ADVANCES IN SURFACE IRRIGATION MANAGEMENT ON ALFALFA

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Rubicon Water has a vision to improve the productivity of the world's farmers in an environmentally sustainable way. We do this by delivering advanced technology to managers of gravity fed irrigation networks that enables them to operate and manage their water resources to unprecedented levels of efficiency and control.

There are sizeable opportunities for water savings in the gravity-fed water delivery networks via irrigation districts and gravity fed surface irrigation on-farm within the USA. The dominant water saving opportunities are with the manually operated reticulation networks (e.g. canals), referred to as gravity-fed water delivery networks and on-farm using manually operated flood irrigation application methods.

It is estimated that only half the storage-based water released from reservoirs and supplied by gravity-fed water delivery networks and flood irrigation methods on-farm are finally used for crop consumptive use. It is contended that the excess water is being lost because of antiquated and restrictive operating practices that, in the large part, force inefficiencies at the farm level (Moller and Zaccaria, 2024).

The water savings opportunity is the water which is not used by the crop or for crop production practices. For many reasons, it is best this water remains in the upstream reservoir and be strategically allocated and managed, rather than on an ad-hoc access to it by downstream users.

The water savings can be realized via a modernized and automated on-demand supply (i.e. water orders of flexible duration, flexible timing, and variable flow) and the subsequent enabling of efficient on-farm application methods (e.g. micro, sprinkler, and advanced surface irrigation).

Accurate metering and flow control at the delivery turnouts are an important element of:

- Delivering an automated on-demand supply that matches crop consumptive use
- Leveraging the investment made by irrigators in on-farm efficient irrigation methods
- Ensuring the accurate management of an irrigator's water allocation (a growing asset of an irrigation enterprise)

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Advanced water technologies are now available for irrigation district managers of gravity fed irrigation networks that enables them to operate and manage their water resources to unprecedented levels of efficiency and control. Irrigation authorities can now deliver accurately measured, constant high-flow, on-demand water to farmers utilising existing open channel systems with limited outfalls at the end of canals. With this level of service, farmers are better positioned to make irrigation management decisions, receiving the water their plants need, when they need it at the rate they need it, avoiding wastage and fertiliser runoff.

1.1 TRANSFORMING INEFFICIENT MANUALLY OPERATED FLOOD IRRIGATION INTO ADVANCED SURFACE IRRIGATION

The water savings can be realized via a modernized and automated surface irrigation system to irrigate field crops (alfalfa, fodder, corn, cotton) to improve the productivity of the world's farmers in an environmentally sustainable way. High flow surface irrigation together with automation and accurate and precise timing gives what can be termed **Advanced Surface Irrigation**.

In evaluation studies conducted by the CRC for Irrigation Futures (Smith et al., 2009 and Gillies et al., 2010) in Australia, higher irrigation flows have been shown to offer very much improved application efficiencies, well above those achieved across the irrigation district where the study was conducted (Goulburn Murray Water, Victoria Australia). On all but the lightest soils efficiencies in excess of 85% are achievable, reaching as high as 95% on some soils.

Similar results have been observed in California (Bali, 2019) with University of California Division of Agriculture and Natural Resources (UC ANR), at its Desert Research and Extension Centre, located in Holtville, California, have demonstrated the gains in application efficiencies possible using optimally-managed, automated, high-flow bay irrigation in California for alfalfa and furrow irrigation in Holtville, California for sugar beet production.

A secondary objective is to demonstrate and evaluate the techniques for calculating in real time the time to cut-off for each irrigation, using data captured during that irrigation, in sufficient time to provide optimum control of that irrigation.

On-farm **Advanced Surface Irrigation** uses automation, sensor technology, science and data analytics, real time optimization and irrigation scheduling methods to reduce water applied and increase yields, by upgrading inefficient manually operated flood irrigation from 50-60% application efficiency to 85-90% application efficiency for Advanced Surface Irrigation.

Advanced Surface Irrigation increases water efficiency in crop production by at least 20 to 30%, through the combination of the following two improvements:

- Surface irrigation system design (high flow rates), infrastructure (irrigation automation and sensor technology) and real time optimization of the irrigation system, can achieve a conservative 10% to 15% increase in on-farm water efficiency.
- Irrigation Scheduling and crop water management with sensor technology, data analytics, prediction, and prescription of irrigation events with the surface irrigation

automation can achieve a conservative 10% to 15% increase in on-farm water efficiency.

Surface irrigation system design (high flow rates), infrastructure (irrigation automation and sensor technology) and real time optimization

Irrigation system design, infrastructure (irrigation automation and sensor technology) and real time optimization of the irrigation system, University and Academic Research has demonstrated that it is feasible to transform inefficient manually operated flood irrigation systems having 50%-60% application efficiency to achieve high performance surface irrigation with 80%-95% application efficiency. In many cases yield was also increased, significantly improving the ratio of productivity/volume of water applied, in some cases producing double the dry matter per acre foot of applied water.

The border check bay width ratio to flow rate is an important design criteria element. This requires the replacement of several low flow discharge outlets with a single high flow outlet per border check, thus increasing the discharge rate (Q) and reducing the time to cut-off (Tco), which is proven to significantly increase Distribution Uniformity (DU) and Application Efficiency (AE). With improvements in application efficiency with surface irrigation, the applied water (using higher flow rates) ends up in the root zone, evenly distributed along the bay, resulting in losses by deep percolation (DP) and runoff (RO) being small, thus increasing water efficiency in crop production, which is not possible with low flow, manually operated, flood irrigation systems.

With improvements in real time optimization of the surface irrigation system, applied volume to the bay is precisely controlled by canal flow meter and continuously measured, irrigation evaluation data combined with flow depth measurements during an irrigation event pre calculates time to cutoff (Tco) early within the wetting advance (25% to 50% along the bay) and automatically adapts the irrigation program to increase or decrease time of the bay gate opening to significantly reduce run-off and deep percolation, resulting in higher water efficiency gains.

Irrigation duration (or time to cut-off) is critical in reaching those efficiencies. As flow rates are increased, the optimum duration decreases dramatically. Consistent with this, the accuracy and precision required in estimating and controlling the irrigation duration increases. The difficulty is compounded by the fact that conditions can change with each irrigation, for example, changes in irrigation flow rate, crop density, soil moisture, and hence the optimum time to cut-off (*Tco*) also changes. Management needs to adapt to these changes.

Automation of bay irrigation, such as the Rubicon's FarmConnect® solution (http://www.rubiconwater.com), provides the needed certainty in managing irrigation durations (along with very substantial labour efficiencies). Measurement of flow rate (AgPod Smart Meter) and the irrigation advance (SmartFront sensor) early in each irrigation provides the data needed to calculate the precise time to cut-off required for that irrigation. Various methods are available and include empirical guidelines (Smith *et al.*, 2013), volume balance calculations, and full hydrodynamic simulation (Smith *et al.*, 2012).

Irrigation Scheduling and crop water management

Irrigation scheduling and crop water management with sensor technology, data analytics, prediction, and prescription of irrigation events with the surface irrigation automation, University and Academic Research by Australian CSIRO and the CRC for Irrigation Futures showed better irrigation scheduling could boost water efficiency by 20-60% (Charlesworth, 2005), Colorado State University cites research in Nebraska, (where most water is pumped), shows that irrigation scheduling provides an average 35 % savings in water and energy (CSU Fact Sheet 4.708 Irrigation Scheduling) and Pacific Institute (Sustaining California Agriculture in an Uncertain Future, 2009) states a Kansas study found that irrigation scheduling reduced water use by 20% while also reducing energy, fertilizer, and labor costs. (Buchleiter et al. 1996).

