WETTING FRONT DETECTOR

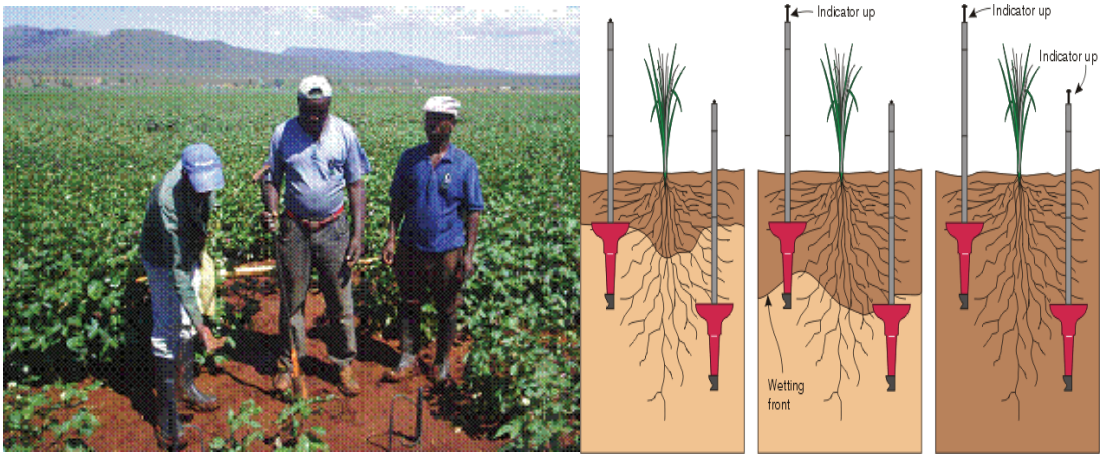
TRANSFER OF TECHNOLOGY

Report to the
WATER RESEARCH COMMISSION

by

JOE STEVENS AND RICHARD STIRZAKER

UNIVERSITY OF PRETORIA



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1. INTRODUCTION

Over two years between 2004 and 2006 we have engaged with small-scale farmers, commercial farmers, large corporate farming enterprises, irrigation equipment manufacturers, sales staff, designers, retailers, teachers, extension workers and opinion leaders. The key lessons learnt from each of these encounters are summarized in this report.

Small-scale farmers were generally keen to participate with the project team, readily understood the Wetting Front Detector (WFD) concept, and prepared to try it out. Some promising starts were made, but few lessons were consolidated, as summarized in the four case studies. The extension service was not able to offer adequate support to farmers in the absence of the research team, highlighting the urgent need for training.

The WFD should be incorporated into a formal training package that encapsulates the lessons we have learnt so far. We have shown that the WFD provides a platform on which to build a practical understanding of irrigation management, because farmers can relate to it. We demonstrated how this training could be initiated through the implementation of the principles of experiential learning.

Interest in the WFD in the commercial sector has been huge. Almost 6000 units have been sold in South Africa, and about 3000 in other parts of the world. Those familiar with the irrigation industry agree that these sales numbers are extremely high for this type of technology.

However it is still very early days and we have identified a number of challenges. The commercial partner noted that the WFD needs strong promotion, which they have been unable to provide of late because of key staff changes. The sale figures dropped during the second season after release.

Based on the feedback received from WFD users and the experiences of team members in the field we realized that we are still on a steep learning curve. We have changed the filter sand in an attempt to increase the sensitivity and improved some of the plastic fittings. We have reviewed placement depths for different applications. The six-page instruction sheet (*Appendix A*) has been re-written and re-published to incorporate our new learning, including a 'troubleshooting' section. The web site has also been over-hauled to accommodate the experiences from users and members of the project team.

Although we are highly satisfied with the start we have made, we have also deepened our understanding on how to improve the design and operation. The key task now is to retain the momentum generated over the last two years, because it is clear that most have only just started on the learning journey.

2. OBJECTIVES AND METHODOLOGY

Change is a complex process consisting of many steps, including pressure for change, the vision for change, capacity to change, actionable first steps and role models. The project focused on the latter two with the aim to show farmers how to start the journey of improving on-farm water use efficiency and work with selected farmers to produce role models who have moved some way down the path. Our methodology was to facilitate the "mutually stimulating dialogue" between the farmers, extensionists, sales staff, facilitator and the scientific support as key stakeholders. The dialogue required each party to play their roles and started with the clients explaining 'why they do what they do'.

The general aims set for this project were the following:

1. To build an extension approach that can deliver results to the small–scale farmer based on the wetting front detector and the dialogue with a trained facilitator.
2. To actively support three small-scale farmer groups through the "dialogue" *via* monthly farm visits.

3. To actively support two commercial farmer networks through their first year of using the WFD through farm visits, exchange of information and providing answers to their questions.
4. To run an email “list” circulated to all those nominated by the commercial partner (Agriplas) to provide immediate feedback on questions/problems encountered in the field.
5. To demonstrate and document an extension approach, extension networks throughout the country can replicate that.

Guided by the terms of reference the following objectives were set to achieve in the final output:

- Brief reflection on the lessons learned from the small-scale irrigation-farming sector in using the WFD.
- Report on the experience gained from training provided to extension officers from Limpopo Provincial Department of Agriculture (LPDA) and Mpumalanga Department of Agriculture (MPDA) in irrigation management using the WFD.
- Report on the lessons learned from the use of the WFD by commercial farmers as experienced for one production season.
- Report on the development of an extension package to be used during the dialogue with small-scale and commercial irrigation farmers.
- Reflection on the role of the product champion to help fine tune the deployment of detectors.
- Report on the learning and capacity building of irrigation equipment manufacturers, sales staff, designers and retailers.
- Recommendations regarding the way forward.

