PREDICTING THE OPTIMUM TIME TO APPLY MONOLAYERS TO IRRIGATION CHANNELS

Michelle Winter and Bruce Albrecht, Goulburn Murray Water, Victoria

03 5833 5613, michellew@g-mwater.com.au

Summary

Evaporation water losses from irrigation channels are an important component of total irrigation system losses and could be as much as 12% in the Goulburn Murray channel network. The effectiveness of monolayers has been widely studied in still water storages. This research project investigated the potential of using chemical monolayers on irrigation channels in order to suppress evaporation.

Monolayers consist of a film one molecule thick that covers the entire water surface and reduces water evaporation. This project reviewed current knowledge, undertook field and laboratory trials and developed some decision support tools.

The study found there is a need to continue extensive testing of the technology in field situations prior to launching into full scale application of monolayers to irrigation channels. Of highest importance is the need to devise a method to allow the product to pass submerged irrigation culverts, thus allowing full utilisation of the product life and increasing cost effectiveness.

The general principles of achieving the greatest $/ML water savings are:

- Apply monolayer during periods of high evaporation
- Apply monolayer to longer pools (where the product travel time is increased between obstacles)
- Do not apply monolayer when the wind exceeds 25km/hr
- Apply monolayer when the wind is parallel, opposite or oblique to the channel flow, but not perpendicular to the channel flow (which will reduce coverage on the channel)
- Best results will be achieved by applying monolayer when the wind is opposing the channel flow, but the wind speed does not exceed 3.33 x channel flow (this will ensure the monolayer flows downstream, but very slowly, therefore staying on the channel longer and reducing the product quantity required)
- Ensure that all irrigation customer service points either take water from below the surface or are bunded to ensure the monolayer does not escape the channel

Introduction

Water in open channels is subject to high evaporative losses. Some 70[1] gigalitres of water is lost annually through evaporation from channels in Northern Victoria.

Research and field trials carried out by many workers over the last 50 years[2,3] has shown that applying small quantities of chemicals to form a monolayer, or surface film, on the water surface is a cost effective method of suppressing evaporation on bodies of water such as dams. The potential water saving from the use of such monolayers on Goulburn Murray Water irrigation channels is approximately 11GL/year.

This project expands the scope of previous commercial trials, which have focused on large water storages and farm dams, to consider evaporation suppression on irrigation channels. There are researchable questions regarding the efficacy, cost and application methodologies that relate specifically to evaporation suppression in channels.

The purpose of this report is to summarise the findings from field trials and modelling into a series of insights that irrigation authorities can consider when evaluating, researching or applying monolayers to irrigation channels in order to suppress evaporation.

---

1 Goulburn Murray Water Document # 2828686 Baseline Year Water Balance - Draft

2 La Mer, V. K. (Ed.). 1962. *Retardation of evaporation by monolayers: transport processes*. New York and London, academic Press.

3 Barnes, G. T. *The potential for monolayers to reduce the evaporation of water from large water storages*. Agricultural Water Management 95 (2008) 339-353

