NATIONAL PROGRAM FOR
Sustainable Irrigation

LONGSTOP:
A more sensitive Wetting Front Detector

Milestone 1 Report

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Disclaimer

About NPSI

The National Program for Sustainable Irrigation focuses research on the development and adoption of sustainable irrigation practices in Australian agriculture. The aim is to address critical emerging environmental management issues, while generating long-term economic and social benefits that ensure irrigation has a viable future.

The Program has 14 funding partners who are: Land & Water Australia (Managing Partner); Sunwater, Queensland; Horticulture Australia Limited; Goulburn-Murray Water, Victoria; Cotton Research and Development Corporation; Harvey Water, Western Australia; Lower Murray Water Authority, Victoria; Wimmera Mallee Water, Victoria; Ord Irrigation Cooperative, Western Australia; Australian Government Department of Agriculture, Fisheries and Forestry; Department of Natural Resources and Mines, Queensland; Department of Primary Industries and Resources South Australia; Department of Environment Water and Catchment, Western Australia; and Department of Agriculture, Western Australia.

Project reference no: CLW 81

Project title: LongStop: A more sensitive Wetting Front Detector

Principal investigators: Richard Stirzaker

Project duration: 10 months

Due date for milestone report: 30 May 2006

Project objectives:

1. Field test a simple device that alerts growers that drainage of water below the rootzone has reached unacceptable levels.
2. Compare versions of the Wetting Front Detector with different sensitivity limits.
3. Evaluate different fill materials for the LongStop that ensure the instrument remains in hydraulic equilibrium with the soil.
4. Provide guidelines as to how to deploy a wetting front detector on a cracking clay soil
5. Utilise the Cotton and Grains Knowledge Project (CRD1), the CRCIF and CRC cotton extension networks for communicating the project results to irrigators.

Alteration to original objectives: Nil.

Milestones Requirements

Build LongStops and test fill materials

Purchase soil water monitoring equipment and install together with FullStops and LongStops in cotton field

Monitor performance of Wetting Front detectors through one irrigation season

Achievement criteria:

1. Equipment built, installed and functioning in field
2. Data sets of wetting fronts detected against irrigation and tension measurements

Results for achievement of Criteria 1

The FullStop Wetting Front Detector was designed to be a simple, inexpensive and robust device that gives a yes/no answer to whether a wetting front has reached a particular depth in the soil. When searching for simplicity and low cost, tradeoffs need to be made with sensitivity; in the case of FullStop the decision was made to detect a 2 kPa strength wetting front. From a theoretical perspective, the FullStop Wetting Front Detector is not well suited to furrow irrigation, deep placement, cracking soils or where soil disturbance must be minimized. The LongStop Wetting Front Detector has been specifically designed for the above applications. Prototypes have undergone limited field testing in sandy soils, and this pilot study evaluates the performance of the LongStop under a furrow irrigated cotton crop on a cracking grey clay.

A LongStop (LS) is comprised of two concentric tubes. The outer tube is filled with a porous material and the inner tube is filled with air, with the tubes connected via a screen filter near the base. For this pilot, LSs were built to have sensitivities of 6 and 10 kPa, i.e. the LS would give a signal to the irrigator when a wetting front, having a strength of 6 or 10 kPa, reached the depth it was buried.

The LS must be filled with a material with a high hydraulic conductivity. If the soil is drying rapidly around the LS, the material in the LS must be able to transmit water sufficiently fast such that the suction in the soil equals the depth to the water level in the inner tube. Since the hydraulic conductivity decreases rapidly as suction increases, it is important that the fill material has a high conductivity at a suction equal to the length of the LS.

Two fill materials were evaluated for their particle size and hydraulic characteristics. Diatomaceous earth is well known for its high unsaturated hydraulic conductivity. Although the particle size is quite large (>100 microns), it has a micro-structure giving a dense network of small interconnecting pores. The fine sand material contained 50% particle size less than 100 micron by mass. It was much easier to pack into the LS than diatomaceous earth, but has a lower conductivity at 100 cm suction.