3. LESSONS LEARNED

3.1 Small-scale sector

Working in the small-scale sector is extremely demanding. Sites are often remote, farmers are hard to contact and frequently illiterate. It takes a lot of time to set up any trial or demonstration, and there is no guarantee that any data will be collected. We use case studies below to typify the range of experiences we encountered.

The Mafefe and Grootfontein experience

We received an official request from RESIS facilitators to run two training courses for farmers and Limpopo Province Department of Agriculture (LPDA) extension staff. Despite weeks of prior notice and confirmation, hardly any extension workers turned up at Grootfontein. We were led to believe that RESIS and LPDA extension workers boycott each other's initiatives.

Figure 1: Project team explaining the working of the wetting front detector to farmers and community members of Mafefe, Limpopo

We went ahead with farmer demonstrations at Mafefe where 70 farmers attended and good interaction took place aided by an excellent interpreter. However, it became clear that the problem facing these farmers was broken infrastructure and poor bulk water delivery. Until that was fixed, the WFD technology has nothing to offer.

The Malegale and Elandskraal experience:

In both cases farmers were aware of their irrigation problems, which included high pumping costs, poor quality water and poor response to fertilizer. The farmers were keen to work with us and enjoyed learning about the WFD. They reported a response rate of the shallow and deep WFDs that made sense to us, but the recording sheets were not filled in due to poor literacy.

Farmers did not continue to use WFDs after we partially disengaged, claiming they wanted on-going support, which the extension officers were unable to provide. One farmer has significant commercial success with a 5ha wheat crop, which he attributed (in part) to the WFDs. However this farmer was not prepared to participate in the WFD project the following year due to cultural constraints and none of the general lessons learnt were consolidated or built upon.

Tswelopele experience:

Tswelopele is a large cotton irrigation scheme (450 ha) where the NSK Co-op supports farmers. The majority of farmers undertakes a three-week training course at the Lowveld College of Agriculture and receives financial and technical assistance from NSK. The farmers were organized into a well functioning farmer group with a representative management committee to take care of daily decisions and negotiations on the irrigation scheme. The 92 farmers were highly motivated and participated actively in the WFD training session provided.

Figure 2: Small-scale cotton growers at Tswelopele irrigation scheme

The response of WFDs through the season was very low – with only one or two responses at each depth. The irrigation scheduling prescription was 10 hours every 7 days at 5.1 mm/h, giving 51 mm per week – which should have activated shallow and deep detectors on a frequent basis. We subsequently identified that almost all WFDs were activated after 40 mm rain, casting doubt on the alleged irrigation schedule. Subsequent enquiries revealed the actual water applied was closer to 20 mm per week, in which case the WFD records make more sense. Farmers also realized that their system performance was poor (different sized nozzles and length standpipes), and steps were taken to rectify this. The average production yields recorded were relative low (3 t/ha), which lead to financial losses by many farmers on the irrigation scheme. The general support by extension workers and RESIS facilitators were inefficient and farmers relied mainly on advice from NSK officials and members of the project team.

The Bon O'Dire experience:

The 17 farmers at this food garden were keen to improve their irrigation expertise and eagerly engaged with the project team. They decided to compare the efficiency of short (13 m) and long furrow (110 m) irrigation, by installing pairs of WFDs at the head and tail end of the furrows. Under long furrows, there was a much greater WFD response at the head end of the furrow than the tail. Under short furrow the responses were virtually the same at head and tail end.

Figure 3: Furrow irrigation at Bon O'Dire

The farmers were prepared to dig holes to check water penetration and to compare the WFD response to the crop yield. It is important to note that the WFD did not tell these farmers how to schedule irrigation. These farmers had a question about furrow length and uniformity, and the WFD helped them think it through. The farmers obtained 'believable' feedback, which helped them to learn faster.

Training of extension workers

Early on we realized that short field demonstrations to extension workers were insufficient to give them confidence to use WFD. Several full days sessions were conducted with extension workers from LPDA and Mpumalanga Department of Agriculture. Surprisingly, none of the LPDA attendees had any

formal training in irrigation and crop production. They rated their own skill base relatively low and suggested irrigation was a problem belonging to the engineering domain. Skills and experience in irrigation management were considerably higher in Mpumalanga and many received formal training and attended short courses in irrigation management. This level of competence appears to be due to the involvement of the sugar industry.

The dialogue with extensionists during the training sessions revealed that many of them perceive irrigation scheduling and water management as to do with the distribution of water on the irrigation scheme. Therefore many of the extension officers that were interviewed perceived the support of irrigation farmers with regard to irrigation scheduling as rather an aspect that belongs to irrigation engineers.

Feedback revealed that the WFD tool makes the introduction of irrigation management tangible and realistic. The facilitator or trainer who is involved in offering training to extensionists and small-scale farmers must understand the intervention process that is required and the importance of simplification of complex learning tools and irrigation management concepts to the potential learners. The terminology that is often used by scientists is not familiar to farmers and also not to many of the irrigation extensionists. It is important to use images, pictures and ideas that are familiar to the audience as means of creating shared understandings that will allow the potential learners to associate with. The WFD CD was found to be very useful during the conceptualization of the principles applicable for irrigation management in a format that people can understand and relate to. The biggest advantage of the interactive CD in training was to overcome barriers of illiteracy and cultural differences. It ensures the trainees participate actively and also encompass their perceptions during the discussions that followed. However the extension workers need to use the WFDs first hand and learn for themselves before they can have the confidence to pass on their understanding to farmers.

Recording sheet

We produced recording sheets where the irrigation run time and rainfall are recorded against the response of the deep and shallow detectors. This simple

exercise is an important starting point to get a quantitative feel for field practice of irrigation, from which the farmer and the knowledge support system can learn.

The English version of the recording sheet was translated in Sotho, Xhosa and Zulu with the help of farmers and extension workers in the respective geographical areas (*Appendix B*). This ensures that farmers associated better with what they are recording and helped them to optimize the potential learning through the interpretation of the recorded data. .