Field Trials

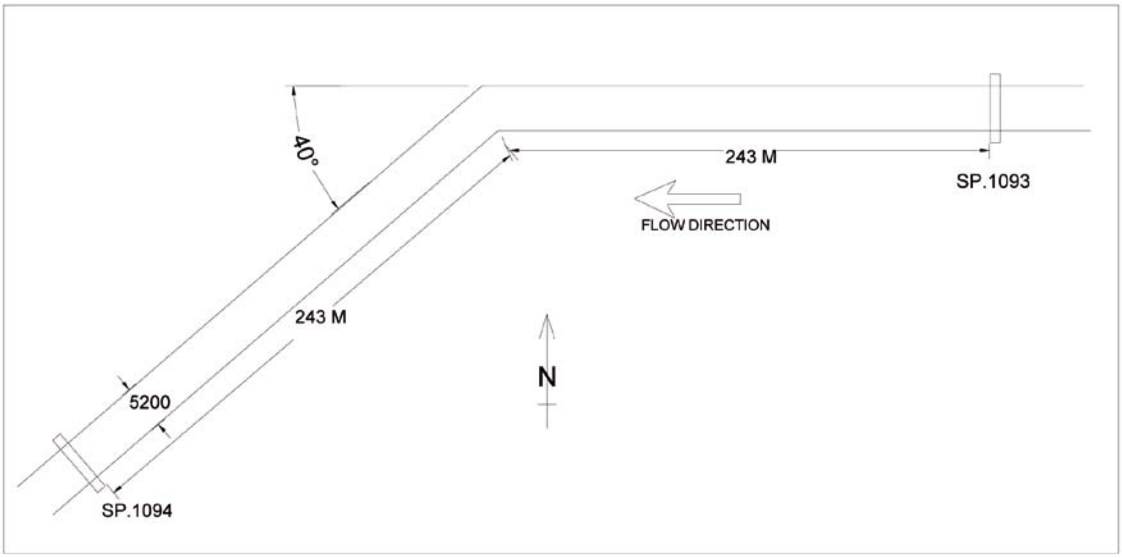
Field Trial Site

The test site chosen for the Goulburn – Murray Water trials was the second last pool of the East Goulburn 30 Channel in the Shepparton Irrigation District (Figure 1)

Figure 1 Location of trial site within Irrigation Region

Figure 2 shows a schematic of the test channel pool. The pool was approximately 500m long, 5.2m wide and up to 600mm deep and is bounded by regulators SP.1093 and SP.1094 .

Figure 2 Schematic of test-channel pool



A number of different instruments were used to measure water depth, water temperature, wind speed, wind direction and rain. Water depth was initially measured at different locations in order to estimate the channel "wedge effect". Channel wedge can be due to either water flow or due to wind blowing along the channel pool and pushing the water to one end of the pool, and can create variation in water level measurements which is not due to water losses.

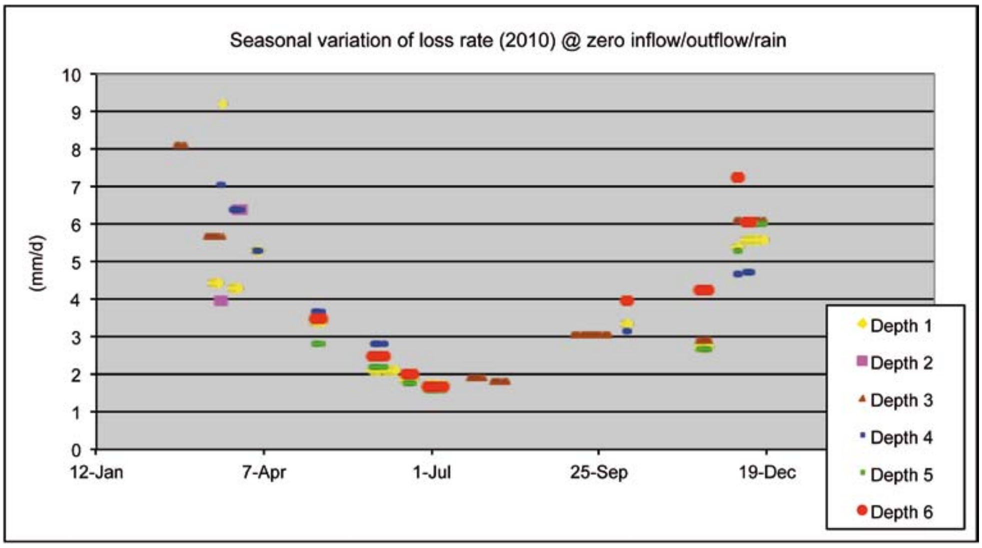
Calculating Base Seepage & Leakage

The aim of the Goulburn Murray Water trials is to determine the evaporation reduction effectiveness of monolayers applied to irrigation channels. Firstly it is necessary to determine the baseline loss rate of the channel, that is, the losses that are present whether or not a monolayer is applied.

To determine the baseline losses, it was necessary to measure the loss rate of the channel at times when there was no rainfall and no inflow or outflow. Any losses during these periods can be attributed to seepage, leakage and evaporation. Seepage and leakage are considered to be constant (providing the channel depth is not fluctuating significantly) and present throughout the year, whereas evaporation will vary over the season.

Figure 3 shows that the minimum loss rate observed was approximately 2mm/day (June – August). The minimum evaporation loss as given by the adjusted pan evaporation from Kyabram during this period was 1mm/d. Therefore the baseline loss of the pool is 1mm/d, that is seepage and leakage equate to 1mm and the remaining loss is evaporation. The soil that the channel is located on is heavy and impervious, therefore a low leakage/seepage rate is expected.

