Improved Flow in Irrigation Bays

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EXECUTIVE SUMMARY

Border-check is a surface irrigation practice used by over 90% of irrigated dairy farms in the southern Murray Darling Basin and is also very common in the Macalister Irrigation District in Gippsland Victoria. It is very commonly used on sites that have elevation gradients of less than 1 in 250 and soils that have relatively low permeability.

Border-check irrigations have a fundamental problem that arises because drainage of excess surface water from bays is very much slower than the process of applying the water. Variable and excessive ponding durations within conventional border-check bays are caused by slow soil profile infiltration rates, low bay slope and irregularities in bay surfaces that develop after landforming.

Slow surface drainage from border-check irrigations is a common cause of reduced pasture production and of water losses on dairy farms. Longer periods of ponding also increase the duration of saturation in the rootzone with each irrigation. This can reduce root zone oxygen, stressing pasture and crop species while favoring weeds adapted to waterlogging. Longer periods of root zone saturation also increase vulnerability to damage by stock and machinery.

While computer models can help understanding the likely performance of different bay designs, the 1D models that have typically been used in the past cannot simulate irrigations on non-uniform bay surfaces nor phenomena such as ponded water that may remain on the surface after irrigation cut-off. A 2D model that can simulate water flow across an irregular surface is required to better understand irrigation water distribution and infiltration over modified, non-uniform bay surfaces.

This project applied an adapted version of the 2D ANUGA model to identify new border-check irrigation bay designs that improved surface drainage after cut-off and reduced water ponding duration and variation. The criteria used to select the most promising design included bay hydraulic performance, establishment cost, robustness, maintenance requirements and complexity.

The two most promising modified bay designs ("shallow drains" and "trench") were then installed and measured against conventional bays on two dairy farms, one in the Goulburn Murray Irrigation District (GMID) and one in the Macalister Irrigation District (MID). The shallow drains design and trench design were both evaluated at the GMID site on bays planted with a grazed sorghum crop. At the MID site the shallow drains design was evaluated on an established perennial ryegrass pasture. Field measurements were collected from the two sites. These measurements were used to evaluate ANUGA model performance and compare the irrigation performance of the two chosen bay designs.

Our surface irrigation modelling indicated that the "shallow drains" design surface is very robust as it should work well across a wide range of bay slopes, bay sizes, inflow rates, surface roughness and soil types, and will reduce both the ponding duration and the variation in ponding duration. In contrast, the 'trench' design is less robust but can reduce ponding duration on bays that have a low elevation gradient. However, the trench design did not reduce variation in ponding duration and on sites with greater bay slope and/or less surface roughness, trench designs have increasing difficulty pushing surface water to the corners of bays.

Field measurements confirmed that both these designs reduced the duration of surface water ponding and infiltrated depth, allowing faster irrigations with reduced water loss to deep drainage. The surface drains design also substantially improved the uniformity of irrigations, while the 'trench' design required additional inflow to ensure that surface water spread to the entire bay.

In our field experiment, production data varied widely both spatially and temporally. There was no statistically significant effect on sorghum or pasture production due to bay surface design. Similarly, at the MID site there was no difference in the observed pugging damage by cows between the bay surface treatments. Our interviews with a small set of farmers that are already using these bay designs indicated that they perceived higher and more uniform production with the modified bays. The "shallow drains" design allowed earlier grazing after irrigations or rainfall events and reduced pugging damage. The annual cost to maintain the shallow drains bay surface by mechanical means was estimated to be $71/ha. The trench design has been used for many years by a lucerne grower on very flat, low permeability soils, allowing him to achieve high inflows while retaining bay slope. Cost to maintain the trench design have been comparable with what would be expected on a conventional bay. For both designs, an efficient surface drainage and reuse system is required to handle the greater peak flow rate of runoff generated on these bays.

Bay designs that reduce the duration and variation of ponding on bays will improve water productivity, increase irrigation performance and reduce environmental impacts of irrigation by more efficiently distributing irrigation surface water within bays, thereby increasing plant production while saving water through reducing deep drainage and evaporation losses. These modified bays, combined with a modernized supply system and automation, enable precise irrigation scheduling and optimization of irrigations for the entire bay.

We are yet to demonstrate best practice border-check surface irrigation as a package using

- Modified bay surfaces for irrigation uniformity
- Automated irrigation scheduling with forecasting
- Integrated automation of irrigations and reuse systems

The ‘shallow drains’ modified bay surface developed in this project provides uniform irrigations across an entire bay surface. This enables precise, automated scheduling of irrigations for the entire bay. Automated scheduling with forecasting has the potential for substantial improvements in water productivity and the reduction of off-site impacts caused by irrigation, while integrating automation of irrigations and reuse systems enables optimal farm surface water management with labour and water savings.

Implementing this package on a demonstration site such as the Macalister Demonstration Farm is a logical next step in this work.

INTRODUCTION

Project identification

Project title:	Improved Flow in Irrigation Bays
Project leader:	Faith Githui
Contact details:	255 Ferguson Rd, Tatura, VIC, 3616
CMI number:	105376
Contract number:	C100001316
Commencement date:	1/02/2015
Completion date:	30/06/2018

Project outcome

More efficient border irrigation designs are developed, demonstrated and communicated to stakeholders

Project background

Slow surface drainage from border-check irrigations leading to excessive ponding duration and uneven water distribution within bays is a common cause of reduced pasture production and water losses on dairy farms in northern Victoria. Controlling the duration of water ponding has the potential to increase pasture production, reduce water losses through deep drainage and evaporation, and reduce the environmental impact of border-check irrigated dairy production.