1.2 INDUSTRY DEMONSTRATION PROJECTS

Collaborative Research Program – Holtville California USA – 2012 to Present

Rubicon, in collaboration with the University of California Division of Agriculture and Natural Resources (UC ANR), has a number of projects with the principal objective to demonstrate the gains in application efficiencies possible through the use of optimally-managed, automated, high-flow bay irrigation in California for alfalfa and furrow irrigation in Holtville, California for sugar beet production.

Recently, UC ANR commenced collaboration with the Sugar Beet industry to identify solutions solving the problems associated with labor cost with furrow irrigation. This project utilizes Rubicon's FarmConnect solution of smart automation systems for furrow irrigation (of sugar beet) at UC ANR's Desert Research and Extension Centre, located in Holtville, California.

It applies the best available automation, flow control infrastructure and in-field sensor technology integrated with adaptive irrigation control and simulation software to maximise water efficiency performance of surface irrigation systems. The significance of this project for sugar beet growers with furrow irrigation is that it will provide avenues to deliver similar application efficiency performance as pressurised systems at lower capital and operating costs.

Local research carried out by UC Davis at the UC Desert Research and Extension Center in Holtville, ran the Imperial Valley Sugar Beet industry research project over the 2019 – 2021 irrigation seasons, and demonstrated it is possible to achieve an Application Efficiency (AE) of 85% (Bali & Kaffka) in Imperial valley with surface irrigation using automated furrow.

Collaborative Research Program - Australia –Furrow Surface Irrigation – 2014 to 2018

Rubicon Water partnered with the Australian Cotton Research and Development Corporation (CRDC) and the University of Southern Queensland (USQ) on a specific research project evaluating Smart automated furrow irrigation of cotton (Uddin, J et al 2015, Uddin, J et al 2018) to demonstrate that automation of surface irrigation (with furrows, by replacing a manual system with siphons), and real time optimization can achieve high application efficiencies of

85%+ compared to traditional manually operated flood irrigation with 50-60% application efficiencies. The project included extensive use of surface irrigation automation, soil moisture sensors and interpretation of data, supplied by Rubicon, as part Smarter Irrigation for Profit (SIP 1) program (1st July 2015 to 31 May 2018). A prototype of smart commercial automation equipment for furrow irrigation was designed, trialed, and evaluated on a cotton farm in Australia.

Some key findings from the research project evaluating Smart automated furrow irrigation of cotton, can be summarized as:

> The study demonstrated that automation of furrow irrigation in cotton is feasible, practical, and able to be implemented immediately using commercially available equipment and innovative infield design. Real-time optimization (or prediction of time to cutoff) using a simple field-specific algorithm can deliver improved application efficiencies easily and reliably. (p8 in the Smart Automated Furrow Irrigation of Cotton paper - 2018)
>
> Results found that together with automation of furrow irrigation and real-time optimization they deliver a modern surface irrigation system with water and labor savings equivalent to the pressurized center pivot and lateral move machines at a lower capital cost and without the ongoing energy costs (p8 in the Smart Automated Furrow Irrigation of Cotton paper - 2018).
>
> The research also highlighted that with well-designed and managed surface irrigation systems employing real-time optimization of individual irrigation events, application efficiencies in excess of 90% should be possible, as demonstrated in simulation studies by Smith et al. (2005) and Khatri and Smith (2007) and in field evaluations by Koech et al. (2014b) (p1 in the Smart Automated Furrow Irrigation of Cotton paper - 2018).

Reference: Uddin, J., Smith R. J., Gillies, M, H., Moller, P., and Robson, D., (2015). 'Smart automated furrow irrigation of cotton' Commercial prototype smart automation system for furrow irrigation. National Centre for Engineering in Agriculture. Cotton Research Development Corporation Final Report NEC1302 pp. 40-58.

Reference: Uddin, M.J. Smith, R.J. Gillies M.H. P Moller, D Robson (2018) "Smart automated furrow irrigation of cotton" Journal of Irrigation and Drainage Engineering 144 (5), 04018005 (Published by the American Society of Civil Engineers)

Collaborative Research Program – Victoria, Australia – Border Check Surface Irrigation – 2013 to 2016

Rubicon Water, collaborated with University of Southern Queensland (USQ) on a research project evaluating the performance of automated bay irrigation (Smith, R.J., et al 2016). Previous evaluations of bay (or border check) irrigation in northern Victoria have shown that higher irrigation flows offer very much improved (volumetric) application efficiencies, well above those currently achieved. However, having the correct irrigation duration (or time to cut-off) is critical in reaching those efficiencies.

Automation of bay irrigation provides the needed precision in managing the shorter irrigation durations that result from the higher flows. Hence, the objective of the study was to demonstrate the application efficiencies achievable using automated, high-flow bay irrigation.

Some key findings from the research project evaluating the performance of automated bay irrigation, mostly for the dairy industry for fiber production, can be summarized as:

> The results from the evaluations demonstrate that application efficiencies in excess of 90 % are indeed achievable and being achieved through correct and precise management
>
> of automated surface irrigation (p5 in the Evaluating the performance of automated bay irrigation paper - 2016)
>
> Of the nine commercial farms evaluated with surface irrigation automation, four of the farms evaluated in this study are already operating at that level. For four of the other five farms, strategies have been identified that will raise their efficiency close to or above 90 % (p5 in the Evaluating the performance of automated bay irrigation paper - 2016)

Reference: Smith, R.J. Uddin, M.J. Gillies M.H., Moller P., Clurey, K. (2016) "Evaluating the performance of automated bay irrigation" Irrigation science 34 (3), 175-185

1.3 CASE STUDY – INCREASED PRODUCTIVITY USING LESS WATER

The following case study is an example of how using an integrated system of Automation and Crop Management can achieve increased productivity using less water. Russell and Cathy Pell operate a dairy and mixed cropping 2,000 acre property in Victoria Australia irrigated by border check surface irrigation, supporting a modern dairy milking a herd of 750. Since 2011 they have operated FarmConnect's Advanced Surface Irrigation system to irrigate their maize crop (silage), pasture and alfalfa which included the automation of 80 x 5 acre bays. The benefits and financial success during the 2011-12 irrigation season with the maize crop (silage) included 20% water savings (0.6ac-ft/ac), 22% increased productivity (5tn/ac), doubling of dry matter production per acre (5.4tn per ac-ft), and revenue increase ($404/ac) with the capital investment of $560/ac which achieves a return of investment (ROI) in two - three seasons.

