Optimizing irrigated pastures using soil moisture monitoring systems and decision support tools

Developing collaborative Natural Resource Management with irrigators and farming systems groups

Presented by Natural Resources SAMDB with the support of the SAMDBNRM Board and the National Landcare Program

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Presentation overview

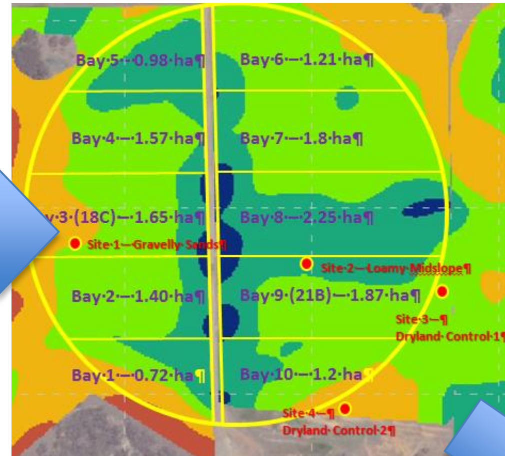
1. Project & Trial Site objectives
2. Groundwork and components of a monitoring system
3. Trialling a systems approach, season 2016/17
4. Monitoring, adapting & troubleshooting
5. Productivity outcomes – 2016/17
6. Findings and recommendations
7. Questions

Project and trial site objectives

- Demonstrate through the integration of the use of advanced monitoring systems, decision support tools and system and site benchmarking the benefits to annual irrigated pasture productivity
- Identify the strengths and weaknesses of using decision support tools in everyday real life production settings where there is not a prior history of systems or data usage
- Use the combined information resources from the trial site to establish a longer term irrigation scheduling approach that will optimise water resource usage and productivity further into the future
- Provide trial site reference data to the broader community

Project and trial site objectives

Demonstrate the benefits of site and soil characterisation



Soil moisture, weather and volumetric data

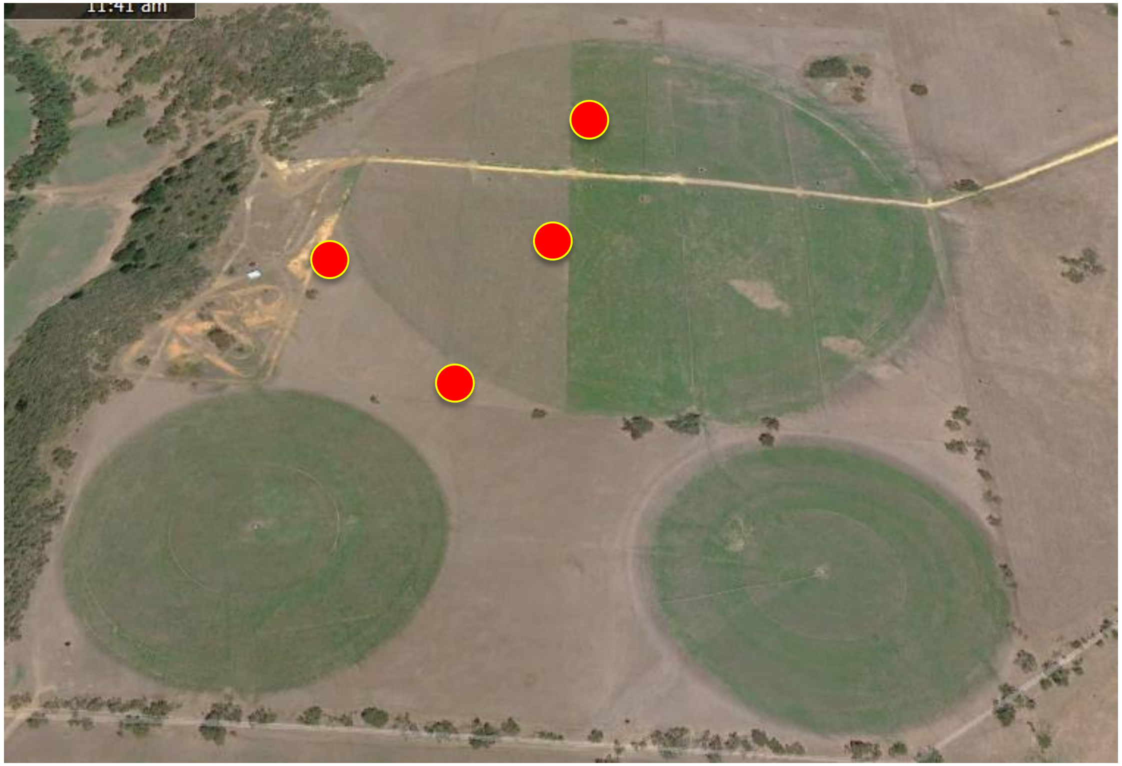
Hydraulic and energy system performance ok – mm by varying speeds known, soil recharge potential per irrigation known

Essential information on hand to make informed decisions on the go

The trial site - Cleland's Mt. Compass, South Australia

Lee, Heath and Jill McKenzie and Scott Alksne ~ Cross breds, ~500 milkers on average

- Site has 3 x pivots and one lift pump running off of dam/bore pump – limitations in peak heat
- Van der Bosch movables sometimes used in season
- Main pivot is 15.1 ha in size - small pivots are ~ 4 ha in size each
- Site is elevated and has a slope change of ~6.7% dropping ~30 m from the top to bottom

