurately	
Channel filling = 20,000 Mls	40,000 Mls to fill system; 20,000 used at end of season.	**11** Replace channels with pipes	20,000 MLs	Not feasible

Cost of works compared to the commercial value of the water saved

The above table clearly shows that water released from escapes is the only loss that could be feasibly saved by full automation of the channel system. The cost of full automation is estimated to be $75 M and would be expected to save 60,000 ML in most seasons. Assuming this investment was funded by Murray Irrigation, this water would be available for use on farm.

The current commercial value of annual (temporary) water purchased on the market is approximately $30/ML. At this water price the savings have a value of $1.8 M. It should be noted the annual water price does vary between and within seasons depending on water availability.

(An alternative, higher value for the water would be to look at the farm business operating surplus for the water. The median operating surplus/ML using BizCheck for Rice data 2000/01 was $88/ML. Using this value the saved water is worth $5.2 M.).

Social benefits of improving the hydraulic performance of the channel system

This study did not include a qualitative or quantitative assessment of improving the hydraulic performance of the channel system. Based on Murray Irrigation's experience with providing irrigation supply services to irrigators it is possible social benefits could arise from improving the hydraulic performance of the channel system in the following areas;

- Full automation of the channel system will reduce the occupational health and safety risks associated with manual operation of irrigation supply infrastructure.
- Full automation will change the workforce requirements of irrigation supply companies. Staff with more specialist skills will be required. Fewer staff are likely to be required which will reduce the employment opportunities in rural areas, particularly for semi skilled labour. Murray Irrigation currently employs over 30 staff in water distribution across three centres.
- Full automation is expected to improve irrigators ability match plant demand with irrigation water availability. For irrigators to capitalise on this improved service irrigators will need well developed irrigation management skills. This is likely to create opportunities in education and training and greater investment in farm irrigation scheduling.

Environmental benefits of improving hydraulic efficiency

The environmental benefits of improving hydraulic efficiency were not assessed directly.

However the following comments about environmental benefits based on Murray Irrigation's previous work and experiences over the last seven years are relevant.

Murray Irrigation's conclusion from previous channel sealing projects is that there are significant local environmental benefits of channel sealing. Minimising seepage reduces land degradation and associated road infrastructure damage adjacent to the channel. The water savings associated with minimising seepage are problematic, difficult to measure and likely to be small relative to the cost.

An environmental consequence of improving hydraulic efficiency by reducing escape water flows is that the flow of low EC channel water into downstream waterways is reduced. In some cases the escape flow has contributed to maintaining or improving the water quality in the downstream waterway. In particular, in the Murray Irrigation area of operation it has reduced the salinity of the waterway.

Objective 4 - *To develop incentives to encourage both water managers and irrigators to achieve optimum irrigation and drainage efficiency and minimise impacts on streams and aquifers*

This project resulted in a simple model developed using (Microsoft Excel 97) to allow the operation of the channel system to be assessed relative to the Benchmarks or other systems.

Murray Irrigation considers a successful incentive has the following elements;

- It is supported by institutional arrangements that are clearly defined, provide certainty and are long term. The institutional arrangements need to identify ownership of any water savings
- It is commercial and affordable i.e. it makes good business sense for the company
- It is practical i.e. it is technically and operationally feasible
- It can be implemented in a staged way over time

Institutional arrangements

Murray Irrigation's institutional arrangements where diversions are measured at the offtake provides the Company and its shareholders with an incentive to improve hydraulic efficiency of the channel system. This has been done by improving internal operations, particularly water ordering and strategic investment in more accurate measurement of escape flows.

The institutional arrangements place responsibility for Murray Irrigation's operation efficiency on the Company and its shareholders. Any attempt by Governments to access operational efficiencies achieved as a result of the Company's investment will remove this incentive.

Murray Irrigation's irrigation water property is also influenced by the nature of the 'right' determined under the *Water Management Act 2002 (NSW).* At best this Act only defines water security for a 15 year period with a major review of water sharing arrangements after five years.

Adoption:

The conclusions reached from this project indicate that the only true loss of water in an irrigation system is through evaporation and seepage that accounted for a loss of 54,754 MLs in Murray Irrigation's total diversion of 1,557,785 MLs.

To eliminate this loss would require the open channel system to be converted to a piped system; the cost of which would be prohibitive due to the size of the system and to the flat terrain.

Water released from escapes is a potential loss and needs to be reduced. Consequently, Murray Irrigation have moved to increase the efficient operation of the channel system by installing automatic gates and measuring devices on escapes, automating each channel offtake, and have increased funding for the on-going remote control of regulating structures.

Murray Irrigation recently obtained Quality Endorsement under Australian Standard ISO9001. The Benchmarks, and other indicators, resulting from this research are being used as Key Performance Indicators in the water distribution section of the Quality Management System.

Commercial incentive

This project identified that if Murray Irrigation spent $75 M to upgrade its channel system it could save 60,000 ML or $1,250/ML. To fund this investment Murray Irrigation would have to charge an extra $6 ML or $ 9 M/year, for the next 25 years.

The current value of irrigated agriculture cannot justify the costs of this investment. An expenditure of $9 M/year cannot be justified when the commercial value of the water saved is between $1.8 M and $5.2 M depending on how you value the water.

Practical

The actions the incentive aims to encourage need to be technically feasible and able to be implemented successfully by the Company. This will require the close involvement of the organisations/people expected to implement the incentive in the development of the incentive.

Additional Information:

Additional information and access to data collected is available by contacting the Principal Investigator. The project findings will be available on the Murray Irrigation Website (murrayirrigation.com.au) when the final report has been accepted.

Supporting Documents

(1) Channel flow data 1998 - 2001
(2) Water ordered and metered to farms 1998-2001
(3) Measurement of depth to watertable levels and supporting maps
(4) Electro-magnetic survey maps of channel system.
(5) Microsoft Powerpoint presentation of Project Results.
(6) Microsoft Excel 97 model to assess channel efficiency.
(7) Map of Infrastructure