The FarmConnect solution has assisted the Pell's to:

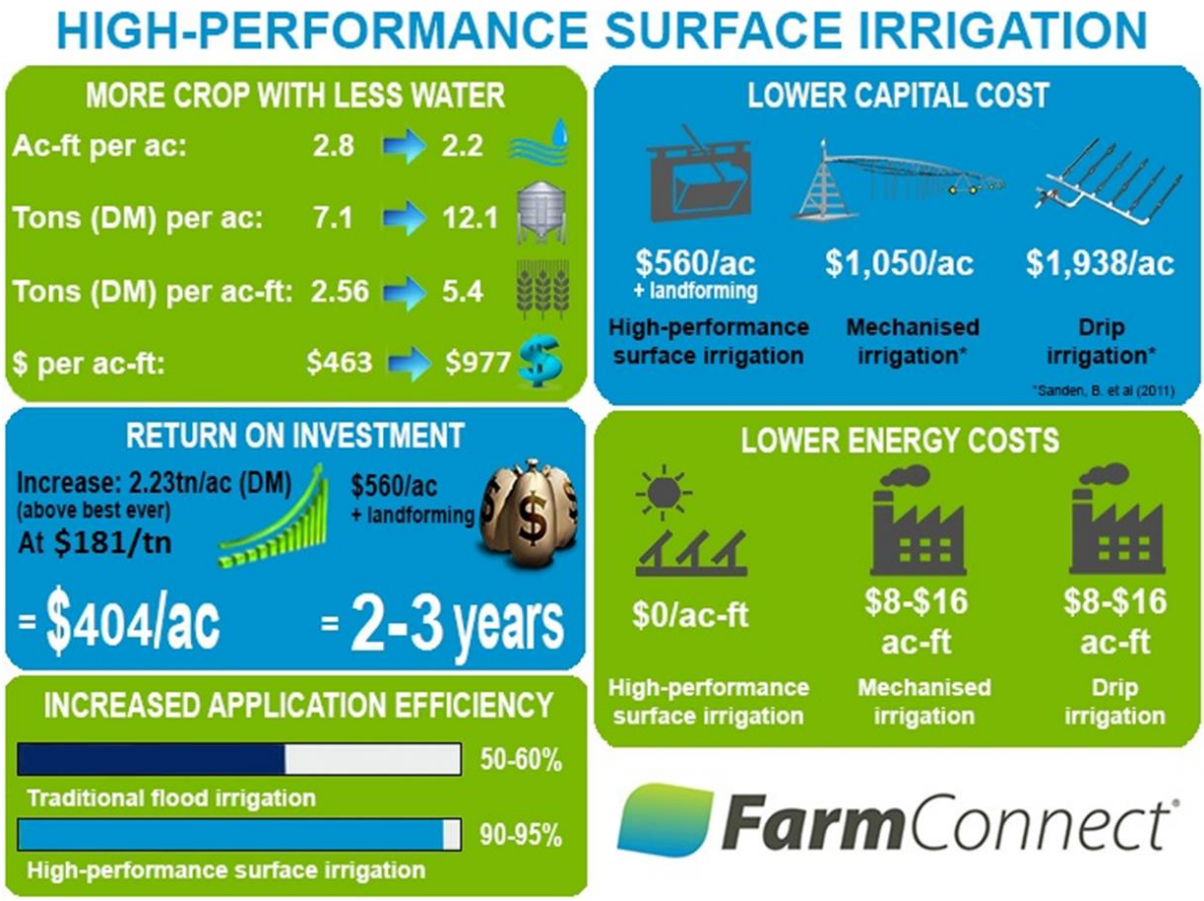

Figure 1 Example of Benefits with Pell Farm Victoria Australia

Surface irrigation is the predominate method of irrigation for food and fibre production worldwide. The potential for wider adoption is significant with on-farm application efficiencies for surface irrigation in the range of 85 to 95% achievable. Combining Advanced Surface Irrigation (with high flow) with accurate cut-off times through automation reduces water use by over 20%.

In addition, yield increase of 20% is achievable through smart sensor technology, connected devices and hardware, data analytics and agronomy and science.

1.4 FARMCONNECT WATER MANAGEMENT SYSTEM

Automation

This state-of-the-art automation system from Rubicon Water, achieves the benefits of high flow rates and shorter run times, essential for achieving Advanced Surface Irrigation. This involves installing remotely operated BladeValves and RiserDrive Valves (for pipe and riser systems) or BayDrive actuators (for bay gate systems) on high flow bay outlets, an on-farm LoRaWAN® radio communication network and web-based cloud computer software which is used to manage all aspects of irrigation on the farm.

Figure 2 BayDrive actuation for border check systems - closed

Figure 3 BayDrive actuation for border check systems

Figure 4 BayDrive actuation for furrow systems

Figure 5 BayDrive actuation for furrow systems

Figure 6 RiserDrive valve automation for alfalfa pipe and riser systems

The software collects data from soil sensors to determine plant water demand, dispatches irrigation schedules to control the opening and closing of bay outlets and in-channel checks, and automatically sends email, SMS alarms and status updates to keep the irrigator's informed of irrigation performance. Integrated GPS within each LoRaWAN® Radio Node makes it quick and easy to add more sensors and automated bay outlets over time, and enable each device to be displayed on a satellite map of the farm. It also provides real-time coordinate information for location-tagging of data for spatial analysis. Because the system utilises cloud software the irrigator can remotely access the system when in the field or when absent from the farm, using mobile devices connected to the internet – providing up- to- the- minute information on crop status, remote management of irrigation schedules and monitoring.

Demand-side management

By installing soil moisture sensors, which are managed within FarmConnect's crop management module using the same software system as the automation, Rubicon have introduced science and agronomy to the process of determining when to water and how much to apply.

Smart sensors measure the soil profile every 4inch down to a depth of 36 inches. Precise measurement of soil moisture has enabled a number of water-saving strategies to be

implemented. Measurement of soil moisture gives the irrigator the confidence to extend each irrigation interval without any reduction in crop productivity reducing the number of irrigations during the season with an estimated water savings of 20%. Measurement of consumptive use of available water and utilisation at all levels of the crop's root zone provides a soil profile with increased capacity to accept the infiltration of the next irrigation, avoiding post irrigation waterlogging stress and thus increasing productivity.

Measurement accurately predicts the number of days till the next date of irrigation and provides the ability to defer irrigations to 'harvest' anticipated rainfall occurring between irrigation events.

1.5 FARMCONNECT WEB SOFTWARE

FarmConnect is a single platform to deliver the water saving for Advanced Surface Irrigation.