3.2. Commercial sector

Part Four of the WRC report "Building capacity in irrigation management with Wetting Front Detectors" explored the acceptability of the idea to the large and small-scale sectors. Although the WFD was originally conceived as a tool for the smaller-scale grower, we found it struck a chord with the commercial sector. Even for those versed in the more sophisticated irrigation scheduling tools, the WFD was seen as an additional tool that could complement other methods. There was also a strong signal that commercial farmers saw opportunities in the capability for solution sampling. Over all, 100% of the 54 users surveyed during this testing phase reported that the WFD concept was easy to understand, and 82% of users had a positive perception towards the detector after using a prototype for a short time. The important role of opinion leaders in the decision-making process regarding new technology and practices were illustrated.

Product release:

There is of course a vast difference between encouraging survey results and actually putting a new tool into the market. The interest displayed during the prototyping phase did, in fact, translate to sales. The Agriplas factory has produced over 9500 Wetting Front Detectors, of which over 90% have been sold. Almost 6000 of these have been sold in South Africa, mostly into the commercial sector, with about 4000 sold in the first season after release and 2000 in the second. The remainder has been sold overseas, principally in Australia.

There is general agreement that these sales figures are very high for this type of product, as the irrigation market has been resistant and skeptical as the value of

soil water monitoring. For example, Australian census figures show that almost 4 out of 5 commercial irrigators do not use any of the 20 products available on the market to measure soil water status.

Sales staff has mentioned to us that just because a farmer purchases a WFD, it by no means guarantees they put it in the ground! They have seen a number still sitting in the office. Furthermore we have had little feedback from those who have installed.

It's hard to interpret the drop off in sales between the first and second season. There may have been pent up demand in the first year because the product release was delayed for several years. The commercial partner reported poor sales of all irrigation equipment in year two, coinciding with a severe downturn in the sector. They also did less promotion. However we dare not just blame the general market downturn. Other factors must be considered.

Teething problems:

Inevitably there are teething problems when putting a tool that has no precedent into the market. The biggest challenge we face is responding to the issue of the 'non-responding' deeper detector. When irrigators say the deeper detector was not activated, the most obvious reason is that the water did not get down that far. However there are a number of cases where we think the water did. This is where the yes/no simplicity of the WFD can work against this technology. If a weak wetting front passes without being detected how do we know and does it matter?

There are three ways to address the 'weak front' problem. The first is to make sure that WFDs are not installed too deep, because wetting fronts get weaker with increment of depth. The second is to optimize the properties of the filter sand. The properties of the filter sand appear to have a much greater influence on sensitivity than we initially thought. The third response is to design a different shaped funnel that will respond to weaker fronts.

Less-than-perfect instruction manual and inappropriate filter sand are some of the R&D issues that have been revealed as the WFD is used more widely. Although both issues are subsequently been addressed, these issues may have already impacted negatively on sales.

Depth of placement:

It seems our early experiments with WFDs were weighted towards sites where wetting fronts penetrated deeply, and this has trickled through to our instruction manual. In general the recommended depths were too deep, leading to poor responses in some situations. Experiences with certain classes of soils (fine sands and silty soils) revealed it is harder to detect wetting fronts, particularly from sprinkler irrigation.

We need to help farmers to optimise depths through experience. For example, if the shallow detector is too shallow, then it responds to every irrigation event – large and small. There is little incentive for the farmer to change practice. Conversely, when it is too deep, it may rarely respond to the weak fronts, and the farmer gets no feedback at all. WFD placement is about right when the shallow detector responds most of the time, but not after shorter irrigation events. The deeper detectors should respond occasionally, and to the larger amounts. Basically a 60-80% response rate at shallow and a 10 to 30 % response rate at depth give the farmers space to experiment, get different WFD responses, and learn accordingly.

In retrospect it would have been better to advise farmers to install at several depths. The initial investment would have been higher, but we would have been able to 'fail more safely'.

The experiences of farmers collated were used to re-write the guidelines on the assembling and installation of WFDs to give much clearer direction on optimal placement depths.

Role of the product champion:

Early adopters and innovators play an important role to help us determine the optimum depths and response rates for a variety of different situations. These product champions help to fine tune the deployment of the detectors, and take some of the risk out for those who follow. An opinion leader like Chris Barnard has been incredibly effective in this regard, but even he was found to be on the early part of the learning curve.

Figure 4: Opinion leaders like Chris Barnard helps with the fine-tuning of a new product

We have found it extremely difficult to get in depth feedback from users. Generally we hear a positive 'vibe' but without more detail it is difficult for us to know exactly where we need to improve. Slow feedback is probably because the farmers are also in learning mode and have not yet conceptualized their experiences. We know that most farmers use the WFD in conjunction with other scheduling devices and most are interested in monitoring nutrients, despite the fact that we have provided little in the way of guidelines for this.

There is very little awareness of the huge resource at www.fullstop.com.au. The few who have been exposed to it have found it extremely useful. We have highlighted the web address on the front page of the new instructions.

Installation method:

An opinion leader like Chris Barnard plays a significant role in the adoption process by influencing potential WFD users' attitude and behaviour. He recommends a different method of installing to the proposed method explained in the guidelines (point 3, page 5). His recommendation is that the WFD should be installed 'from the side' when going into permanent crops. This entails far more work than installing 'from above' via an auger hole and has been mentioned by several people as an impediment to uptake. Barnard's reasons for side installations stem from his experience with soil pits in orchards. He has observed roots grow back faster into the disturbed area (after refilling) and even noted tensiometer readings were drier in disturbed soil. He expected this might flow through to the auger installation method we recommend.

Barnard's observations are important and the testing of this perception has been included into a research program conducted on his property. Preliminary indications are that the mode of installation is not critical to performance.

Workshop and training

Three mini-workshops were conducted in Pretoria, Nelspruit and Cape Town. These workshops served to collate first-hand experiences from commercial farmers as well as from sales staff and distributors of irrigation technology.