Figure 3: Loss Rate of Test Pool – No Monolayer



1 The different "Depths" represent different locations at which the depth was measured.

Static Trials

Static trials were undertaken to determine the effectiveness of monolayers on suppressing channel evaporation without having to account for channel flow (which can have an error in measurement far greater than the evaporation). The monolayer materials used were WaterSavr® and the Goulburn Murray Water emulsions of cetyl and stearyl alcohols.

Albrecht, 2010, states: " that water savings of between 10 and 30% are possible. Savings of at least this magnitude were expected but the table also shows 'negative' savings i.e. loss rates after application of monolayer are greater than before. A possible interpretation is that the changes in depth that we are looking for are too small to be detected amongst the 'noise' – the random fluctuation in water depth due to wind. So it is difficult to have confidence in these findings."

$$\%\ saving = \frac{a-b}{a}\ \%$$

The percentage savings in evaporation is given by:

where ***a*** is the loss rate without monolayer,

b is the loss rate with monolayer and

loss rate is the gradient of the graph of water depth vs time.

The loss rate with monolayer is the loss rate during the test period. The loss rate without monolayer is obtained from reviewing the change in depth just prior to application of the monolayer. Ideally, the loss rates would be measured simultaneously but this would require two independent and parallel channel sections - a situation that does not exist in Goulburn Murray Water's irrigation system.

In order to obtain greater confidence in the quantity of evaporation that monolayers can save on irrigation channels, the testing is being repeated over greater time periods.

Goulburn-Murray Water is currently developing monolayer dispensing equipment that can operate unsupervised for several days. This will enable Goulburn Murray Water to undertake testing of several days duration using Aquatain®, WaterSavr®, ES300® (emulsion formulations developed by The University of Melbourne) and emulsions of cetyl and stearyl alcohols, in order to reliably establish the percentage savings that can be achieved with monolayer applied to the irrigation channel.

Flowing Trials

Two flowing tests were conducted to test the ability of the Melbourne University Emulsion monolayer to withstand turbulance created by regulating structures and to determine whether the monolayer was capable of reforming and attaining pressure.

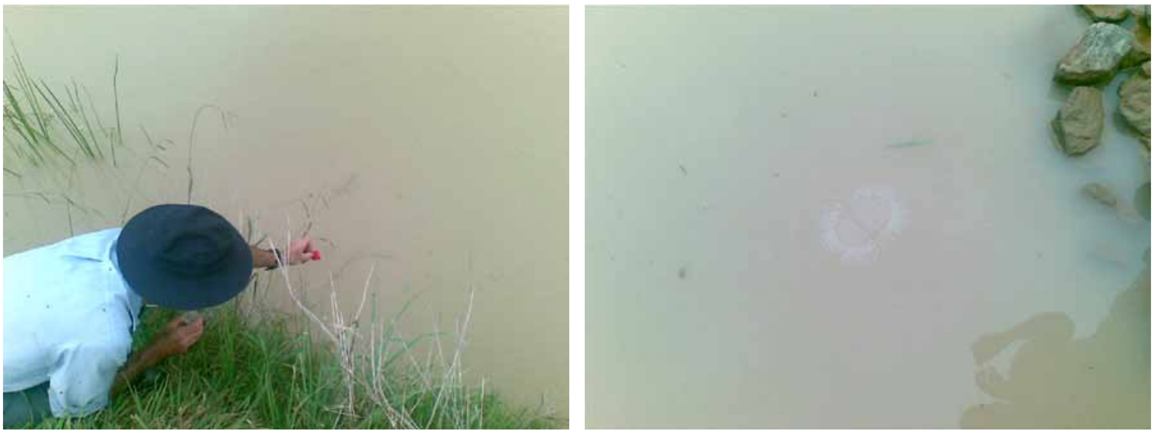
The tests involved pumping emulsion into the segment of channel upstream of a regulator while the channel flow was approximately 20ML/day. The emulsion flowed over the regulator and indicator oils were used to test the surface pressure at regular intervals downstream.

Within both tests, coverage of the pool was achieved and waves dampened (Figure 4). The indicator oils demonstrated that the layer was compressed to > 30 mN/m except for a 100 m stretch directly downstream of the regulator (Figure 5).