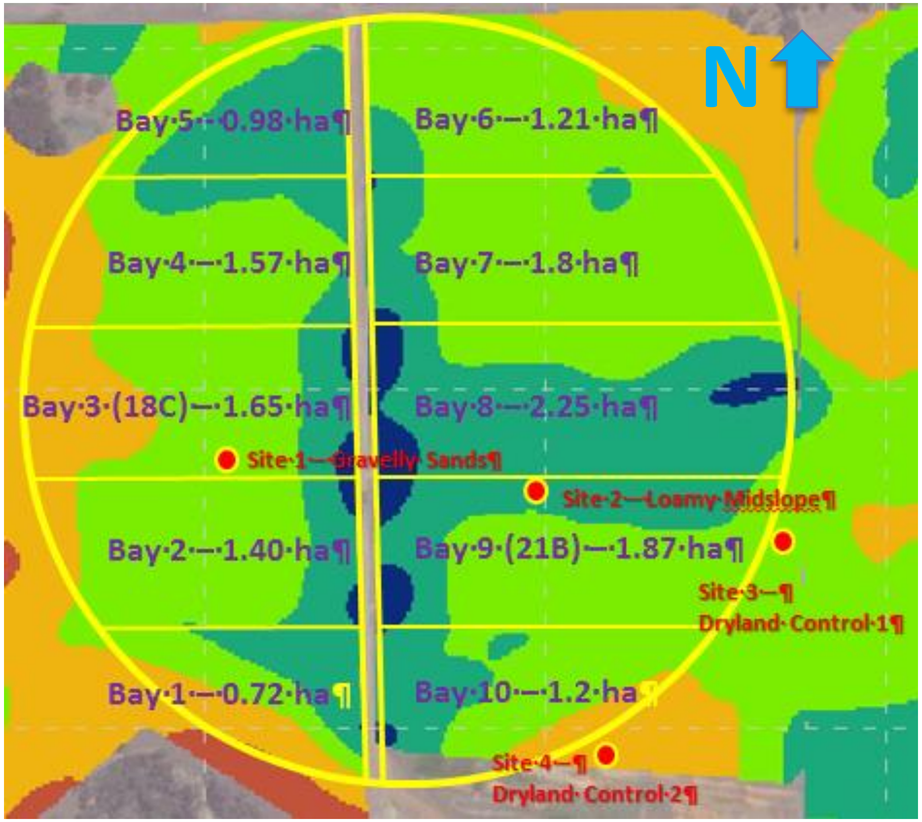


Groundwork, tools and establishing monitoring systems

- Site selection and soil mapping via EM mapping (50cm), soil coring and soil characterisation, appraisal of soil physical characteristics, RAW value determination by key zones
- Irrigation system benchmarking, energy usage, hydraulic assessment and overall irrigation and pumping system performance
- Installation of capacitance probe monitoring system x 4 sites to 60 cm depth, installation of comparable gypsum block systems at 30, 60 and 90 cm soil depth
- Companion installation of automatic weather station at nearby location
- Web availability of data streams by login or direct access
- Basic paddock history monitoring through 15/16 and 16/17

Groundwork, tools and establishing monitoring systems

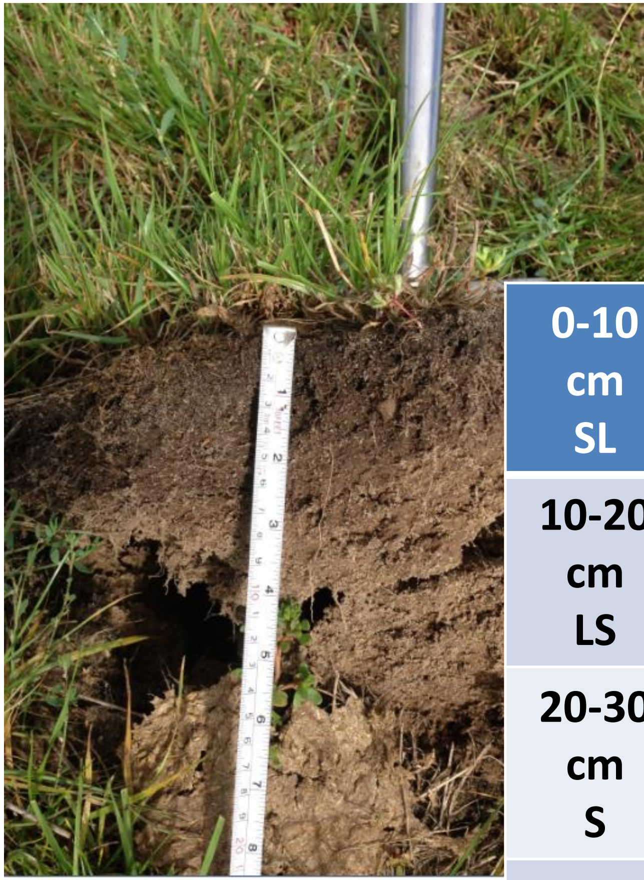
Electro Magnetic Soil Mapping (EM38) & Soil Coring



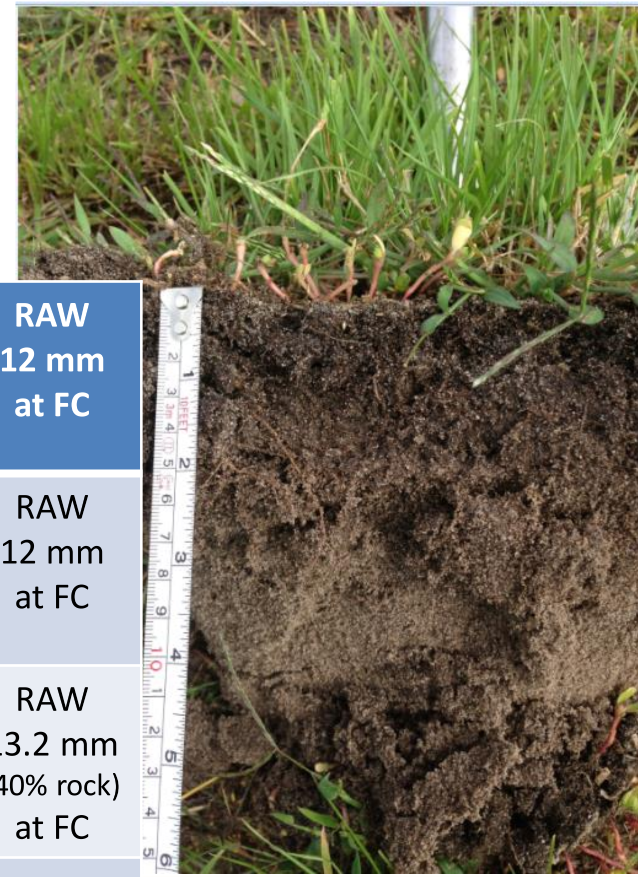
- Soil conductivity results to 50 cm show in a spatial map the soil type differences, results can be geo-referenced in field with GPS
- EM at trial site provided the overarching basis for determination of 3 key soil zones at site – 2 of which are irrigated
- It also revealed areas of drainage run-off and inundation

Groundwork, tools and establishing monitoring systems

Soil characterisation and Readily Available Water (RAW)



0-10 cm SL	RAW 12 mm at FC	0-10 cm SL	RAW 12 mm at FC
10-20 cm LS	RAW 8 mm at FC	**10-20 cm SL**	RAW 12 mm at FC
20-30 cm S	RAW 6 mm at FC	**20-30 cm LMC**	RAW 13.2 mm (40% rock) at FC
26 mm max at field capacity in top 30 cm		**37.2 mm** max at field capacity in top 30 cm	