Landformed bays develop microtopography that impedes water movement and surface drainage within irrigation bays. This project will develop improved border irrigation designs that substantially control water ponding times without increasing bay runoff. In 2013/2014, project C100000838 - Improved Flow in Irrigation Bays demonstrated the suitability of a 2D surface water model for studying improved bay designs. The project also surveyed dairy irrigators, finding that bay modifications were likely to be adopted if they demonstrated improved performance.

This project proposes to use the 2D model developed under project C100000838 to identify most promising bay modification designs and design principles, then confirm model predictions with field measurements. Optimal designs found by modelling will be installed and measured on at least three representative farms which will then be demonstration sites. Design and management guidelines for modified bays will be published, as will the model software.

The project addresses Dairy Moving Forward priorities under the Natural Resource Management & Climate Change focus area, specifically the investment priority area of Increased profit per ML of irrigation water used in the dairy industry.

This study had a partner project “Smart Irrigation: when and how much” (DA C100001573) funded by Dairy Australia and the Commonwealth Department of Agriculture and Water which resourced a substantial proportion of work undertaken in the Macalister Irrigation District.

Project objectives

The objectives of the project were:

1. To develop and document the modified ANUGA irrigation model
2. To identify the most promising bay designs that control ponding duration on bays
3. To evaluate improved bay designs in the field
4. To ensure that revised design and management guidelines for border-check irrigation are communicated to stakeholders.

METHODS

Modelling

The ANUGA model

Existing border-check irrigation surface water flow models are classified as one dimensional (1D) because the surface flow is simulated in one direction only – from the top of the bay to the bottom. The bay surface is assumed to be perfectly smooth and with no slope across the bay width. Water is assumed to be uniformly spread and behaving identically across this width. While these models capture the process of irrigation advance well, they are less satisfactory in simulation of the more subtle and slower processes of surface drainage. They cannot simulate the effects of surface irregularities on flow pathways within bays, the formation of puddles or the effects of modifications made to the bay surface. Due to these limitations of 1D models, we use of a 2D surface irrigation model.

ANUGA is an open source 2D inundation model developed by the Australian National University and Geosciences Australia (https://anuga.anu.edu.au). It is a hydrodynamic modelling tool that models flow through complex geometries and is based on a finite-volume method for solving the shallow water wave equation. Although ANUGA was specifically written to simulate the impact of tsunamis on coastal areas, it has the potential to simulate a wide range of water flow scenarios. These applications range from very small scales, such as water flow in a kitchen sink, to catchment scale (Van Drie et al., 2008; Simon et al., 2009; Martin et al., 2014; Van Drie et al., 2011; Roberts et al., 2008). ANUGA does not simulate infiltration so in order to simulate irrigations we incorporated an infiltration function in the model based on the modified Kostiakov infiltration equation (Githui et al., 2015).

An ANUGA model is set up by defining a study area (called a 'domain') represented by a mesh of triangular cells. Attributes of each triangle vertex in the mesh include the land elevation, water surface elevation and frictional resistance. Initial values for attributes such as water height and the domain boundary conditions must be specified, and external effects such as rainfall, inflows, and water abstraction (including infiltration) can be applied. Once the setup is complete, the model is run over time steps, and water depth and volume on the triangular mesh are tracked over time. Model outputs include depth hydrographs, water runoff and total volumes of infiltration and water ponding times for each mesh triangle.

Model evaluation

The ANUGA model was evaluated by comparing field measurements to model simulations. The goodness of fit measures were percent bias (PBIAS), Nash Sutcliffe efficiency (NSE) and root mean square error – observation standard deviation ratio (RSR) (Moriasi et al., 2007). The quantities evaluated were infiltration, runoff, water advance and water depth.

Bay surface modification simulation

Modifications to bay surfaces were done using functions developed by us in the Python programming language. Bay surface designs were constrained by their site physical features. As with conventional bays, the channel water supply elevation at the bay inlet and drainage elevation at the bay outlet limit the overall bay gradient. Modified bay designs were therefore constrained to the same top and bottom elevations as the existing bay, and therefore the same overall slope. A further constraint applied to designs was that the volume of cut and fill material had to nearly balance. This eliminated potential bay surface designs that would be impractical to implement across many bays on a farm.

Several criteria were used to select the 'best' bay designs. Criteria included the surface irrigation performance measures of application efficiency (Burt et al., 1997), requirement efficiency (Walker, 1989), and distribution uniformity, ponding duration and variation in ponding duration within the bay, as well as factors such as establishment and maintenance costs. Of the potential designs, the 'shallow drains' bay design outperformed other designs, followed by the 'trench' bay design. Detail of the performance of these designs is provided in the results of this report.

i) 'Trench' bay design

This design consists of one or more 3.5 m to 5 m wide shallow trenches, which start from zero depth near the top of the bay to between 5 cm and 10 cm deep at the end of the bay.

ii) 'Shallow drains' bay design

The shallow drains design was formed by initially creating a conventional bay and then using a tractor mounted rotary drain digger to incise parallel shallow surface drains at 10 to 15 m spacing, approximately 2 cm deep and 20 to 25 cm wide down the length of the bay.

Field irrigation assessments and data

Field assessments of irrigations on modified and conventional bays were carried out on two sites, one in Goulburn Murray Irrigation District (GMID) and one in Macalister Irrigation District (MID), as described in Table 1. Both the 'trench' bay design and 'shallow drains' bay design were installed and assessed at the GMID site. Only the 'shallow drains' design was assessed at the MID site.