The water release characteristics of the fill materials influences the response time of the LS. Diatomaceous earth remains near saturation over the 0-100 cm suction range. This means that the material within the LS does not need to fill and empty as the soil suction changes within its sensitivity range. In contrast, the fine sand takes up water as the soil wets, which may delay the response time of the instrument. However, diatomaceous earth holds so much water that the material in the LS could act as a reservoir of water; as the soil dries around the LS opening, this 'reservoir' could cause local changes in soil water status.

The experiment was carried out at the Australian Cotton Research Institute (ACRI), Myall Vale, NSW. The soil is a self mulching grey Vertosol (clay percentage 50% dominated by smectites). The furrows were 200 m long. Cotton was planted in October 2005 and harvested in April 2006.

Two lengths of LongStop were compared, 60 and 100 cm, equating to sensitivities of 6 and 10 kPa respectively. These are referred to as LS_60 and LS_100. Each length LS was either filled with diatomaceous earth (d.e.) or the fine sand material. LongStops were installed to monitor fronts passing depths of 50 and 100 cm at the head and tail end of the furrow. A total of thirty-two LongStops were installed (2 lengths x 2 fill materials x 2 depths x four replicates).

A 'push tube' was used to create a 50 mm diameter hole, which in the case of a LS_100 monitoring at 100 cm depth, needed to be 200 cm deep. The LongStop was then inserted into the hole. Diatomaceous earth or fine sand (the same as the material inside the LS) was then poured down the hole to fill any gaps between the LS and the wall of the hole and to provide a 10 cm 'wick' above the LS. The role of the wick was to keep the LS and the soil in hydraulic equilibrium. Bentonite clay was added above the wick, so that no water could enter the LS via the disturbed soil. The water had to enter the LS radially via the wick immediately above it.

Six of the LongStop installations were monitored with pairs of Watermark capillary matrix sensors, so that soil water potential could be monitored on a four hourly basis. For each LS, one sensor was placed in the wick material just above the LS, and the other in the soil about 50 cm away at the same depth.

16 FullStop wetting front detectors were also installed in the centre of the beds (cotton row), 25 and 50 cm below the depth of the furrow. Half the FullStop wetting front detectors were filled with the same fine sand as used in the LongStops and the other half were filled with clay soil. The FullStop funnels were filled with fine sand in an attempt to stop them being triggered by preferential flow. The fine sand has a very high affinity for water, so if water was delivered to the funnel via a crack, the fine sand would wet up and transmit water to the surrounding soil, so that saturation would not occur at the base of the funnel until all the surround soil was wetted to about 2 kPa suction.

Results for achievement of Criteria 2

Due to the late signing of the agreement there was a delay in getting funds released to build the equipment and purchase the soil water monitoring sensors. Complete installation of all equipment (16 FullStops, 32 LongStops, 12 Capillary matrix sensors) was therefore only completed in January 2006. Results will therefore be presented over the last four irrigation events, which took place between January and March 06.

All shallow FullStops (25 cm depth) were triggered by each of the four irrigation events, regardless of whether they were filled with the clay soil, or the fine sand. The same occurred with the deeper placement at 50 cm depth (Table 1).

Table 1. The number of FullStops activated for each depth and fill class at each of the four irrigations. The maximum number in each class is 4.

WFD Type	FullStop			
Depth	25 cm		50 cm	
Fill	Clay Soil	Fine Sand	Clay Soil	Fine Sand
14 Jan 06	4	4	4	4
30 Jan 06	4	4	4	4
14 Feb 06	4	4	4	4
1 March 06	4	4	4	4

The 100% response rate of FullStops was not expected, particularly at the deeper depth. The possibility of preferential flow to the FS detector is the most obvious reason for a ‘false positive’. There are three reasons why preferential flow does not appear to be the dominant factor. First, the FullStops filled with fine sand contained almost 2000g of material that needed an 18% change in water content to move from 10 kPa to saturation – or 360 ml. If a crack delivered water to the sand in the funnel, then the wet sand would be in contact with 300 cm^2 of dry soil, which would effectively remove water from the funnel. Second, the FullStops could not be reset for several days after irrigation. If the FullStops were triggered by preferential flow, they should self empty quickly after irrigation because the soil around them would not be saturated. Third, the EC in the water collected by the FullStop was 2 to 5 times higher than the irrigation water, suggesting that nutrients or salt were mobilized by matrix flow.

