Predicting the Optimum Time to Apply Monolayers to Irrigation Channels

A dissertation submitted by

Michelle Winter, Bachelor Engineering (Civil) (Honours)

For the award of

Masters of Engineering Research

2012

Predicting the Optimum Time to Apply Monolayers to Irrigation Channels

Michelle Winter

Modernisation, Goulburn-Murray Water

Abstract

The research project aimed to investigate the potential of using chemical monolayers on irrigation channels to reduce evaporation losses. Monolayers consist of a film one molecule thick that covers the entire water surface and reduces water evaporation. The effectiveness of monolayers at reducing evaporation from still water bodies has been widely studied, with the technology having been adopted by some irrigation authorities on storage dams. However, little research has been done into investigating the effectiveness of monolayers in reducing evaporation in flowing situations. Goulburn-Murray Water has an extensive network of irrigation channels of which evaporative losses are a major component of the total yearly water losses (approximately 70 GL/year). The purpose of this work was to establish a decision support system to predict under what situations it is most appropriate for Goulburn-Murray Water to apply monolayers to irrigation channels.

Closed and flowing channel trials were conducted by Goulburn Murray Water. The closed channel trials indicated that using monolayers on irrigation channels could result in potential savings of between 10% and 30%, while the flowing trials gave promising preliminary results into the ability of ES300 to pass a regulating structure and reform with surface pressure adequate to suppress evaporation.

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. The model needed to take into consideration many variables including evaporation rates, wind impacts, material costs and channel dimensions.

Modelling also indicated that where monolayers are unable to pass culvert structures, cost effectiveness is increased if the flow of the monolayer down the channel can be slowed, thereby retaining the monolayer on the channel for longer and reducing the number of times it needs to be reapplied. Methods to achieve this include applying monolayer to the longer pools and applying when wind direction opposes channel flow.

If no technique can be found to allow monolayers to pass culvert structures then this technique remains a costly method of saving evaporation water due to the continual reapplication of product. Its main attractiveness for use is that it can be used when and where required without large capital investment and at times when the cost can be warranted by the value of water.

The model is specific to the Goulburn-Murray Water channel system, however flow charts have been developed to enable other irrigation authorities to characterise their irrigation network in order to apply the model to their situation. In order to use the model, Goulburn-Murray Water needs to set the maximum $/ML that it is willing to pay at that time and then review the model output to determine where to apply monolayers to achieve that result.

Depending on the drivers to save water, monolayers are most suited to application on the longest pools. Savings at well below $200/ML can be achieved by applying ES300 to the 1% longest carrier channels when evaporation is 4.5 mm/day or greater, however the total volume that could be expected to be saved under these conditions is only 70 ML or 0.1% of the current total losses due to channel evaporation. The total savings achieved and the average cost of achieving those savings are intrinsically related and an improvement in one will detrimentally affect the other.

Keywords:

Monolayer, irrigation, channel, Victoria, flow, agriculture, evaporation

Certification of Dissertation

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

Signature of candidate	Date
Signature of Supervisor	Date
Signature of Supervisor	Date

Acknowledgements

Name	*Details*
Bruce Albrecht	G-MW employee working on the evaporation mitigation project, provided guidance, review, field and laboratory results
Mark Bailey	G-MW manager, provided guidance
Matthew Davis	G-MW employee, provided review
Peter Egglestone	G-MW manager, provided review
Nigel Hancock	USQ supervisor
Fiona Nioa	G-MW manager, provided review
Jeremy Nolan	G-MW manager, provided review
Derek Poulton	Former G-MW employee & manager, provided guidance and review
Rod Smith	USQ supervisor
Willem Vlotman	Former G-MW employee & manager, provided guidance and review

Table of Contents

1 INTRODUCTION

The research project aimed to investigate the applicability of using chemical monolayers on irrigation channels to reduce evaporation losses and to establish a decision support system to predict the optimum times, environmental conditions and locations for Goulburn-Murray Water (G-MW) to apply monolayers. To date, minimal research has been done into reducing evaporation losses from irrigation channels, with the main available methods being pipelining, shade cloth covers and plastic covers. Monolayers potentially provide a low cost water savings solution which can be targeted for use during high evaporation periods. However, monolayers are not without their problems and many difficulties have been experienced in their use including: application difficulties, wind displacement and rapid bacterial/microbial degradation.

The project reviewed past and present research into monolayers and where possible utilised test results from the application of monolayers to irrigation channels being undertaken by G-MW in a parallel project. The decision support system produced can be used to determine the "best" set of conditions that produce the lowest cost ($/ML) of water savings (that is the most cost effective water savings). This can be extrapolated to the full extent of G-MW's channel network to determine if it is feasible to make use of monolayers on irrigation channels to reduce evaporation.

1.1 Significance of the issue

Over the past ten years prior to 2009/10 much of Victoria, including the Goulburn-Murray Irrigation District (GMID) in the north of the state, experienced significant dry conditions with rainfall well below average and irrigation allocations being the lowest on record. Scarce water resources were stretched to their limits with demand by the environment, irrigators and urban Melbourne, reflected in record high prices for both permanent and temporary water sales (refer to Figure 1.1 and Figure 1.2).

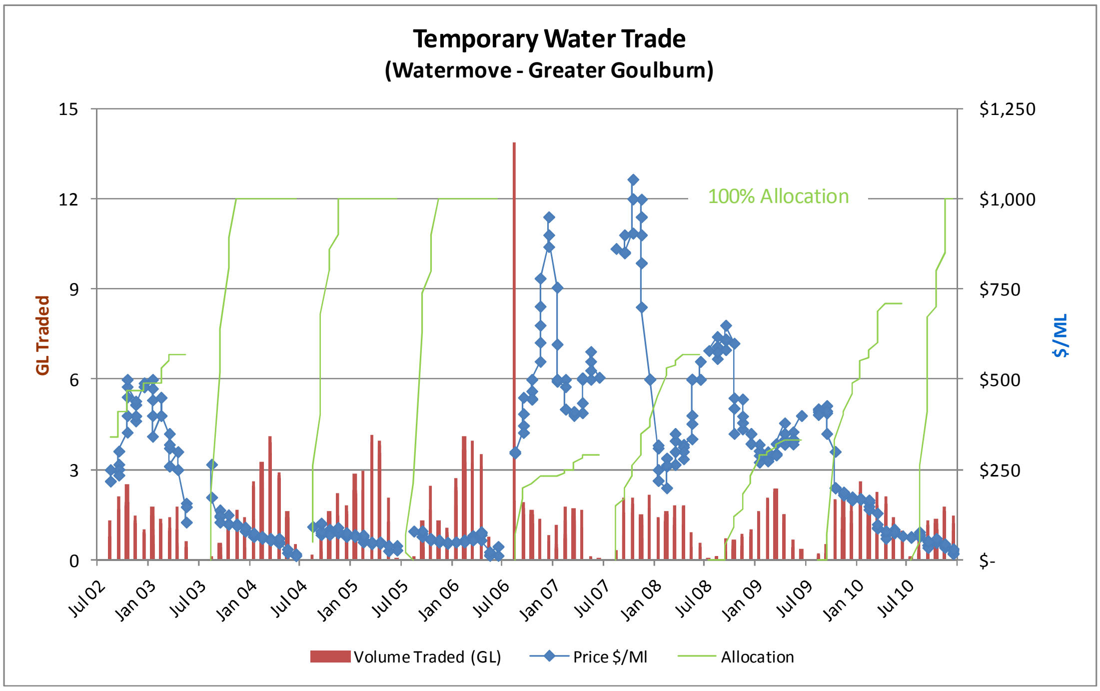


Figure 1.1 Temporary water price trends

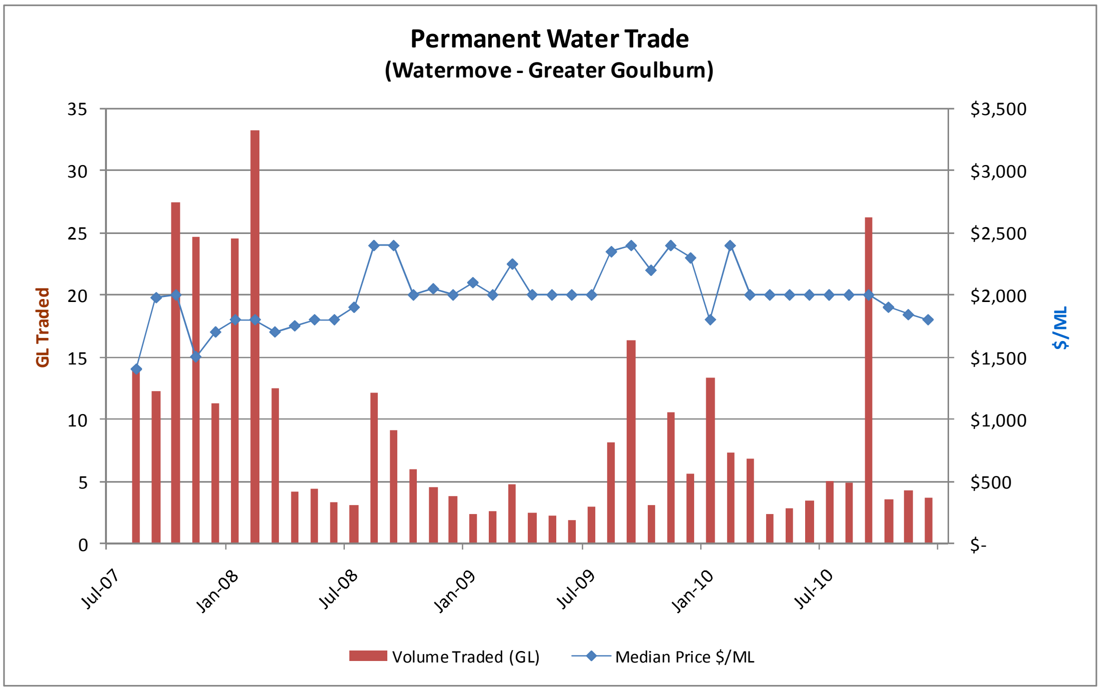


Figure 1.2 Permanent water price trends

Many water savings projects are underway to conserve this limited resource. Losses from the G-MW channel system consist of leakage, seepage, evaporation, measurement error, outfalls and theft. Current water savings initiatives focus on a number of strategies such as:

- removing a channel from use (saving all losses on that channel section);
- channel automation (saving outfalls and leakage);
- meter replacement (saving measurement error and meter leakage);
- channel lining (saving seepage and leakage); and
- pipelines (saving seepage, leakage and evaporation, but limited to small channels).

Latest estimates (refer to Figure 1.3) indicate evaporation losses from channels could be as much as 12% of the total channel network losses (Goulburn-Murray Water, 2010).

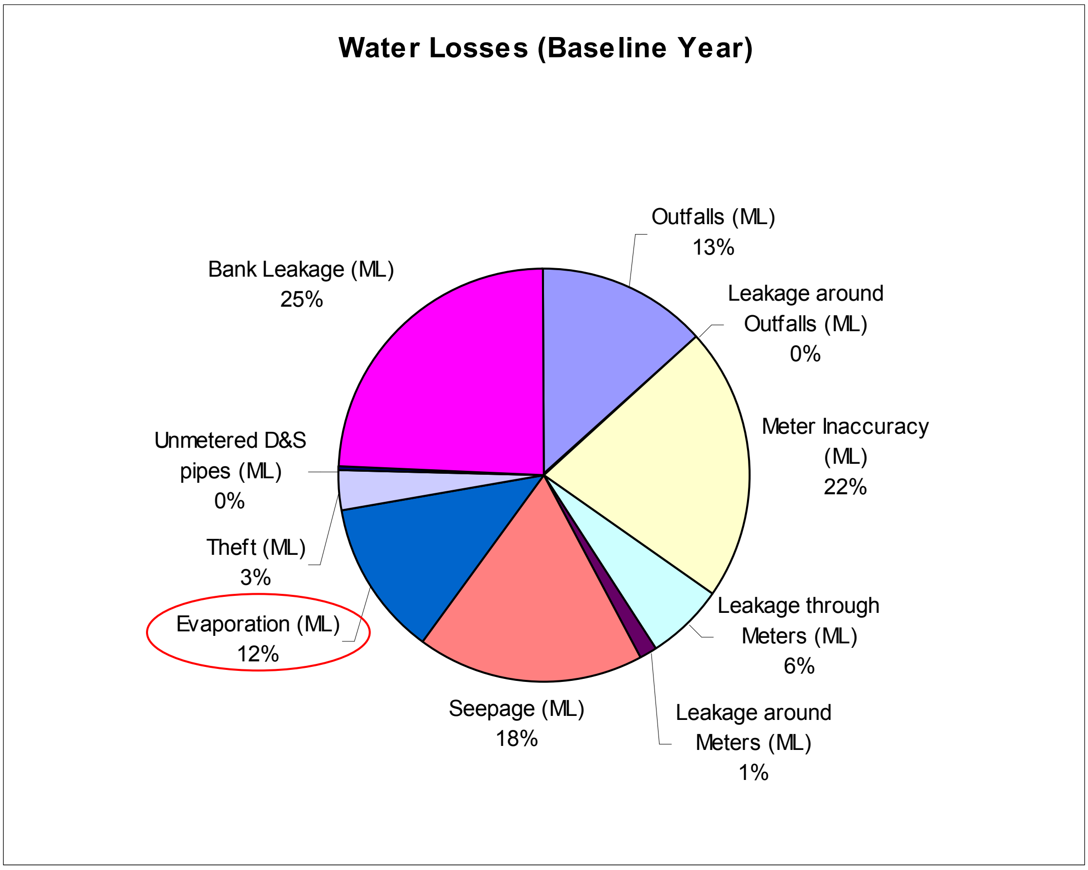


Figure 1.3 Baseline water losses in the GMID (Goulburn-Murray Water, 2010)

1 The baseline year is essentially 2004/05 except for Campaspe which uses 2003/04 and Central Goulburn 1-4 Channels which use 2005/06 in place of 2004/05. 2004/05 was a 100% allocation year.

1.2 Aim of the Research Project

The research project aimed to investigate the applicability of using the monolayer method on irrigation channels to reduce evaporation losses and to establish a decision support system to predict the optimum times, environmental conditions and locations for G-MW to apply monolayers.

The decision support system provides an estimate of \$/ML of water saved (by extrapolating the mm/day results to “average” pool dimensions) when applying monolayers to irrigation channels under a given set of input conditions. The decision support system can be used to determine the “best” set of conditions that produce the lowest cost (\$/ML) of water savings (that is the most cost effective water savings). This can be extrapolated to the full extent of G-MW’s channel network to determine whether it is feasible to implement monolayers on irrigation channels to reduce evaporation. Changing variables with time (such as increasing or decreasing willingness of G-MW and/or external investors to fund water savings projects at increased costs or continued changing climatic conditions) will make the application of monolayers to channels more or less attractive with time.

Broadly, the research project aimed to address the following questions:

- Can monolayers be effectively utilised on water that is flowing in channels?
- In what situations is it most appropriate for G-MW to apply/not apply monolayers to irrigation channels?
- What evaporation savings can potentially be achieved by using monolayers extensively on the G-MW network? and
- What gaps still exist in our understanding and knowledge of monolayers?

Creating a decision support system, in the form of a spreadsheet model, was considered to be the best way of answering the research questions posed above.

Tasks required to be undertaken included:

- Characterising the channel network; and
- Creating a model to predict when and where it is best to apply monolayers.

Goulburn-Murray Water also undertook a parallel project to apply monolayers to irrigation channels in the field, a project that I also had a significant role in and the results of which were used to inform this research project. The aims of the field work were:

- Applying monolayers to an irrigation channel that was non-flowing;
- Determining rate of savings that could be achieved on the non-flowing channel and comparing to other studies;
- Applying monolayer to a flowing channel and determining the management issues created or the boundaries for application and the situations under which it is effective or not effective; and
- Applying different commercially available monolayers to enable contrast and comparison.

The outcomes of this research project (and the concurrent field work) are:

- Update current knowledge in the use of monolayers on irrigation channels;
- Review the use of monolayers on irrigation channels in the field (from involvement in the concurrent G-MW project); and
- Development of a decision support system to inform the application of monolayers on irrigation channels.

1.3 Structure of the Dissertation

The dissertation comprises the following chapters:

- Introduction
- Background

  Review of available literature on: evaporation volumes, methods of reducing evaporation, past monolayer research and products; and issues in the use of monolayers particularly in a flowing situation.

- Development of the Decision Support Model

  Development of a model to enable G-MW to determine the best set of conditions to apply monolayers within the channel network.

- Results & Discussion

  Presentation of the results of the modelling.

- Conclusions and Recommendations

  When and where should G-MW apply monolayers to achieve a particular $/ML outcome and what additional research needs to be undertaken into the use of monolayers on irrigation channels.

- References, Glossary of Terms & Appendices

2 BACKGROUND & LITERATURE REVIEW

This section of the thesis reviews the total volume of water lost to evaporation, methods of evaporation reduction, past monolayer research and results; and obstacles to monolayer use in irrigation channels.

2.1 Principles of Evaporation

Evaporation is the transformation of water from the liquid state to the gas state (water vapour). This process requires:

- energy to perform the process;
- a free surface layer for the water molecules to move through;
- unsaturated air (low relative humidity) above the water surface; and
- air movement above the water surface to move the water vapour away.

Therefore evaporation is influenced by: solar radiation, temperature, humidity, wind speed and water depth. Total evaporation from a water body increases with increased water body area.

2.2 Evaporation Volume

The quantity of evaporation from the irrigation channel network is large due to the extent of exposed water surface and due to the climatic conditions within the region.

Estimates of yearly evaporation volume can be based on Class A Pan evaporation, pan factor, rainfall, channel area and consideration of channel bank degradation. Calculation of losses within the GMID has been reviewed for the Northern Victorian Infrastructure Renewal Project (NVIRP), with the agreed losses as presented in Table 2.1. The estimated total yearly evaporation (less rainfall) is 70 GL within the 2004/05 baseline year (Goulburn-Murray Water 2010).

A considerable portion of the gravity network system is proposed to be rationalised (abandoned or privatised) under NVIRP stages 1 and 2. The proposed rationalisation would result in a reduced channel surface area and reduced yearly evaporation of 47 GL (Goulburn-Murray Water 2010). Refer to Table 2.1.