The tests indicate that the monolayer material ES300 is capable of passing through a regulating structure and reforming downstream. They also highlight that it takes time for the product to attain adequate pressure to retard evaporation.

Figure 4: Wave damping due to monolayer application

Figure 5 Testing for monolayer presence using indicator oils[1]



1 The rainbow dispersion in the right indicates that monolayer is not present or has not achieved the required pressure of the indicator oil. If it had achieved pressure, the indicator oil would not disperse and only a very small "bubble" would be visible.

Laboratory trials

Various laboratory trials were undertaken by Goulburn Murray Water including testing the effectiveness of the various products within a laboratory situation. The most important of the observations from the Goulburn Murray Water laboratory work is the potential the monolayer products may be able to withstand turbulence caused by channel regulating structures. This preliminary testing indicated that ES300 may be more resilient and capable of passing regulating structures, however further testing should be conducted to substantiate this result.

Application Equipment Investigations

Application equipment required to apply evaporation suppressant monolayers to a water surface (dam, lake or channel) is dependent on the formulation of the monolayer itself.

Monolayers may be different formulations as detailed below:

- **Liquid / Emulsion**

  A liquid formulation is called an emulsion and consists of chemical monolayer material combined with another agent such as an organic solvent or water with an emulsifying agent. Organic solvents are undesirable when the product is to be applied on a large scale because of pollution, toxicity and cost.

  Aquatain® is a liquid formulation which consists of a mixture of polydimethylsiloxane (a liquid silicone polymer) and a surfactant (detergent).

  ES300® is being developed by the CRC Polymers and is currently undergoing trials and may soon be released commercially. It is a solid material but available as an emulsion or solution in an organic solvent. Products investigated by Goulburn Murray Water were in an emulsion form.

- **Solid**

  A solid formulation of a chemical monolayer may or may not include added agents to enhance spreading properties or provide bulking, and can be in various forms including: solid blocks, flakes and powdered. Each of these forms potentially requires a different means of applying.

Watersavr® is a powdered formulation and consists of a mixture of cetyl alcohol (C16H33OH), stearyl alcohol (C18H37OH) and hydrated lime (Ca(OH)2). The two alcohols make up approx. 10% of the mixture, with the rest being lime.

- **Slurry**

  A slurry is a suspension of the powdered substance in water. Some means of providing continuous mixing is required to prevent the solid from settling to the bottom of the container.

Monolayer application equipment generally consists of a storage compartment for the product and a pump to dispense the product. Various forms of "programming" or automating the application of the monolayer exist.

Goulburn-Murray Water used a peristaltic pump to deliver emulsified cetyl and/or stearyl alcohol to the test channel. The pump was powered by 12V lead-acid batteries. Two speeds were available: selected by switching the batteries to provide 12V (low speed) or 24V (high speed). The corresponding delivery rates were 2.4 L/min or 5.0 L/min.

Where finer control of delivery rate was required and this was achieved by plumbing changes whereby some of the output was diverted back to the storage tank.

The benefits of this application method are:

- Relatively inexpensive
- Simple and reliable
- Accurate delivery

Potential enhancements and recommendations:

- remote control or automation

If undertaking monolayer application on a larger scale it would be desirable to incorporate a number of automatic features to correspond with the output of the Decision Support System model that decides the optimal time to apply monolayer.

There is the potential to tap into existing knowledge of control systems currently used for herbicide delivery.

Economic Assessment

Table 1 details the cost per megalitre of water savings of systems addressing evaporation losses from dams as reported in the literature (for those systems where the cost and efficiency data is available). Note: only capital costs have been allowed for, because minimal information is available on the maintenance costs of the different techniques.

Table 1: Dam evaporation mitigation systems (Source: Winter 2011)

Method	Potential evaporation savings	Installation Cost / m2	Cost / ML saved (NPV @ 6% over 30 years – capital only)	Product Life
Floating Covers				
E-VapCap	90%	$7[1]	$390	12 years[2]
REVOC	95%	$30[3]	$1,060	30 years[3]
Defined Sump	95%	$30[2]	$1,110	25 years[2]
Evap-Mat	90%	$3.50[2]	$130	30 years [2]
Fabtech	95%	$7[2] (excludes earthworks)	$340	15 years[2]