Soil Zone 1 (Site 1) Gravelly Sands

Soil Zone 2 (Site 2) Loamy mid-slope

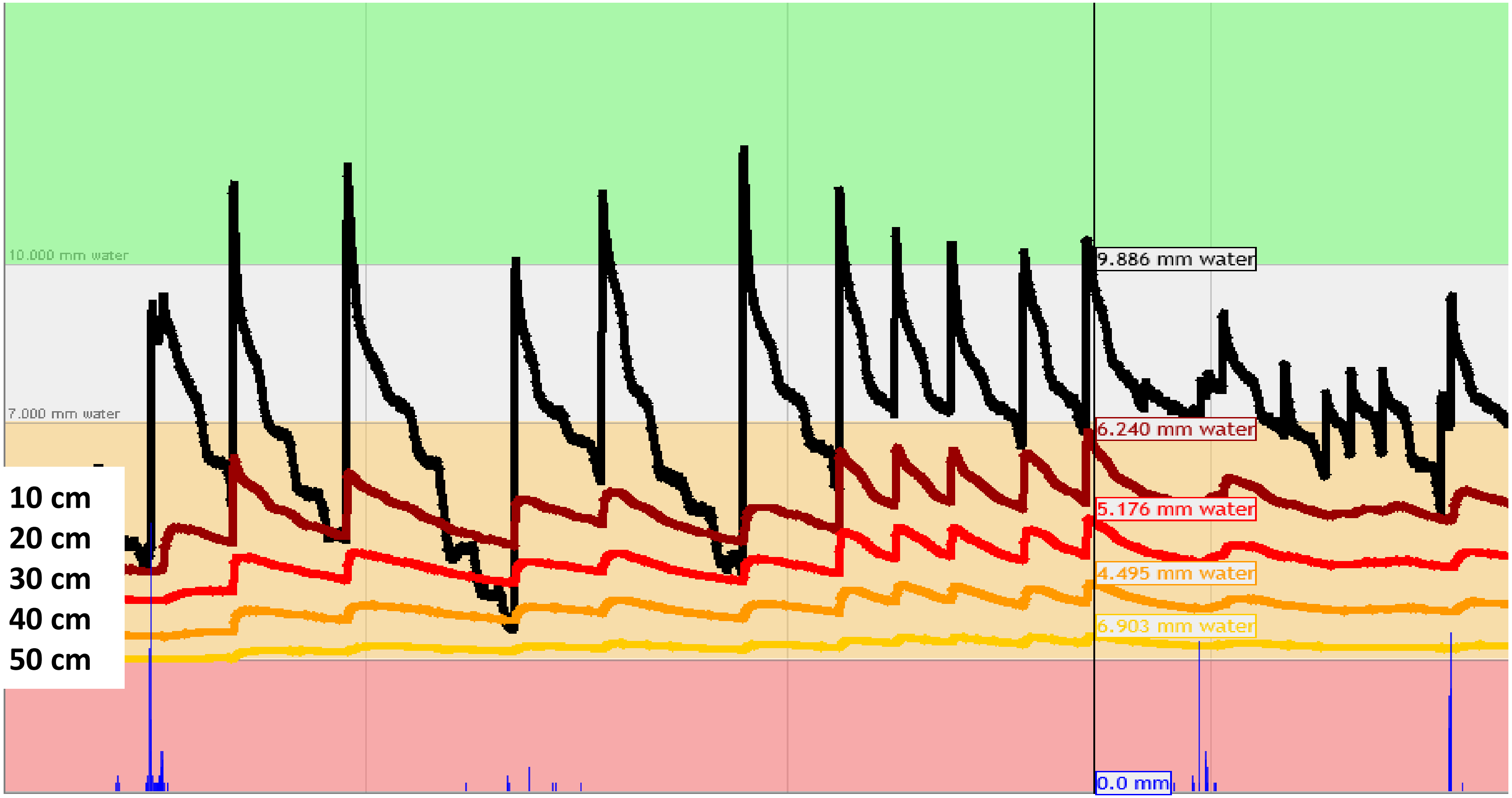
Groundwork, tools and establishing monitoring systems

Comparable probe values found through the trial

Site 1 – Gravelly Sands	RAW at FC	Probe RAW at obs FC	Site 2 – Loamy Midslope	RAW at FC	Probe RAW at obs FC
0-10 cm SL	12 mm	10 mm	**0-10 cm SL**	12 mm	8 mm
10-20 cm LS	8 mm	6.5 mm	**10-20 cm SL**	12 mm	9.5 mm
20-30 cm S	6 mm	5.5 mm	**20-30 cm LMC**	13.2 mm	22 mm
26 mm max at field capacity in top 30 cm			**37.2 mm** max at field capacity in top 30 cm		

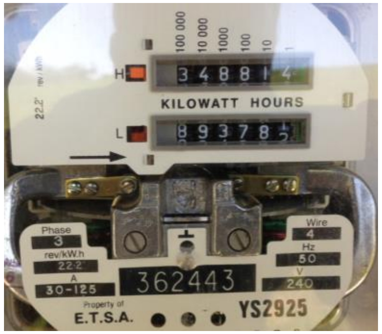
Groundwork, tools and establishing monitoring systems

Setting final values through mixture of RAWs and probe generated values



Groundwork, tools and establishing monitoring systems

Irrigation system performance & benchmarking



Main findings:

- In 15/16 the pumping system was found to be just up to task – poor pivot DU at high elevation runs was due to insufficient head generation
- Pump motor energy usage higher than normal – motor failed one year later
- Motor replacement rectified poor DU

- Pumping system audit against specs
- Re-calculation of friction losses and comparison of total duty head requirement against actual - reconciliation against observed pressures
- Centre pivot performance at 50% and 100% speeds, flows and mm/hour (88% DU found)
- Audit provided beneficial system benchmarking results and made the landholder aware where the system's strengths and weaknesses were

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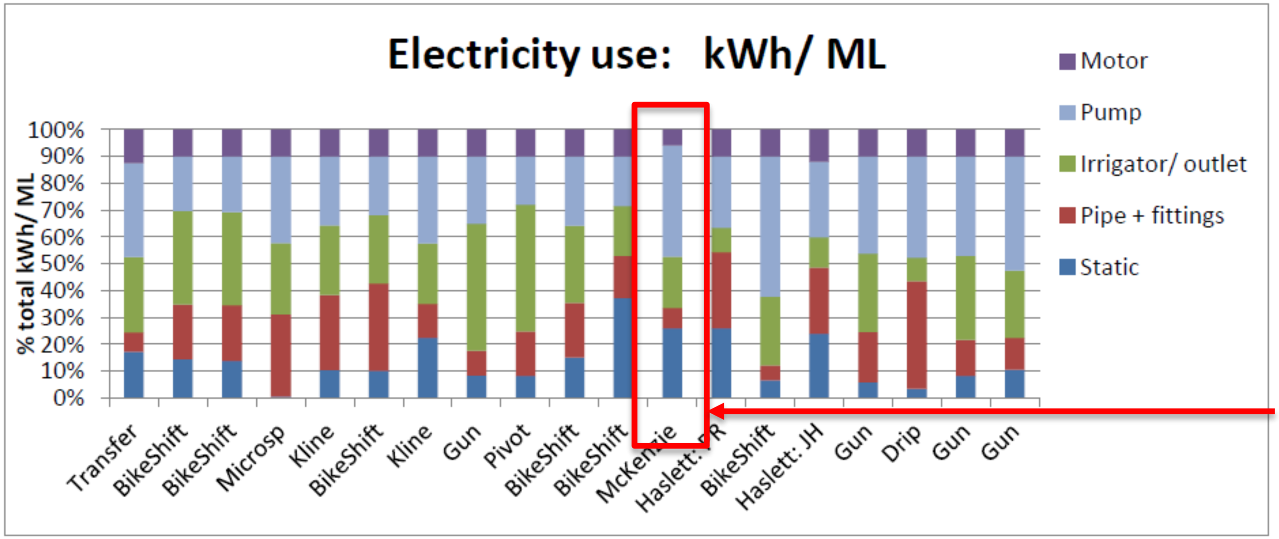
Groundwork, tools and establishing monitoring systems