The electrical conductivity of the water sampled by the FullStop fell from over 1.5 dS/m to around 0.6 dS/m between December and March. Slightly higher EC was recorded at 50 cm during the middle period and slightly higher EC at the tail end of the furrow. We did not analyse the composition of the samples. Another researcher working close by using FullStops (after he saw them installed at our site) recorded high nitrate levels in the range of 250 to 500 mg/l, which would correspond with EC values above 1 dS/m.

The response rate of LongStops at 50 cm depth was not 100%. Ignoring the final irrigation event, which was a 'small irrigation', the response rate of diatomaceous earth LSs was just over 75% and considerably lower for the sand filled LSs. At 100 cm depth about one third of the LSs were triggered by irrigation.

Table 2. The number of LongStops activated for each depth, length and fill class at each of the four irrigations. The maximum number in each class is 4.

WFD Type	LongStop							
Depth	50 cm				100 cm			
Length	60 cm		100 cm		60 cm		100 cm	
Fill	d.e.	sand	d.e.	Sand	d.e.	Sand	d.e.	sand
14 Jan 06	3	1	3	2	0	0	0	0
30 Jan 06	3	1	3	3	1	1	1	2
14 Feb 06	3	2	4	4	2	1	2	2
1 March 06	0	0	1	1	2	0	1	1

A more detailed analysis of LS performance can be gained from comparing the data from the Watermark capillary matrix sensors. The Watermark sensors showed irrigation water did not penetrate to 100 cm in two of the three locations monitored at 100 cm depth. The LS at these two sites were not triggered. At the third site the Watermark sensors recorded very weak fronts after irrigations one and four and fairly strong fronts after irrigation events two and three. These 'stronger' fronts were within the range of the adjacent LS, and it was trigged on both occasions. Thus the two methods were in agreement at 100 cm depth.

The Watermark sensors recorded relatively strong fronts passing 50 cm depth at all three locations, at least for the first three irrigation events. At one of the monitored sites, the Watermark revealed that the minimum soil suction was within LS sensitivity range, but no water was found in the LS. The reason for this appears to be the delay between when the LS was manually sampled for water and the time of irrigation. Although the logged soil suction record showed the soil at 50 cm depth fell below 6 kPa shortly after irrigation, the site could not be visited until two days after irrigation, by which time the soil suction had risen to above 10 kPa. At this suction all the water would be removed from the LS. Thus it is possible that the LS filled and emptied before it could be sampled. This problem was not experienced with the FullStop because of the magnetic latching of the indicator, which remains in the ‘up’ position after all the water has been removed by capillarity.

A second reason for non-response of certain LSs may be due to the fact that the push tube smeared the soil surrounding the hole at installation. This smeared surface may present a barrier to the movement of water between the soil and LS. As the soil undergoes wetting and drying cycles, the impact of smearing should be reduced.

Variations required to future milestones: Nil

Financial Issues and Human Resource Issues

The project received considerable in-kind support from CRC Cotton.

Communication Achievements

The final milestone, due in July 06 concerns communication. A full report will be written up and circulated to key people in the cotton industry to get their opinion on what aspects could be communicated to the industry as a whole.

Listing of Attachments: Nil

Other comments

Almost all the expenses associated with the pilot trial involved the building, purchasing and installation of equipment. Thus it was somewhat disappointing that the delayed start meant that we were not able to monitor a full season.

Most of the equipment has been left in the ground, with the ‘top’ portions removed so that the field can be prepared for next season’s cotton crop. Should funding become available, monitoring could easily be continued over subsequent crops.

Summary

The pilot trial was successful. 48 wetting front detectors comprising variations on the FullStop and LongStop design were installed and monitored. The results demonstrated that these devices perform in the field according to the underpinning theory. The wetting front detectors provided information on depth of penetration of irrigation water, the changes in solute concentration with depth and field position over time, and identified the periods of waterlogging.

Given that monitoring was only carried out over 4 irrigation events, we do not yet have sufficient research experience to actively promote these technologies to the cotton industry. However, the pilot trial has demonstrated the potential utility of these devices, a platform that could be built on should funding support continue.