Table 2.1 GMID losses (Goulburn-Murray Water, 2010)

Water Losses (Baseline Year)	*Total (Pre Modernisation)*	*Backbone*	*Non-Backbone*
Outfalls (ML)	76,650	40,350	36,300
Leakage around outfalls (ML)	150	50	100
Meter inaccuracy (ML)	121,950	56,700	65,250
Leakage through meters (ML)	35,900	17,250	18,650
Leakage around Meters (ML)	7,400	3,600	3,800
Seepage (ML)	101,550	67,850	33,700
Evaporation (ML)	70,300	47,350	22,950
Theft (ML)	17,050	8,200	8,850
Unmetered D&S pipes (ML)	1,900	1000	900
Bank leakage (ML)	140,400	64,100	76,300
Natural carrier losses (ML)	74,400	35,150	39,250
TOTAL (ML)	*647,650*	*341,600*	*306,050*

1 The Campaspe district is included within this table, although it is now in the process of being rationalised.

2 Backbone and non-backbone are explained in further detail in Table 3.1.

3 These losses were calculated for the 2004/05 baseline year and have not been converted to long term averages

Evaporation as detailed in Table 2.1 is net evaporation, that is evaporation less rainfall. Goulburn-Murray Water is interested in the total losses from the system and balancing these with the system inputs, therefore only considers net evaporation when reporting total water losses.

The use of Class A Pan evaporation is G-MW's adopted method of calculating evaporation from water bodies. The limitation of this method is that it tends to overestimate the evaporation, therefore corrections factors (pan factor) are used to adjust the observed pan evaporation to estimated evaporation from a large water body. However, the pan factor is specific to the type of pan used, the location of the pan and type of water body. G-MW adopts a pan coefficient of 0.8 (SKM, 2009 & Department of Sustainability and Environment, 2010).

More accurate methods exist for the calculation of evaporation from water bodies which include:

- mass balance – where all inflows, outflows and other losses are measured and the remainder is attributed to evaporation;
- energy budget – measures the difference between energy inputs and energy outputs but requires site specific measurements;
- bulk transfer – a method which is suited to very large water bodies;
- combination methods – combine the energy budget and mass transfer methods, which again require site specific measurements.

The accurate calculation of the evaporation volume from irrigation channels is beyond the scope of this thesis and therefore G-MW's adopted method of Class A Pan evaporation has been used within the modelling to determine the total savings that could be expected to be achieved by applying monolayers to irrigation channels. The $/ML savings have been calculated for different evaporative rates and are unaffected by the method of calculation.

If the rate of evaporation was found to be a major driver to the cost effectiveness of the application of monolayers to irrigation channels than it would be necessary to review the way in which the evaporation is calculated in order to substantiate the total savings that could be achieved if the method was adopted.

2.3 Value of the Lost Water

There are a number of ways to consider the value of the lost evaporation water, ranging from the gross value of production that could have been achieved, to the value of the water on the temporary trading market. It can also be compared to current water savings initiatives and the price investors are willing to pay for the water savings achieved.

The 2004/05 Water Account (Australian Bureau of Statistics, 2006) indicated that Australia wide, the gross value for water consumption across all agricultural sectors was $744/ML (varying from $162/ML for rice to $3,867/ML for vegetables). The baseline evaporation losses from G-MW's channel network was calculated to be 70 GL (refer Table 2.1) which would have equated to a gross value of approximately $270M if fully utilised and not lost to evaporation. Following modernisation, yearly evaporation would equate to a gross value of approximately $180M if fully utilised.

In an "average" irrigation season, that is 2003-2006 when water scarcity did not cause excessive temporary transfer prices, water entitlement on the temporary trade market generally costs $60 - $80/ML. Following modernisation, yearly evaporation would equate to a value of approximately $3M annually based on temporary trade prices. During the drought, the temporary trade market reached a peak value on of $1000/ML in December 2007.

The most recent water savings initiative is NVIRP. Stage 1 of the project has a budget of 1.004 billion dollars and is estimated to produce annual water savings of 225 GL (NVIRP, 2010), that is $4,500/ML of water savings permanently achieved. Stage 2 is still being finalised, but is estimated to produce water savings at $5,500/ML. The NVIRP project is a once off capital investment. Monolayers are an operational investment or procedure, and can be utilised when and where required and only achieve the savings in a single irrigation season, not in perpetuity. The most recent comparable operational investment is the pumping of Waranga Basin which allowed G-MW to access dead storage and make this available to customers during drought conditions. The cost of pumping varied between $33/ML in 2006/07 and $18/ML in 2008/09.

Regardless of the way it is calculated, evaporation losses from the gravity irrigation network are of considerable value and are therefore worthy of investigating savings that can be achieved. Further, as the easier water savings are achieved through improved metering and reducing leakage, the focus will shift to the more expensive water savings options, including reducing evaporation.

2.4 Available Methods for Reducing Evaporation

The main methods for reducing evaporation on existing water bodies include:

- limiting the surface area exposed which reduces how much water is available for evaporation;
- reducing the temperature which reduces the energy available for evaporation;
- reducing the wind speed over the water surface which reduces how fast the water molecules can be moved away; and
- providing a barrier to the movement of the water vapour molecules away from the surface.

Design features are a means for reducing evaporation on new water storages, while biological covers such as floating plants offer a limited evaporation reduction.

Depending on the method used to reduce evaporation, it may or may not allow rainfall to enter, and therefore either reduces the total evaporation from the storage, or the net evaporation.

The measure of performance of an evaporation reduction technique is the effectiveness of the technique at reducing evaporation. For example, if a technique has an effectiveness of 20%, this means that it has the potential to save 20% of the total evaporation, therefore reducing the evaporation to 80% of its original value.

2.4.1 Shading Materials

Shading materials reduce evaporation from the water surface by reducing the temperature and wind speed over the water surface.

Generally a framework is required to support the shading material above the water surface. The cost of the framework and shading material can make this method cost prohibitive for larger dams or irrigation channels.

Mesh shade covers allow the rainfall to enter, reducing total evaporation. Table 2.2 details the potential effectiveness of different shading materials in reducing evaporation.

Table 2.2 Shading materials

Shading Materials - Evaporation Reduction Effectiveness			
Shading material	*Effectiveness (%)*	*Experiment Scale*	*Experiment Location*
WPE (white polyethylene mesh) [1]	54.7	Class-A pans	Southern Spain
2WPE (double layered white polyethylene mesh) [1]	68.5	Class-A pans	Southern Spain
BPE (black polyethylene mesh) [1]	75.1	Class-A pans	Southern Spain
2BPE (double layered black polyethylene mesh) [1]	83.5	Class-A pans	Southern Spain
GPE (green polyethylene mesh) [1]	76.2	Class-A pans	Southern Spain
BLPE (blue polyethylene mesh) [1]	77.6	Class-A pans	Southern Spain
ALU (aluminized net) [1]	51.5	Class-A pans	Southern Spain
Shadecloth[2]	70	Dam	Southern Queensland, Australia

1 Martinez Alvarez, et a., 2006

2 Craig, et al. 2007

2.4.2 Floating Covers & Objects

Floating covers and objects work by reducing the surface area exposed and reducing the wind speed over the area that is exposed.

Floating covers are generally constructed from polyethylene or polypropylene and form an effective and impermeable barrier against evaporation, being up to 100% effective (Watts, 2005). However, they generally do not allow rainfall penetration and depending on the product, a support system may be required.

From an environmental perspective, floating covers prevent light entering the water, therefore reducing algae growth and improving water quality (Craig, 2005), however, they can have a harmful effect on aquatic life due to potential anaerobic conditions in the water, and can cause a loss of habitat for birds and other life (GHD, 2003).

In addition, floating covers reduce wave action and therefore reduce bank erosion (Craig, 2005).

The potential effectiveness of floating covers at reducing net evaporation are summarised in Table 2.3.

Table 2.3 Floating covers

Floating Covers - Evaporation Reduction Effectiveness	
Product Name	*Effectiveness (%)*
E-VapCap	90% + [1]
REVOC Floating Cover	95% [2,3]
Defined Sump Floating Cover	95% [2,3]
Evap-Mat	90% [2,3]
Fabtech	95% [2,3]
VapourGuard	98% + [4]
Aquaguard Evaporation Cover	90% [2,3]

1 Evaporation Control Systems Pty Ltd, n.d.

2 NCEA Evaporation Control, n.d.

3 Craig, 2008

4 Plastipack Limited, n.d.

Floating objects consist of many individual floating units placed on the water surface which may or may not be attached to each other. They are easier to install and allow for rainfall penetration, however cannot achieve the same high level of effectiveness as floating covers. Environmentally, floating objects are not as harmful as floating covers because some water surface is potentially exposed (GHD, 2003).

The potential effectiveness of floating objects in reducing total evaporation are summarised in Table 2.4.

Table 2.4 Floating objects

Floating Objects - Evaporation Reduction Effectiveness	
Product Name	*Effectiveness (%)*
AquaCaps	85% average [1] 70% when 80% water surface covered [2]
AquaArmour	95% [3] 89% [4]
Agfloats	80% [5]
Raftex (Devised design)	95% + [6]
Euro-matic Bird Balls / Shade Balls	90% [4,7]
HexDome TM	90% [4,7]
Hexa-Cover	95% [8]
QUIT Evap Modular Floating Cover	85-90% [4,7]

1 Polarity, 2008

2 Weekly Times Now, 2009

3 Water Innovations, n.d.

4 NCEA Evaporation Control, n.d.

5 Reclaim Industries Ltd, n.d

6 F Cubed (Australia) Pty Ltd, n.d.

7 Craig, 2008

8 Hexa-Cover Aps, n.d.

2.4.3 Polyacrylamide

Polyacrylamide (PAM) is a product mixed into the water which increases the viscosity (thickens the water), thereby making it less susceptible to evaporation. Average evaporation saved at trials in Queensland was 37% (Craig, et al. 2005). PAM can potentially give rise to toxic breakdown products.

2.4.4 Chemical Covers - Monolayers

Monolayers consist of a one molecule thick film of a water-insoluble organic compound spread across the water surface. Each molecule consists of hydrophobic (water-hating) and hydrophilic (water-loving) parts. At low surface concentrations of the monolayer material, the distance between molecules is large and their interaction weak. At higher surface concentrations, ie, when the molecules are pushed together by a sideways force or surface pressure, they pack together with the hydrophilic head anchored in the water and the hydrophobic tail pointing into the air away from the water surface. Figure 2.1 shows the orientation of the molecules at different monolayer concentrations, of which only the condensed phase significantly impedes the movement of water vapour molecules from the surface thereby reducing evaporation.

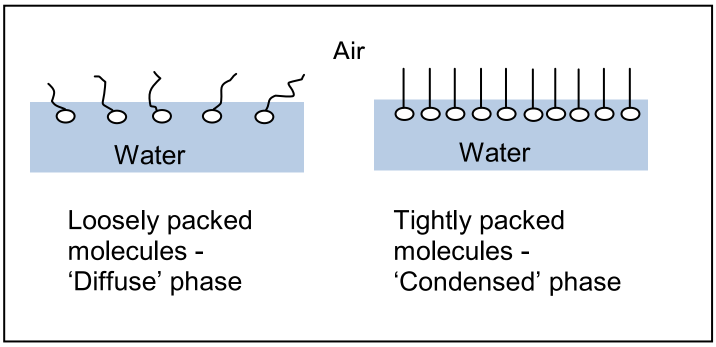


Figure 2.1 Packing of Monolayer Molecules at Different Concentrations

Monolayers reduce evaporation by restricting the free passage of water molecules through the air water interface. Referring to Figure 2.2, there are a number of layers within the water and air, below and above the water surface, which all play a role in determining the magnitude of water vapour transport (evaporation).

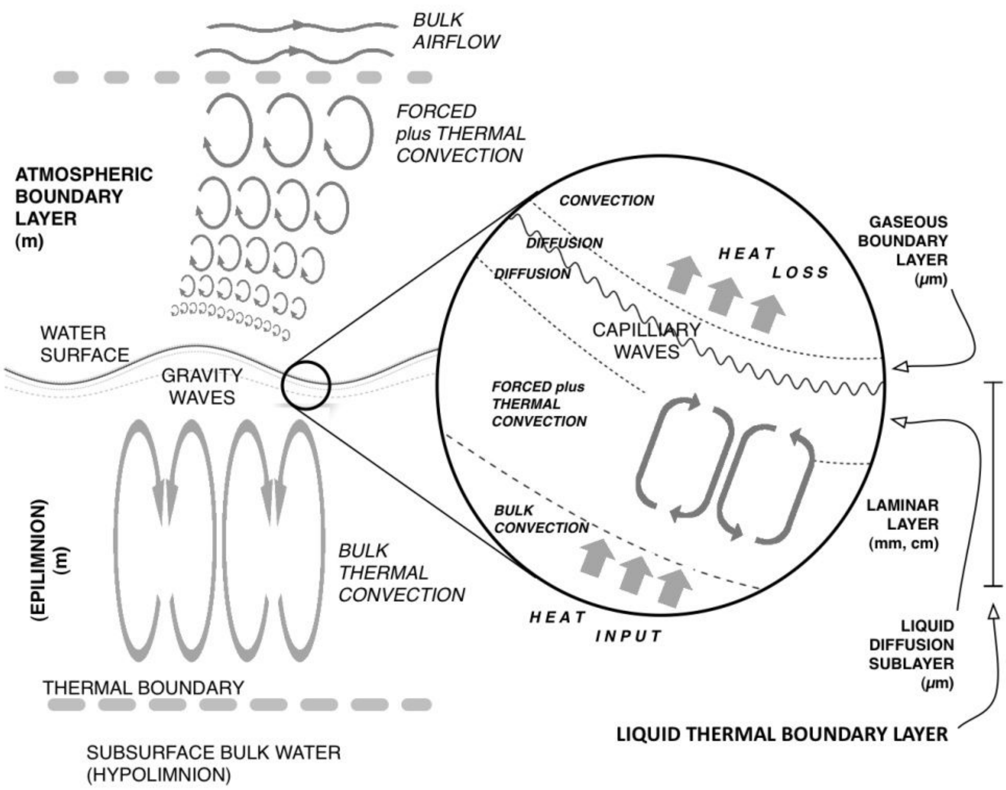


Figure 2.2 Physical Transport Processes at an Open Water Surface, at both macro-scale (left) and micro-scale (right) (Reproduced from Hancock, et al. 2011)

The thin layer above the water surface, called the diffusion sub-layer, is not very efficient at transporting water vapour. If the thickness of the diffusion sub-layer is increased then its ability to transport the water vapour is further decreased. It is suggested that monolayers are also capable of increasing the thickness of the diffusion sub-layer (and therefore further reducing evaporation) in a number of ways, including by calming the small-scale (sub-millimetre) capillary waves on the water surface.

However, the thickness of the diffusion sub-layer is greatly affected by diurnal variation, in particular the relative temperatures between the sub-surface water, the water surface and the air above (Gladyshev, 2002). Therefore if the diffusion sub-layer is already relatively thick and suppressing evaporation, the addition of a monolayer will not produce any noticeable reduction in evaporation rate. The rate of evaporation is also affected by climatic conditions, therefore during high humidity when the air is already moisture laden, there is no benefit achieved from applying a monolayer to the water surface. Both factors can greatly affect the evaporation suppression ability of a monolayer during a trial and contribute to varying results from repeated trials.

In addition, it has been found that monolayers are only capable of reducing the water molecule movement when they are exerting a surface pressure of 15mN/m or greater (Hancock, et al. 2011). The pressure (and surface concentration) increase as more material is added because it is confined by the banks of the water body. Further detail on the processes impacting on the way in which monolayers reduce evaporation has been reviewed by Hancock, et al. (2011).

Under suitable weather conditions (light winds and good sunlight) it is possible to visually see the presence of a monolayer due to its ability to dampen capillary waves (Lange & Huhnerfuss, 1977).

Monolayers have been investigated since the 1960s, however they were not adopted in any scale at that time or subsequently. Lack of adoption may have been due to the many difficulties experienced in the use of monolayers including: application difficulties, wind displacement and rapid bacterial/microbial degradation. Essentially, monolayers were not performing in the field as they did in the laboratory. Commonly available monolayer compounds degrade very quickly in the environment and require continuous or repeated applications to be effective. In addition, tests to date report widely varying results of the effectiveness of monolayers (up to 50% in the field) and have generally been conducted on a very small scale. The considerable literature relating to the use of monolayers for evaporation suppression has been comprehensively reviewed by Brink (2011).

In comparison with other evaporation-mitigation strategies, such as physical covers, monolayers have the benefit of being able to be applied only when required during periods of high evaporation (and when wind speed is not too high) or when water resources are scarce. Under these circumstances they are potentially cost-effective as a water saving strategy (Brink, 2011).

Unfortunately, given the complexities of monolayer science and difficulties associated with experimental trials (Hancock et al. 2011), it is not yet possible to estimate the potential maximum degree of control provided by the different monolayer chemicals.

2.4.5 Biological Covers

Some plants such as duck weed and water lilies can form a cover over the water surface and help reduce evaporation. However, the potential savings from plant covers are low and there may be associated impacts including a reduction of light and dissolved oxygen, and a restriction to channel flow. Additionally, there is potential for the plants to spread into other waterways which may result in environmental harm.

Reported evaporation savings from biological covers are summarised in Table 2.5.

Table 2.5 Biological covers

Biological Covers - Evaporation Reduction Effectiveness	
Name	*Effectiveness (%)*
Duckweed	9%[1], 10%[2], 11%[3], 33%[4]
Mexican water lily	Not available

1 Community Education and Extension Support Unit and Rural Water Use Efficiency Initiative Department of Natural Resources and Mines, Queensland 2002

2 National Program for Sustainable Irrigation 2005

3 Seidl, et al. n.d.

4 Skillicorn, Spira & Journey, n.d.

2.4.6 Unusual Methods Employed in Other Countries

During 2006 and 2007, a creeper was grown on a frame to shade an on-farm reservoir in India in order to model the evaporative savings achieved by a biological cover. A saving of 50% was achieved when compared to an on-farm storage without shading (Sahoo, et al. 2010).

During 2009, mats constructed of palm leaves were floated on the water surface of pools in Saudia Arabia. A savings of 63% was achieved for a pool fully covered and 26% for a pool half covered (Al-Hassoun, et al. 2009).

2.4.7 Design Features

The water body may be designed and built to limit potential evaporation by increasing depth, reducing surface area, incorporating high banks to form wind breaks and planting tree belts to form windbreaks. These solutions can be difficult and costly to incorporate into an existing water body, and assessment of the effectiveness is difficult.