Table 1: Site characteristics

Site	Location	Soil type and profile description	Final infiltration rate, (mm/hr)	Crop	Bay length x width (m)	Average slope (%)
GMID	36°18'36.89" S 144°56'02.86" E	Wanalta loam: a loam topsoil, with a strong texture contrast at approximately 20 cm depth to a clay subsoil of low permeability which cracks when dry (Skene, 1963).	Based on 16 sampling points. mean = 2.48 range = 0.01 to 10.26	grazed sorghum	335 x 57	0.13, 0.12
MID	38°24'05''S 146°55'05''E	Wooundellah loam: sandy loam topsoil with an abrupt change at 25 cm depth to a medium clay.	Based on 6 sampling points mean = 1.06 range = 0.48 to 1.37	grazed perennial ryegrass	215 x 54	0.2, 0.17

Previous reports have described field experiment data acquisition methods at the GMID site (Milestone 6 – Field evaluation of border-check bay surface designs) and at the MID site (Smart Irrigation: when and how much - A report on the results from the modified irrigation bay experimental site, (Morris, 2018)). A summary of the field data collected at the two sites is provided in Table 2.

Table 2: Data collected on irrigation bays

Data	Data points	How
Rainfall	2 sites	Logging rain gauge
Infiltration rate	GMID: 6 Bays x 2 points MID: 4 bays x 2 points	Ring infiltrometers
Inflow rate	2 sites	GMID: G-MW meter with adjustment for channel volume change or pump meter MID: acoustic doppler flow meter
Inflow duration	GMID: 6 bays MID: 4 bays	WT-HR water depth meter
Surface water depth	GMID: 3 distances down each bay x 4 across at each distance x 6 bays MID: 3 distances down each bay x 4 across at each distance x 4 bays	WT-HR water depth meters
Runoff	GMID: 6 bays MID: 4 bays	Flumes
Production (dry matter consumed)	Samples from the top, middle and bottom third of each bay	Plate meter with calibration cuts

Soil moisture wireless sensor network

A wireless sensor network (WSN) was designed and developed, but was not successfully installed at the MID site. Design and deployment of the WSN was more problematic and complex than originally envisaged. As a result, there was not sufficient time within the project to resolve all the issues required to ensure successful deployment in the field. The technical issue that is not yet resolved occurs during commissioning and deployment of the WSN. The commissioning process requires a short sleep / wake cycle while end nodes are synchronised and deployed to their locations in the field. There is then a procedure that ensures that each node has established a route for transmitting data through the mesh network. When that procedure has successfully completed, the final step is to set the short deployment network sleep cycle to a much longer, operational cycle. At present communication with the end nodes is lost while stepping the meshed XBee radios from a one minute deployment sleep/wake cycle to their four hour operational cycle.

Sensors

The sensor adopted for the WSN was the Vegetronix VH400 (www.vegetronix.com) which is a relatively inexpensive, capacitance based soil moisture probe that has a linear response to volumetric moisture content (VMC) and is suited to sensor network applications (Bitella et al., 2014). VH400 sensors were installed at 7.5 cm, 10-20 cm, 20-30 cm and 45-55 cm depth at each of eight end node locations on each of the four irrigation bays at the MID site (Figure 1). We planned to calibrate the sensors in situ, after installation, by relating sensor readings to a set of soil samples taken for determination of gravimetric moisture content (GMC) before, after and between irrigations. To relate GMC to VMC and to plant available water at the site, samples were taken for laboratory determination of topsoil and subsoil bulk density and moisture characteristic. These data were reported in the technical report “Smarter Irrigation, when and how much - Macalister site establishment” (Morris, 2017).

Figure 1: Installing soil moisture sensors on the MID site

End nodes

WSN end nodes were based on the Arduino Fio microprocessor board. The Fio is an inexpensive, 3.3V, small format board designed for low power wireless applications. With appropriate programming the Fio can effectively hibernate between sensor readings, enabling deployment for several months before its battery requires recharging. Four VH400 sensors were connected to each Fio using a printed circuit board designed by us and fabricated in China (Figure 2). The custom circuit board enabled reliable connection of the sensors using standard fittings and provided an efficient supply of 5V power to the sensors (Figure 3).