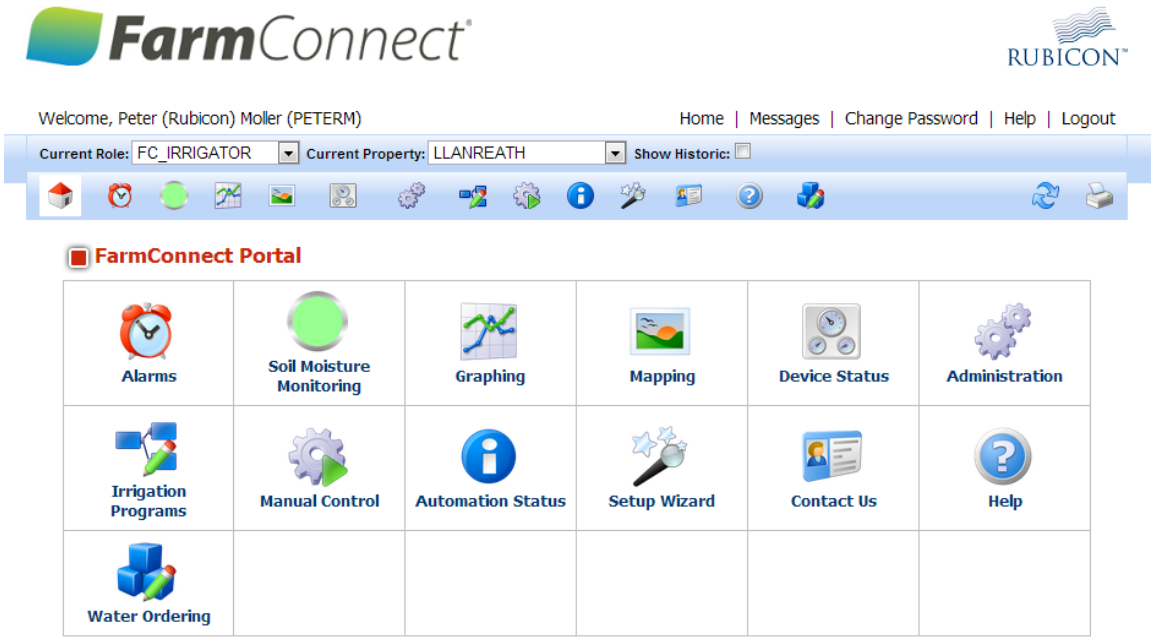

Figure 7 FarmConnect WEB Interface Used by Irrigators

The web based portal incorporates:

- control and automation (using LoRaWAN® radios with Rubicon BayDrive Actuation, BladeValve or RiserDrive),
- irrigation system monitoring (pressure, flow, water level, remote pump)
- auto detection for cut-off times (using SmartFront) and
- sensing plant water demand for irrigation commencement (using soil moisture probes)

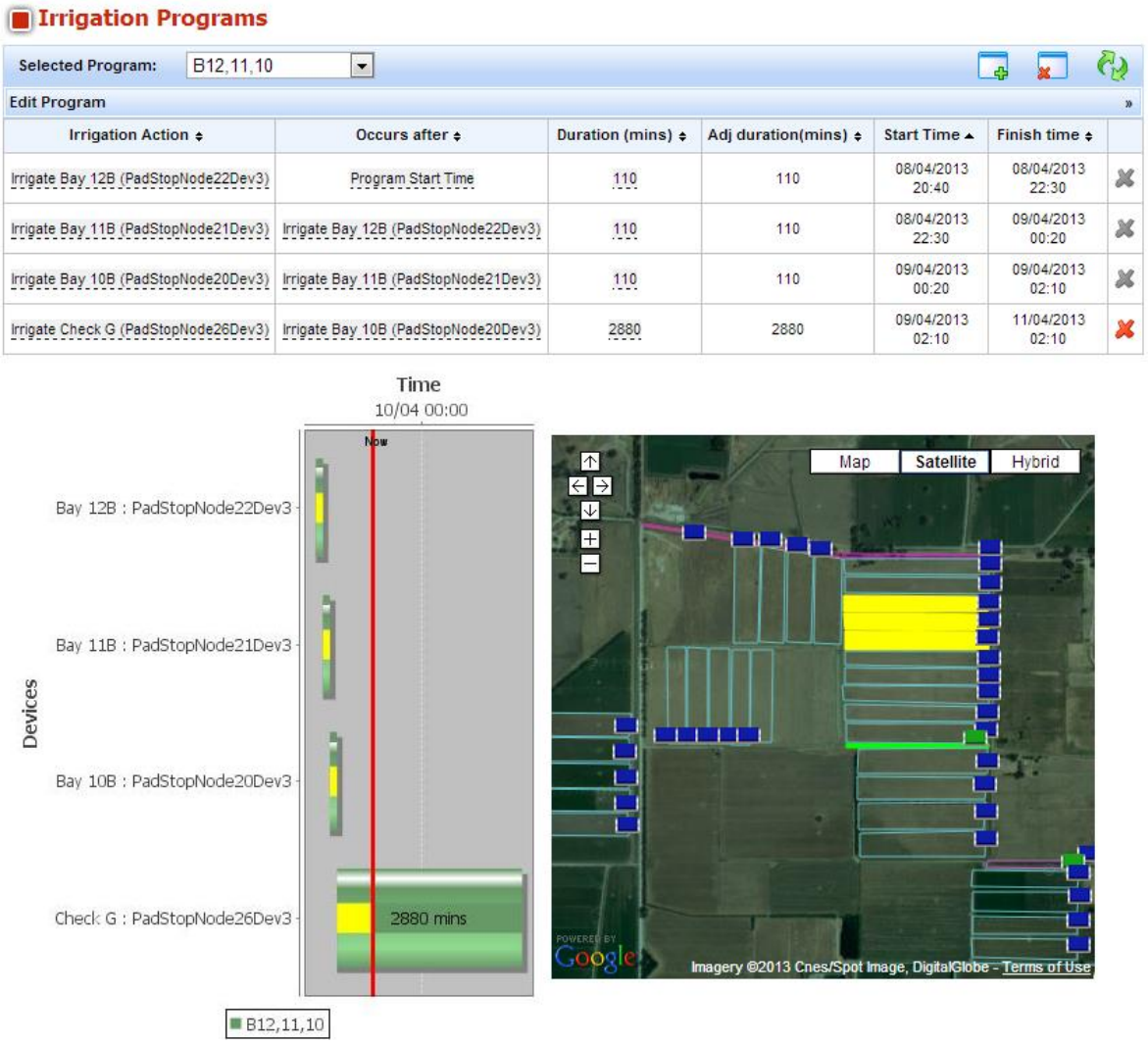

Figure 8 Automatic Irrigation Program for 3 BayDrives and 1 inline Channel check

Each irrigation schedule is easily setup in a program. The schedule can be checked graphically to ensure correct sequence and spatially to ensure each bay that is intended to be irrigated is included in the irrigation program.

Figure 9 Automatic Irrigation Status

Once an irrigation program is setup the irrigation completes the task by releasing the 'presets' for each radio via the web based software. Acknowledgement is received ensuring the instruction (preset) for each individual radio to open and closes is valid and in ready mode.

Progress of an irrigation program can be monitored remotely to ensure each bay is being irrigated at the instructed time slot and its status is indicated as completed or in progress.

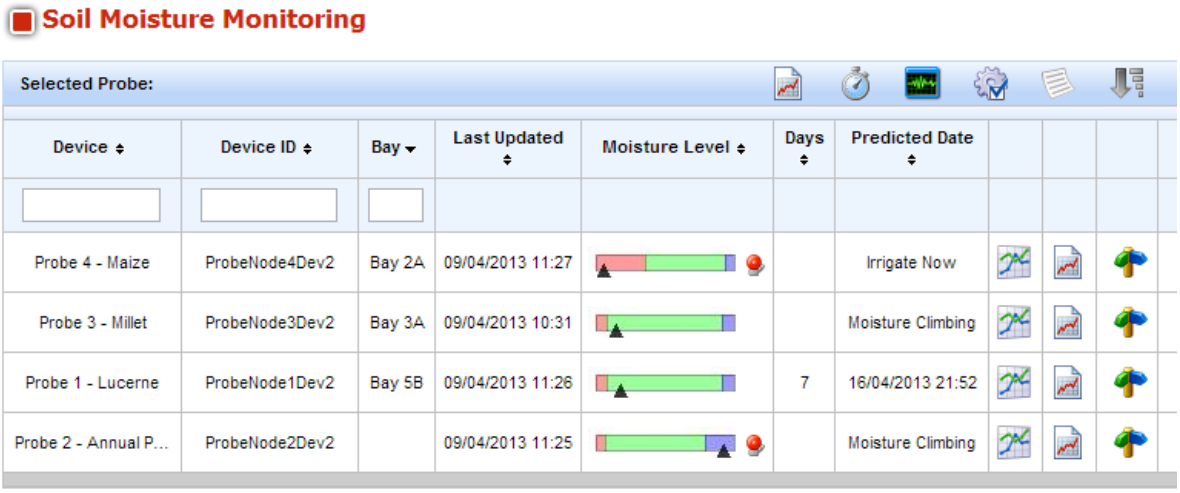

Figure 10 Soil Moisture status for 4 crops and predictive date for next irrigation

Prediction of next Irrigation is indicated graphically or summarised in a table form. This information is extrapolated from the trend of current crop water use, estimating future soil moisture decline. The trend line automatically updates providing the latest trend to determine when the next irrigation is due (when the trend line intersects the refill point).