2.4.8 Pipelines

Pipelines provide a permanent means of saving evaporative losses, however generally come at a high capital cost and are only practical for smaller channels with flows less than say 30 ML/day. Pre NVIRP modernisation this represents approximately 25% of the channel network length, however after modernisation it represents only 3%.

2.5 Potential Costs associated with Water Savings

Table 2.6 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.

Table 2.6 Dam evaporation mitigation systems

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[3]	$390	12 years[4]
REVOC	95%	$30[4]	$1,060	30 years[4]
Defined Sump	95%	$30[3]	$1,110	25 years[3]
Evap-Mat	90%	$3.50[3]	$130	30 years [3]
Fabtech	95%	$7[3] (excludes earthworks)	$340	15 years[3]
Floating Objects				
AquaCaps	85%	$17[4]	$750	20 years
Agfloats	80%	$10[5]	$440	25 years[5]
Raftex	95%	~$4.50[3]	$470	5 years[3]
HexDome TM	90%	~$6.50[3]	$260	25 years[3]
QUIT Evap Cover	87.5%	$7[3]	$490	~9 years[3]
Other Methods				

Method	Potential evaporation savings	Installation Cost / m2	Cost / ML saved (NPV @ 6% over 30 years – capital only)	Product Life
Shade cloth	70%	\$7 - \$10[1]	\$410	30 years[2]
Chemical monolayer	5% - 30%	\$0.00 - \$0.38[1]	\$130 - \$1200[1]	

1 Craig, Green, Scobie, and Schmidt, 2005

2 National Program for Sustainable Irrigation, 2005

3 NCEA Evaporation Control, n.d.

4 Craig, 2008

5 Reclaim Industries Ltd, n.d

2.6 Monolayer Chemicals

The requirement of this thesis and the concurrent G-MW field research was to investigate monolayers as they relate to irrigation channels.

Currently within Australia there are two commercially available evaporation suppressing chemicals, WaterSavr™ and Aquatain. WaterSavr™ is a true monolayer, while Aquatain is more like an oil slick and is many molecules thick. A comparison of the properties of the two products was presented by McJannet, et al. (2008). No negative environmental impacts of either product have been reported to date.

The Cooperative Research Centre for Polymers (CRC Polymers) is investigating new monolayer compounds that can overcome some of the issues that have been experienced with monolayers in the past. In addition, G-MW has investigated polymer compounds to enable field comparison with the commercially available products and CRC Polymer's new product, ES300.

2.6.1 WaterSavr™

WaterSavr™ consists of cetyl and stearyl alcohols mixed with hydrated lime. The manufacturer states potential evaporation savings of up to 30% are achievable. Application of the powder is by use of commercially available application units. Correct application to the water surface is considered essential for efficacy of the product. The manufacturer states that the product is suitable for use on "slow moving" irrigation channels (Flexible Solutions International Inc, n.d), however no literature of field trials is available to support the statement. It has a field life of 2 to 3 days (Watts, 2005), although daily application is recommended (McJannet, et al. 2008).

2.6.2 Aquatain

Aquatain is a silicone based product with a re-application period of 10 days (McJannet, et al. 2008) and potential savings of 50% (Aquatain Products Pty Ltd, n.d(a)). It can be applied by directly pouring onto the water surface or using a commercially available applicator.

Aquatain indicates that the silicon based product has no adverse environmental impacts, specifically it does not affect the chemistry of the water, prevent the water from oxygenation, harm aquatic life or adversely impact potable water (Aquatain Products Pty Ltd, n.d(b)).

2.6.3 ES300

CRC Polymers are working on the development of new monolayer products with greater life and better durability under wind conditions, however, no further information or test results are available from CRC Polymers at this stage.

Goulburn Murray Water has been undertaking independent laboratory trials on ES300. Preliminary results indicate an initial efficiency of between 60 – 70% in saving total evaporation. Figure 2.3 shows the loss rate of water before and after the monolayer material is added. Red points and blue points are duplicates. The loss rate, given by the gradient, has reduced following the application of monolayer material. The tests were concurrent duplicates undertaken on 100mm petrie dishes and were repeated to ensure consistency.

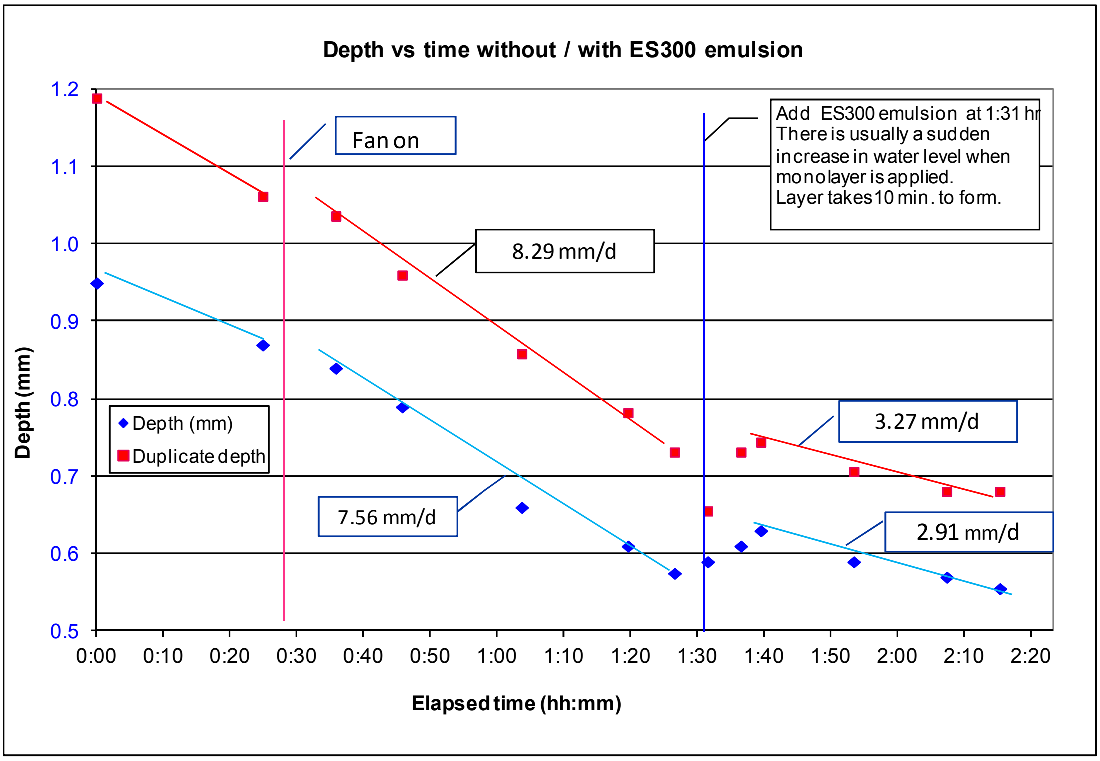


Figure 2.3 ES300 laboratory tests conducted by G-MW (Albrecht, 2011)

Further testing is required to determine the initial and final efficiency and field life of ES300

2.6.4 Emulsions of Cetyl and Stearyl Alcohols

Monolayer materials exist as solids and can be applied to the water surface in a number of ways:

- in solid form such as a powder or flakes;
- mixed with a solvent such as petrol or ethanol;
- mixed with a carrier such as lime; or
- as a slurry with water.

There are a number of disadvantages associated with each of these methods including: distributing the material uniformly, clumping of the material and potential environmental issues associated with the solvents or carrier materials (Winter, 2011).

To avoid these issues, G-MW investigated a liquid form of monolayer material (an emulsion) that could be applied automatically and at a controlled rate using a peristaltic (dosing) pump. Michael Herzig (University of Southern Queensland) also developed emulsion monolayers, but using Brij 78 as the emulsifying agent (Michael Herzig, pers. comm.) which is considered to be cost prohibitive. Therefore G-MW investigated emulsions using sodium sterate (soap) as the emulsifier.

Emulsions of the two alcohols (cetyl and stearyl), either separately or mixed, are easily formed using soap as the emulsifying agent and contain no toxic components. A summary of the formulations developed by G-MW are detailed in Table 2.7 (Albrecht, 2011).

Table 2.7 Emulsions (Albrecht, 2011)

Emulsions developed in G-MW Laboratory				
Cetyl Alcohol quantity (g)	*Stearyl Alcohol quantity (g)*	*Emulsifier Type and quantity (g)*	*Laboratory Effectiveness (%)*	*Field Effectiveness (%)*
-	10	0.5 soap	-	
-	10	0.25 soap (pre dissolved)	-	
-	10	0.25 soap	66%	
10	-	0.25 soap	60%	

Emulsions developed in G-MW Laboratory				
5	5	0.25 soap	69%	Up to 34% achieved[1]

1 Result obtained in one short field trial.

2.7 Australian Monolayer Field Trials

Most recent Australian monolayer trials undertaken in the field have used WaterSavr™.

Coliban water has been trialling the use of WaterSavr™ since approximately 2006. It has been used on Barkers Creek, Cockatoo, Caledonia, Korong Vale, Raywood and Wychitella reservoirs and storages. Coliban's 2007 annual report indicates it is difficult to determine the amount of water saved from the trials (Coliban Regional Water Corporation, 2007), although Flexible Solutions indicate an average savings of 29% was achieved at Korong Vale reservoir during 2006 (Flexible Solutions International Inc, 2006).

Other trials of WaterSavr™ include:

- Byrock, NSW (Trialled 2006, still being used 2007)
- Dirranbandi Qld (Cubby Station) and Peak Downs Shire Council, Capella, Central Highlands, Qld

No reference to large scale trials in Australia for other monolayer products has been found.

2.8 Issues in the use of Monolayers

2.8.1 Monolayer Effectiveness in the Laboratory

The literature generally reports that monolayers are effective at suppressing evaporation within laboratory situations. Following are examples of high efficiencies reported in the literature:

- O'Brien, et al. (1976) achieved a maximum savings of 59% by ultra high purity stearyl alcohol;
- Gugliotta, et al. (2005) achieved savings of up to 57% for mixed films of cetyl and stearyl alcohols applied to "natural" water samples;
- Hightower & Brown (2004) achieved 60-70% using dodecanol; and

- Goulburn-Murray Water laboratory tests on emulsions of cetyl and stearyl Alcohols achieved up to 69% (Albrecht, 2011).

2.8.2 Monolayer Effectiveness in the Field

The effectiveness of monolayers in field situations varies widely. Gugliotta, et al. (2005) reported that the first field trials were conducted in Australia during the 1950s and achieved savings of 30%, while Craig, et al. (2007) reported that savings of up to 50% were achieved in the field in the 1950s and 60s. Walter (1963) reported a much lower figure of 20% savings achieved using a cetyl/stearyl mixture on a lake in Madras. Fitzgerald & Vines (1963) reported savings due to cetyl alcohol of 40% or greater for wind ≤ 8 km/hr, 10-20% for wind between 8 and 16 km/hr and approaching 0% for wind greater than 24 km/hr.

In static trials undertaken by G-MW on a trial irrigation channel, savings of between 10% and 30% were achieved using WaterSavr™ and ES300. However the tests were conducted over a short time frame which makes measurement of savings very difficult in a channel situation where wind can cause water level changes greater than the potential evaporation.

Orica have achieved an efficiency of 60% for ES300 in recent field trials under “ideal” conditions (Craig Clarke, pers. comm.).

Reasons for the variation in field trial results have been offered by Hancock, et al. (2011) based on the analysis of field trials undertaken during 2008. One of the requirements of the evaporative process is unsaturated air (low relative humidity) above the water surface. High humidity impedes the evaporation process on unprotected water and adding monolayer to the water surface does not produce any noticeable change in the already low evaporation rate. The analysis and comparison of field effectiveness must take into consideration measurements of air and water temperatures at the water surface.

2.8.3 Biological Considerations

In the field, monolayers are degraded by bacterial/microbial action. Essentially they form a food source for various aquatic species. Research is being undertaken to develop monolayer products that are resilient to microbial degradation (Craig, et al. 2007, Pittaway & Ancker, 2010). In addition, characterisation of the water body will help to inform the appropriate monolayer product to use in order to limit the extent of microbial degradation (Brink, et al. 2009b).

As detailed in Section 2.6.2, Aquatain indicates that the silicon based product has no adverse environmental impacts and does not harm aquatic life, however no literature has been found to determine whether it will be utilised as a food source by aquatic species.

2.8.4 Longevity in the Field

It has been found that most monolayer products generally have a maximum field life of 2 days (Craig, et al. 2007) and Gugliotta, et al. (2005) recommended an application interval of two days. Flexible Solutions indicate that their WaterSavr™ product degrades in two to three days (Flexible Solutions International Inc, n.d), although McJannet, et al. (2008) recommended daily application. The implication of the short field life of monolayer products is the requirement to reapply regularly which has the effect of increasing the cost of the treatment.

Aquatain is recommended to be applied to the water surface every 10 days (Aquatain Products Pty Ltd, n.d(a)).

2.8.5 Environmental Impacts

Studies to date indicate no adverse environmental effects associated with monolayers.

Pittaway & Ancker (2010) tested the impact of monolayer products and a silicon oil film on biological oxygen demand, surface tension and pH and reported that "further study is required to determine whether including hydrated lime in the monolayer formulation or the oxygen scavenging properties of the silicone oil adversely affects aquatic organisms active at the air/water interface".

Previous studies undertaken on a mixed cetyl / stearyl monolayer indicated that "No significant water temperature, pH, hardness or alkalinity changes occurred in the experimental systems" (Wixon, 1966).

2.8.6 Human Health Impacts

Studies to date indicate no adverse human health impacts associated with monolayers.

- Dodecanol is a food grade surfactant (Hightower & Brown, 2004), Cetyl alcohol and stearyl alcohol are used in many cosmetics and skin product applications.

- Aquatain (n.d.(a)) reports that their product is safe and indicates that "silicones are used in hundreds of applications including water-repellent sealers, hair conditioners and lipsticks. They are also used to reduce foam in commercial food applications and as non-stick sprays in the baking trade".

- McJannet, et al. (2008) reported the following when discussing areas of further monolayer study: "A better understanding of possible health impacts of the product (including by-products) is needed. Long-term risks of exposure need investigation. If aerial spraying is to be used for application, the implications of the drift of chemicals onto people, vegetation, fauna etc. needs to be assessed."

2.8.7 Monolayer Natural Expansion Rate

Vines (1962) gave the rate of expansion of a monolayer of cetyl alcohol when wind speed was zero as 0.03 – 0.05 m/s (0.05 – 0.1 km/hr), based on extrapolating monolayer drifts rates under varying wind speeds to the zero wind speed condition. He determined that the critical wind speed that would limit monolayer expansion and result in drift of the monolayer was 3.2km/hr which appears to be independent of temperature. Refer to Figure 2.4.

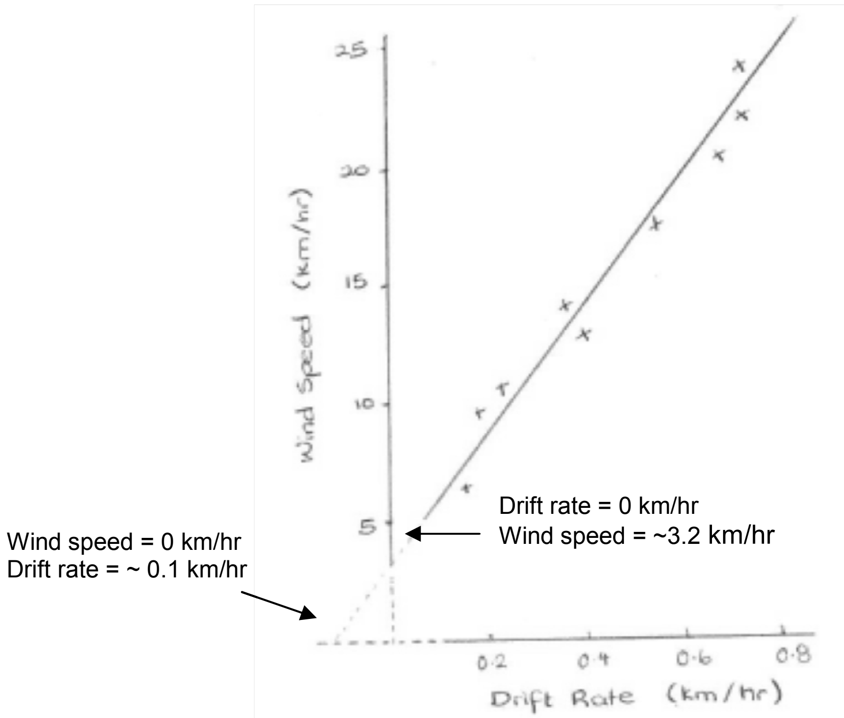


Figure 2.4 Monolayer drift vs wind speed (adapted from Vines, 1962)

Brink (2010) undertook laboratory tests to determine the spreading rate of stearyl alcohol on the water surface. The results show that the expansion rate is not constant with time as shown in Figure 2.5 and Figure 2.6. Note: the only difference between the two graphs is the time scale shown.