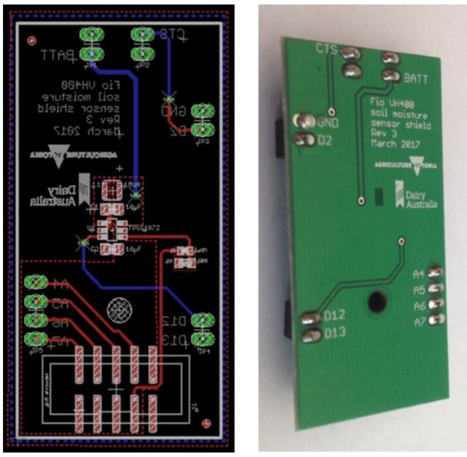

Figure 2: Printed circuit board design and the assembled board

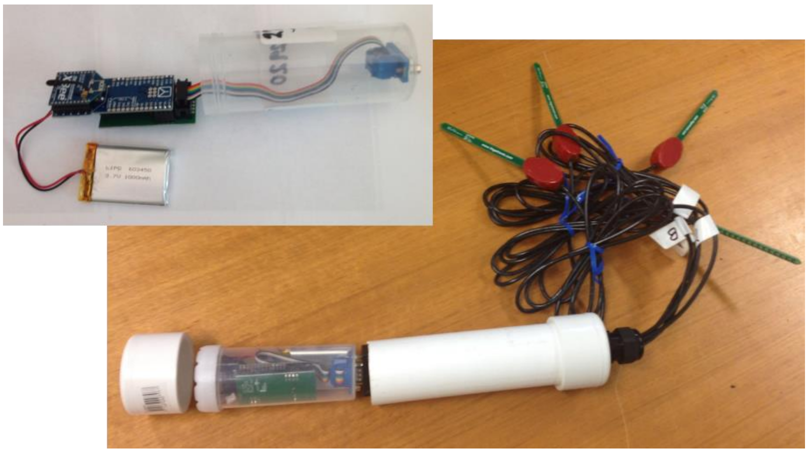

Figure 3: Node electronics and assembled sensor node

Aggregator/gateway

The aggregator/gateway receives and processes data transmitted by the end nodes. The core of the aggregator/gateway is a Raspberry Pi (RPi) computer board running a Linux operating system to which is connected an XBee radio which receives the end node data, and a 4G modem that connects with the internet. The RPi stores a local copy of received data and transfers a copy to internet cloud storage via the 4G modem (Figure 4). The aggregator/gateway can also send status reports and report error conditions via SMS text messages, and can action a suite of remote commands sent to it by SMS.

The aggregator/gateway is powered by a 12V car battery that is kept charged by a solar panel. A Fio board has an XBee attached to it that coordinates the sleep/wake cycle of the entire WSN. The Fio is programmed to switch on power to the RPi with sufficient time for it to boot up before the WSN wakes. The RPI processes and sends the data it receives to the internet, then shuts down. When the Fio detects that the RPi has shut down, it switches off the power to it.

Cloud storage and retrieval

Data from the aggregator / gateway is sent to an Amazon Web Services (AWS) S3 bin which provides long term, secure and inexpensive cloud storage. A prototype retrieval application has been created that maintains an SQLite database of sensor data which is used to create a range of scalable SVG graphs that can be delivered via a web page (Figure 5) and/or mobile apps.

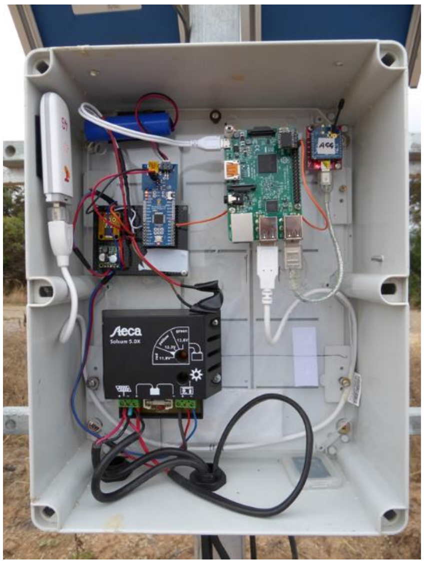

Figure 4: Aggregator / gateway

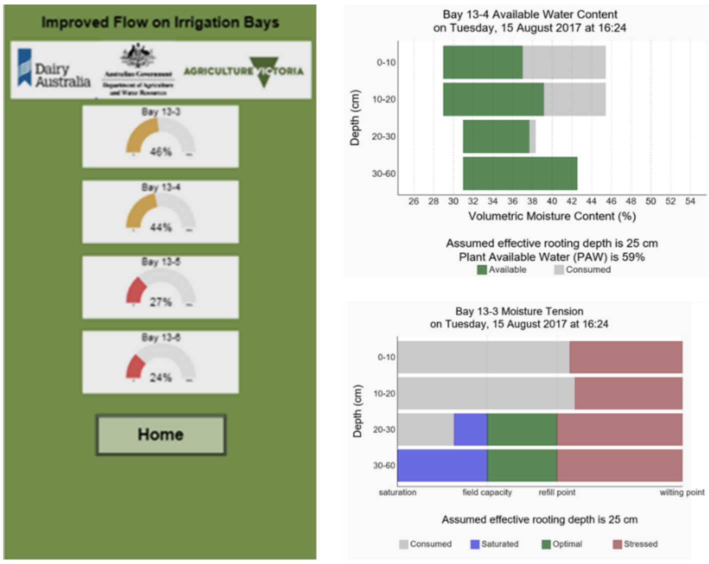

Figure 5: Prototype database output graphs

Maintenance and longevity of existing modified bay surface sites

Two farmers in the GMID with experience using the “shallow drains” design and one farmer with experience using the “trench” bay design were interviewed. A questionnaire (Appendix A11) was prepared for the interviews with the aim to determine:

- how they implement and manage the modified bay design;
- their motivation for adopting a modified design;
- perceived benefits;
- additional costs of establishing the design;
- additional maintenance required and costs of maintaining the modified bay surface
- impacts of the design.

KEY RESEARCH FINDINGS

Modelling

Model evaluation

The ANUGA model was evaluated and found satisfactory by simulating several irrigation events on various irrigation bays and compared with measured data (Morris et al., 2015; Githui et al., 2015).

Bay surface modifications

The ‘trench’ design (Figure 6) was the only design among those assessed that could reduce the median ponding duration on border-check bays without the use of shallow surface drains. However, it was found to increase variation in ponding duration within bays. This occurs because some areas of the bay drained more quickly from the steeper gradients associated with the ‘trench’ design, while there were other areas of the bay that were unaffected by the trenches. Our conclusion was that the ‘trench’ design could improve irrigation performance on bays that have a low elevation gradient and limited command height. However, on sites of greater bay slope and/or less surface roughness, trench designs have difficulty pushing surface water to the corners of bays.