Table 1: Dam evaporation mitigation systems (Source: Winter 2011)				
Method	**Potential evaporation savings**	**Installation Cost / m2**	**Cost / ML saved (NPV @ 6% over 30 years – capital only)**	**Product Life**
Floating Objects				
AquaCaps	85%	$17[3]	$750	20 years
Agfloats	80%	$10[3]	$440	25 years[4]
Raftex	95%	~$4.50[2]	$470	5 years[2]
HexDome TM	90%	~$6.50[2]	$260	25 years[2]
QUIT Evap Cover	87.5%	$7[3]	$490	~9 years[3]
Other Methods				
Shade cloth	70%	$7 - $10[4]	$410	30 years[5]
Chemical monolayer	5% - 30%	$0.00 - $0.38[2]	$130 - $1200[5]	

A Decision Support System to Inform When and Where to Apply Monolayers to Irrigation Channels

The Decision Support System (DSS) is a model to inform when and where to apply monolayers to irrigation channels in order to achieve particular outcomes. Those outcomes may be the lowest $/ML water savings, water savings below a required $/ML threshold or a required volume of water savings. The Decision Support System will provide the following boundaries for monolayer application to meet the requirements:

- Channel type: Carrier, Trunk, Spur
- Which channels: all, longest 25% or longest 10%
- Wind conditions: wind speed and wind direction relative to channel flow
- Evaporative rate
- Monolayer Type
- Structure Impediments

For example, within the GMID savings of less than $1000/ML may be achieved by applying ES300 to the 10% longest carrier channels when wind is less than or equal to 25km/hr and evaporation is greater than or equal to 4.5mm/day.

The current Decision Support System is limited to the GMID, for it to be utilised by another irrigation system operator it will require the appropriate asset, wind and evaporation data to be entered. The steps below describe use of the DSS by Goulburn Murray Water.

- Enter the price limit established in the BMG "The maximum cost of achieving water savings in a given year" into the DSS
- The DSS will show (colour coded) those situations which meet the $/ML criteria.
- The user then decides in which of those situations to apply product, if any.

The following table presents a sample of the output of the DSS, in this instance WaterSavr applied to Trunk channels.

Assuming a limit of $1000/ML it can be seen that the only times this can be achieved is when the wind is between 19.6 and 25km/hr and opposing the channel flow, and the evaporative rate is 3-6mm/day or 6-9mm/day.

Product	WaterSavr						
Channel Type	Trunk						
Evaporative Rate	1.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$20.3 K						$20.3 K
1.6	$18.6 K						$18.6 K
3.9		$22.0 K	$15.1 K	$21.0 K	$16.2 K	N/A	$18.6 K
7.1		$24.8 K	$12.3 K	N/A	N/A	N/A	$18.6 K
12.2		$29.3 K	$7.9 K	N/A	N/A	N/A	$18.6 K
17.3		$33.8 K	$3.4 K	N/A	N/A	N/A	$18.6 K
22.4		$38.3 K	$1.1 K	N/A	N/A	N/A	$19.7 K
35	N/A						

Evaporative Rate	4.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$6.8 K						$6.8 K
1.6	$6.2 K						$6.2 K
3.9		$7.3 K	$5.0 K	$7.0 K	$5.4 K	N/A	$6.2 K
7.1		$8.3 K	$4.1 K	N/A	N/A	N/A	$6.2 K
12.2		$9.8 K	$2.6 K	N/A	N/A	N/A	$6.2 K
17.3		$11.3 K	$1.1 K	N/A	N/A	N/A	$6.2 K
22.4		$12.8 K	$0.4 K	N/A	N/A	N/A	$6.6 K
35	N/A						

Evaporative Rate	7.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$4.1 K						$4.1 K
1.6	$3.7 K						$3.7 K
3.9		$4.4 K	$3.0 K	$4.2 K	$3.2 K	N/A	$3.7 K
7.1		$5.0 K	$2.5 K	N/A	N/A	N/A	$3.7 K
12.2		$5.9 K	$1.6 K	N/A	N/A	N/A	$3.7 K
17.3		$6.8 K	$0.7 K	N/A	N/A	N/A	$3.7 K
22.4		$7.7 K	$0.2 K	N/A	N/A	N/A	$3.9 K
35	N/A						

<= $1000/ML
>$1000/ML and <= $5000/ML
> $5000/ML

The general principles of achieving the greatest $/ML water savings are:

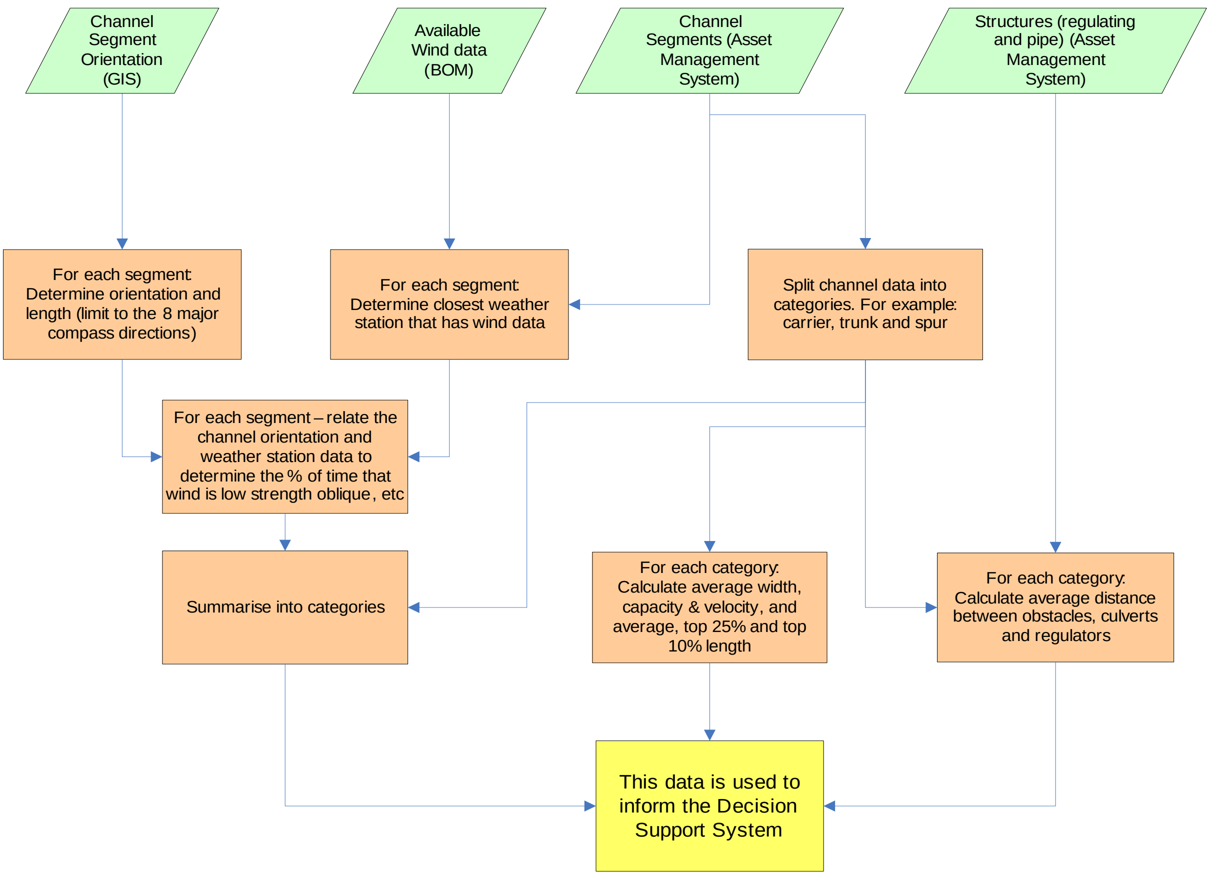
- Apply monolayer during periods of high evaporation
- Apply monolayer to longer pools (where the product travel time is increased between obstacles)
- Do not apply monolayer when the wind exceeds 25km/hr
- Apply monolayer when the wind is parallel, opposite or oblique to the channel flow, but not perpendicular to the channel flow (which will reduce coverage on the channel)
- Best results will be achieved by applying monolayer when the wind is opposing the channel flow, but the wind speed