Irrigation system performance & benchmarking

- The pivot produced a benchmark of 374 kW/hr/ML - based on power prices in 15/16 this equated to an electricity cost of around $82.80/ML
- Based on a total system head requirement of 75.4 m head the system produced a 4.96 kW/hr/ML/m of head benchmark which is in the higher end range of efficiency, nationally



The results of the audit revealed that the system utilizes the majority of its electricity in actual pumping, followed by overcoming static head – overall the pump was the main component where improvements may be beneficial – cost dependent

Groundwork, tools and establishing monitoring systems

Installation of soil moisture monitoring systems

A total of 4 sites were installed by trenching in sites and coring probes into ground using parent soil slurries only – this is essential to get an accurate soil moisture response

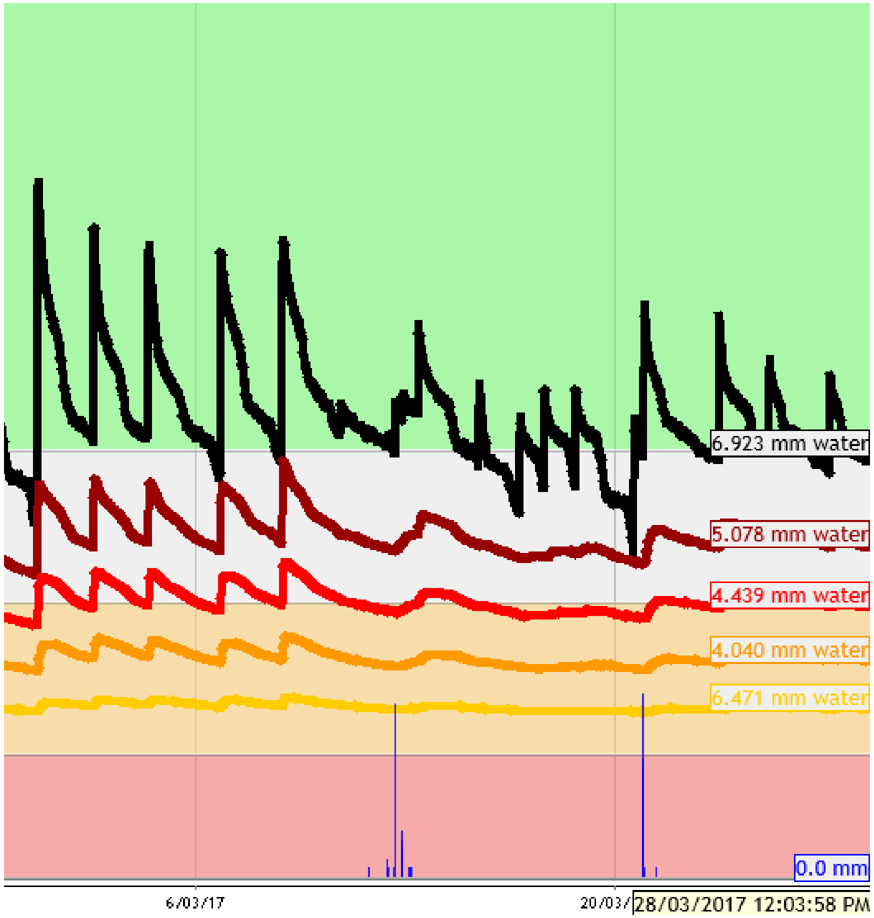
Top level sensor is removable to enable site sowing – site telemetry was fenced in on existing fence lines obviously under pivot drop tube reach

Technology works on gauging conductivity differences between two plate capacitors

Groundwork, tools and establishing monitoring systems

Installation of soil moisture monitoring systems

- Results are sent by mobile phone network to server – users login to view soil moisture summaries
- Results appear as either a ‘stacked’ level summary (every monitored soil depth) or as a ‘summed’ (all soil values added together) to provide a single line trace
- Rainfall is logged and the recorded volumes evaluated
- Sites can be calibrated to soil type and ‘full’, ‘re-fill’ and ‘dry’ thresholds set



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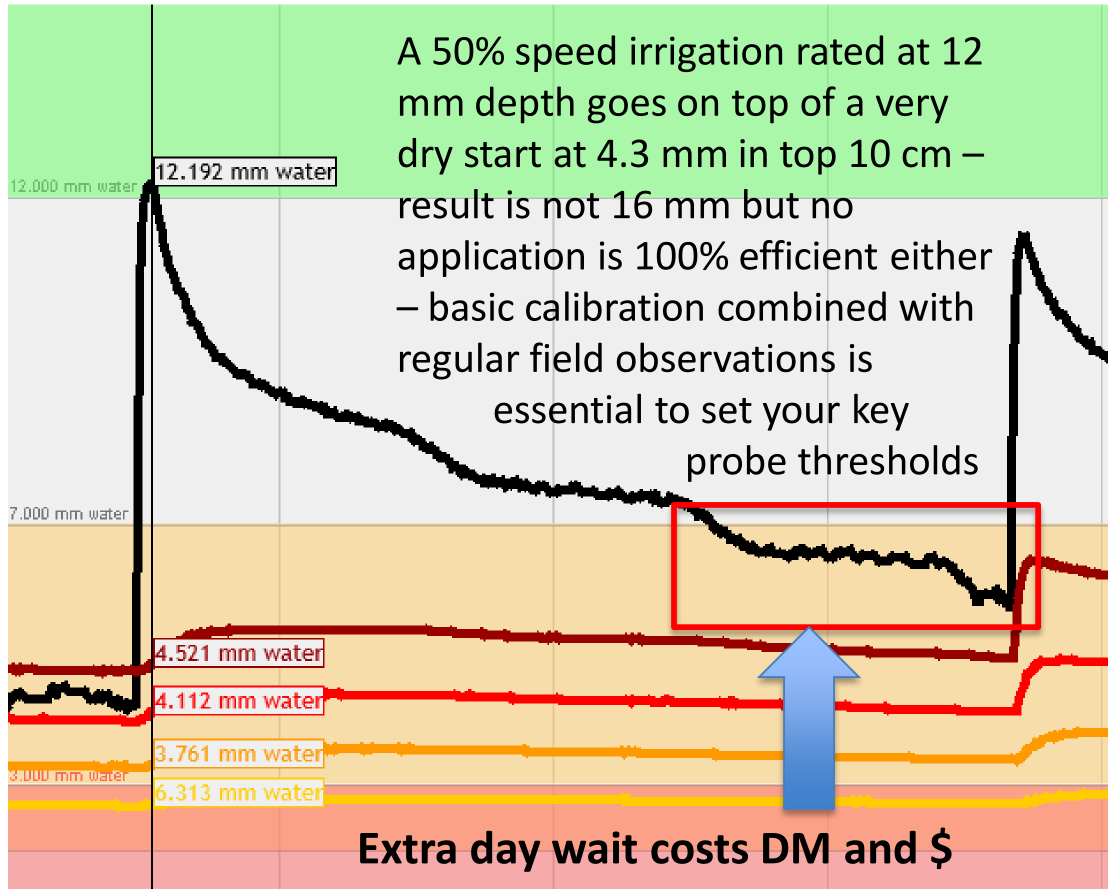
Groundwork, tools and establishing monitoring systems