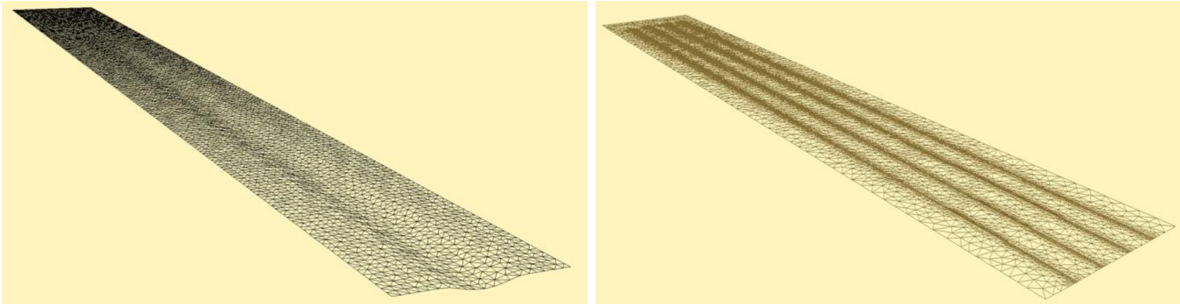

Figure 6: Trench design (left) and Shallow drains design (right)

In contrast, the “shallow drains” design surface was very robust. This bay surface should work well across a wide range of bay slope, bay size, inflow rate, surface roughness and soil type, and will reduce both the ponding duration and the variation in ponding duration within irrigation bays.

Field assessments and data

Measured duration of inundation at the GMID site (Figure 7) showed that both the ‘trench’ and ‘shallow drains’ designs reduced both the duration of surface water ponding and the variation in ponding duration across the bay surface compared with the conventional bay surface (Morris et al., 2016). The ‘shallow drains’ design reduced ponding duration by an average of 3.6 hours, while the trench design reduced ponding duration by an average of 4.4 hours. At the estimated final infiltration rate of 1.6 mm/h, this represents a potential reduction in infiltration of 6 to7 mm, or about 8% of irrigation water applied. Although our modelling indicated that the trench surface performed well, additional inflow than would be usually applied on a conventional bay, was required for the ‘trench’ design to ensure that the bottom corners of these bays were watered. This was demonstrated by our GMID site farmer who found the trench design more difficult to manage and achieved full irrigations only by running more water each irrigation to ensure that the water reached all corners of the trench design bays. As such, this design can work well within a relatively narrow specification but is likely to require tailoring to specific locations and crops, which would be problematic for its widespread adoption.

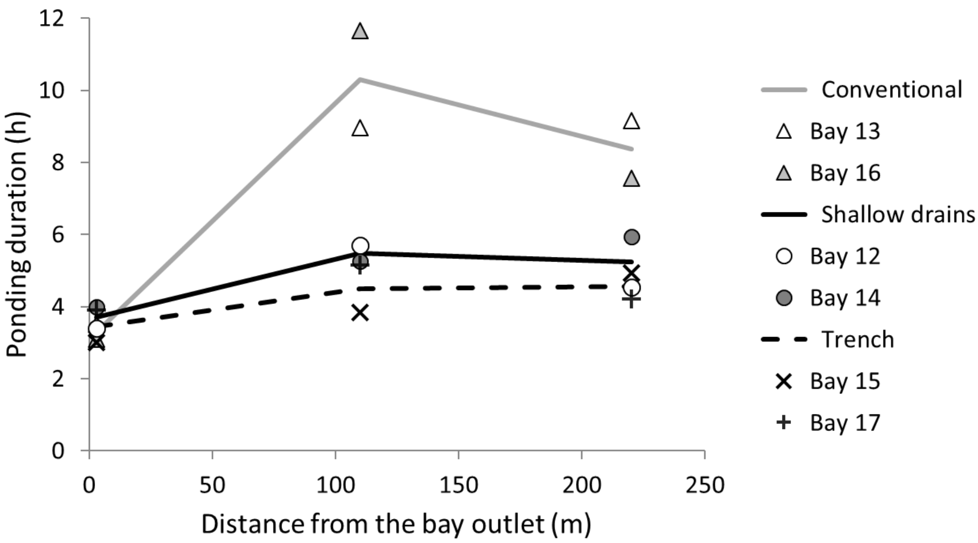

Figure 7: Average duration of surface water ponding on conventional, shallow drains and trench bay surface designs in GMID.

Similarly, in the MID the “shallow drains” design consistently achieved reduced ponding duration compared to conventional bays (Figure 8), particularly at the bottoms of bays.

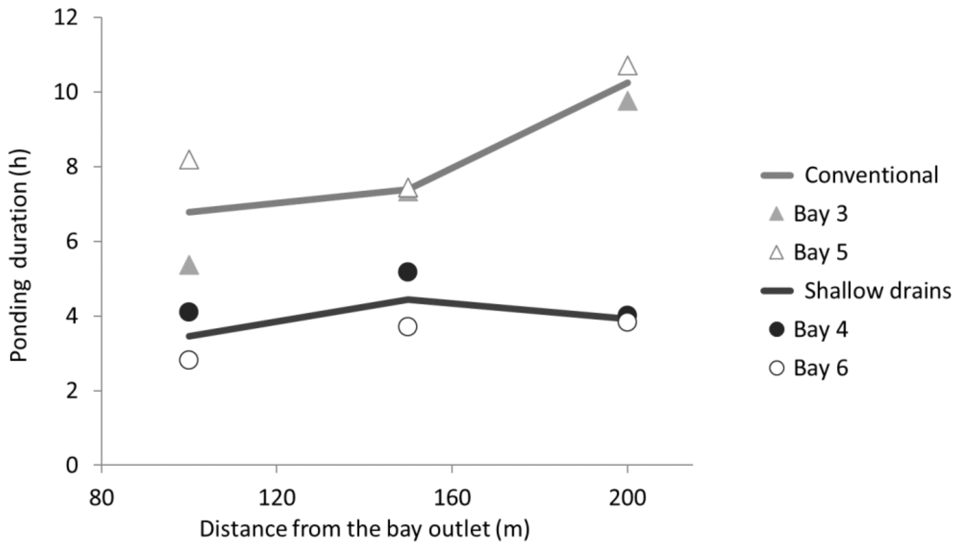

Figure 8: Average duration of surface water ponding on conventional and shallow drains bay surface designs in MID.