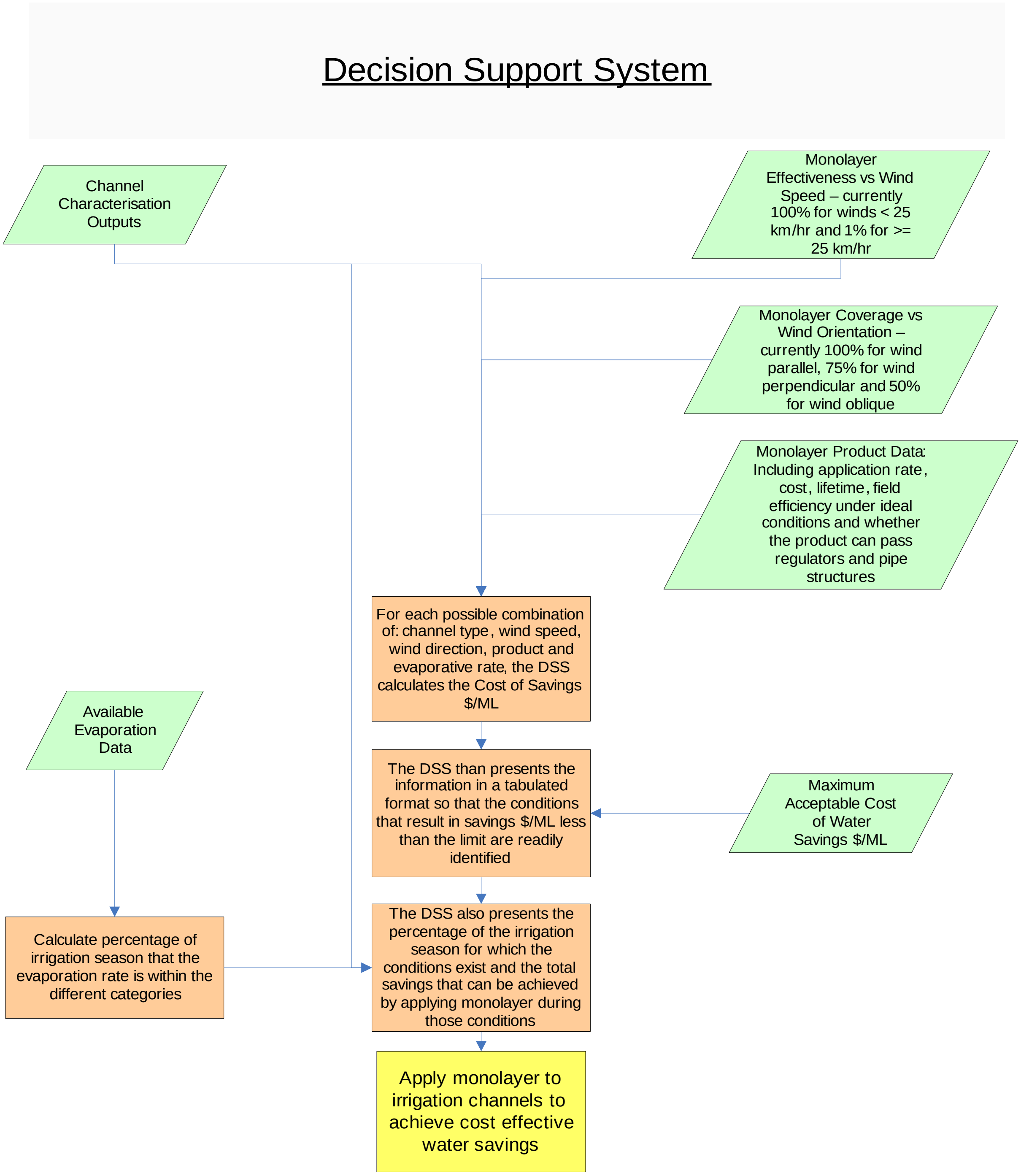
does not exceed 3.33 x channel flow (this will ensure the monolayer flows downstream, but very slowly, therefore staying on the channel longer and reducing the product quantity required)

- Ensure that all irrigation customer service points either take water from below the surface or are bunded to ensure the monolayer does not escape the channel

The following flow charts detail the channel characterisation process (which sits behind the DSS) and the DSS process.

Channel Characterisation Process





The current Decision Support System is limited to the GMID, for it to be utilised by another irrigation system operator it will require the appropriate asset, wind and evaporation data to be entered.