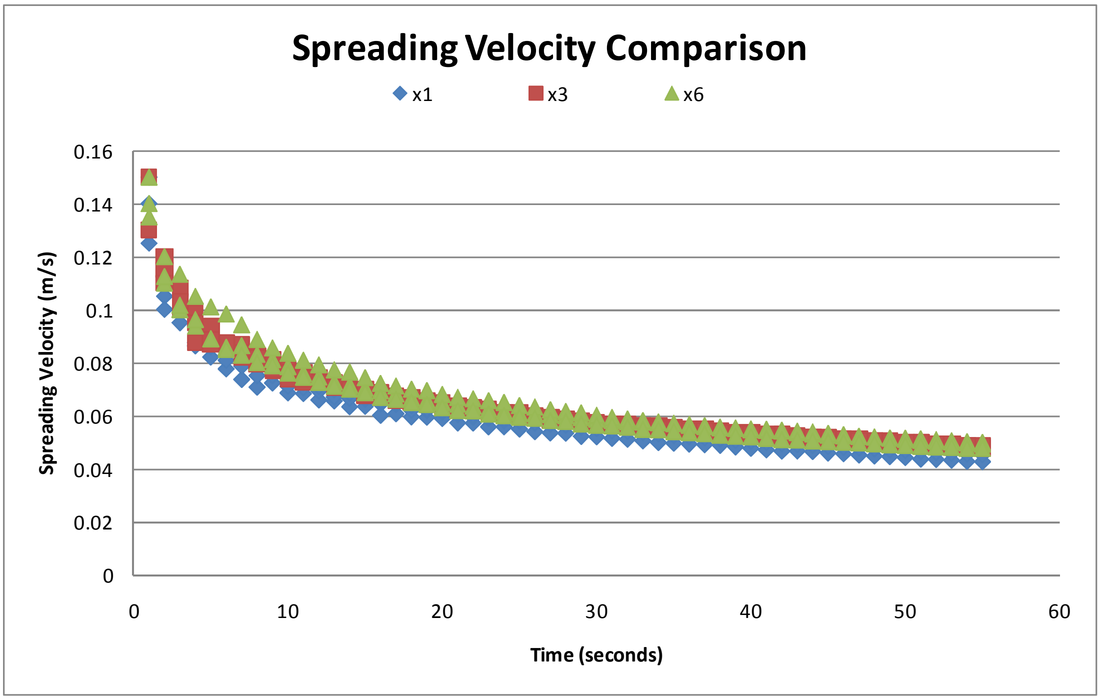


Figure 2.5 Monolayer velocity vs time (Brink, 2010)

1 The legend item X1 refers to the application of product quantity appropriate to the container size, while X3 and X6 are 3 and 6 times the product quantity of X1

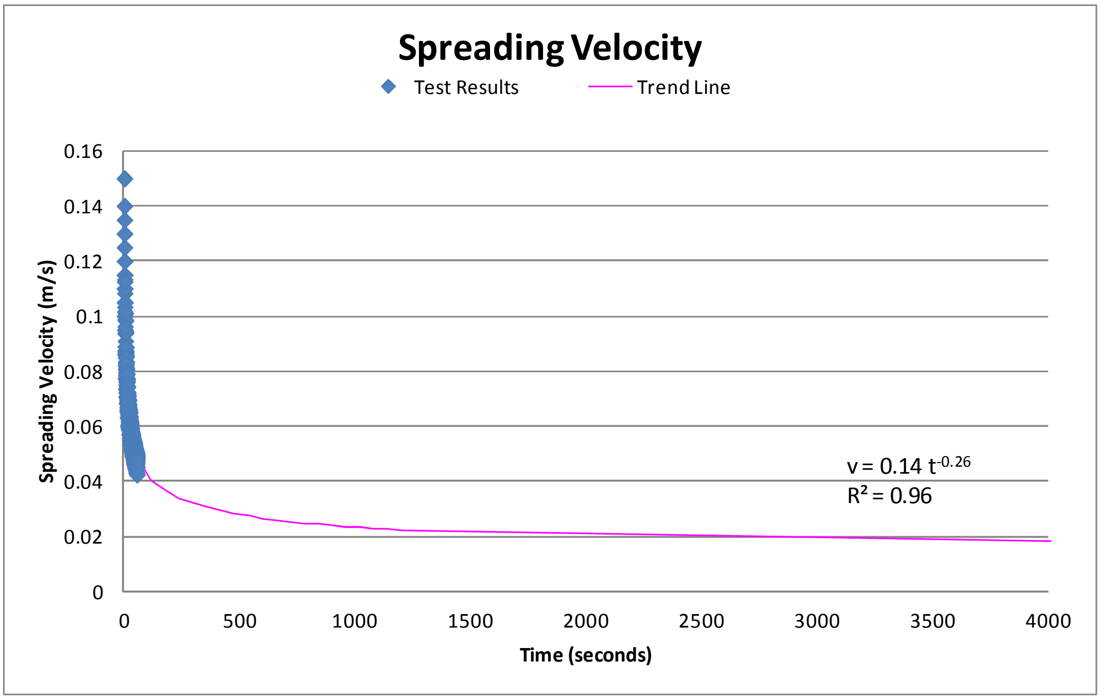


Figure 2.6 Monolayer velocity vs time (Brink, 2010)

1 All test results (regardless of quantity of product applied) have been combined

From these tests, the monolayer expansion rate can be described by the equation:

$$v = 0.14\, t^{-0.26} \tag{2.1}$$

where *v* is the velocity of the monolayer front at a time *t* seconds after application.

At a time of 2000-3000 seconds the expansion rate has levelled out after the initial high expansion period and tends to 0.02 m/s which is of the same order of magnitude as the theoretical value given by Vines (1962). Although Brink (2010) obtained this result by applying monolayer to the centre of a large trough such that the monolayer could expand in all directions, if we consider a field application where the monolayer may or may not be confined by banks, it is assumed that confining the monolayer does not increase the expansion rate in the unconfined direction.

2.8.8 Wind & Waves

Wind affects monolayers in two ways, firstly by causing the monolayer to drift and potentially exposing areas of water surface that are not protected by monolayer and secondly by causing waves that "break up" the monolayer and cause heterogeneities within its surface.

Walter (1963) reported the results of applying a monolayer of cetyl/stearyl alcohol on a lake of approximately 12 hectares in Madras, with applicators located on shore and mounted on a boat. The lake's surface was observed to be completely covered by monolayer at a wind speed of 1.9 km/hr but was only half covered at a wind speed of 4 km/hr.

Crow & Sattler (1958) reported that an "Inverse relationship exists between the portion of reservoir covered by film and wind velocity" (Manges & Crow, 1965).

Vines (1962) determined that the critical wind speed that would limit monolayer expansion and result in drift of the monolayer was 3.2 km/hr. For wind speeds between 0 and 3.2 km/hr, the monolayer is capable of expansion to a varying degree. Refer to Figure 2.4.

Crow (1963) reported that the limiting speed to applying monolayer was 24.2 km/hr: "Applying hexadecanol [Cetyl alcohol] as a slurry from a boat they concluded that it appeared to be impractical to attempt to maintain any appreciable coverage when winds exceeded 15mph".

For wind speeds between 3.2 and 25 km/hr the monolayer is moved across the water surface. It is generally agreed that the rate of monolayer movement is approximately 3% of the wind speed. The literature reports the following values:

- Vines (1962) gave the water surface speed (or drift rate) as 1/30th of the amount by which the wind velocity exceeded 3.2km/hr
- Lange & Huhnerfuss (1977):
    - Lies between 2.6-5.5%
    - Laboratory studies 3.5 ± 0.7%
    - Field studies 4.4 ± 0.9%
- Fitzgerald & Vines (1963) gave the ratios ws / w = 0.03 for clean water and 0.045 for a fully damped surface (wind > 19.8 km/hr), where ws = the water surface speed and w = the wind speed.

Brink (2010) tested wind speeds in the range 13.3 km/hr to 29.9 km/hr, the results of which are shown in Figure 2.7 plotted in the same format as the results of Vines (1962).

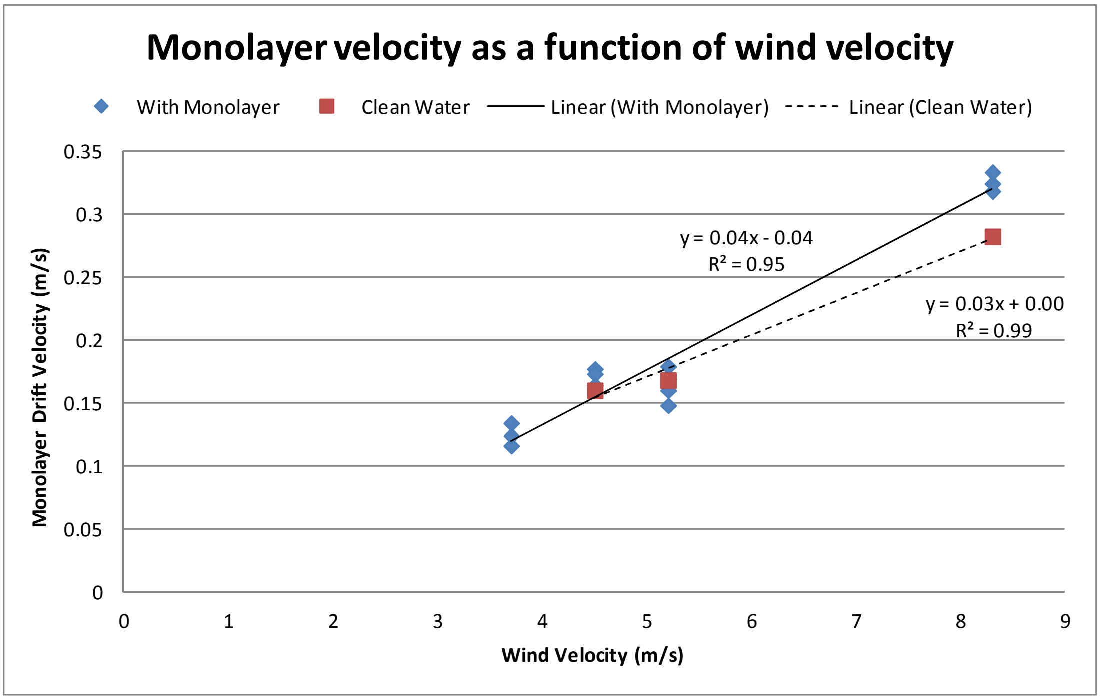


Figure 2.7 Monolayer velocity vs wind velocity (Brink, 2010)

1 Monolayer drift velocity was measured by the movement of polystyrene balls applied to the water surface

For wind speeds greater than 0 m/s the monolayer movement is given as 0.04 x wind speed – 0.04 which is in the same order as 3% of the wind speed published by previous researchers.

Within the model, a rate of monolayer expansion of 3% of the wind speed has been adopted for wind speeds greater than 3.2 km/hr, being the generally agreed value based on past research.

2.8.9 Turbulence

As detailed in section 2.8.8, turbulence caused by waves has the effect of breaking up the monolayer, in some instances to the point that it cannot reform. Therefore, it would follow that any equivalent turbulence, however caused, would have the same effect. Irrigation channels contain regulating structures which control the flow and level of the water within the channel. These structures tend to cause turbulence for a number of metres downstream of the structure. Rock beaching is placed downstream of the structure to limit the damage to the earthen banks and bed. It is therefore hypothesised that the turbulence caused by regulating structures is going to have the effect of damaging the monolayer integrity and effectiveness.

Studies undertaken in the USA into the use of monolayer to reduce evaporation and therefore limit the amount of water available to hurricanes and reduce their resulting strength, investigated the effect that the turbulent conditions caused by hurricanes would have on the monolayer integrity. The tests were conducted within a laboratory and consisted of measuring the surface pressure of the water with monolayer, before and after rapidly dumping water upon the monolayer surface. The monolayer material chosen for use was Hexadecanol [cetyl alcohol]. It was shown that the "monolayer could not reform itself after being torn apart by water" (Hsin, 2002).

This has implications for the use of monolayers on irrigation channels where turbulent conditions will be experienced at every regulating and offtake structure. In the worst instance it may be necessary to reapply the monolayer material downstream of each regulator.

Goulburn Murray Water (Bruce Albrecht, pers. comm.) has been undertaking laboratory testing of WaterSavr™ (cetyl and stearyl alcohols combined with lime). Preliminary results indicate that shaking, to emulate the turbulence of going over a regulator structure, **does not** inhibit its ability to reduce evaporation. Figure 2.8 shows the loss rate of water before and after the monolayer material is added. Red points and blue points are duplicates. The gradient of both sets of results has reduced following addition of WaterSavr™ indicating reduction in the loss rate. Figure 2.9 gives the loss rate with shaken monolayer material. Red points and blue points are duplicates. The loss rate, given by the gradient, in both instances is less that the loss rate given in Figure 2.8 before monolayer material was added, indicating that the shaken monolayer material still has the ability to reduce evaporation.

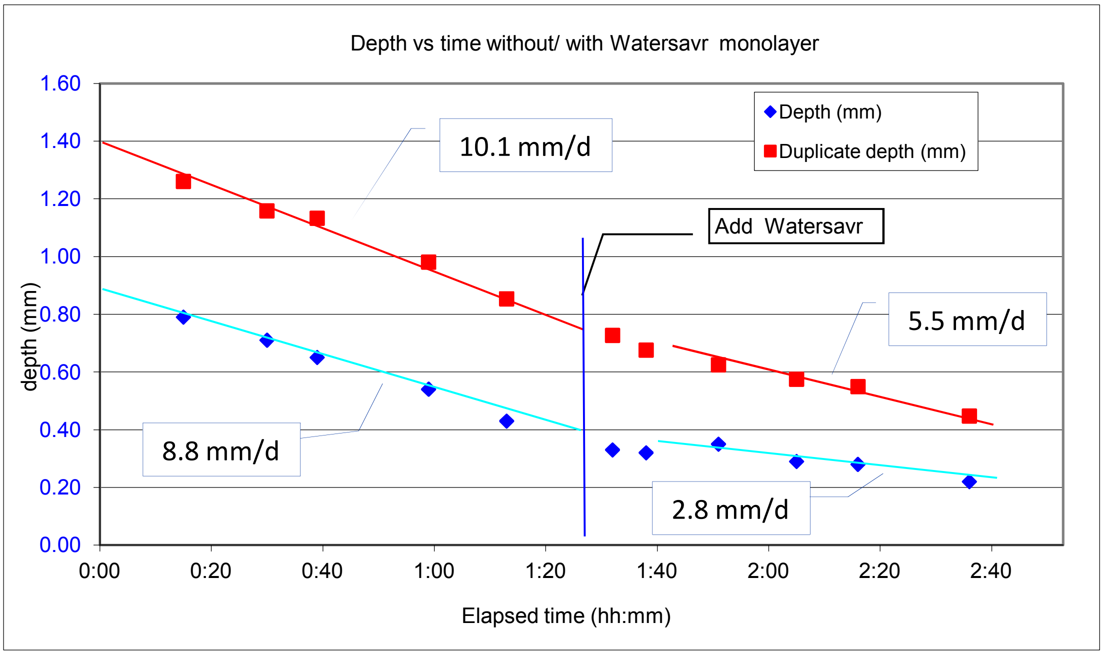


Figure 2.8 WaterSavr™ laboratory tests conducted by G-MW (no shaking) (Albrecht, 2011)

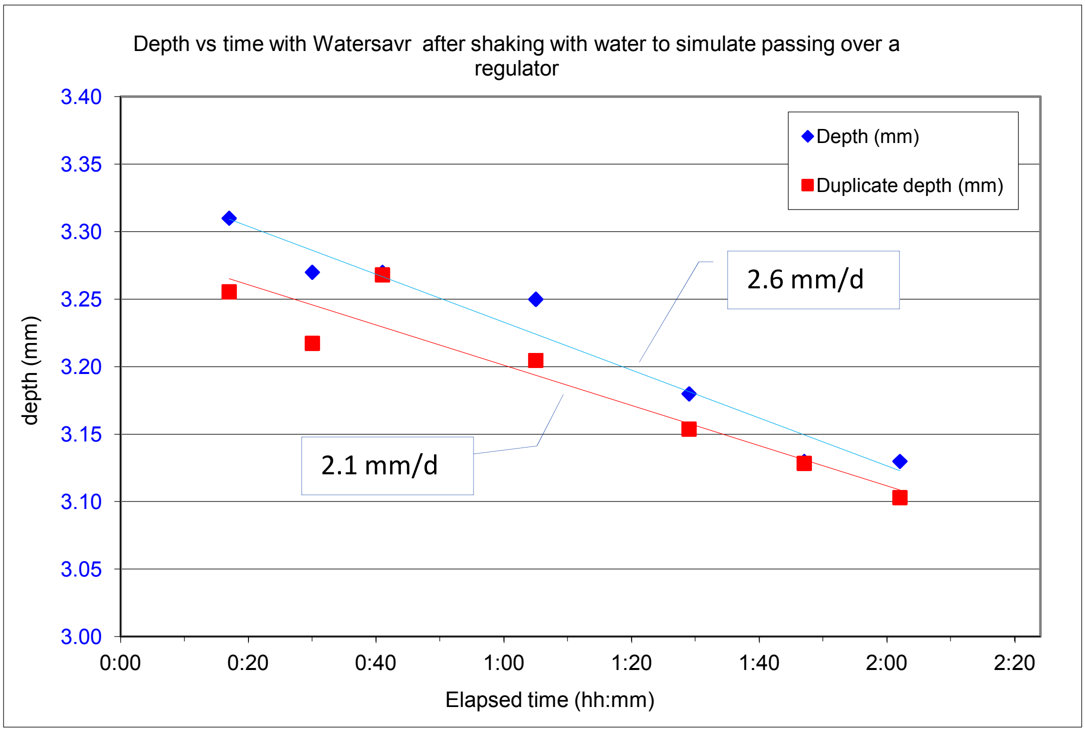


Figure 2.9 WaterSavr™ laboratory tests conducted by G-MW (shaken) (Albrecht, 2011)

Research to date indicates that WaterSavr™ is not resilient to turbulence caused by wind and waves, and that cetyl alcohol alone is not resilient to the turbulence caused by dumping water upon the surface of the monolayer (Hsin, 2002). The result of this shaking test for WaterSavr™ which indicates continued evaporative resistance following shaking, conflicts with current knowledge of the resilience of WaterSavr™. Further testing is required to determine the validity of the results.

Tests have been undertaken by G-MW into the evaporative resistance of ES300. Following shaking to emulate the turbulence of going over a regulator structure, the efficiency appears to be 80 - 90% (in comparison to the loss rate of the unshaken ES300 which was 60 – 70%). This indicates that the monolayer has sufficient stability to withstand turbulence in the field. This will greatly improve the cost effectiveness of the product as it will not need to be reapplied at every regulating structure. Figure 2.10 shows the loss rate of water before and after the shaken monolayer material is added. Red points and blue points are duplicates. The loss rate, given by the gradient, has reduced following the application of shaken monolayer.