Maintenance and longevity of existing modified bay surface sites

The chosen modified bay surface designs used in this study were already being used by some early adopters in the GMID. Three of these farmers were interviewed about the management, longevity, costs and benefits of the modified bay design on their farm. Overall, farmers using the ‘shallow drains’ design believed that the improvements in production make the “shallow drains” bay design worthwhile. They have seen improvement in drainage of the bay surfaces allowing earlier grazing after irrigations or rainfall events and reduced pugging damage. An efficient surface drainage and reuse system with sufficient capacity to handle larger surface drainage flows is required.

- *Shallow drains design*

Due to their shallow nature, these drains need to be maintained in order to adequately drain the bays by removing grass and weeds. This drain maintenance requires regular use of a medium size tractor and a rotary drain digger. The shallow drains on one farm are mechanically cleaned with the rotary digger after every second grazing during the irrigation season. Bays modified 7 years ago are still in reasonable condition but some erosion is occurring at the ends of the surface drains, requiring minor maintenance. The potential for chemical control of weeds in surface drains to reduce the required frequency of mechanical clearing of drains, thereby reducing the rate of drain deepening and reducing maintenance costs has not yet been investigated. With more widespread use of shallow drains, installation and maintenance could be provided by contractors. Pasture production is consistently high. Improved drainage of bay surfaces allows grazing 48 hours after an irrigation and gets winter rainfall off quickly, reducing damage by cows. The design generates more runoff than a conventional bay, so an efficient reuse system is required. Drain maintenance can increase the depth of the drains, which is not desirable because deeper surface drains can be a hindrance during regular machinery operations and potentially an injury risk for stock.

- *Trench design*

The trench surface modification has been used for some years in an irrigated lucerne production system. The modification lasts for the duration of the lucerne stand and is “touched up” prior to each sowing in the same way a conventional bay would be. While this design does not require ongoing maintenance, it does require high bay inflows to create sufficient water depth on the bay surface to flood laterally out of the trench and to the check banks. Getting water to the corners can be difficult when surface friction is relatively low prior to crop establishment. Therefore, water is applied for a longer duration in order to inundate the whole bay. This generates more irrigation runoff thus requiring an efficient surface drainage and reuse system with sufficient capacity to handle greater surface drainage.

Costs

Costs for the ‘shallow drains’ and ‘trench’ designs were reported in a previous technical report ((Milestone Report No. 7) and include both the installation cost and ongoing maintenance.

- *Shallow drains design*

Based on the management practices on one farm with shallow surface drains installed, the installation cost was estimated to be $29 per hectare, with annual maintenance cost of $71 per hectare. The majority of this cost was labour (43%) and fuel (36%).

- *Trench design*

Modification costs for the 'trench' design costs are limited to the formation of the trench in a single scraper pass during conventional land-forming. On a 4-hectare bay that is 500 m long, an earthmoving scraper with a 3.6 m wide cutting blade would need to relocate 108 m^3 of undisturbed earth (approximately 150 m^3 heaped), which would require less than 1 hour to complete. At a typical earthmoving contract rate of $90 per hour, the cost of installing the trench would therefore be less than $23 per hectare. Given that the trench material provides an efficient source of earth for check-banks, the impact on the overall cost of landforming could be substantially less than this.

Pasture production

Pasture production data varied widely both spatially and temporally, and no significant differences were observed between the bay surface treatments in either the GMID or the MID sites (Figure 9). This could be attributed to the potential for non-treatment effects (pasture measurement errors, irrigation scheduling, grazing management, and weather) to mask possible effects due to the differences in bay surfaces. As both sites were on commercial farms, there were spatial and temporal inconsistencies in farm operations across the experimental bays that would have confounded treatment effects. It is also clear that productivity improvement arises from getting everything right, not just changing the bay surface.

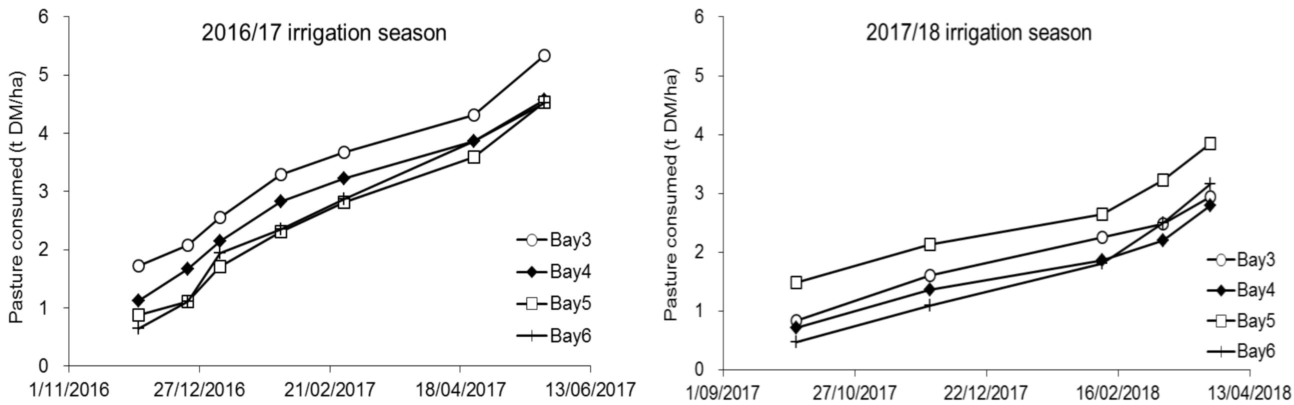

Figure 9: Pasture consumed during the 2016/17 and 2017/18 irrigation seasons in MID

Wireless sensor network

Status of the wireless sensor network

- *End nodes*

Fabrication and programming of the sensor network end nodes has been completed.