The majority of delegates that had practical experience with the WFD were satisfied with the performance of the WFD. The workshops succeeded with the dissemination of the newest information with regard to the development of the WFD.

3.3. Marketing, product development and support

There has been an excellent relationship between the manufacturer and the scientific team, but this has been challenged by key staff loses. The CEO, chief engineer, head of marketing and head of the factory have all moved to new positions during this development and early product release phase. The public/private sector partnership must be maintained until the product is properly established in the market.

Marketing:

Despite the high sales, we are not at the stage where the WFD 'sells itself'. When it is promoted at a field day it sells well, but when there is no active promotion there is little interest. The WFD seems to have infiltrated specific locations and industries around a few product champions. We need to understand the route to market and then successful deployment on farm, so we can underpin the process with better-targeted technical support and training.

We have largely failed to penetrate overseas markets. Considering that Australia and South Africa contain less than 4% of the world irrigated croplands combined, and there are no competitor products in the price range, it would seem that the world market could be substantial. Failure to penetrate overseas markets is largely due to lack of resources – mainly personnel who can adequately champion and support the product. The product is also bulky and therefore expensive to transport.

Troubleshooting:

Another feature of early stage product release is there is few people are aware of the simple troubleshooting procedures. We recently spent a long time with one of our key champions searching for reasons why one deep detector did not respond to irrigation. However the 30-second field check revealed the floats had been jammed in the float housing and could not respond no matter how much water the detector collected. Even the champions don't troubleshoot! There is an urgent need to invest in training at all levels.

This experience urged the project team to revisit the instructions and a simple "Four Quick Checks" troubleshooting section was included in the guidelines (page 6 of the guidelines; *Appendix A*)

Service pack

Farmers using WFDs often find it difficult or impossible to replace broken floats, indicator caps, syringes and extension tubes. This need by farmers and other users of the WFD was addressed by the development of a "service pack" by the manufacturers.

New Developments / Products:

Several modifications are being made to the original moulds to get an easier fit between the various pieces and guard against leakage.

We may require a second 'funnel shape' to cover for situations where the original version appears to be inadequate i.e. deeper placements for sprinkler irrigation. This funnel would fit with all the other pieces that go into making the commercial version of the FullStop, but would be better suited to deeper placement. We now have the theoretical and practical understanding on how to do this.

We also know how to make more sensitive designs, but at this stage the new designs do not have the full simplicity of the original. There is also a potential to confuse the market with new versions, so we need to take care to separate the commercial realities and the science.

4. THE WAY FORWARD

The widespread adoption of the WFD has quickly highlighted areas that need more work. We are in a fortunate position to have a follow-up project, but still must act quickly to capitalize on a good start and minimize the impact of the inevitable teething problems.

Two lessons stand out from this technology transfer project. As a project team we need to learn faster from each experience. In retrospect not enough information was collected from farmer's fields to be confident of what was happening. We should have installed more WFDs at each site and at more depths. 'Sacrificial' detectors should have been placed at depths where we thought they would always or never respond, just to cover a wider range of possibilities and to generate more 'obvious' lessons for the farmers. Although a limited number of rain gauges have been installed to relate the WFD response to rain more are needed to extrapolate the response of WFDs to the management of furrow irrigation and from that get some idea of effective application rates. Regular electrical conductivity and nitrate test strip readings are essential, since the salt and nitrate reading tell us a lot about irrigation practice.

Second, we do not have the time or resources to keep learning anew from each different situation. If the WFD is to spread through the small-scale or commercial sector, then it needs to be incorporated into training packages that encapsulate the lessons we have learnt so far. We have tried to do this by the development of the interactive way of the website, but unfortunately thus has not been widely utilised.

Perhaps we have been far too ambitious about the nature of training. Hardly any of the growers we worked with checked application rates with a rain gauge, or could relate irrigation run time of drip irrigation to a depth of irrigation.

For example, we uncovered a problem at Tswelopele after numerous visits and conversations between scientists, farmers and trainers. Had we collected the actual amount of water applied we would have diagnosed the problem immediately and all learnt more quickly.

In many ways a WFD is an 'underground' rain gauge. Water can only enter if it can fill up the drier soil between the soil surface and the device. Being able to relate the amount of irrigation applied to WFD response is absolutely critical to learning. We are considering adding a rain gauge to the WFD pack. This would most likely need to be specially moulded to fit inside the existing funnel for packaging purposes. Our aim is to produce a 'straight-sided' gauge. This could not be read to the resolution of a normal conical version; the aim is to show that

a certain depth of water when through the soil surface – and the WFD tells how deep. The gauge would double up as a means for evaluating flow rate from drip emitters.

We envisage a ‘recording sheet’ going in with each of the boxes similar to the format that is currently been used by farmers. Irrigation run time (which many growers record) could then be translated in to amount, against which a detector response is marked. This exercise makes the field practice of irrigation quantitative, provides a record from which we can learn and links the grower to other sources of information, such as average district practice or model output.