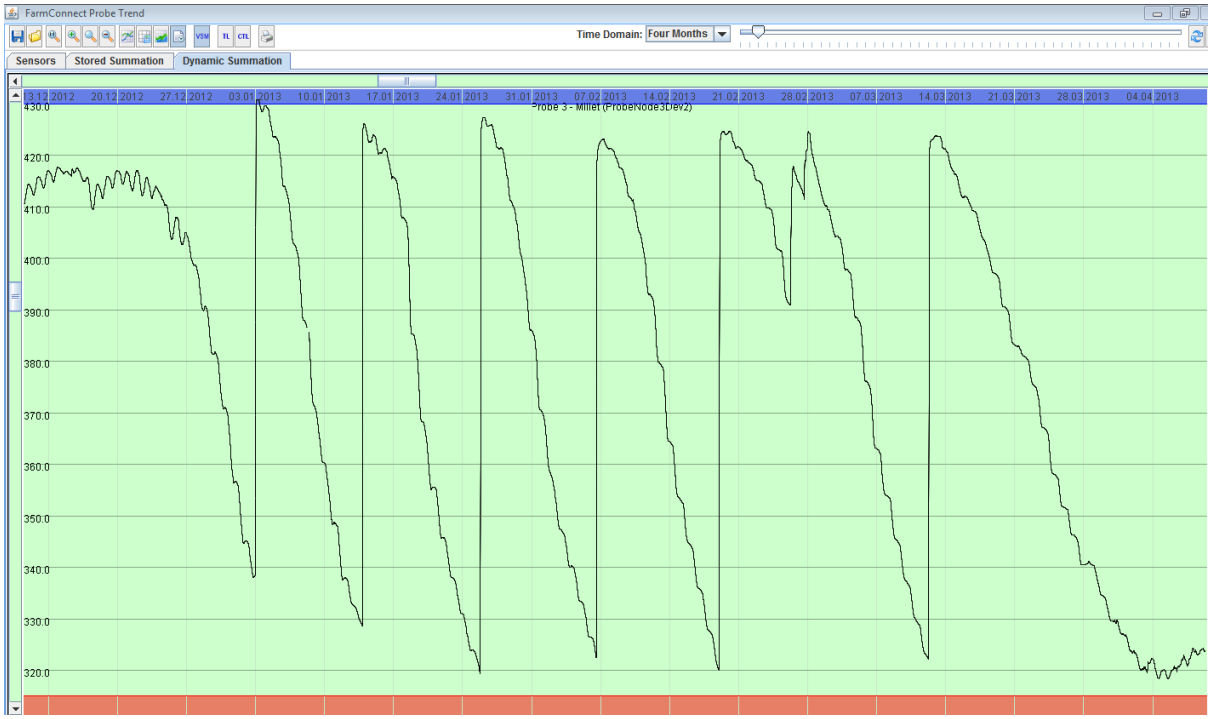

Figure 11 Soil Moisture Graph for 4 months – total profile for root zone

Summed Graph can quantify:

- daily water use rate
- irrigation effectiveness
- when to irrigate
- how much to irrigate
- establish upper & lower limits

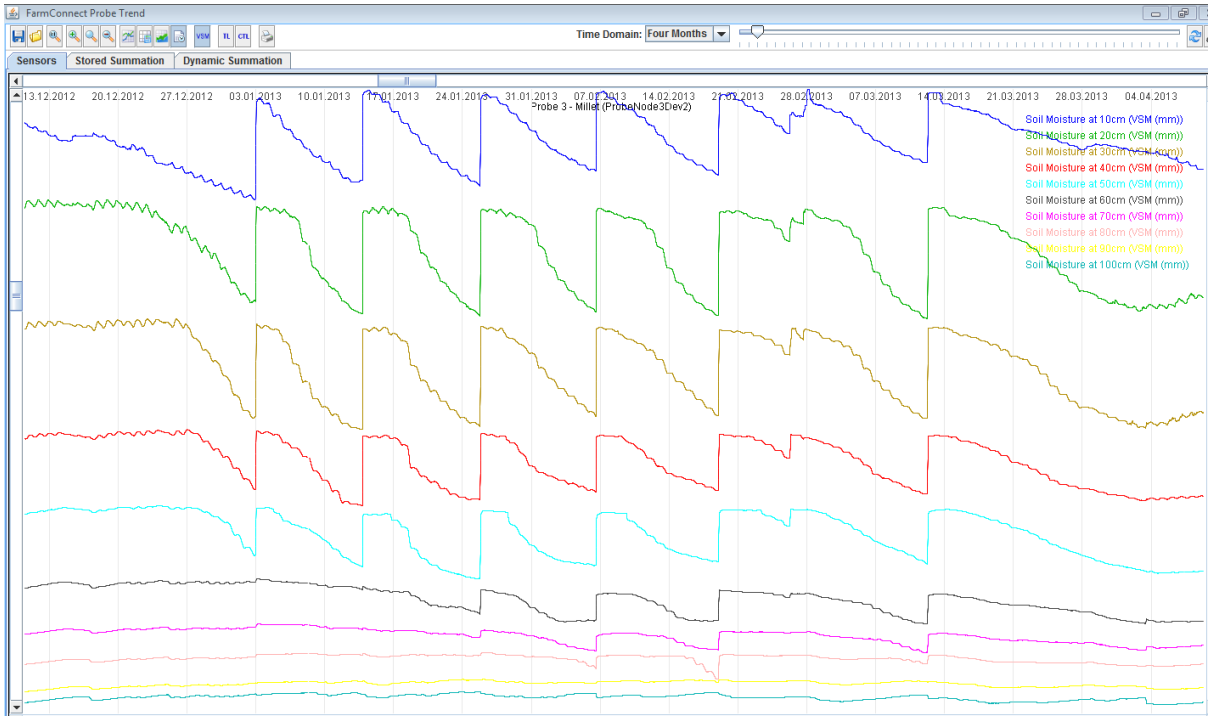

Figure 12 Soil Moisture Graph for 4 months – Separate layer profile for 10 layers

Separate Layer Graph can quantify:

- through drainage & infiltration rates
- where most root activity occurs
- soil moisture stress at each layer

1.6 AGPOD SMART METER

Rubicon's flow metering and flow control technology also comes with the capability for 'smart meter' connectivity between the off-farm supply system and the on-farm operations. The AgPod Smart Meter represents a significant advance in on-farm flow metering technology and reporting. The AgPod Smart Meter is a piece of hardware that enables the service point meter to be linked with the customer's on-farm automation system.