- *Aggregator / gateway*

Construction and programming of the aggregator / gateway has been completed for both the Fio power controller and the RPi aggregator / gateway.

- *Cloud storage and retrieval*

Cloud storage has been created as a AWS S3 bucket and test transmissions of data from the aggregator / gateway in the field to cloud storage have been successful. Prototyping of output graphing functions has been done, but programming of the updating of the graphics database and graphs as AWS Lambda functions has not been completed.

- *Commissioning and deployment*

The commissioning and deployment of the WSN has proved to be more difficult than expected. The commissioning process requires a short sleep / wake cycle while end nodes are synchronised and deployed to their locations in the field. There is then a procedure that ensures nodes have established routes for transmitting data through the mesh network. When that procedure has successfully completed, the final step is to set the short deployment network sleep cycle to a much longer, operational cycle. At present nodes are failing to change their sleep cycle, causing them to be “lost” from the network.

Future directions

- *Technological change*

There has been a significant change in the availability of low cost, low power, long range radio technologies since the WSN was designed. Technologies such as LoRaWAN and Narrowband will simplify the topology of wireless networks at farm scale, allowing individual nodes to send data either directly to the cloud or via an aggregator / gateway that can be sited in the farm office rather than in the paddock.

The implication of technological change for this project is that a proportion of the hardware used and software developed will rapidly become obsolete. Both the hardware and software are modular, so the impact will mainly affect the modules directly associated with the XBee radios and the gateway modem. The remaining software and hardware remains a useful foundation for future development.

- *Project repository*

A GitHub repository https://github.com/betterflowinbays/ has been established. Source code and supporting documentation will be progressively uploaded to this site.

CONCLUSIONS

On sites with low permeability soil profiles, bay surface modification increased border irrigation performance by reducing the duration and variation in duration of inundation. This can be expected to reduce the depth of infiltration and potential deep drainage.

- The “shallow drains” design surface was more robust compared to a conventional bay and the “trench” design.
- Both the “shallow drains” and “trench” designs reduced the duration of surface water ponding and infiltrated depth, allowing faster and more uniform irrigations with reduced water loss to deep drainage.
- The ‘shallow drains’ design substantially reduced variation in ponding duration within bays.
- There was improvement in drainage of the bay surfaces for both designs allowing early grazing after irrigation or rainfall and reducing pugging damage. However, an efficient surface drainage and reuse system is required to handle the large rates of runoff generated on these bays.
- Production data varied widely both spatially and temporally. There was no evidence of an effect on sorghum or ryegrass production due to bay surface design. However, interviews with farmers indicated that there were improvements in production with the “shallow drains” bay design.

The field experiments have highlighted that production improvement depends on many factors that are integrated within a farming system. Changing any one factor, such as irrigation performance, may only impact on production when the whole system has been adapted to the change. This could mean changes to irrigation scheduling and/or changes to grazing management. Aligning these factors to achieve greater production requires motivation and time.

PROJECT DELIVERABLES

Table A: Contracted Project deliverable status

Deliverables	Status	If not completed, please describe any impact on project delivery	Please explain how these products and services were delivered to the next user
Milestone 1: Brief report • Documentation of the Anuga irrigation application • Evaluation criteria for bay designs agreed	Achieved		A technical report on the application of Anuga for irrigation and evaluation of criteria for bay designs was provided to the project steering committee and Dairy Australia
Milestone 2: Report • Documentation of field assessment protocols (pre-schedule documentation) • Identification of suitable farm demonstration sites (Signed Farm Use Agreements) • Initial bay designs based on hydraulics and modelling completed (Technical Report)	Achieved	Due to seasonal conditions the identification of suitable field sites was slightly delayed but this did not impact on project delivery.	Field assessment protocols and initial bay designs based on hydraulics and modelling completed. Information was reported to the project steering committee and Dairy Australia
Milestone 3: Report • New bay designs completed • Pre-treatment irrigations measured • Soil moisture WSN technologies reviewed and best option identified	Achieved	The undertaking of pre-treatment irrigation measurements was slightly delayed due to the need to wait until after engineering work on the bays was completed. This did not impact on project delivery	The new bay designs and best options for WSN technology were provided to the project steering committee and Dairy Australia
Milestone 4: Brief report • Crop establishment on experimental sites after land-forming • WSNs deployed and operational	Partially achieved	The development of the soil moisture WSN proved to be more complex than originally perceived. The successful deployment of this component was not able to be completed during the project.	An update of the progress in crop establishment at field sites after landforming and the proposed delivery design for the soil moisture WSN was provided to Dairy Australia.