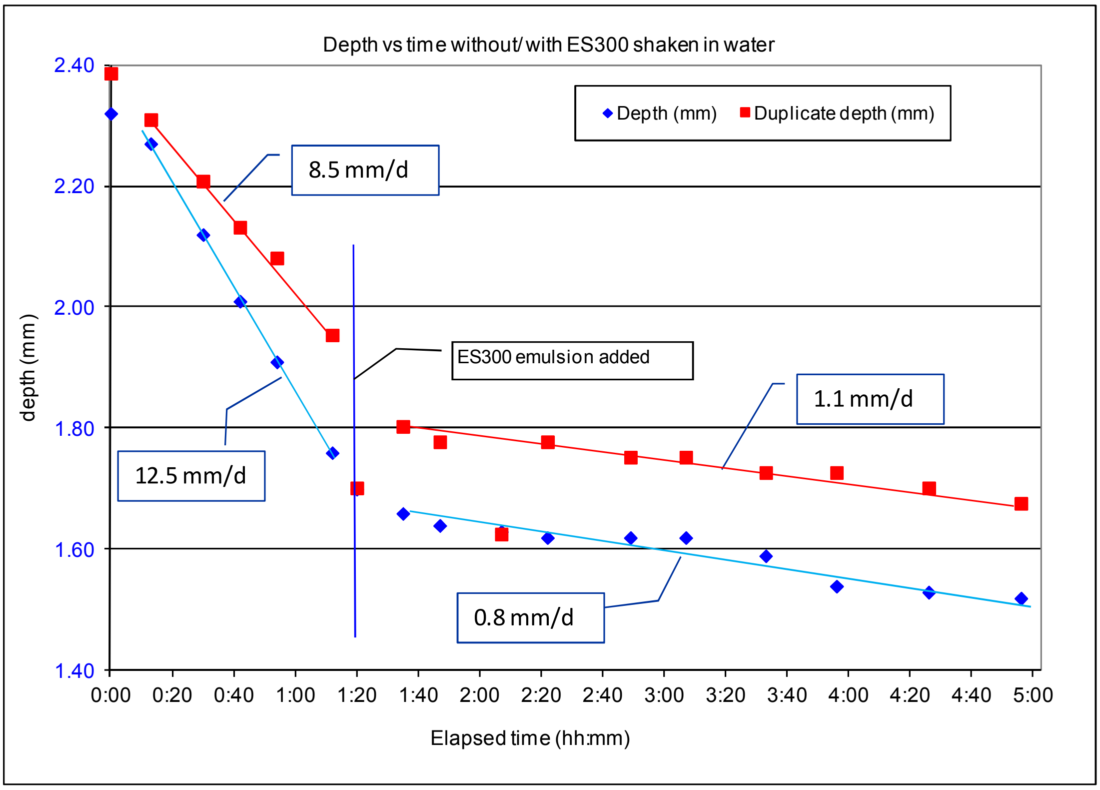


Figure 2.10 ES300 laboratory tests conducted by G-MW (shaken) (Albrecht, 2011)

This preliminary testing indicates that ES300 may be more resilient and capable of passing regulating structures, however further testing should be conducted to substantiate this result.

2.8.10 Obstructions to Monolayer Movement

Many structures are located along the length of irrigation channels. The structures perform different functions including controlling the level and flow of the water (regulators and offtakes), allowing access over the irrigation channel (bridges and culverts), allowing farmers to use the water (irrigation outlets) and in some instances to take the irrigation water under another water course such as a river, creek or natural depression (syphons). The monolayer products applied to the irrigation channel will travel down the channel with the channel flow and wind, and will be impacted by the different irrigation structures.

Clear span bridges do not impact the flow of water and will therefore not impact the monolayer movement. Some monolayer may be lost to bridge piers although this will be negligible compared to the weeds growing at the channel edges and in some instances within the channel waterway.

Figure 2.11 Clear span bridges

Regulating structures generally consist of overshot flume gates and cause disturbance of the water surface, which may impact the integrity of the monolayer.

Figure 2.12 Regulating structures

Offtake structures may be undershot or overshot, that is water may flow over them (as per a regulating structure) or water may flow beneath a vertical lift gate.

Figure 2.13 Offtake structures

Structures with a submerged water way area such as pipe culverts, syphons and concrete dome culverts are expected to cause the monolayer to "bank up" on the upstream headwall of the structure, therefore preventing the progress of the monolayer down the channel. Goldacre (1949) found that surface films on natural bodies of water were trapped at barriers such as floating branches and were unable to pass beneath the obstacle. Measurements of surface pressure indicated the natural layer was not present on the downstream side of the obstacle. Monolayers exhibit many similar properties to natural surface films and it is therefore likely they will also be unable to pass through a submerged pipe structure when the monolayer is located on the water surface.

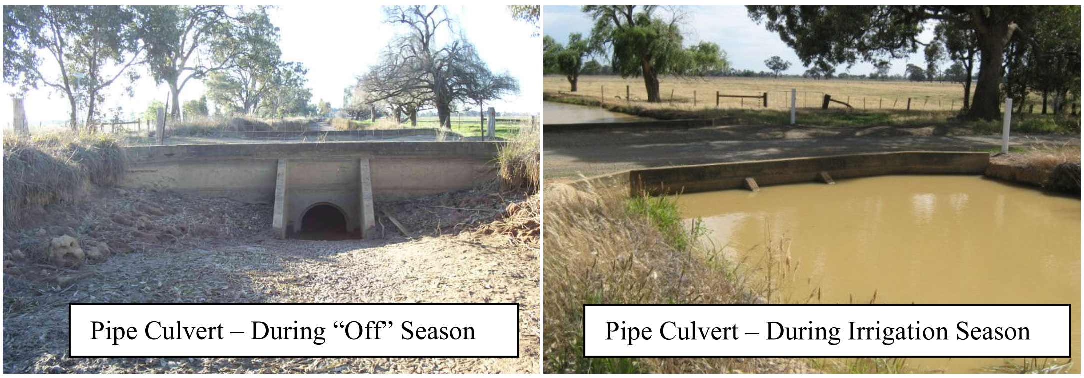


Figure 2.14 Pipe structures

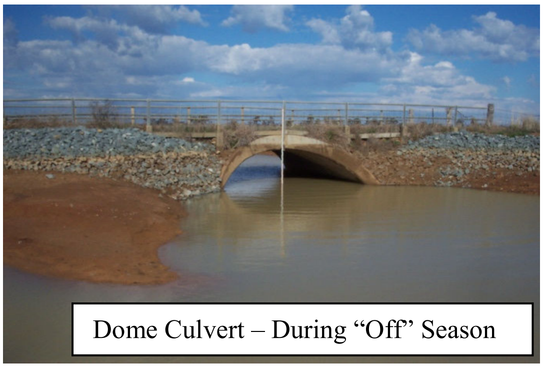


Figure 2.15 Concrete dome structure

Combine structures perform more than one purpose and generally consist of a culvert and a regulating structure. If the regulating component is located upstream of the culvert, the monolayer may be transported through the culvert with the turbulence. If the regulating component is downstream of the culvert, the monolayer is likely to "bank up" on the upstream headwall as per a standard pipe structure. For the purpose of the model all combines have been treated like a culvert structure. Further testing is required to determine whether monolayer materials are capable of passing this type of structure.

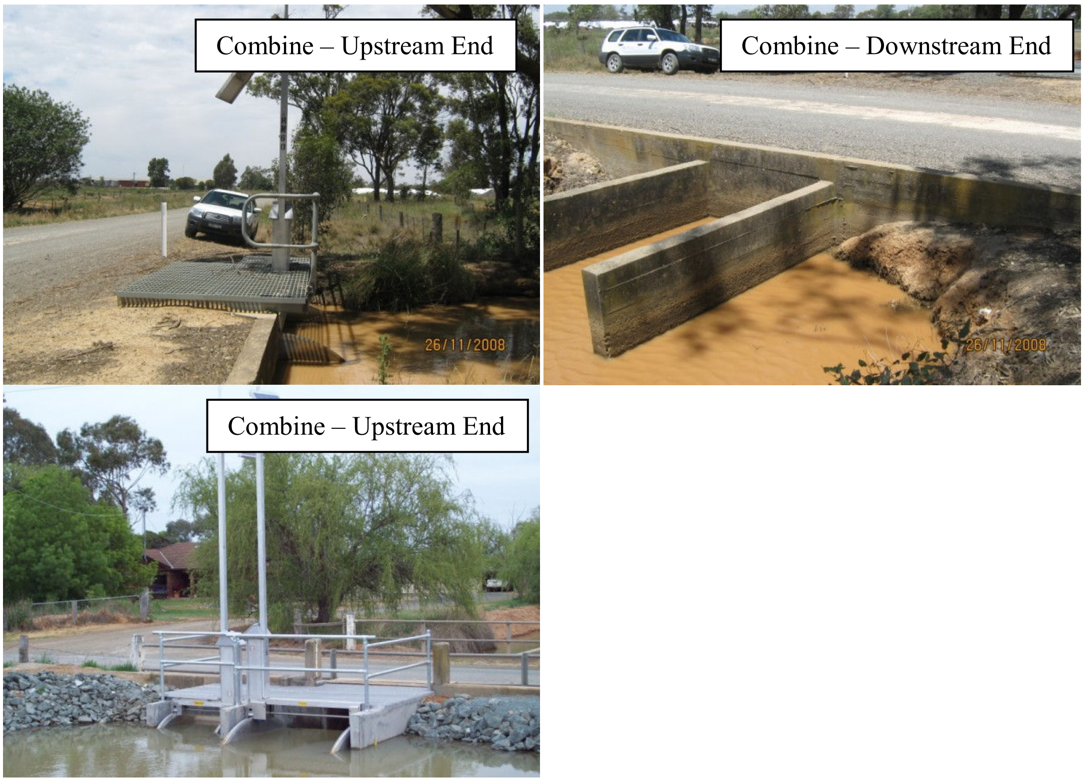


Figure 2.16 Combine structures

Irrigation outlets are generally undershot and will therefore allow the farmer to irrigate without allowing the layer to pass through and be wasted.

Figure 2.17 Undershot irrigation outlet

A small portion of irrigation outlets are overshot (flume gate outlets) and will require bunding upstream of the irrigation outlet to prevent the monolayer going onto the farmers property.

Figure 2.18 Overshot irrigation outlet

2.8.11 Application of Monolayers to Running Water

Even at very low wind speeds, monolayers drift on the water surface, therefore, it is unlikely that monolayers will be capable of withstanding channel flow (expanding upstream against channel flow). It has been assumed that their natural rate of expansion is lower than the water speed. As detailed in Section 2.8.7, the natural expansion rate of a monolayer (from most recent testing) tends to 0.02 m/s. Approximately 10% of the GMID channel network has a velocity of 0.03 m/s or less (assuming the channels have 1:1 batters). Therefore channel flow will override monolayer expansion in most instances. Further details of the channel network are provided in Section 3.1.

Conceptually, application of monolayer to an irrigation channel is simpler than for a lake or other water body, since a low rate application can be made downstream of an obstacle and the natural flow of water will carry the monolayer downstream. In a lake, the product must be spread at many points in the water body to achieve coverage and spread is reliant on the expansion of the monolayer only.

2.9 Field Trials

Goulburn-Murray Water is currently undertaking a concurrent project with the National Program for Sustainable Irrigation (NPSI) to apply the available monolayer products to irrigation channels in a field situation which expands the scope of previous commercial trials. Where possible, the results of the G-MW field work has been used to inform sections of the modelling.

2.9.1 Field Trial Site

The test site chosen for the G-MW trials was the last pool of the East Goulburn 30 Channel in the Shepparton Irrigation District (refer Figure 2.19 and Figure 2.20). The pool is almost 500 m long, 5.2 m wide and 600 mm deep.

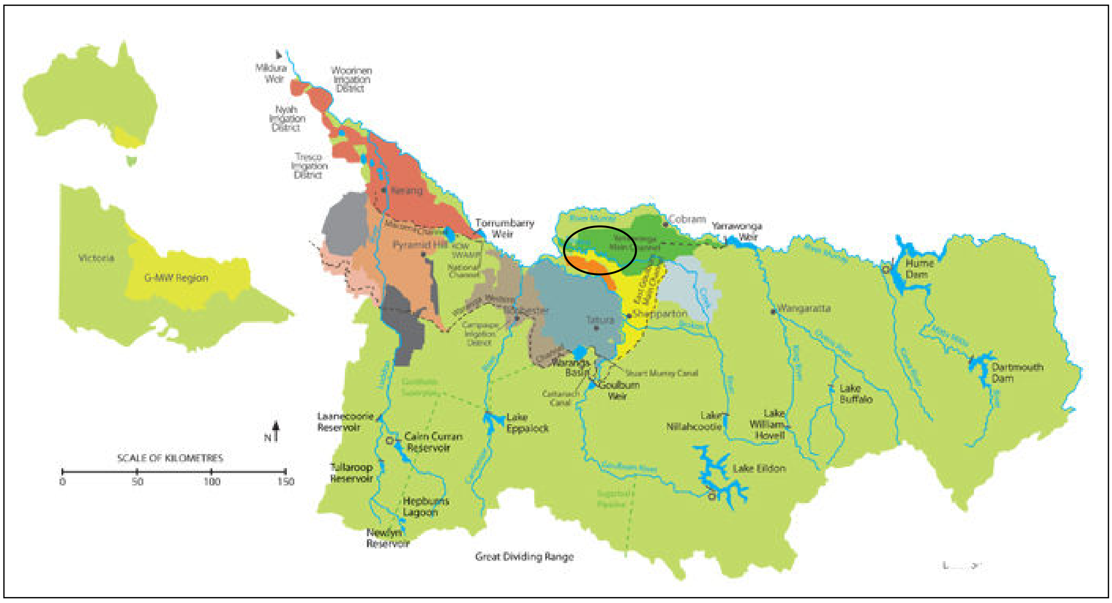


Figure 2.19 Location of trial site within Irrigation Region (Albrecht, 2011)

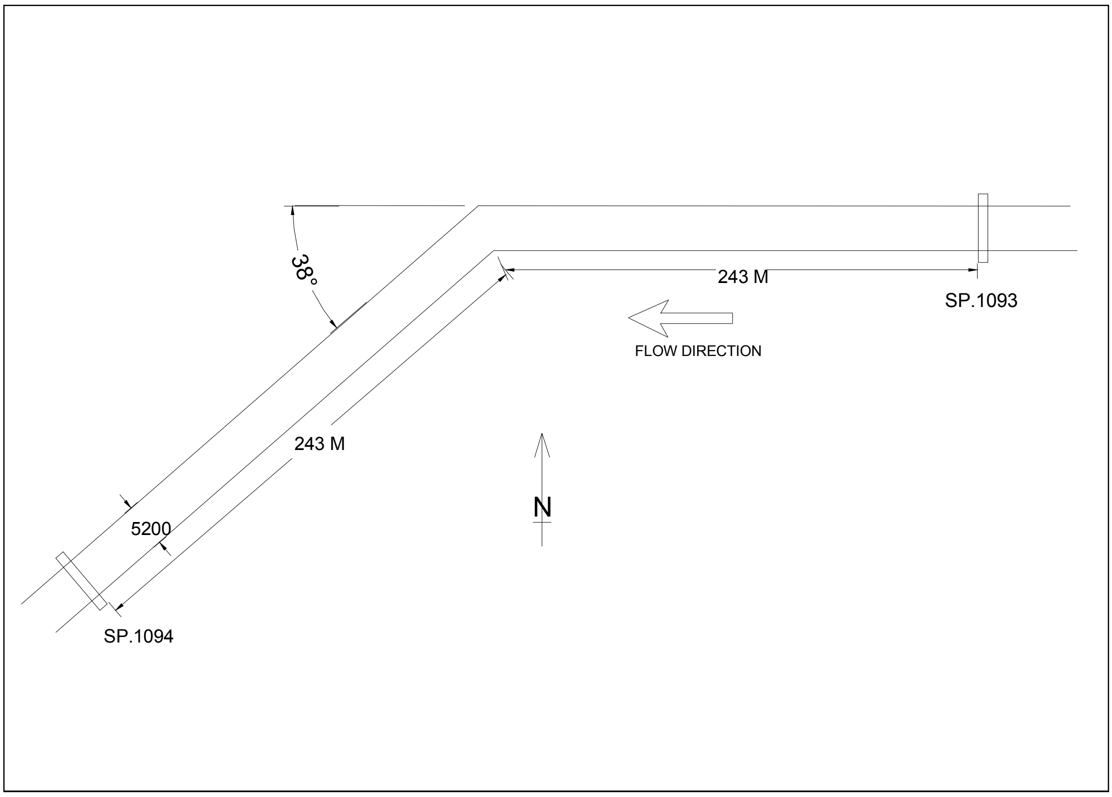


Figure 2.20 Trial Channel Site (Albrecht, 2011)

A number of different instruments were used to measure water depth, water temperature, wind speed, wind direction and rain. Water depth was 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.

2.9.2 Calculating Base Seepage & Leakage

The aim of the G-MW trials was 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, the loss rate of the channel at times when there was no rainfall and no inflow or outflow were compared. Any losses during these periods can be attributed to seepage, leakage and evaporation. Seepage and leakage are considered to be constant (providing the channel level is not fluctuating hugely which can causes changes in leakage) and present throughout the year, whereas evaporation will vary over the season. Refer to Figure 2.21.

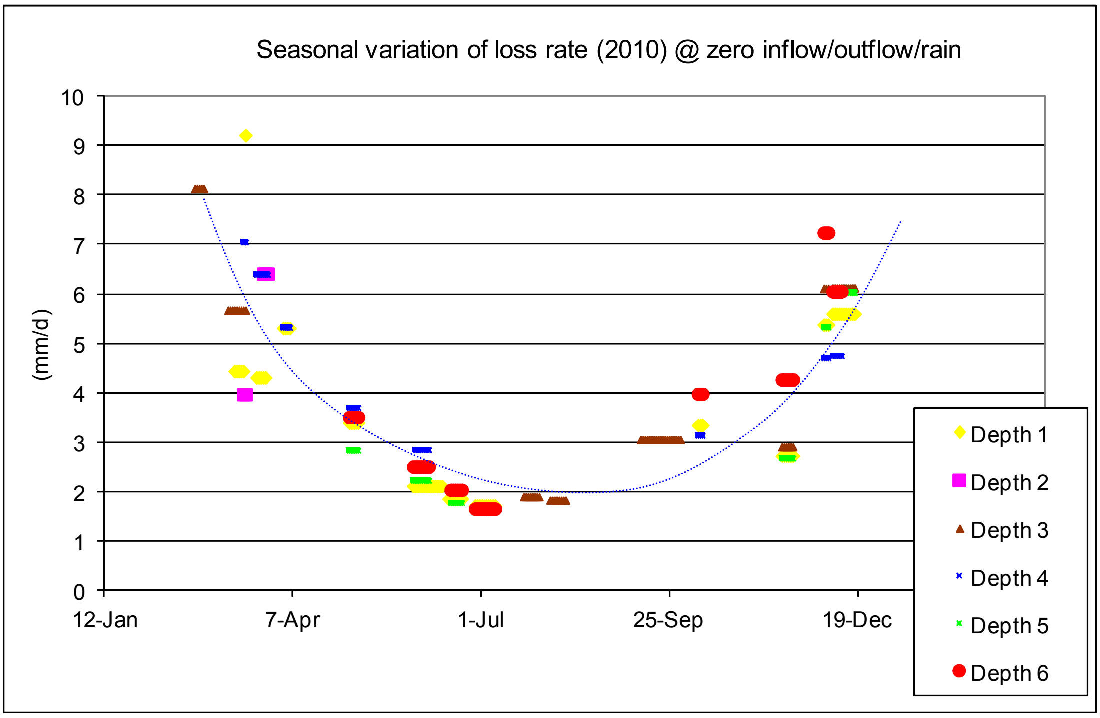


Figure 2.21 Loss Rate of Test Pool – No Monolayer (Albrecht, 2011)

The minimum loss rate observed was approximately 2 mm/day (June – August). The minimum evaporation loss as given by the adjusted pan evaporation from Kyabram during this period was 1 mm. Therefore, the baseline loss of the pool is approximately 1 mm, that is seepage and leakage equate to 1 mm 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.