There are many benefits from the integration of these two operational systems via a direct seamless connection. The AgPod Smart Meter is designed to allow third party on-farm products to interface and will provide access to the following information.

a. Meter operating status
b. Current Flow rate
c. Current Usage Meter (Volume)
d. Stored Water Order Information

The on-farm automation system (FarmConnect) records the real-time flow data obtained from the AgPod Smart Meter for each irrigation program. The flow information is be used as part of the adaptive control process to increase or decrease the volume required for each bay by automatically calculating and adjusting the runtime and cut-off intervals for each irrigation event. This can also be applied to varying the flow, if time is fixed.

The water order start and stop events obtained from the Smart Meter will be used to trigger actions defined within the on-farm automation program (e.g. when service point opens the on-farm program will send an instruction to open a bay gate).

During an irrigation event the volume data will be collated down to a bay level allowing the water use efficiency to be quantified accurately and subsequently aggregated on a growing season or crop basis.

The AgPod Smart Meter is physically mounted on the mast of TCC® (Total Channel Control®) Pedestal located at the customer's service point. The Smart Meter effectively acts as a firewall, isolating the meter's hardware and software functionality from the on-farm automation system. This will ensure there is no impact on TCC operation (both locally and at the host), on the metrology system and on the TCC communication system. The device includes the necessary electronics, wireless transceiver hardware and embedded software.

Figure 13 AgPod Smart Meter connected to a Farm Turnout flowmeter (SlipMeter)

Figure 14 AgPod Smart Meter

1.7 SMARTFRONT SENSOR

Rubicon's integrated solution adds science to the decision to determine the optimal time to shut the bay outlet to avoid tail water losses. The precise time to stop the flow onto the bay from the bay outlet or riser valve is dynamic due to:

- seasonal changes in ground cover changing the resistance for water flow across the bay
- a difference in soil moisture content from the previous irrigation changing the actual runtime required for cut-off

This device is an essential requirement to ensure that irrigations with higher flow rates lead to high water application efficiency. Irrigation runtimes have been reduced from 6 hours under

traditional flow rates with small outlets to a total of 90 minutes under modernised irrigation outlets using higher flow rates.

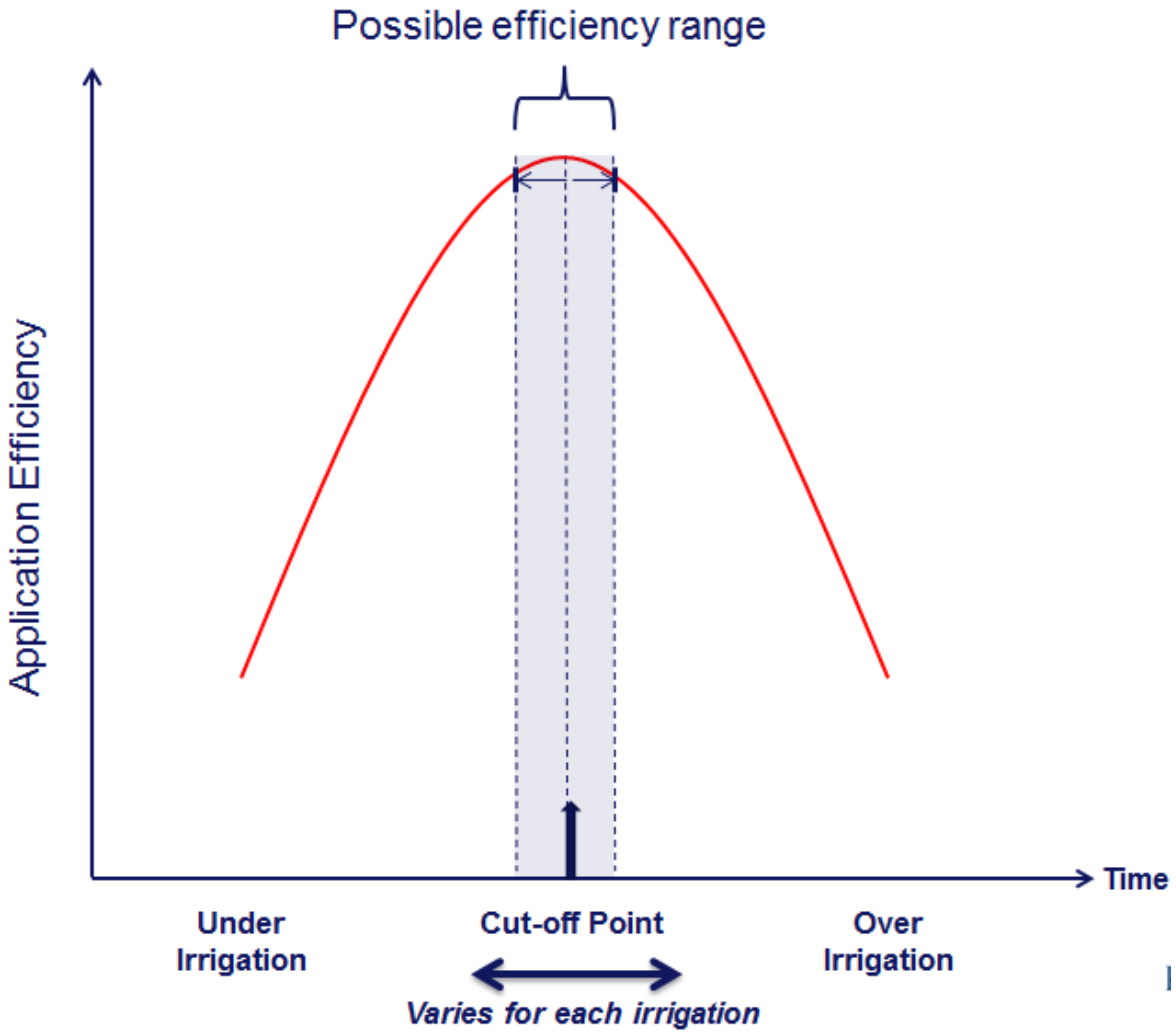

Figure 15 Operational Envelope for Advanced Surface Irrigation Management

The graph above shows that importance of having precise cut-off times, particularly with higher flows rates under a modernised system as the application efficiency reduces rapidly when bay changeovers are not done on time. Traditionally this decision to changeover was made through observation and guess work with manual visits to each bay regularly during the total irrigation schedule that could be 48 to 72 hours long in duration.