Installation of soil moisture monitoring systems

RAW's taken at install were subsequently used as a GUIDE to 'customising' probe values to get figures closer to real moisture values

The result is closer to the actual but it is essential that the user undertake regular field obs of pasture conditions to validate the thresholds of full, re-fill and dry.

Re-fill will then trigger re-irrigation



Groundwork, tools and establishing monitoring systems

Companion Automatic weather station installation and promoting the use of BOM predictive data service

- Weather station data streams available 24/7, key data recent records for reference ET_0, rainfall, wind speed & direction, temperature and humidity, GSR, Delta T and soil temp
- New trial service utilizing BOM predictive 5 day outlooks proving valuable, temperature, humidity, wind speed, ET_0 and rainfall –enabled earlier and better decisions

	2017-03-29	2017-03-30	2017-03-31	2017-04-01	2017-04-02
Min T (℃)	11.50	10.40	9.80	10.80	10.10
Max T (℃)	22.50	16.70	16.50	17.80	20.50
Mean T (℃)	15.45	13.47	13.30	14.37	15.55
Min RH (%)	47.20	42.20	48.30	46.90	44.80
Max RH (%)	94.80	68.20	76.70	76.80	88.00
Mean RH (%)	71.63	56.18	63.82	63.74	64.59
Min Wind (m/s)	3.40	1.95	0.87	2.01	2.78
Max Wind (m/s)	8.69	5.61	3.24	4.63	6.33
Mean Wind (m/s)	5.76	3.74	1.75	3.40	4.68
Et_0 (mm)	3.80	3.20	2.20	2.80	3.50
Rain (mm)	3.17	0.63	0.25	1.07	0.08

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Trialling a systems approach 2016/17

- ***Scope of the project*** – to trial the practical adoption of the use of advanced soil moisture monitoring and irrigation scheduling approaches where there has been no prior usage – gauge outcomes including water usage, energy usage and productivity
- Support provided by DairySA, the SAMDBNRM Board and the National Landcare program
- Assistance to evaluate and implement improved scheduling and the use of monitoring equipment and tools provided by Natural Resources SAMDB for duration of 16/17 irrigation season
- Agronomic planning, site monitoring and support provided by FP AG (Mt. Compass)

Trialling a systems approach 2016/17

Operational aspects of the trial

The structure of the ongoing approach of the trial has been largely been:

1. Jointly evaluate soil moisture monitoring trends and field observations

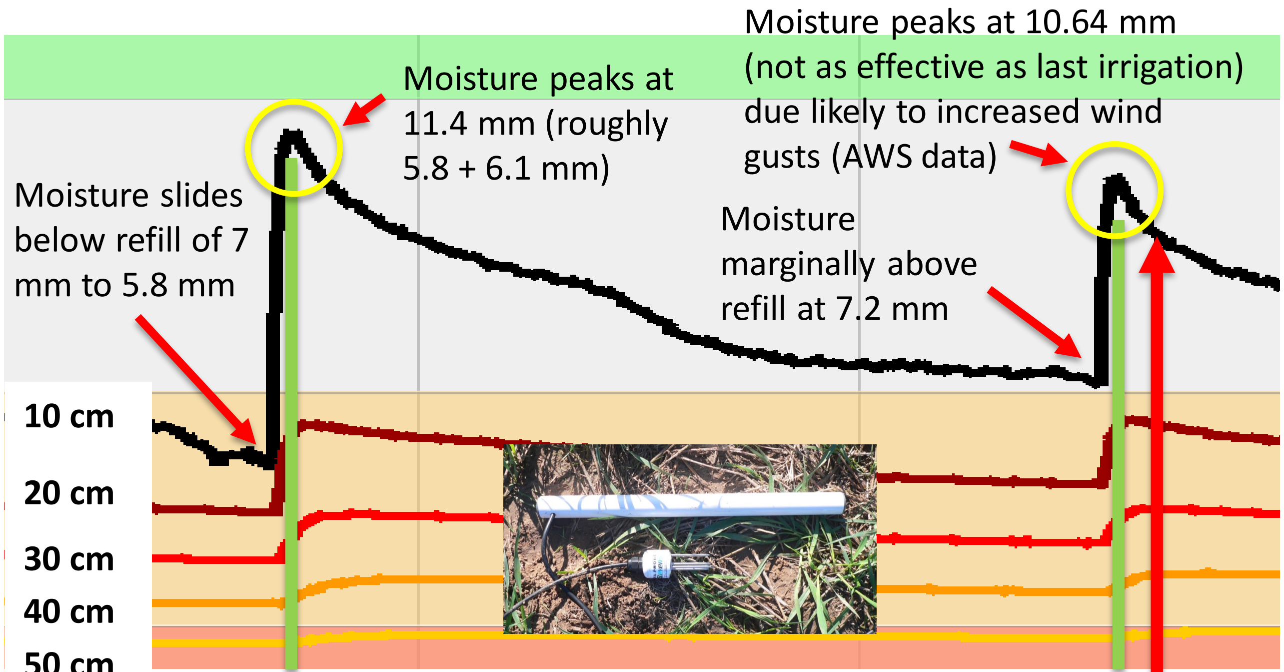
2. Observe and use the trigger points set in the soil moisture monitoring system and activate irrigations around these trigger points as close as possible to the 're-fill' point being reached for each site

3. Trial the practical integration of predictive ET_0 data and weather station data and validate observations of crop water use derived from the capacitance system

4. Refine the full, re-fill and dry points respectively around observed pasture behaviour to develop longer term values as defaults

Trialling a systems approach 2016/17

Evaluating soil moisture monitoring trends and set trigger points



28/2 – 4.57 p.m.
100% speed irrigation goes in at 6.1 mm depth

2/3 – 12.43 p.m.
100% speed irrigation goes in at 6.1 mm depth

This moisture graph shows the fundamental approach used this season. The approach relies on determining and setting full, re-fill and dry points based on your soils RAW's.