Appendix A

FullStop™ Wetting Front Detectors

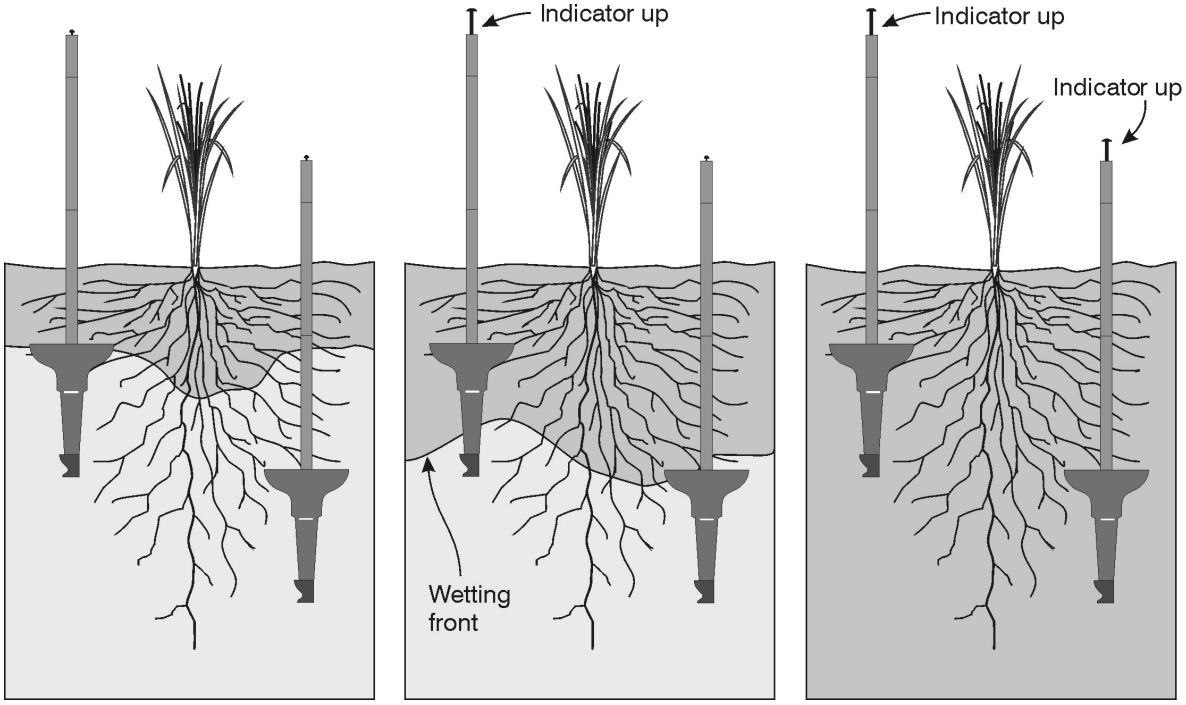
Important: Please read these instructions before assembly

The ***FullStop***™ Wetting Front Detector shows how deep water infiltrates into the soil after irrigation or rain. It takes a soil water sample so that the movement of plant nutrients and salt through the soil can be monitored.

The Wetting Front detector can be used to:

- find out if you are irrigating too little or too much
- assist in the management of fertilizer and salt
- show if the soil is water-logged.

The FullStop Wetting Front Detector helps you to "see" what is happening down in the root zone when you irrigate the soil. Wetting Front Detectors are usually buried at two depths in the root zone and pop up an indicator to show when the infiltrating water goes past. They also capture and store a sample of water from the wetting front.



Shallow Indicator: DOWN **Deep Indicator: DOWN**	**Shallow Indicator: UP** **Deep Indicator: DOWN**	**Shallow Indicator: UP** **Deep Indicator: UP**
If neither indicator is triggered, then watering is generally too shallow	Water has moved *past* the shallow detector to the lower part of the root zone.	The deep indicator should be triggered only when it is necessary to fill the whole root zone.

For more detailed instructions on assembly and use of the Wetting Front Detector for irrigation, fertilizer and salt management see

www.fullstop.com.au

Assembly

This box contains

- red funnel (x2)
- base piece with steel mesh filter (x2)
- black extension tubes (x5)
- locking ring (x2)
- indicator cap (x2)
- foam floats (x14)
- green flexible tubing (x2)
- syringe (x1)
- bag of filter sand (x1)

See picture opposite and follow 7 steps below.

Before starting step 1, practise joining the base to an extension tube. A cup of very hot water is needed. Dip the last 5 cm of the wide (female) end of the extension tube into hot water to soften the plastic. Insert the base piece into the wide end of the extension tube by lining up the lugs, pushing and twisting hard. The fitting will be in the locked position after a quarter of a turn clockwise. Undo this fitting and follow the steps below.

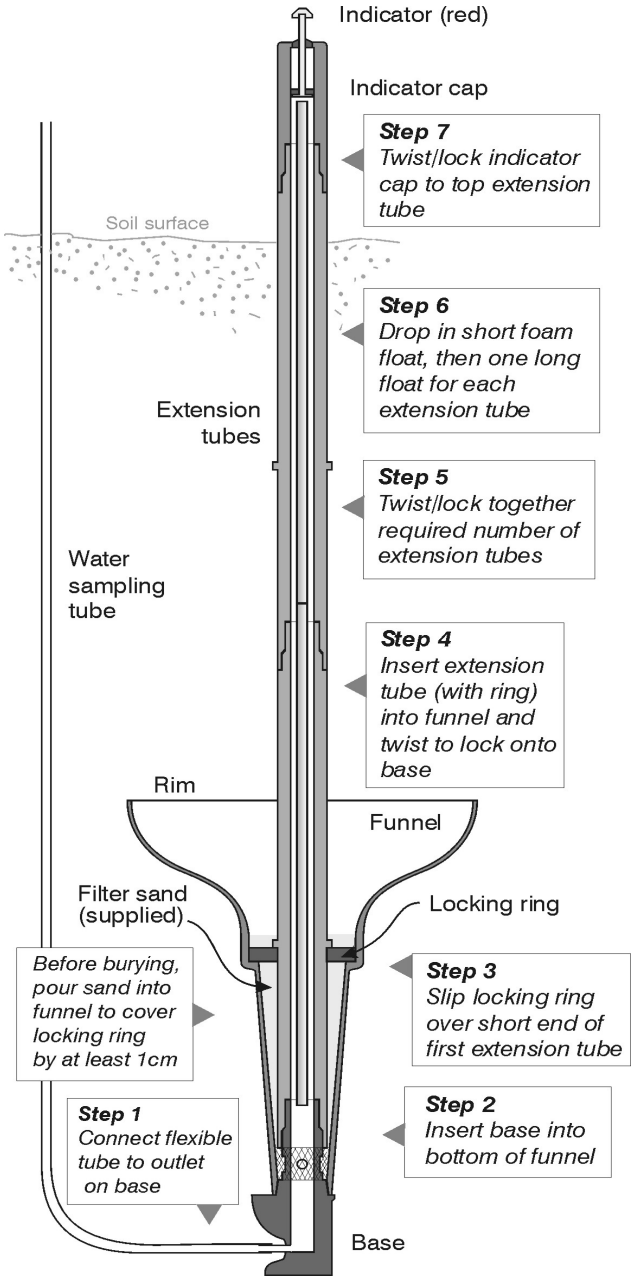
Step 1: Dip one end of green flexible tubing into hot water and connect to the 4 mm barbed outlet on base piece.
Step 2: Insert the base into the bottom end of the funnel and push in as far as it will go.
Step 3:
Slip the locking ring over the wide end of extension tube that was previously dipped into hot water. Move locking ring one third of way up to the ridge on the extension tube. The spokes on one side of the locking ring are rounded. The rounded side should face upwards.
Step 4: Dip the wide end of the extension tube (with locking ring) into hot water again. Pick up the base piece and funnel and join the extension tube to the base through the funnel. This requires a firm pushing and twisting action (quarter turn). When correctly joined there will be a watertight seal with no gap between the base and the funnel.
Step 5: Add one or two more extension tubes, depending on depth of installation (no hot water treatment needed).
Step 6: Drop in the foam floats. 5 floats are required if two extension tubes are used and 7 floats are needed if three extension tubes are used. Use the float marked with blue paint last (it is shorter). The last float must protrude 1 to 2 cm above the opening of the extension tube.