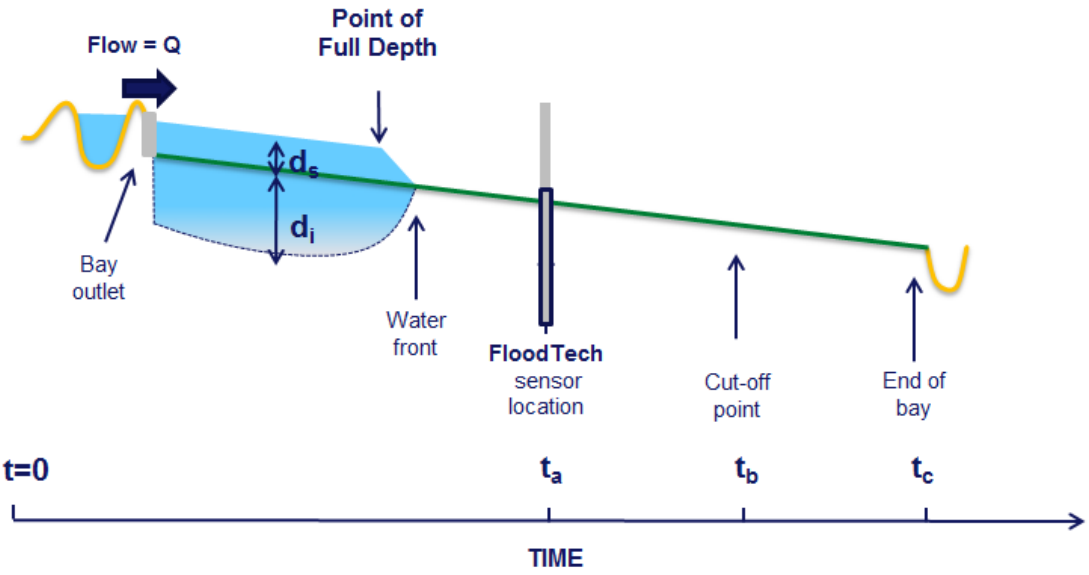

Figure 16 Data components of a SmartFront Sensor Installation

By sharing the flow data from the Service Point meter via the AgPod Smart Meter to Rubicon's FarmConnect software, the total volume (Q) of water being applied to a bay is measured and length of time (ta) is analysed to define the volume of infiltration (di) into the soil profile preceding the SmartFront sensor which is placed midway down the bay. A calculation can then be generated on the remaining minutes (tb) an irrigation event needs to run before cutting off the bay gate and ending supply of water from the Service Point Meter. Only enough water (ds) is allocated to pass the SmartFront sensor so it fully infiltrates the soil (di) with no runoff into the tail water drain at the end of the bay (tc).

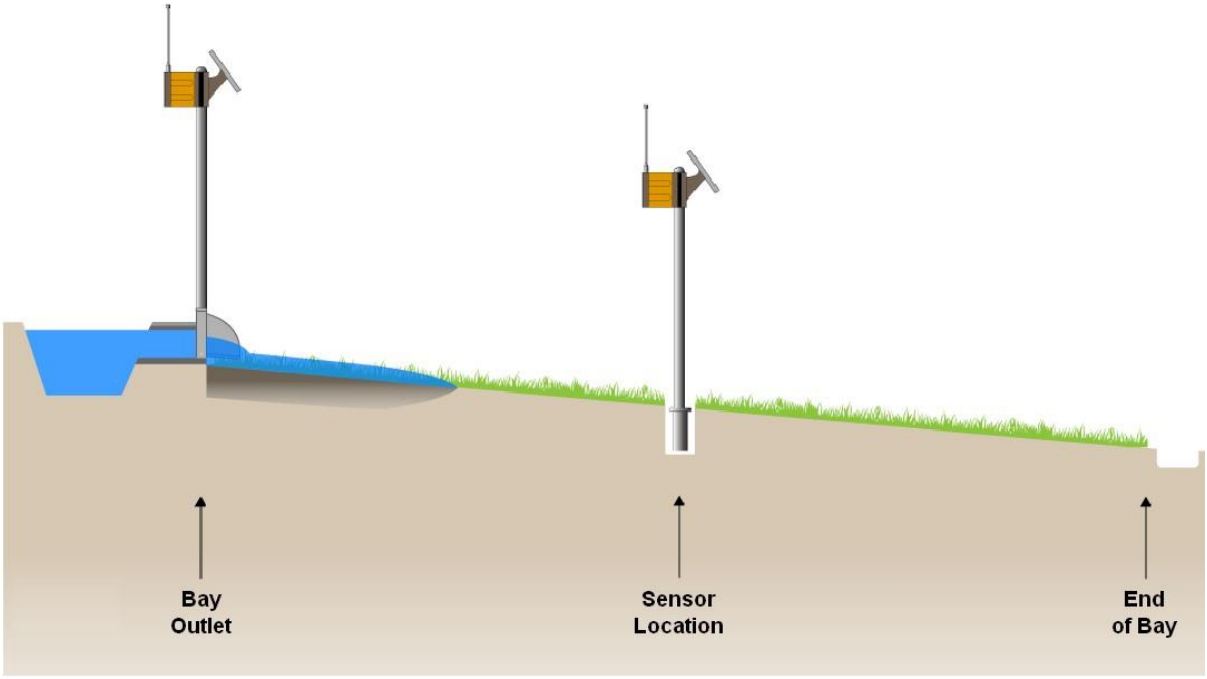

Figure 17 Sequence pre SmartFront Sensor Installation

The automatic irrigation schedule commences with a wireless command (preset) to open the BayDrive or BladeValve. The total volume (Q) of water being applied to a bay is measured and length of time (ta) it takes to reach the SmartFront sensor is recorded.

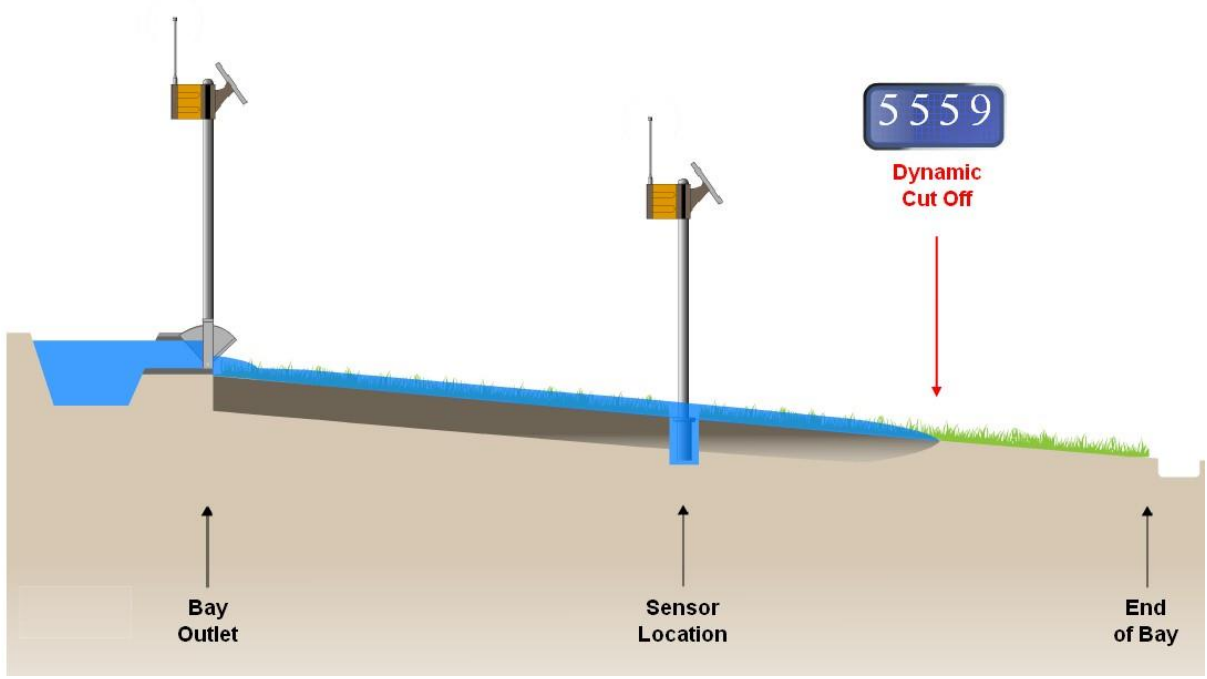

Figure 18 Sequence post SmartFront Sensor Installation

Upon the wetting front advancing to the SmartFront sensor, the flow and time data is used to calculate remaining volume to be supplied from the Service point Meter to infiltration into the soil profile without runoff. The Dynamic Cut Off time is delivered into the program to automatically change the total irrigation program for the current bay and the following bays that are similar in crop type, soil texture and topography.