These points then need to be validated through field observation and soil examinations to correlate them

Essentially what falls out of this process is the difference between the theoretical – your RAW's and a set of probe default values

With off the shelf probes it is unlikely that they will generate default values that will match your RAW's as sheer values, you have to correlate to derive a fresh relationship

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Trialling a systems approach 2016/17

Predictive and historical climate data

- This trial utilized a predictive climate data service provided by BOM's commercial arm that generates daily predictive outlooks for rainfall, humidity, temperature, wind speed and reference ET_0
- The trial was also supported by the continuous data feeds from the NRM weather station network. This data constituted the actuals reviewed in assessing climate influences on the trial site – mostly ET_0, rainfall and wind speed data was used
- For the purposes of this trial a rough parity between the ET_0 calculated daily crop water loss figure in mm was decided upon – this in the trial was principally used as a gross guide between mm applied and likely mm lost – this data was promoted more widely to the community in the form of water balances

Trialling a systems approach 2016/17

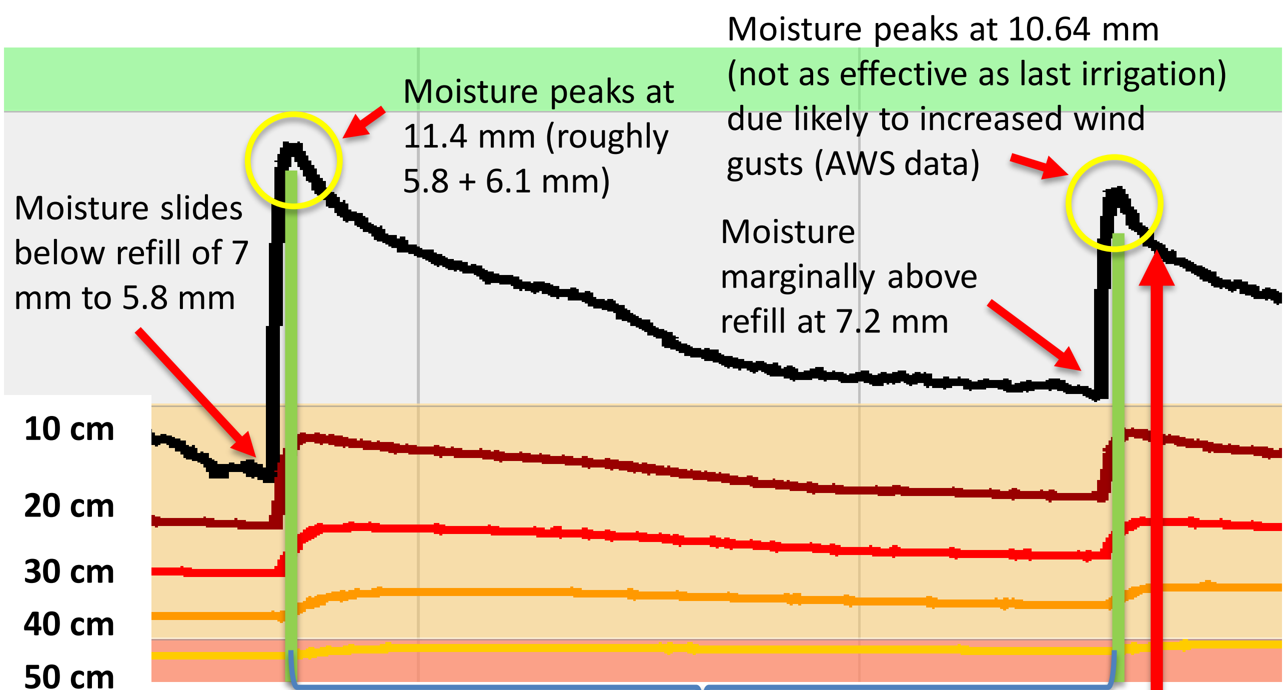
Practically using climate data in the trial

Predictive ET_0 – At the trial site using the predictive ET_0 showed that the estimate was higher than the true crop water use, but the incidence and correlation with actual conditions was gold data for irrigation planning both at the trial site and more broadly

- The key value of this data was that it was possible to develop an outlook around the predictive and then refer to the actuals from the weather station and soil moisture depreciations by graph trace and trigger point to validate the overall scenario
- Future improvements to the use of this data will come from developing a range of coefficients that will provide a more direct relationship to a target pasture
- i.e. Ref ET_0 x a crop coefficient, e.g. 1.1, .9, .7, .6 etc will enable the development of direct calculations of soil water depreciations around trigger points and the projection (against soil water remaining in mm) the time remaining before the trigger point will be reached – these can be developed on site

Trialling a systems approach 2016/17

Practically using climate data in the trial



28/2 – 4.57 p.m.
100% speed irrigation goes in at 6.1 mm depth

Ref ET_0
BOM Projected ET_0 = x
AWS Actual ET_0 = 11 mm
SMM depreciation = 5.5 mm

2/3 – 12.43 p.m.
100% speed irrigation goes in at 6.1 mm depth

Using ET_0 data more exactingly requires the development of coefficient values

A basic approach can be achieved through a soil moisture monitoring system IF we are sure that the trigger values of full and re-fill points (derived from our RAW's) are holding up

We can then review depreciations in soil moisture in the crop root-zone (albeit including some drainage) and derive a basic ongoing relationship that will shift with climate

This example suggests that actual SMM depreciation was 50% of the AWS actual for the period analysed – longer term data sets provide more confidence