Monolayer Environmental & Social implications

Use of monolayers on irrigation channels must consider the environmental and social impacts:

- Within the channel
- On farm
- To downstream users

The basic steps to accomplish this are described below:

- Don't discharge to waterways such as rivers to eliminate the potential for negative public perception regarding the natural environment
- Consult with neighbouring landowners
- Put together a fact sheet
    a. Product makeup
    b. Product life within the natural environment
    c. The benefits of product use – irrigator benefits
    d. Comparison with other commonly used products ie. makeup
    e. Comparison with naturally occurring monolayers
    f. Potential benefits from use and potential for landowners to implement on-farm
- Ensure bunding of overshot outlets (flume gate outlets) so that the monolayer is not discharged to landowner properties
- Establish an acceptable maximum field life for monolayer products that ensures they remain within the channel system and do not enter natural waterways
- Maintain Material Data Sheets for all monolayer products in use
- Check environmental approvals and read product labels carefully.

Conclusion

The following conclusions are made:

- Savings of between 10 and 30% with the different monolayer products seem possible but need confirming. It has not been possible to show definite, consistent water savings from static tests
- The monolayer materials ES300 and WaterSavr appear capable of withstanding the turbulence created by regulator structures, demonstrated by laboratory testing
- The ability of ES300 to withstand regulator turbulence was demonstrated by field testing in which it reformed and obtained pressure adequate to suppress evaporation
- Monolayer materials are incapable of passing submerged pipe culverts.
- Further field testing is required to determine whether the use of monolayer materials on irrigation channels is a feasible method of reducing evaporation.
- There is not a single $/ML associated with the monolayer technique, because there are many variables that affect the cost effectiveness. An acceptable $/ML needs to be established and monolayers only applied during the periods that can achieve the required cost effectiveness.

- Modelling the use of monolayers on irrigation channels has shown that the most critical barrier to the cost effectiveness of monolayers is the ability to pass culvert structures. Therefore, it is imperative that investigations are undertaken to determine whether a technique can be developed to allow monolayers to pass culvert structures.

Recommendations

The following recommendations are made:

- Perform further closed-channel trials with monolayer applied for periods longer than several days i.e.weeks
- Undertake field trials with other monolayer products such as WaterSavr to determine whether they are capable of passing regulating structures. This will enable further comparison with the performance of ES300.
- Undertaken investigations to determine whether a technique can be developed to allow monolayers to pass culvert structures.

Further review costs associated with the monolayer technique including: cost of maintenance and filling and actual costs of application equipment including linkage into the SCADA system.

Reference

Winter, M (2011) "Predicting the Optimum Time to Apply Monolayers to Irrigation Channels" Research Masters Thesis, The University of Queensland

Acknowledgements

Goulburn Murray Water collaborated with The University of Southern Queensland (USQ) through the CRC Irrigation Futures, and National Program for Sustainable Irrigation to understand how this technology can be applied to channels.

(Footnotes)

1 NCEA Evaporation Control n.d., *Product Review,* NCEA Evaporation Control, University of Southern Queensland, Toowoomba, Qld, viewed 6 October 2010, <http://evaporationcontrol.ncea.biz/Downloads/Product%20Review.pdf>

2 Craig, I.P 2008, *Loss of storage water through evaporation with particular reference to arid and semi-arid zone pastoralism in Australia*, DKCRC Working Paper 19, The WaterSmart™ Literature Reviews, Desert Knowledge CRC, Alice Springs

3 Reclaim Industries Ltd n.d., *Agfloat,* Reclaim Industries Ltd, Hallam, Vic, viewed 5 October 2009, <http://www.reclaim.com.au/index.php/products/agfloat/>

4 Craig, I, Green, A, Scobie, M and Schmidt, E 2005, *Controlling Evaporation Loss from Water Storages,* NCEA publication, University of Southern Queensland, Toowoomba, Qld

5 National Program for Sustainable Irrigation 2005, Controlling evaporation losses from farm dams, Land & Water Australia, Australia, viewed 5 October 2009, <http://lwa.gov.au/files/products/national-program-sustainable-irrigation/pf050873/pf050873.pdf>

The National Program for Sustainable Irrigation is a partnership of Cotton Research & Development Corporation, Gascoyne Water Co-operative, Goulburn-Murray Rural Water Corporation, Grains Research & Development Corporation, Harvey Water, Horticulture Australia Limited, Lower Murray Water, Ord Irrigation Co-operative, South Australian Research and Development Institute, Sugar Research & Development Corporation, SunWater, Australian Government Department of Sustainability, Environment, Water Population and Communities, and Western Australia Department of Water.

ISBN 192102531Xr 2011