2.9.3 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 potentially have an error in measurement greater than the evaporation). The monolayer materials used were WaterSavr™, the G-MW emulsions of cetyl and stearyl alcohols and ES300.

The percentage savings in evaporation is given by the equation:

$$\%\ \text{savings} = \frac{\text{loss rate without monolayer} - \text{loss rate with monolayer}}{\text{loss rate without monolayer}} \qquad (2.2)$$

Where the 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 and comparing to BOM data during the test period.

Savings of between 10 and 30% seem possible, however G-MW has been unable to show definite and consistent water savings from static tests.

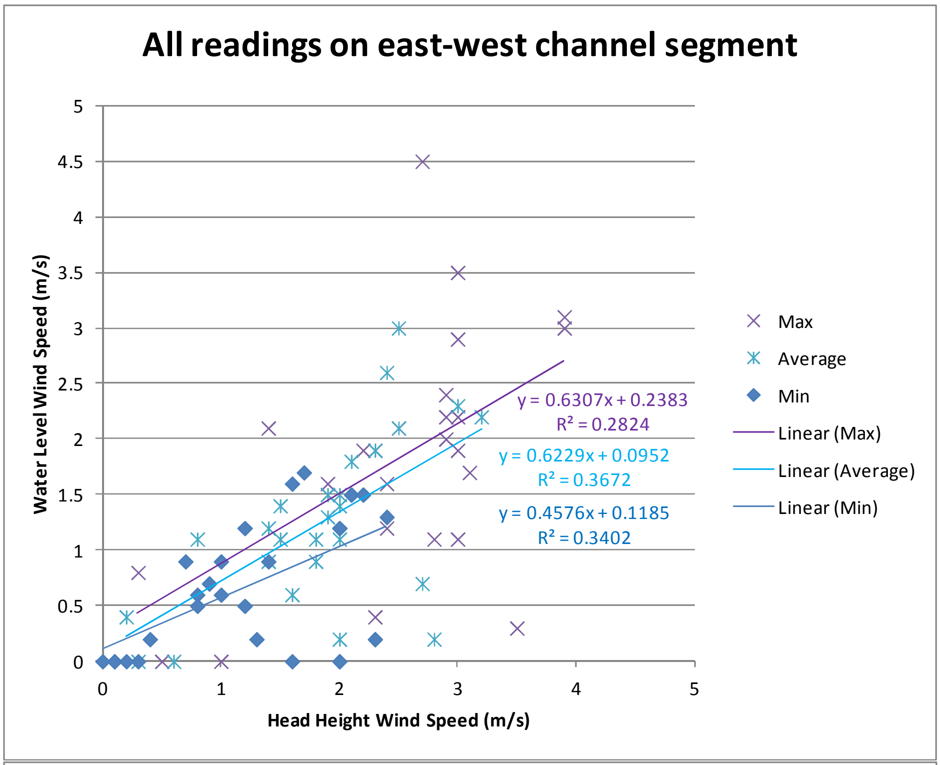
2.9.4 Wind Measurements at Varying Heights

Wind measurements recorded by the Bureau of Meteorology (BOM) are usually measured at a standard height of 10 m above the surface. Measurements made at the field trials site were made at approximately 1.5 m above the surface. The wind measurements made within the literature were close to the water surface (Brink, 2010) and at 1.8 m (Vines, 1962). Therefore, care needs to be taken when using the estimated monolayer drift rate in the literature with the site measured or BOM wind data.

Formulae exist to convert the BOM wind data at 10 m to estimated wind that would be experienced at a height less than 3m (Gowen, et al. 2004). To use the formulae, wind height factors are required that depend on the terrain at the measurement site and at the local site. Within the modelling, every channel segment has been related to a BOM site, however, the wind data has been used unaltered, which potentially overstates the wind experienced closer to the water surface. The wind speed at 1.5 to 1.8m would potentially be in the range of 80% of the BOM measured wind (assuming that both the BOM site and channel sites are Terrain Category 2 - Water surfaces, open terrain, grassland, with few, well-scattered obstructions having heights generally from 1.5 m to 10 m).

Within the model, a rate of monolayer expansion of 3% of the wind speed has been adopted for wind speeds greater than 3.2 km/hr, being the generally agreed value based on past research. However, as given in section 2.8.8, the reported rate of monolayer expansion lies between 2.6-5.5% of wind speed. Therefore, as a preliminary estimate of the order of evaporation savings, the use of the unaltered BOM wind data and an expansion rate of 3% is considered adequate.

In addition, measurements at the test site were taken of the wind at the channel surface and at head height (~ 1.5 m) for various points across the channel profile and at channel segments of different orientation to the wind direction. The surface measurements were made using an anemometer on a small raft which was moved by pulling strings from the channel banks .The purpose of these measurements was to enable comparison between the different reported expansion rates based on wind measured at different elevations. There was very poor correlation between surface and head height measurement: R^2 values were as low as 0.02 (refer Figure 2.22). The wind behaviour was very complex with rapid changes in speed and direction. Extensive further work would need to be undertaken to determine the interaction between banks, wind direction and orientation and the wind speed at and above the water surface.



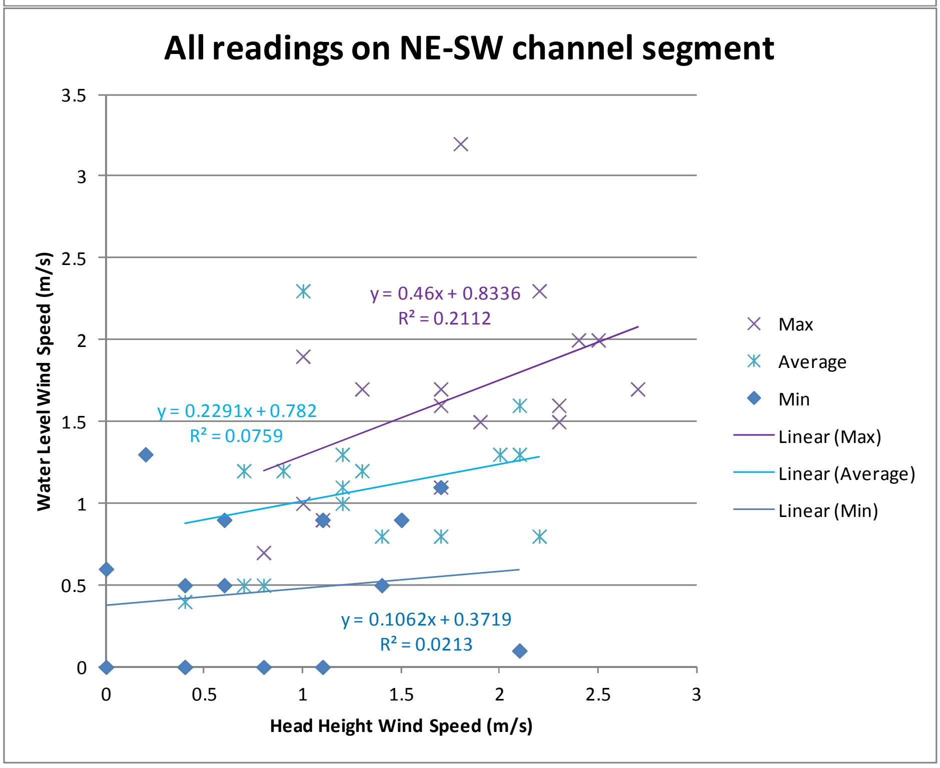


Figure 2.22 Wind Speed Measurements at Trial Site

2.9.5 Flowing Trials

Two flowing tests were conducted to test the ability of the CRC Polymers monolayer, ES300, to withstand turbulence 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 20 ML/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 (refer to Figure 2.23). The indicator oils demonstrated that the layer was compressed to > 30 mN/m except for a 100 m stretch directly downstream of the regulator (refer to Figure 2.24).

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

The flowing tests also allowed measurement of monolayer travel under combined channel flow and wind speed. In the second pumped test, the wind (~ 2 – 2.5 m/s at head height and ~ 1 - 1.5 m/s at water level in the middle of the channel) was opposing the channel flow (at approximately 45% to the channel). The channel flow of 20 ML/day equates to a velocity of 0.1 m/s for the test channel's dimensions. Testing via indicator oils showed that the monolayer had travelled a distance of approximately 125 m after 25 minutes. The predicted speed of the monolayer front = water speed + 0.03 x wind speed (for that portion of the wind that is parallel to the channel). Refer to Section 3.4.5 for more detail of monolayer movement under the influence of an oblique wind. For a wind speed of 1.5 m/s (@ water level) at 45% to the channel and opposing flow, the monolayer speed = 0.1 - 0.03 x 1.5 cos 45 = 0.07 m/s downstream. In 25 minutes the monolayer front should have therefore covered a distance of 0.07 x 25 x 60 = 105 m. The actual distance that the monolayer front had covered (based on the indicator oils) was 125 m. The site did not have continuous recording of the wind speed and direction (only one record taken at the start of the test) and distance travelled was estimated by pacing. Therefore, based on the site limitations, the estimate of the distance travelled by the monolayer front shows good correlation with the field results.

Figure 2.23 Wave damping due to monolayer application (Albrecht, 2011)

Figure 2.24 Testing for monolayer presence using indicator oils (Albrecht, 2011)

The rainbow dispersion in the bottom photo 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.

2.10 Other Current Research

Other investigations into monolayers currently being undertaken include:

- The Cooperative Research Centre for Irrigation Futures (CRCIF) currently has a project to investigate dam evaporation mitigation. A number of the PhD research projects supported by the CRCIF relate to monolayers including:
    - Automatic sensing of evaporation suppressing films – Paul Coop
    - Autonomous systems for the optimal application of chemical monolayer to open water surfaces: design approach – Gavin Brink (Brink, et al. 2010)
    - Reducing water evaporation with novel monolayer materials – Michael Herzig
- In addition, CRC Polymers is undertaking a project to develop improved monolayer materials for evaporation mitigation.

2.11 Conclusions

Research on monolayers to date has tended to focus on their application on storages or dams. However, irrigation channels could also benefit greatly from a cost effective technology to suppress evaporation. Goulburn-Murray Water has recently completed a concurrent project with NPSI to apply the available monolayer products to irrigation channels in a field situation. While these field trials were related and provided input into the establishment of a decision support system, they are beyond the scope of this research project

Minimal research has been undertaken into reducing evaporation losses from irrigation channels, with the main available methods being pipeline, shade cloth covers or plastic covers. The literature review has found no information regarding the use of monolayers on irrigation channels. Monolayers potentially provide a low cost water savings solution which can be targeted for use at high evaporation periods at strategically located sites in the system. Supervisory Control and Data Acquisition (SCADA) systems could be employed to apply monolayer only when the environment (wind, evaporation rate, etc) would lead to cost effective water savings. While further research is required on the efficacy of monolayers on flowing water surfaces, this study addresses the issue of where in the water system monolayers could be employed for minimum cost and maximum benefit.

The learning from past research can be summarised as:

- A number of methods exist that can be utilised to save evaporative losses on water storages including: physical methods such as shade cloth, floating covers and floating objects and chemical methods (monolayers);

- For large water storages, the most cost effective methods of saving evaporative losses is to use a monolayer at targeted periods of high evaporation and when the monolayer will be most effective;

- The main methods used for saving evaporative losses on channels consist of rationalising the channel (through abandonment or privatisation) or replacing it with a pipeline. Minimal use of the methods available to dams has been employed on irrigation channels in the GMID to date;

- Monolayers come at a lower capital cost than the physical methods of saving evaporative losses, however the percentage of savings that can be achieved is much lower and the ongoing maintenance and operation costs are higher; and

- Monolayers are impacted by wind conditions, water quality and biological activity. Application of monolayer products needs to be targeted for the periods of greatest effectiveness and return.

3 DEVELOPMENT OF THE DECISION SUPPORT MODEL

The efficacy of a monolayer on an irrigation channel is predicted to be related to many variables:

- monolayer type and costs;
- water quality;
- flow rates;
- stripping due to edge effects and aquatic vegetation;
- irrigating outlets and inline obstacles;
- channel dimensions; and
- wind effects and weather.

The decision support system that has been developed as the main output of this research is both a tool to enable testing of the sensitivity of monolayer effectiveness to the different variables and an output of the research project which can be refined as further data becomes available.

In addition to the irrigation channels, G-MW is responsible for a large number of major storages, minor storages and other water bodies within the distribution system. These storages would potentially be sites suited to the use of monolayers, however application of monolayers to lakes and storages is outside the scope of this research project.

A water authority, such as G-MW, is only going to adopt a water savings technique where it is economically feasible to do so, particularly because savings must be measurable and reportable given they are normally funded externally to the organisation. That is, the value of the water saved must outweigh the cost of achieving those savings. At this point in time, G-MW has an estimate of the evaporative losses from irrigation channels, but no estimate of the potential water savings that could be achieved by applying monolayers and the cost of achieving those savings. In order to consider this technique further, G-MW requires a broad estimate of potential costs and savings that could be achieved by applying monolayers to irrigation channels. This would then inform G-MW (or any other irrigation authority) whether it is worthwhile undertaking a more detailed assessment of monolayers on irrigation channels. Therefore I chose to produce a broad model to inform G-MW when and where it would be feasible to use monolayers on irrigation channels. This is the first step in determining if this is a feasible method of achieving water savings.

3.1 Preliminary Channel Characterisation

Preliminary characterisation of the channels within the GMID has been on the basis of channel "type" eg major carrier, trunk channel and spur channel as detailed in Table 3.1. Only "earthen" irrigation channels have been included. Goulburn-Murray Water does utilise natural carriers in some of the irrigation areas (for example Broken Creek) however, it is assumed at this stage, that application of monolayer products to natural carriers will not be undertaken.

A map of the GMID area is shown in Figure 3.1.

Table 3.1 Channel characterisation categories

Category	*Definition*
Carrier 	Large scale The major supply channels within the GMID, including: • Stuart Murray Canal • Cattanach Canal • East Goulburn Main Channel • Waranga Western Main Channel • National Channel • Yarrawonga Main Channel
Trunk 	Medium Scale All backbone[1] channels excluding those defined as carriers
Spur 	Small Scale All non-backbone[2] channels being the smaller channels at the ends of the system.

1 Backbone as defined by NVIRP consists of channels with accumulated delivery share volume greater or equal to 20 ML/day

2 Non-Backbone consists of channels with accumulated delivery share volume of less than 20 ML/day

Figure 3.1 Irrigation region (Goulburn-Murray Water, n.d)

Preliminary characterisation of the GMID irrigation network is included in Table 3.2. This table presents "segments" of channel as they are given in the G-MW Asset Management System, however some of these segments may not start or end at a regulating structure, and some may have additional regulating structures within the "segment". Therefore it is not a true reflection of the actual distance between obstacles to the flow of the monolayer.

Table 3.2 Channel characterisation

Preliminary Channel Characterisation			
	Channel Type		
Item	*Carrier*	*Trunk*	*Spur*
# Segments (CH Codes) [1]	189	2,381	3,429
Length (m)	2,338	1,101	927
Width (m) [2]	25.4	10.7	7.5
Capacity (ML/day) [2]	1,702	252	39
Velocity (m/s) 1:1 Batters [2]	0.40	0.18	0.09

[1] Individual channel segments are referenced by CH codein the Asset Management System

[2] Weighted average based on segment length

Table 3.3 has revised the pool length to consider the distance between regulating structures, the distance between pipe structures and the distance between "obstacles" which includes both regulating and pipe structures. The average widths and velocities given in Table 3.2 are weighted averages calculated by taking into the consideration the "segment" length and are still valid.

From Table 3.3 it can be seen that there is a large variation in pool length for the different channel types. The same variation exists for channel width, flow, and number of obstacles. Further refinement of the model should take into consideration the wide range in all channel variables. Figure 3.2, Figure 3.3 and Figure 3.4 show the distribution in pool length graphically. The length used within the model is dependent on the monolayer material being analysed and its ability to reform after either a regulating structure or a pipe structure.