Step 7: Add indicator cap - yellow for the shallow and red for the deep wetting front detector. The indicator should be in the fully down position.

Testing

Test each detector for leaks after it has been assembled by adding a syringe full of water into the funnel, with the flexible tube held upright to ensure water does not escape. The indicator will then rise and be held up by a magnet. No water should be visible at the join between the funnel and the base. Let the water out via the flexible tube and tap the indicator down to release the magnetic 'latch'. The supplied filter sand **must not** be added until you are ready to install the detector.

If you need to disassemble, remove floats first.

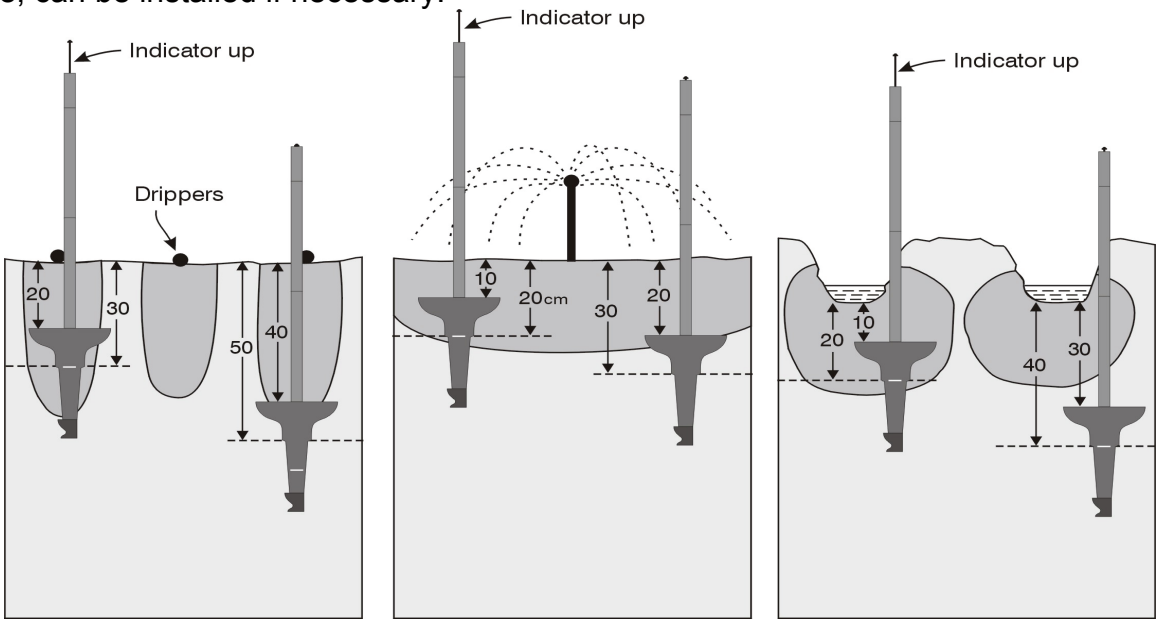


Depth Placement

The optimum depth of placement depends on the irrigation method and the frequency of irrigation, as well as the type of crop and soil. The table below is given as a guide, based on our experience. Placement depths are measured from the **soil surface to the locking ring**. If measuring to the rim of the funnel, subtract 10 cm from the depths in the table. With experience, these recommendations can be adjusted for local conditions.

Type of irrigation	Notes	Shallow Detector	Deep Detector
Drip	Amount applied per dripper usually less than 6 litres at one time (e.g. row crops, pulsing)	30 cm	45 cm
Drip	Amount applied per dripper usually more than 6 litres at one time (perennial crops)	30 cm	50 cm
Sprinkler	Irrigation is usually less than 20 mm at one time (e.g. centre pivot, micro-jets)	15 cm	30 cm
Sprinkler	Irrigation is usually more than 20 mm at one time (e.g. sprinklers and draglines)	20 cm	30 cm
Flood	Deeper placements than shown needed for infrequent irrigations or very long furrow	20 cm	40 cm

When the float is in the up position a wetting front has moved ***past*** the detector. The soil above the detector is as wet as it can be (almost saturated). That is why the above depths may appear to be shallow. A third detector, 10 cm below the deep detector depth shown above, can be installed if necessary.