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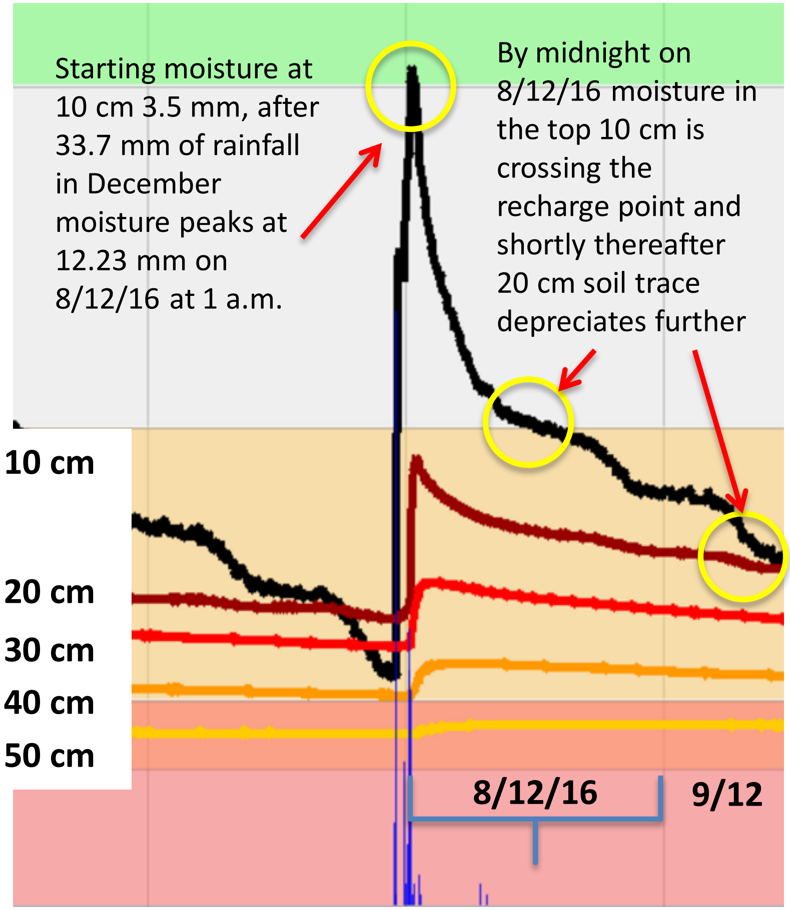
Trialling a systems approach 2016/17

Practically using climate data in the trial – evaluating effective rainfall



Evaluating effective rainfall was a key point this season – graph traces revealed that regardless of the event size that the scenario is generally the same, that is that in sandy soils with shallow rooted pastures that moisture doesn't hang around

In this example it can be seen that despite what we might think about the effectiveness of rainfall in this particular case (given particularly that soils were dry at the outset) rainfall's effectiveness can be well evaluated by graph behaviour

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Monitoring, adapting & troubleshooting

- The biggest challenge this season was having defined interval – enacting and repeating at a set interval repeat irrigations
- There was room for error early in the season and some good rains that tended to send the message that 'all was well' – however into January and February where there was no mercy one or two days extra beyond the set interval on a recurrent basis really knocked back DM production – this is probably the biggest learning for the irrigator this season
- There was also the issue of compaction and rooting depth which became apparent through field monitoring during the season – roots at either of the monitoring sites do not go below 20 cm
- Due to this the pastures live out of the top 20 cm meaning that their RAW's are much more limited – this reduced the interval and with other irrigation commitments made meeting the max of a 48 hour interval difficult

Monitoring, adapting & troubleshooting

Irrigation statistics for focus bays – October 16 – March 2017

Rainfall for the period October 1 – March 28, 2017 was high with some 295 mm being received at the trial site. This provided significant deep soil recharge and reduced the requirement for irrigation in the months of November, December and early January.

The value of the monitoring approach and the technologies has been that it was possible to maximise the usage of this rainfall and correspondingly offset per hectare irrigation applications to be well within water resource plan allocations (~6 ML/ha) for this season. Despite the shallow root zones the frequency of rainfall received made a significant difference to ML applied.

18C – Gravelly Sands

Total irrigation ML applied was 4.3 ML/ha with ~2.36 ML/ha eff rainfall received – total input = **6.66 ML/ha** (to March 27)

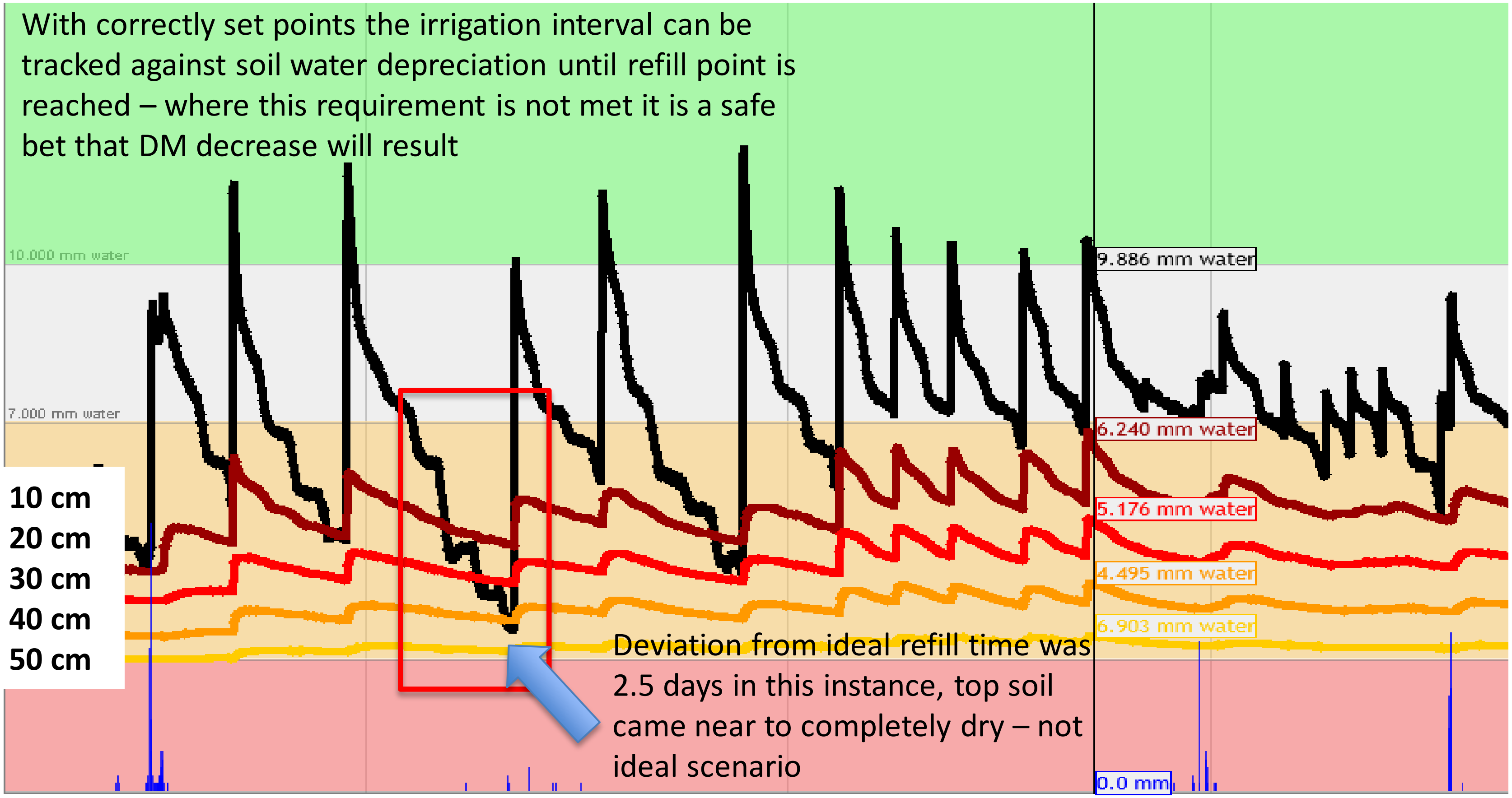
21B – Loamy Midslope

Total irrigation ML applied was 3.18 ML/ha with ~2.36 ML/ha eff rainfall received – total input = **5.54 ML/ha** (to March 27)