Figure 19 SmartFront Sensor Installation

1.8 UNIVERSITY AND ACADEMIC RESEARCH

The goal to achieve an increase of 20 to 30% in water efficiency in crop production, using a conservative 10 to 15% increase in on-farm water efficiency with the Rubicon Water methods and technology for irrigation system design (high flow rates), infrastructure (irrigation automation and sensor technology) and real time optimization of the irrigation system, **and** using a conservative 10 to 15% increase in on-farm water efficiency with irrigation scheduling and crop water management with sensor technology, data analytics, prediction, and prescription of irrigation events, is further supported by the evidence base in the following irrigation research programs:

National Irrigation Research Program - Australia - 1st July 2015 to 31 May 2018

The Smarter Irrigation for Profit (SIP 1) provided growers improved understanding of the implications for capital investment, management, and the resource requirements (water,

energy, and labour) associated with different irrigation systems and the adoption of automation technology and different approaches to farming systems.

Some key finding from Smarter Irrigation for Profit (SIP 1) Final Report, can be summarized as:

> Surface irrigation (be it by furrow or in bays) is the most common form of irrigation due to its low capital cost and low energy requirements. Well-designed and well-managed surface irrigation can achieve application efficiencies of 95%, showing that efficiency comes from design and management, and is not an inherent characteristic of the system itself. Smarter Irrigation for Profit trials showed that application efficiencies for surface irrigation can often be improved by better design and scheduling – reducing losses through deep drainage and run-off. (p5 in the Smarter Irrigation for Profit (Phase 1) Final Report 2018)
>
> Evidence in the project found progressions like improved scheduling can produce step-changes in irrigation operations. (p5 in the Smarter Irrigation for Profit Phase 1 - Final Report 2018)
>
> The flow of irrigation water can now be controlled automatically from source to within a field. It relies on sensors and telecommunication to control automated equipment, permitting the remote control of irrigation through a computer or smart-phone interface. Coupling automation with precision scheduling packages ensures the resultant irrigation is optimal, not just the remote control of automated, poor practice. (p6 in the Smarter Irrigation for Profit Phase 1 - Final Report 2018)
>
> Smarter Irrigation for Profit trialled automated systems across several commodities and irrigation systems. It found significant benefits to irrigators through convenience and time-saving, as well as improved irrigation practice. The work showed that highly automated, if not autonomous (self-controlling), systems are feasible and they have potential for continued development and wider application. (p6 in the Smarter Irrigation for Profit Phase 1 - Final Report 2018)
>
> Using Rubicon Water FarmConnect fully automated sPTB Surface (furrow) irrigation, in the first and third season of trials, optimised run times for furrow irrigation reduced flow durations by one-sixth over normal practice, leading to pumped water savings in the vicinity of 20%, or 2 AF (2.5 ML/ha). (p35 in the Smarter Irrigation for Profit Phase 1 - Final Report 2018)

Reference: Roth G (ed), Foley J, Gall L, Hills J, Jamali H, Jaramillo A, McAllister A, McCarthy A, Morris M, North S, Phelps C, Smith J, Trindall J, White M (2018) Smarter Irrigation for Profit. Final Report. Cotton Research and Development Corporation, Australia.

National Irrigation Research Program - Australia - 1st May 2019 to 30 June 2022

Further research in Australia with surface irrigation automation, optimization, and irrigation scheduling continued in a second phase research project, referred to as Smarter Irrigation for

Profit Phase 2 (SIP2) program (1st May 2019 to 30 June 2022), and was established to increase farm productivity and profit in the cotton, dairy, rice, grains, and sugar industries, by developing new irrigation technologies to increase Water Use Efficiency (WUE).

Some key finding from Smarter Irrigation for Profit (SIP 2) Final Report, relevant to the Rubicon Water's solutions, can be summarized as:

> Development of smart sensing and irrigation automation technologies that have considerable productivity and profit benefits for surface irrigators. Benefits include an 85% reduction in labour and water savings of up to 20%. (p84 in the Smarter Irrigation for Profit Phase 2 - Final Report 2022)
>
> In delivering a scalable, consistent, and predictable bay scale irrigation performance through a simple approach to where, when, and how much, this project has provided the underpinning requirements to support an autonomous approach to water management. The project has seen the building of confidence and knowledge in participant irrigators in using this approach to optimise irrigation performance. The project demonstrated water savings of around 0.73AF (0.9 ML/ha) which represent 10-15% of water use depending on the season. (p104 in the Smarter Irrigation for Profit Phase 2 - Final Report, RRDP 2011 Scaling irrigation management for dairy farms 2022).

Reference: Phelps, C (Ed), Feliv Maia R, Foley J, Gall, L, Gillies M, Hills J, Hornbuckle J, Jamali H, Lescun C, McAllister A, Qiao G, Shultz A, Scobie M, Simmons A, White M (2022) Smarter Irrigation for Profit Phase 2. Final Report. Cotton Research and Development Corporation, Australia.

1.9 BENEFITS

Economic Benefits: Advanced Surface Irrigation projects have demonstrated the extent of the efficiency gains that are possible with this system and the management strategies necessary to achieve those gains. The benefits include:

- increased application efficiency and water use efficiency.
- decreased waterlogging and hence increased productivity with higher yields and increased quality of crops.
- improve the profitability of farms by increasing the crop yield through improved irrigation, and hence increasing the grower income

Environmental Benefits: Advanced Surface Irrigation projects have demonstrated the sustainability of surface irrigated farms by ensuring that only the minimum necessary water is used to maintain the crops. The improved application efficiency and reduced water use will also lead to reduced impacts on the environment by reducing deep drainage.

Social Benefits: Advanced Surface Irrigation projects:

- have demonstrated to the community and stakeholders how high flow bay irrigation together with automation and accurate and precise timing will lead to increasing food and fibre productivity utilising less water
- lead to increasing community knowledge and awareness of the benefits of water efficient gravity feed irrigation systems
- demonstrate how gravity feed irrigation systems have a key role in delivering water for food production with little or no energy inputs and a decreased carbon foot print
- increase the skills capacity of irrigators through knowledge transfer to enable irrigators to adopt management practices to increase the water use efficiency and food productivity

1.10 SUMMARY

Rubicon Water has proven that automation is an essential element of Advanced Surface Irrigation, ensuring the On-Farm development programs achieve increased application efficiencies by using an integrated system of Automation and Crop Management to achieve increased productivity using less water.

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