DRIP

The detector must always be placed **directly under a dripper**.

It is common for detectors to respond quickly under drip because the water is concentrated around the dripper. If so, apply less water more often.

SPRINKLER

Wetting patterns tend to be shallower under sprinkler irrigation than drip or furrow irrigation.

Detectors will usually not be activated by applications under 15 mm, unless the soil is quite wet before irrigation

FLOOD

Detectors should be positioned half under the furrow and half under the bed with the extension tube rising through the shoulder of the bed.

This placement is also suited for sprinkler irrigated crops grown on raised beds.

Installation

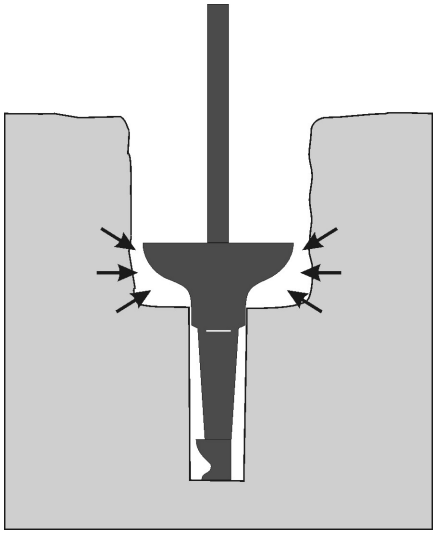
Step 1 – digging the hole

The detector is easiest to install using two augers: an auger (20 cm or larger in diameter) for the wide end of the detector funnel and another (5–10 cm in diameter) for the narrow end of the funnel. Alternatively, a spade and trowel can be used. Keep different soil layers separate when removing them from the hole if the soil type changes with depth. Installation is easiest when the soil is moist, rather than when it is very wet or dry.

Step 2 – add filter sand and insert into hole

Pour the supplied filter sand into the funnel until it covers the locking ring by at least 1 cm. Lower the detector into the hole and measure the distance to the locking ring (or rim of the funnel) to check it is at the desired depth.

Holding the extension tube vertically upright in the hole, fill the funnel with soil removed from the layer at the same depth and firm down lightly. Hold the flexible tube alongside the funnel up to the soil surface. Pack soil under and around the sides of the funnel until it is firmly in place as indicated in the diagram below. The deeper narrow hole does not need to be packed with soil.



Step 3 – Bury the FullStop detector

Break the sides of the hole as you return soil above the detector, as smooth sides may restrict the growth of roots and the movement of water. The hole must be filled by returning the removed soil to its original layer. Soil should be firmed down by hand but not compacted. All the soil should be returned to the hole leaving a slight hump over the installation. After settling, check to make sure the soil level over the installation site is the same as the surrounding soil so that water does not run towards or away from the *FullStop* detector.

Step 4 –Activate the float

Water the site over the detector after installation to trigger the float**.** This may require 20 litres or more for a deeper installation.

Step 5 –Maintenance

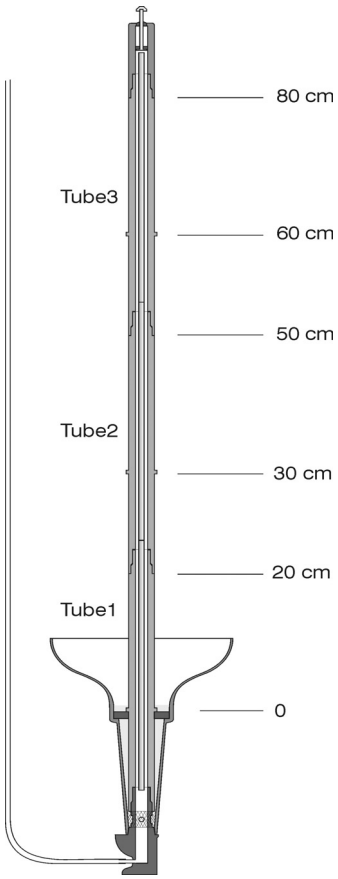
Occasional testing and maintenance should be carried out to ensure the detector is operating as expected.

Ensure there are no leaks before installation. After installation, there are two further checks that should be carried out every few months.

Float mechanism: Inject 30 ml of water from syringe into the green 4 mm tubing. The float should pop up.

Filter: Irrigate till float pops up – then remove water from 4 mm tube with syringe and reset float. Float should pop up again within 5 minutes.

If either test fails, see troubleshooting on back page.



Depth of placement

The depth of placement depends on the irrigation method and the frequency of irrigation.

The indicator pops up when the wetting front has moved about 10 cm below the rim of the funnel, labeled “0” in the diagram below. The position of the lock up ring is the approximate depth of measurement.

The position of the ridge on the extension tube can be used to show the depth after installation. If the ridge on tube 2 is at the surface, the depth of detection is 30 cm. If the ridge on tube 3 is at the surface, the depth of detection is 60 cm.

Improving irrigation practice

When starting out, we recommend you continue to irrigate according to your normal practice while you get a 'feel' for how the detectors are responding. Then compare your normal practice to what the *FullStop* shows you as summarized in the table below.

Once you have developed some confidence in the way the detectors are working, you are ready to improve irrigation, nutrient and salt management. Change your water use practice at the rate at which you are comfortable, taking into account the growth and/or yield response of the plants. Note that it is not necessary to get the desired detector response after each irrigation – the general trends are more important.

Shallow Indicator	Deep Indicator	Meaning*	Action
Down	**Down**	Insufficient water for established crops	Apply more water at one time or shorten the interval between two irrigations
Up	**Down**	Wetting front has penetrated into the lower part of the root zone	Most of the time this is the desired result. During hot weather or when the crop is at a sensitive growth stage, the deep detector should respond. .
Up	**Up**	The wetting front has moved to the bottom or below the root zone	If this happens regularly then over-watering is likely. Reduce irrigation amounts or increase the time interval between irrigations.
Down	**Up**	Soil or irrigation are not uniform or the soil surface is uneven	Go through troubleshooting steps Ensure the soil surface is level over the detectors. Check uniformity of irrigation or location of drippers.