Deliverables	Status	If not completed, please describe any impact on project delivery	Please explain how these products and services were delivered to the next user
Milestone 5: Technical report • Field assessments of bay performance over winter • MID demonstration site established	Partially achieved	Field assessment bay performance at the GMID site over winter was not feasible due to protracted rain and failure of the lucerne crop which required re-sowing to sorghum. In the MID wet conditions also delayed installation of all field equipment. These delays did not impact on the final delivery of the project	A report on the GMID site and establishment of MID site provided to project steering committee and Dairy Australia
Milestone 6: Technical Report • Field assessments of GMID bay performance irrigating a sorghum crop	Achieved		A technical report of the field assessment of GMID bay performance was provided to the project steering committee and Dairy Australia
Milestone 7: Milestone 7 Brief report to the project steering committee • Bay design, management and costs documentation prepared • Potential for establishment of demonstration sites on farms with existing modified bays	Achieved		A report provided to the project steering committee and Dairy Australia of the bay design and the management and costs implications for these designs. A brief report on the potential for establishing demonstrations on existing farms that have the same bay modifications used in this project.
Milestone 8: Project Final Report • Research publication submitted • Survey of the longevity of existing alternative bay surface sites completed and documented	Partially achieved.	A research publication has been drafted and is currently undergoing internal review prior to submission	Report provided to Dairy Australia

Table C: Financial summary

Fund source	*2014-15*	*2015-16*	*2016-17*	*2017-18*	*Total*
DEDJTR	$277,808	$213,843	$221,795	$99,289	$809,223
Dairy Australia	$122,226	$145,401	$421,349	$120,247	$812,735
Total	$400,034	$359,244	$643,144	$219,536	$1,621,958

PROJECT COMMUNICATIONS

Table D: Project Communication Forums

Activity	Audience	Attendance
3 Steering committee meetings (14th October 2015, 2nd March 2016 and 5th July 2017)	Project team, steering committee members (farmers, irrigation system designer, research scientists)	15
Accelerating Change project field day presentation and newsletter article, September 2015.	GMID dairy irrigators	20
Conference presentation Adapting ANUGA model for border-check irrigation simulation. 21st International Congress on Modelling and Simulation, Gold Coast, Australia, 29 Nov to 4 Dec 2015. www.mssanz.org.au/modsim2015	Computer modelling and simulation researchers	30
Conference presentation Application of Anuga as a 2D surface irrigation model. 21st International Congress on Modelling and Simulation, Gold Coast, Australia, 29 Nov to 4 Dec 2015. www.mssanz.org.au/modsim2015	Computer modelling and simulation researchers	30
Conference presentation Alternate design for border-check irrigation bays, Irrigation Australia International Conference, 24-26 May 2016, Melbourne.	Irrigation industry	20
Effect of bay surface modification on water ponding time in border-check irrigation-A field study, Irrigation Australia International Conference, 24-26 May 2016, Melbourne.	Irrigation industry	40
Tatura Seminar Series – Alternative designs for border-check irrigation bays, October 2016.	Research and extension practitioners	20
Workshop presentation Improving flow on border-check irrigation bays. Murray Dairy Accelerating Change Agronomy Network presentation, 9 December 2016, Echuca	GMID dairy industry service providers	30
Conference presentation Improving border-check irrigation precision by modifying the bay surface Irrigation Australia International Conference, 13-15 June 2018, Sydney.	Irrigation industry	40

Table E: Project publications

Activity	Number
Conferences abstract	2
Conference paper (refereed)	2
Journal articles	1 (in preparation)
Technical report (science)	7
Factsheets	1
Technical notes	1
Videos	1

PROJECT IMPACT

The project has

- developed and validated a two-dimensional surface irrigation model that accurately simulates both the wetting and drying of a sloping surface and is suitable for the design and assessment of surface irrigation systems generally. In collaboration with NSW Department of Primary Industries we will be investigating its potential application in the design of bankless channel systems in the next few months.
- identified a simple bay modification that accelerates surface drainage of excess irrigation water from bays, producing much more uniform irrigations than can be achieved with conventional bays
- verified the hydrologic performance of the ‘shallow drains’ design with field measurements on bays with perennial pasture and with forage sorghum.

The future impact of the project will depend on whether dairy irrigators adopt the modified bays. Aspects that facilitate adoption of the shallow drains design include:

- installation does not interrupt production
- the bay modification can be trialled on a farm for little cost
- modified bays can be installed progressively on a farm.

Aspects that may limit adoption include:

- ongoing maintenance, which could be overcome if installation and maintenance were available as a service
- perceived obstruction to vehicles and machinery.

The modified bay surface rapidly removes excess irrigation water from bay surfaces, leading to uniform irrigations across the entire bay surface. A potential impact of the modified bay surface is that the limits on bay size and slope that apply to conventional bays may be relaxed with more efficient, modified bay designs. This could enable farm irrigation designs that have larger bays, more productive area and less laneway, channel and outlet infrastructure.

RECOMMENDATIONS

We are yet to demonstrate best practice border-check surface irrigation as a package using

- Modified bay surfaces for irrigation uniformity
- Automated irrigation scheduling with forecasting
- Integrated automation of irrigations and reuse systems

The ‘shallow drains’ modified bay surface developed in this project provides uniform irrigations across an entire bay surface. This enables precise, automated scheduling of irrigations for the entire bay. Automated scheduling with forecasting has the potential for substantial improvements in water productivity and the reduction of off-site impacts caused by irrigation, while integrating automation of irrigations and reuse systems enables optimal farm surface water management with labour and water savings.

Implementing this package on a demonstration site such as the Macalister Demonstration Farm is a logical next step in this work.

APPENDICES.

Appendix A: Published technical reports and journal papers.

See attached CMI_105376_Final_Report_APENDIXA.docx

Appendix B: Communication

See attached CMI_105376_Final_Report_APENDIXB.docx