Table 3.3 Channel characterisation - variation in pool length (meters)

Channel Type	*Length Item*	*25% Percentile*	*50% Percentile (Median)*	*Average*	*75% Percentile*	**Top 25%** *(Average of segments that exceed the 75% percentile length)*	*90% Percentile*	**Top 10%** *(Average of segments that exceed the 90% percentile length)*	*99% Percentile*	**Top 1%** *(Average of segments that exceed the 99% percentile length)*	*Standard Deviation*
Carrier	*Segment / CH Code* [1]	1,470	2,063	2,338	2,646		3,657		8,778		1,501
	Between Regulators [2]	1,273	2,289	3,909	5,137	9,648	9,883	13,060	16,166	17,367	3,905
	Between Obstacles [3]	726	1,377	2,171	2,469	5,306	4,709	8,032	13,389	13,934	2,460
	Between Pipes [2]	728	1,436	3,996	3,149	12,017	7,768	22,688	43,303	56,722	8,579
Trunk	*Segment / CH Code* [1]	554	887	1,101	1,399		2,076		4,337		857
	Between Regulators [2]	473	787	968	1,227	1,961	1,788	2,706	3,932	5,364	793
	Between Obstacles [3]	279	466	637	784	1,391	1,264	2,003	3,164	4,184	603
	Between Pipes [2]	298	482	789	810	1,954	1,502	3,281	6,208	9,530	1,204
Spur	*Segment / CH Code* [1]	443	760	927	1,210		1,764		3,464		802
	Between Regulators [2]	384	623	724	942	1,386	1,344	1,800	2,438	3,006	495
	Between Obstacles [3]	230	360	432	548	843	805	1,124	1,561	1,921	309
	Between Pipes [2]	249	399	485	608	966	911	1,321	1,827	2,468	372

[1] Individual channel segments are referenced by CH code in the Asset Management System

[2] Length between regulators (or pipes) ignores the arbitrary length of segments within the Asset Management System

[3] Length between obstacles is less than the length between regulators (or pipes) because it includes both structure types

[4] The cells highlighted refer to the average segment length for that channel type and correspond to the lengths in the previous table

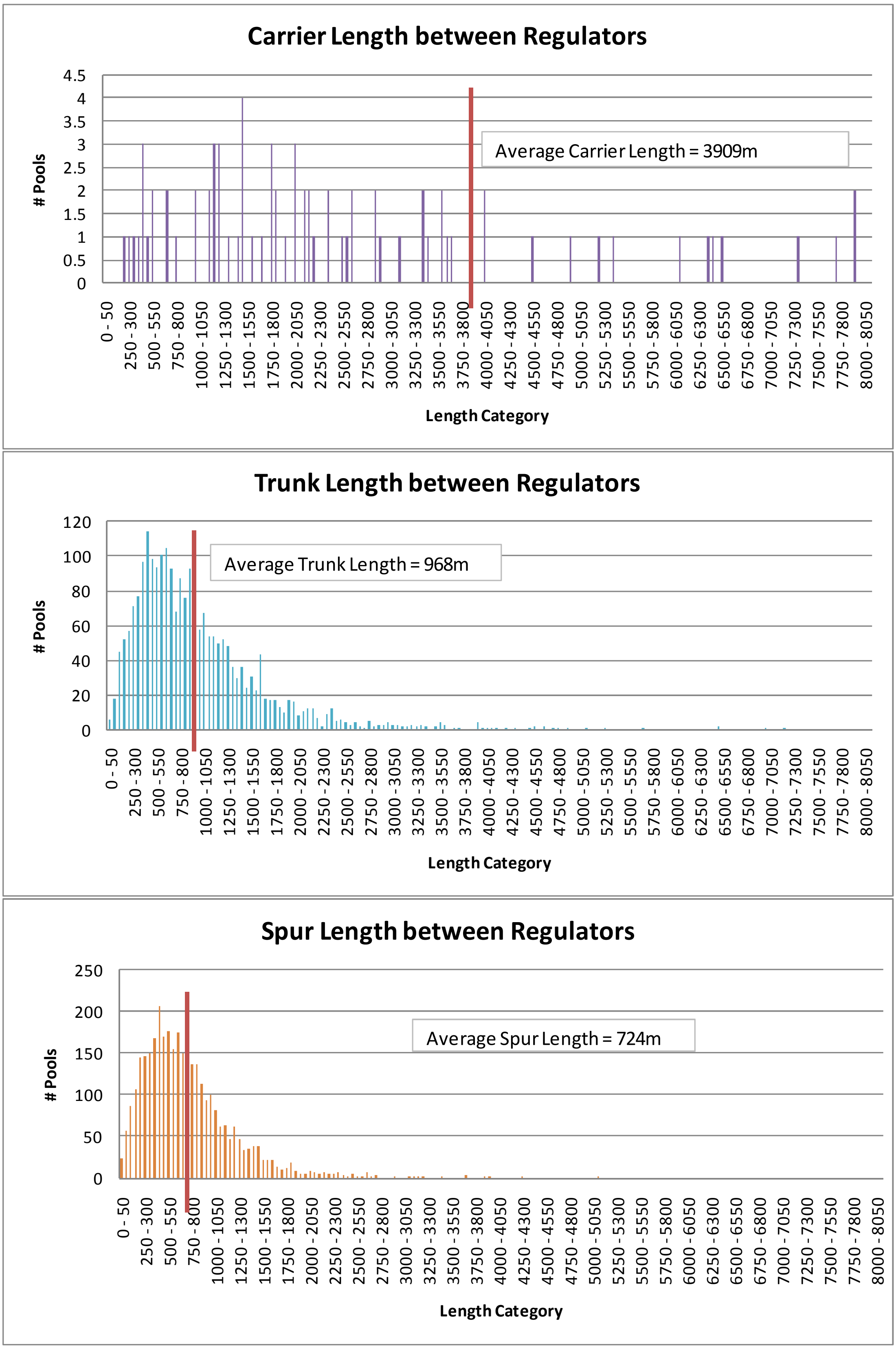


Figure 3.2 Variation in length (meters) between regulating structures

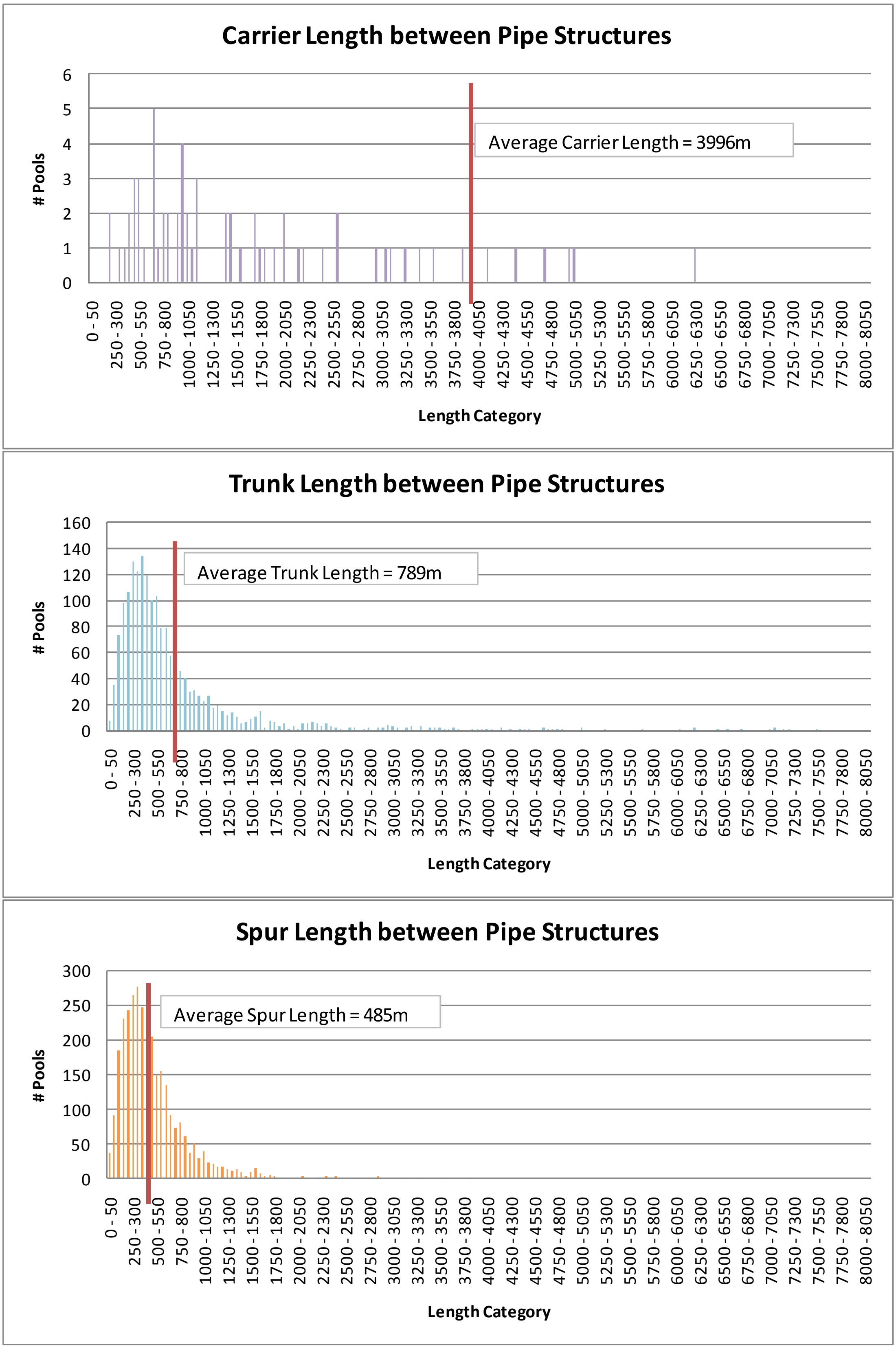


Figure 3.3 Variation in length (meters) between pipe Structures

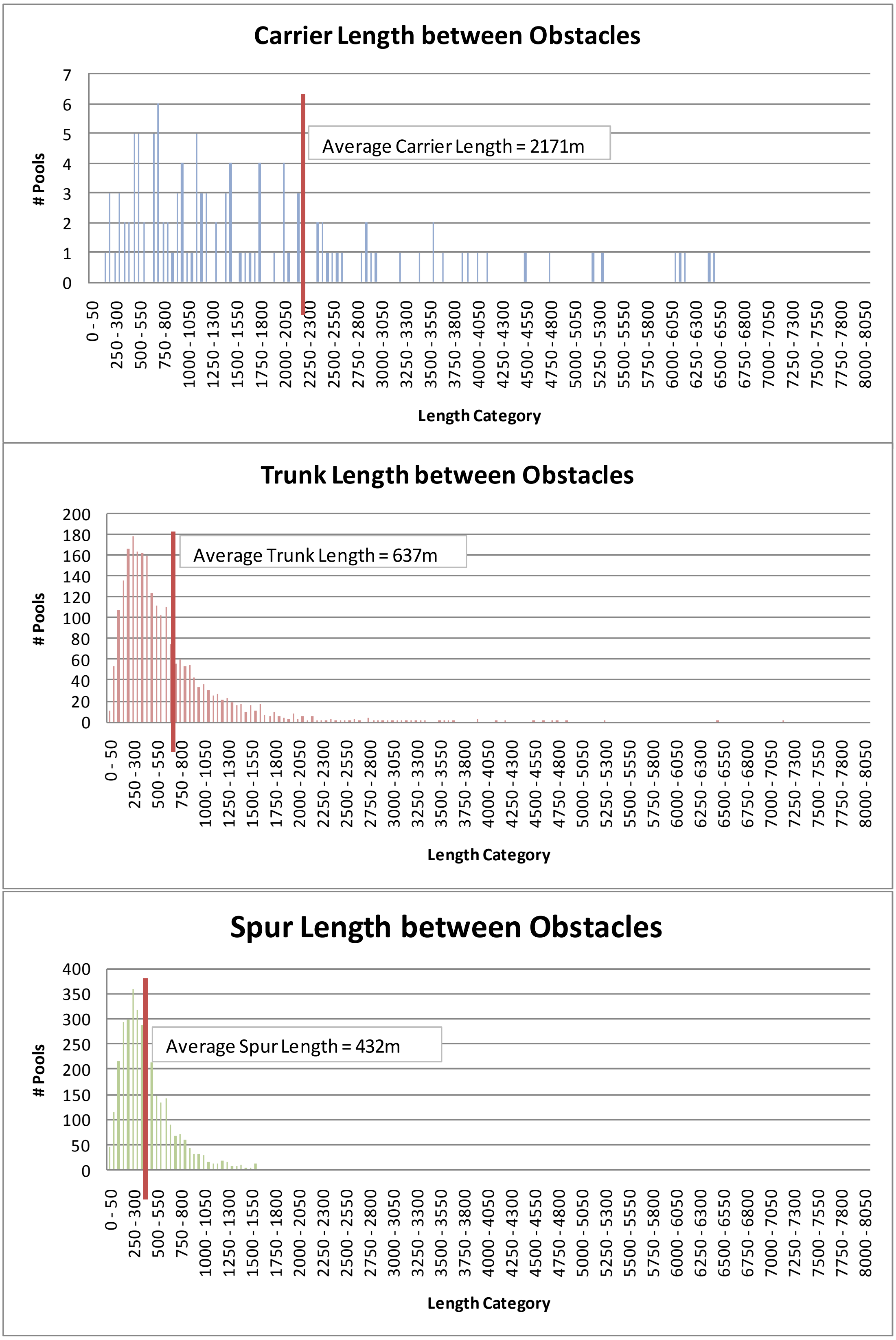


Figure 3.4 Variation in length (meters) between obstacles

3.2 Seasonal Evaporation

Calculations of potential evaporation savings are based on class "A" pan evaporation measurements. A class "A" evaporation pan consists of a trough 1.2 m in diameter and 250 mm high in which the water level is observed and the change recorded daily.

A pan factor of 0.8 has been adopted to convert pan evaporation to channel evaporation (SKM, 2009 and Department of Sustainability and Environment, 2010). The Kyabram pan evaporation figures have been utilised because Kyabram is centrally located within the irrigation region.

Pan evaporation varies throughout the year as shown by the daily average pan evaporation in Figure 3.5 (average of available records – 10 years). Pan evaporation also varies from year to year as shown by variation in the daily average pan evaporation (within each month) over the past 10 years as shown in Figure 3.6. The average daily pan evaporation within each month (based on the 10 years of available data) is shown in Table 3.4.

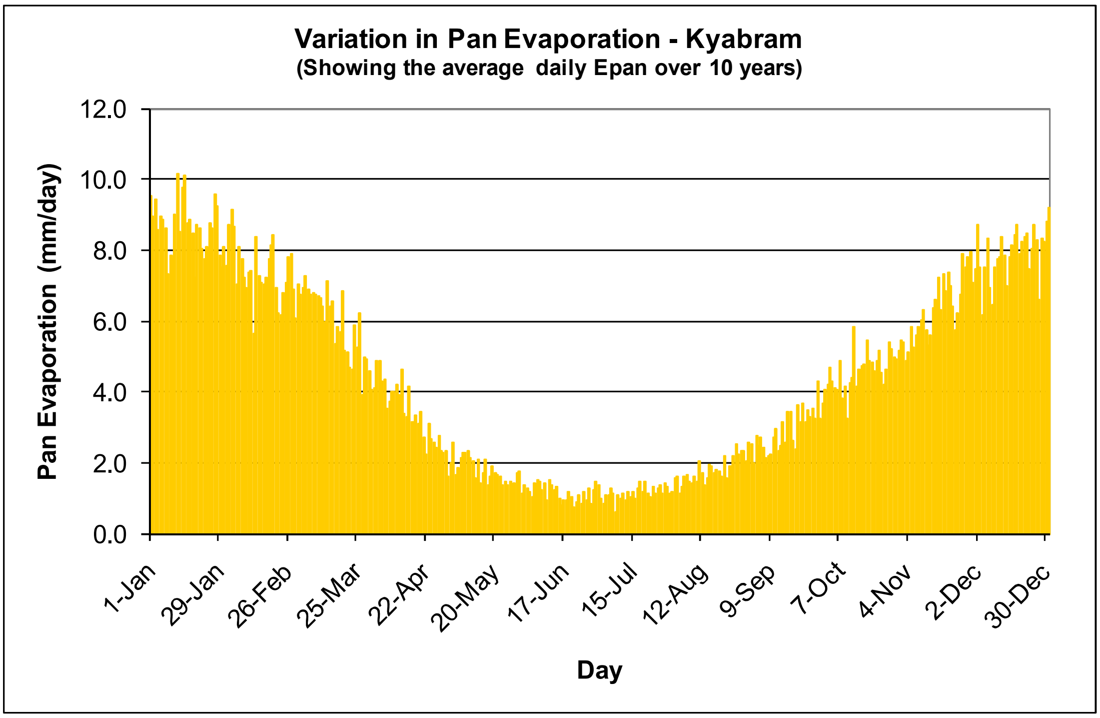


Figure 3.5 Variation in pan evaporation throughout the year

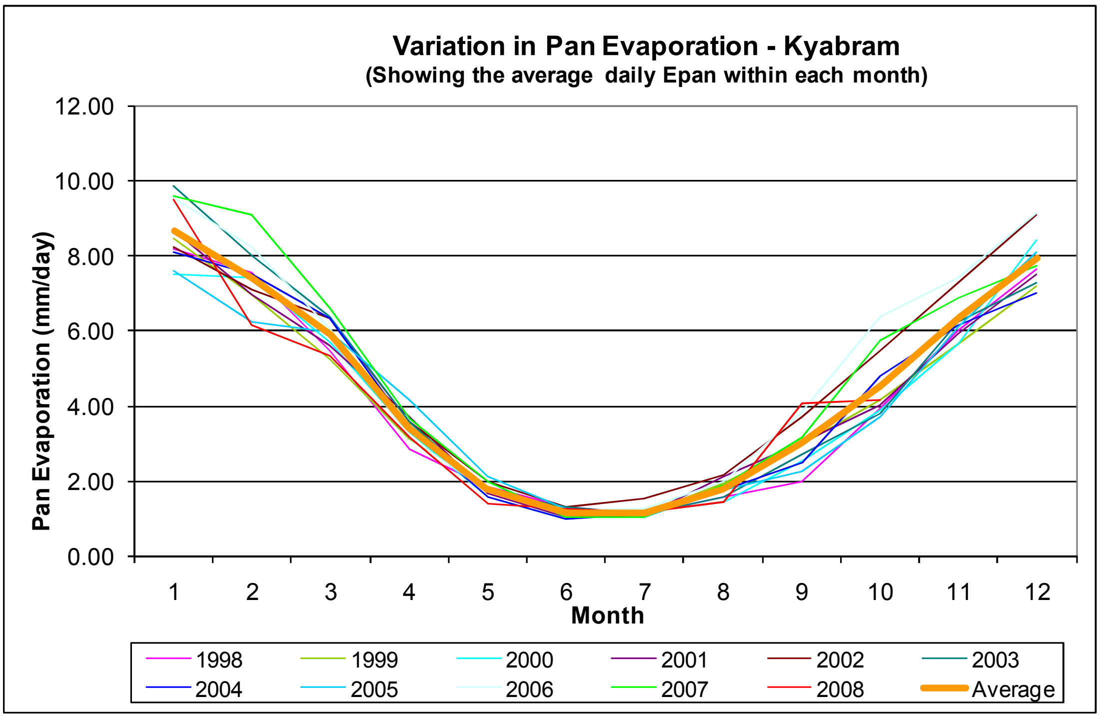


Figure 3.6 Variation in pan evaporation from year to year

Table 3.4 Average daily evaporation

Average Daily Evaporation (mm)							
Month	*Average Epan (mm)*	*Peak Epan (mm)*	*Frequency of Occurance*	*Pan Factor* [1]	*Evaporation (mm/day)*	*Yearly Evaporation (mm/day)*	*Irrigation Season Evaporation (mm/day)*
1	8.66	18.40	0.3%	0.835	7.23	7.23	7.23
2	7.39	14.00	0.4%	0.835	6.17	6.17	6.17
3	5.92	12.20	0.6%	0.835	4.94	4.94	4.94
4	3.43	9.00	0.3%	0.835	2.86	2.86	2.86
5	1.78	7.90	0.3%	0.835	1.48	1.48	1.48
6	1.17	4.30	0.4%	0.835	0.98	0.98	
7	1.17	3.60	0.3%	0.835	0.98	0.98	
8	1.80	9.40	0.3%	0.835	1.50	1.50	1.50
9	2.99	9.80	0.3%	0.835	2.50	2.50	2.50
10	4.56	12.80	0.4%	0.835	3.81	3.81	3.81
11	6.34	13.00	0.4%	0.835	5.30	5.30	5.30
12	7.92	14.00	0.4%	0.835	6.61	6.61	6.61
					Average	3.70	4.24

1 SKM, 2009

Over the calendar year the average daily evaporation is 3.70 mm, while the average daily evaporation over the irrigation season is 4.24 mm. When considering monolayer application, periods of high evaporation could be targeted, such as January with a daily average of

7.23 mm, which would increase the cost effectiveness of the monolayer technique for the period of use.