***** This assumes that detectors have been placed at depths suited to the irrigation system and management regime

Four things you need to know

1. Resetting the indicator

Water is 'sucked out' of the detector after irrigation by the soil around it. You must reset the detector after the indicator pops up by pushing the indicator gently down to release the magnetic latch. If the indicator immediately pops up again, it means that the soil is still very wet. If the detector will not reset for several days after irrigation, the soil is close to waterlogged.

2. Indicator up means a *strong* front has moved *past* the detector

A wetting front will always move deeper than the detector after the indicator pops up. If the soil below the detector is dry, the wetting front will only move a short distance further. If the soil below the detector is wet, the wetting front can move a long way past the detector after the indicator pops up. Therefore it is important not to place detectors too deep, particularly for sprinkler irrigation.

3. Effect of soil disturbance

The soil structure is disturbed during installation of the detectors. This is not a problem for installation into ploughed soil. In the case of perennial crops the soil will need to settle and the roots grow back into the disturbed zone before the detector will give reliable information.

4. How many *FullStop detectors* do you need?

It is best to have three pairs in a field, because irrigation is usually not uniform and soil properties and crop growth vary. Some irrigation systems (e.g. mini-sprinklers) tend to have large variability over small distances. Uniformity of wetting patterns should be measured and detectors placed in 'wetter' and 'drier' spots to give an indication of variability in wetting front depths.

Troubleshooting

Before installation:

1. **Check for leaks**: After assembly there must be no leaks between the base piece and the funnel.
If leaks, reassemble using hot water for extension tube to base fitting. Spokes on locking ring should be 'rounded' side up.

After installation:

2. **Check the Float Indicator:** Inject 30 ml of water from syringe into the green 4 mm tubing. The float should pop up.
If float remains down, remove indicator cap and check that the last float protrudes 1 to 2 cm above extension. Check for stuck floats: Remove indicator cap, pour water down extension tube until all floats pop out. Check float pieces can pass through an extension tube without getting stuck. If indicator will not latch up, check top magnet is secured in ceiling of indicator cap.

3. **Check the filter:** Irrigate till float pops up – then remove all water from 4 mm tube with syringe and reset float. Float should pop up again within 5 minutes.
If not, Back-flush filter: To back-flush, remove indicator cap and one float. Press thumb over extension tube to seal opening. Force 60 ml of water from syringe into 4 mm tubing. Repeat. Back-flushing should be carried out after installation and once per year.

4. **Check the depth:** Look for ring on extension tube. From the ring to the depth of measurement is 30 cm (for 2 extension tubes) or 60 cm (3 extension tubes). Use yellow indicator for shallow detector and red indicator for deep detector.

Service Pack

A service pack containing floats, indicator cap, syringe and extension tube is available

Monitoring nutrients and salt

Water trapped in the detector can be sucked out with a syringe via the flexible tube and monitored for its electrical conductivity or nutrient concentration. Samples should be taken soon after irrigation. Note that the detector retains a small sample of water after self-emptying. This should be removed prior to irrigations from which samples for nutrient analysis are required.

Limitations

The ***FullStop*™** Wetting Front Detector has been designed to respond to 'strong' wetting fronts. In soil physics terms, the strength of the front must be around 2 to3 kPa suction or wetter for the indicator to rise. In practice this means that 'weak' fronts will not be detected and water can move past a detector without activating the indicator. Wetting fronts get weaker as they move deeply into the soil after the irrigation has been turned off. Weak fronts also occur during light rain, or when small amounts of water are applied at frequent intervals.

Disclaimer
Any decisions to change water use should be incremental and must be closely and regularly monitored to ascertain any negative impact on the crop. To the extent permitted by law, CSIRO accepts no liability arising directly or indirectly out of any misuse, negligent or incorrect use of the FullStop, any non-adherence to assembly or installation instructions or any circumstances outside CSIRO's control.

Appendix B: Machingalana record sheet -Xhosa version

UMHLA	Imizuzu Yonkcenkcesho	Intshukumo ka Mantshingilana		Imvula Ngokwe milimitha
		 Umantshinglana omfutshana (Omthubi)	 Umantshinglana Onzulu (Obomvu)	

Lali:……

Gama Lomfama:……

Gxelo neenkathazo ezifumaneke kumantshingilana:
:……
……
……

Appendix B: Machingalana *record sheet –Zulu version*

USUKU	Uchelele Isikhati Gsingakanani	Response of Machingalana		Imvula (mm)
		 Umantshigelana oncombo (Yellow indicator)	 Umantshigelana obomvu (Red indicator)	

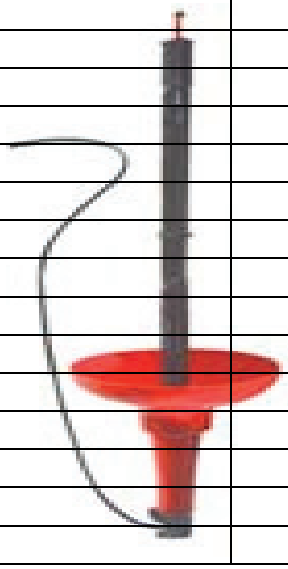
Indawo:……

Igama lomlimi:……

Tzinkinga ohlangabezane nazo ngomshini:
:……
……

Appendix B: *WFD matrix translated in Sotho*

Tsatšikwegdi	Botelele bja nako ya go Nošetša (kadiiri)	Phetolo ka Machingalana		Pula ka di Mmillimetara
		 Boyafase Machingalana (Sorolwana)	 Boyafase Machingalana (Khwibidu)	



Lefelo:……

Leina la Molemi:……

Dikakanyo /mathata ao ba kopanago le ona:
:……
……