Total reference ET_0 losses for the same period measure at the weather station were **7.37 ML/ha**

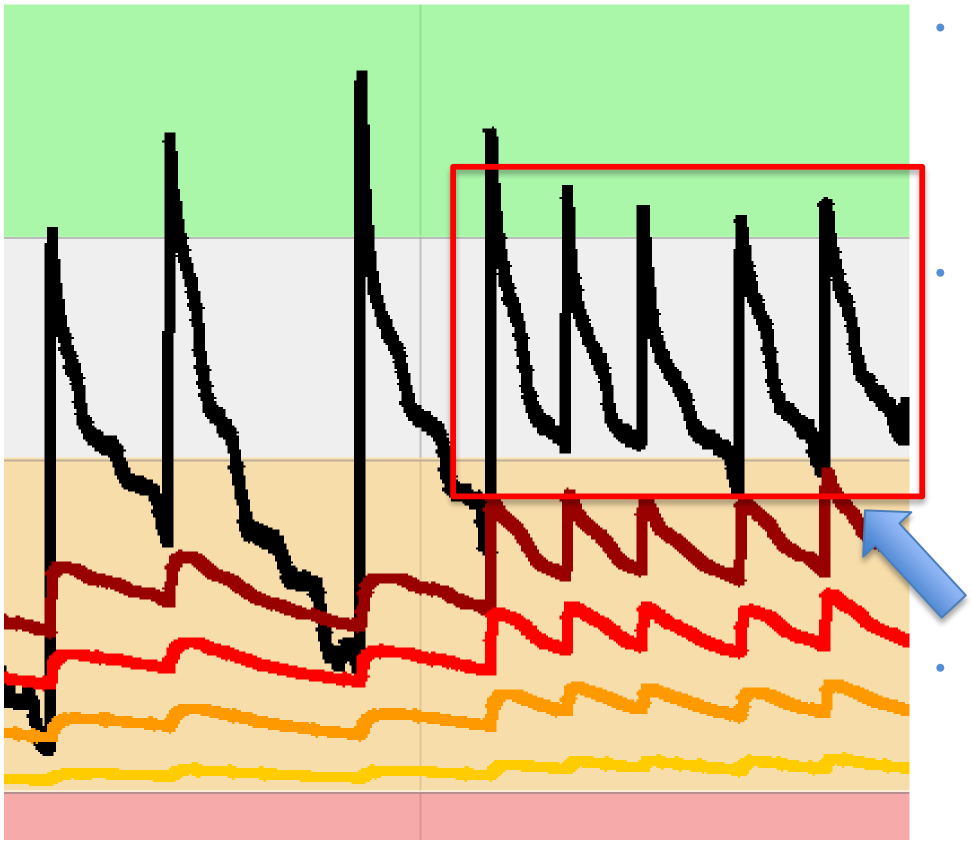
Monitoring, adapting & troubleshooting

Improving understanding of interval - and sticking to it!



Monitoring, adapting & troubleshooting

It's not a question of more water, but a question of the right depth of irrigation at the right time



- At the trial site having established the correct full and re-fill points (through the trial) it was subsequently possible to review issues with DM production clearly
- It was suggested that 'more' deeper irrigations were required – however it has been possible to demonstrate and apply a reduced interval (which works in with other irrigation commitments) and improve DM outcomes without recurrent deep drainage
- This first season scenario can be greatly improved through both pivot speed settings and sticking to the interval and trigger points

Productivity outcomes 2016/17

Bay 18 C – Gravelly Sands – 1.65 ha irrigated bay – September 2016 – March 2017

18 C (1.65 ha)	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Totals
t/DM/Consumed	0.86	1.73	2.24	2.13	1.26	1.20	1.34	10.76
ML total	0	0	1.43	1.2	1.5	1.4	1.62	7.15
t/DM Cons/ML	0.86	1.73	1.57	1.78	0.84	0.86	0.83	
Av t/DM Consumed/ML								**1.50**
Calculated Cost $/t/DM/Consumed								**340.96**

- The gravelly sands produced highest in December with a total application of 1.2 ML yielding its highest in November
- The biggest challenges at this site was the shallow root-zone and having the capacity to meet the maximum 2 day interval with other irrigation commitments
- It is likely if this scenario was further adjusted that the gravelly sands could produce higher but the costs of doing this need to be measured in season to ensure that the increased input costs are justified by the outcomes

Productivity outcomes 2016/17

Bay 21 B – Loamy midslope – 1.87 ha irrigated bay – September 2016 – March 2017

21C (1.87 ha)	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Totals
t/DM/Consumed	1.31	2.72	3.87	2.51	2	1.57	1.63	15.61
ML total	0	0	0.47	0.91	1.13	1.58	1.84	5.93
t/DM Cons/ML	1.31	2.72	8.23	2.76	1.77	0.99	0.89	
Av t/DM Consumed/ML								**2.63**
Calculated Cost $/t/DM/Consumed								**257.57**

- The loamy mid-slope produced heavily in the lead out of a very wet winter into November and rapidly consumed available top soil moisture – with gravelly subsoils and limited root depth the onset of hot conditions soon put into a similar position to its upslope neighbour in the gravelly sands
- Improvements to the scheduling approach at this site are the same as the sands, observe and maintain the interval monitor productivity gains against costs
- It is fair to acknowledge that this soil by virtue of being downslope receives run-off, the trial managed to equalise this to a point but subsoils at 30 cm and beyond remained at saturation all season (tension data)

Findings & Recommendations

- Overall the trial has proven the aspects of practical adoption of advanced soil water monitoring systems – the key has been to work consistently with the irrigator to demonstrate different concepts and to see adoption take place
- The big enemy of DM yield is definitely consistent irrigation and observation of irrigation intervals and re-fill trigger points as being essential to ensuring DM outcomes for the whole season
- Technology such as soil moisture monitoring equipment pays dividends to farm managers through the provision of good information around the effectiveness of irrigation and rainfall – for new users there is an integration and adjustment process and this is what this trial has highlighted
- With the learnings from the first season the team at Cleland's are in a good positon now to refine their irrigation approach for the next season and to better monitor DM outcomes against a number of established benchmarks

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Questions………

Links to capacitance probe network:
http://aqualab-data.dyndns.info/secure/common/main.vm username: samdb password: demo

Link to NRM Weather station network:
http://aws.naturalresources.sa.gov.au/southeast/

Contact: Jeremy Nelson – 0429 845 216
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