Within the model, evaporation has been split into the categories shown in Table 3.5.

Table 3.5 Evaporation categories

Model Evaporation Categories			
Evaporation Category	*Adopted Evaporation for Calculations*	*Approximate Percentage of Year*	*Approximate Percentage of Irrigation Season*
0 - 3	1.5	46%	35%
3 - 6	4.5	32%	38%
6 - 9	7.5	22%	27%
> 9	9	0%	0%

As a comparison, the seasonal variation in loss rate at the G-MW field trial site was calculated during 2010 (refer Figure 2.21). The loss rate was calculated as the change in depth over time for periods of no inflows or outflows and no rain. The loss rate includes seepage and evaporation, and generally appears to be 1 mm/day higher than the converted pan evaporation data at Kyabram. This indicates a baseline seepage rate of 1 mm/day, with the remaining loss being evaporation. This compares favourably to the Kyabram adjusted pan evaporation.

3.3 Available Wind Information

The Bureau of Meteorology records weather information at various locations, which may include wind direction and speed. Locations within Victoria are shown in the map Figure 3.7. The type of wind information available for each weather station is shown in Figure 3.8.

Figure 3.7 Victorian BOM weather stations (Bureau of Meteorology, n.d(a))

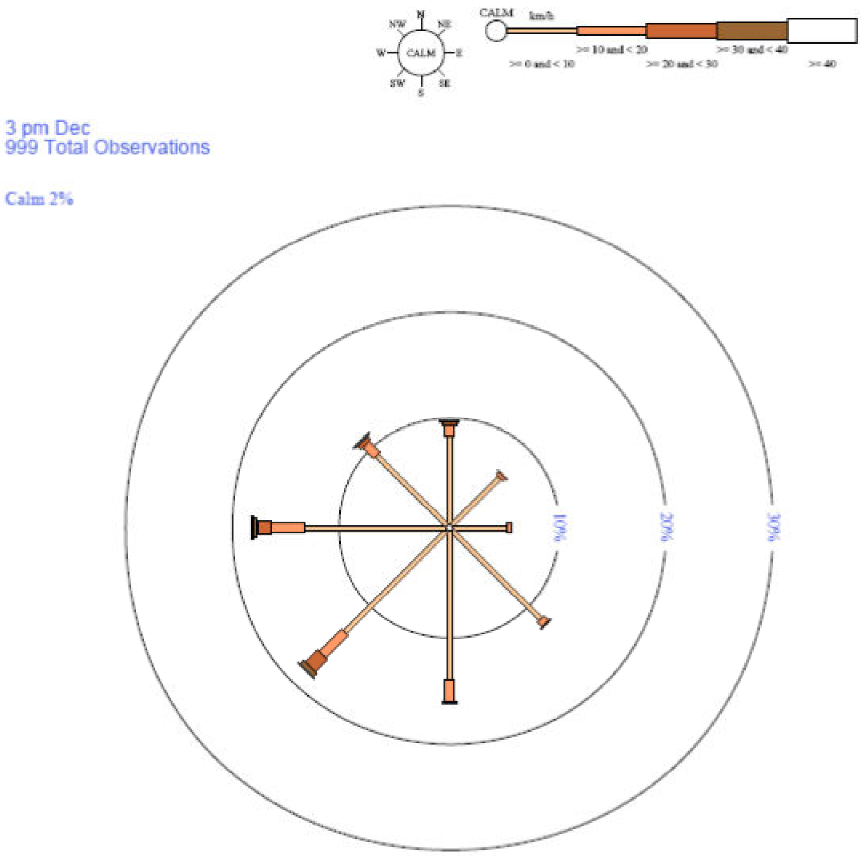


Figure 3.8 Example weather data (Bureau of Meteorology)

Based on Section 2.8.8 the critical wind speeds are 3.2 km/hr at which point the wind controls movement of the monolayer and 25 km/hr above which the monolayer is ineffective. Table 3.6 presents a portion of the raw data split into categories based on the critical wind speeds (the numbers provided in the table are the numbers of observations recorded within that category):

Table 3.6 Example of re-categorised weather site data

			Wind Speed 15 hours				
Station Name	***Month***	***Wind Direction 15 hours***	***Calm***	***> 0 and < 3.2***	***>= 3.2 and < 25***	***>= 25***	***Grand Total***
KYABRAM DPI	***January***	*N*		8	100	12	120
		NE			107	13	120
		E		8	55	7	70
		SE		3	53	4	60
		SW		2	132	19	153
		S		7	196	93	296
		NW		2	87	29	118
		W		5	120	37	162
		Calm	14				14
	January Total		**14**	**35**	**850**	**214**	**1113**
	February	*N*		9	115	15	139
		NE		11	120	13	144
		E		8	75	5	88
		SE		2	50	5	57
		SW		1	101	15	117
		S		9	194	68	271
		NW		6	76	20	102
		W		7	84	21	112
		Calm	16				16
	February Total		**16**	**53**	**815**	**162**	**1046**
KYABRAM DPI Total			**30**	**88**	**1665**	**376**	**2159**

Through use of the weather station coordinates, G-MW's GIS team was able to relate every segment of channel (referenced within the asset system by a unique CH code) to the first, second, etc nearest weather stations. This in turn allows each CH code to be analysed in terms of the prevailing wind conditions it experiences.

Figure 3.9 shows how the wind conditions are related to a piece of channel that flows north.

Table 3.7 characterises the channel network in terms of the prevailing wind speeds based on the weather station nearest to each individual channel segment.

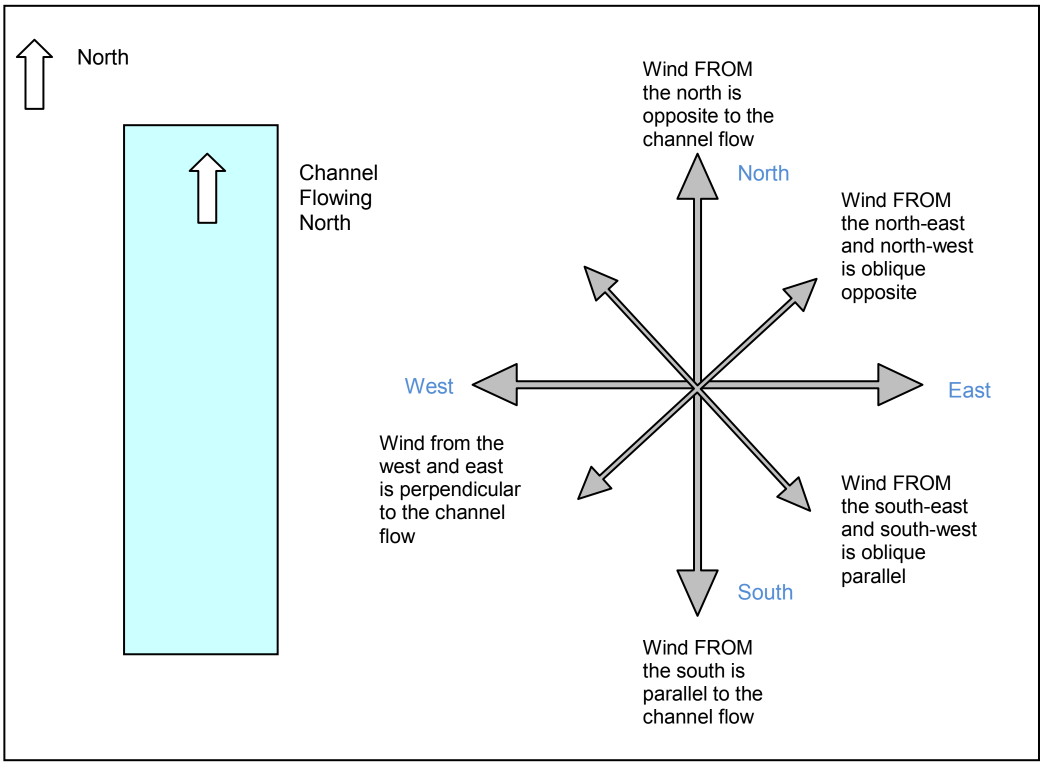


Figure 3.9 Relating Wind direction and Channel Direction

Table 3.7 Channel characterisation – prevailing wind conditions

Yearly Wind Conditions[1]			
	Channel Type		
Wind Speed (km/hr)	*Carrier*	*Trunk*	*Spur*
Calm	5%	5%	5%
> 0 and < 3.2	6%	3%	3%
>= 3.2 and < 25	77%	81%	81%
>= 25	11%	12%	10%

[1] Weighted average based on segment length

Irrigation Season Wind Conditions[1]			
	Channel Type		
Wind Speed (km/hr)	*Carrier*	*Trunk*	*Spur*
Calm	4%	3%	4%
> 0 and < 3.2	6%	2%	3%
>= 3.2 and < 25	78%	81%	82%
>= 25	12%	14%	12%

[1] Weighted average based on segment length

In general, the prevailing wind speed experienced by GMID channels is between 3.2 and 25 km/hr (~80% of the time). Approximately 12% of the winds experienced are greater than 25 km/hr and the remaining 8% are calm or up to 3.2 km/hr in strength.

The resolution of wind data from the Bureau of Meteorology for the GMID is generally 45 degrees, and is therefore the resolution adopted for the purpose of modelling. In the above example, any wind from -22.5 to +22.5 degrees would be considered to be from the north. However, in characterising the channel data, the same level of resolution has also been adopted, such that any channel oriented between -22.5 and +22.5 degrees would be considered flowing to the north. Further investigation is required to determine the impact of the level of resolution on the outcome of the model.

3.4 Monolayer Expansion Under Varying Wind Conditions

Wind has a major effect on the behaviour of monolayers, so an understanding of wind regimes is a critical aspect of this study.

3.4.1 Monolayer Expansion No Wind

Without the influence of wind, the monolayer expansion was as described by equation (2.1) which is assumed to apply to monolayer expansion in any unconfined direction. An alternative way to present monolayer expansion is given in equation (3.1).

$$d = 0.14\, t^{0.74} \tag{3.1}$$

where *d* is the distance travelled in meters on still water within a given time *t* seconds.

If the monolayer is applied to the top of a channel pool under calm wind conditions, then the time taken for the leading edge of monolayer to reach the downstream end of the pool is based both on the channel flow and the expansion rate of the monolayer. The series of diagrams shown in Figure 3.10 describe the monolayer expansion pictorially. The speed of the monolayer front at point P depends on the channel flow and the monolayer natural expansion rate. An example of the time taken for the monolayer to travel the distance between two points is provided in Example 3.1.

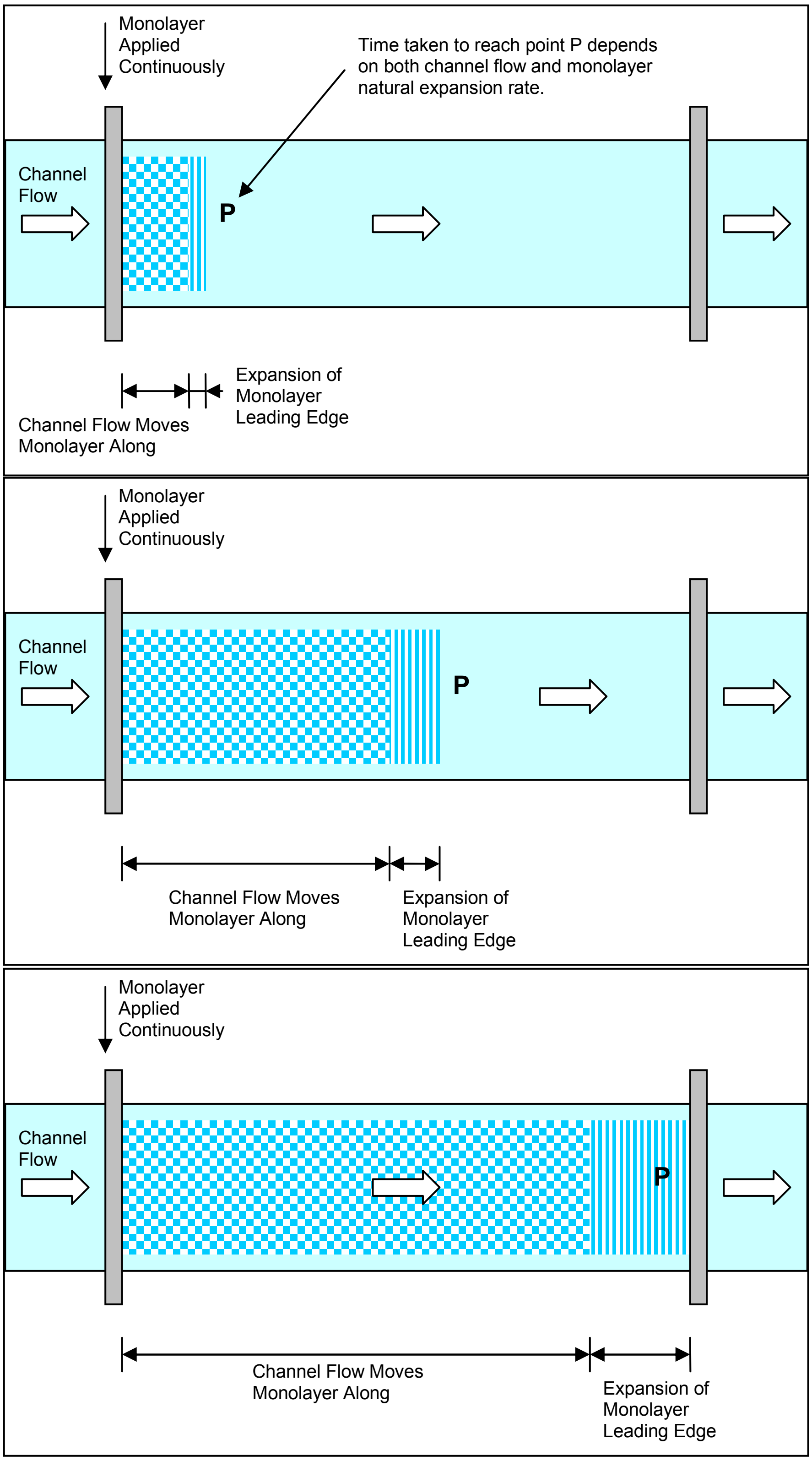


Figure 3.10 Application of monolayer – no wind

Example 3.1 Time taken for monolayer to travel a set distance with no wind

Example:

Channel type: Trunk
Average velocity = 0.18 m/s
Pool length = 1101 m

1. length between obstacles = 637 m (Table 3.3)

2. distance travelled by leading edge of monolayer between obstacles = 637 m
   637 m = x + y
   where: x = distance covered by channel water in time, t
   y = distance travelled by monolayer in time, t.

3. distance covered by channel water = 0.18t

4. distance covered by monolayer = $0.14 \times t^{0.74}$

5. therefore: $637 = 0.18t + 0.14 \times t^{0.74}$
   which solved[1] gives t = 3310 seconds or 55 minutes

It takes 55 minutes hours for the leading edge of the monolayer to travel from the application point at the first regulator to the obstacle (point "P") on an "average" trunk channel within the GMID when there is no wind.

[1] solved on a computer with all decimals remaining

Is this example, the section average velocity of the channel has been used, however velocity is not constant with depth varying from zero at the bottom of the channel to a maximum close to the channel surface. Figure 3.11 shows an example of the velocity distribution in an open channel

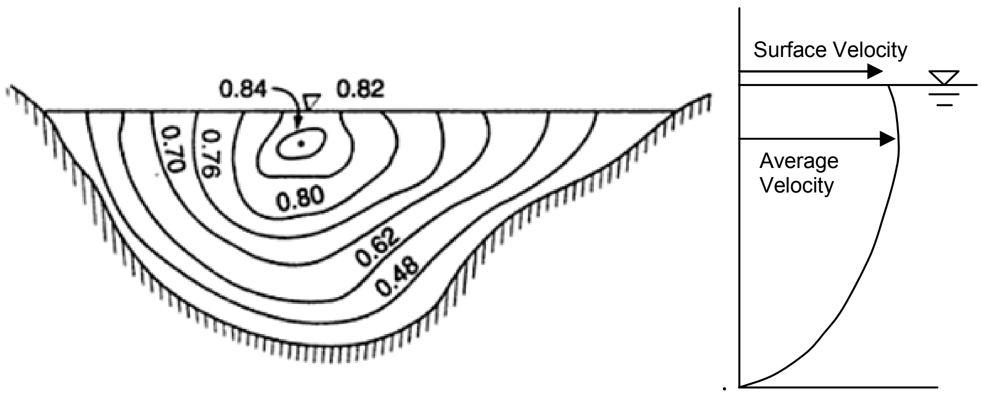


Figure 3.11 Surface Velocity vs Channel Section Velocity (diagram at left reproduced from Subramanya, 2009)

The monolayer material is located on the channel surface. The surface velocity of a channel is given as k times the section average velocity where k varies between 0.8 and 0.95 depending on the channel cross section. This would be critical if modelling the monolayer movement down a particular section of channel. However, channel velocities vary substantially over time and from channel to channel, therefore the section average velocity is considered representative of the conditions that will be experienced by monolayer materials applied to average channels. If the channel velocity was found to be one of the main factors in determining the potential cost and savings of applying monolayers to irrigation channels, than further refinement of the model would be required to convert section average velocity to surface velocity.

3.4.2 Monolayer Expansion – Wind between 0 and 3.2 km/hr

As discussed in section 2.8.7, Vines (1962) determined that the critical wind speed that would limit monolayer expansion and result in drift of the monolayer was 3.2 km/hr. For wind speeds between 0 and 3.2 km/hr, the monolayer is capable of expansion to a varying degree. For wind = 3.2 km/hr, the monolayer will not be able to expand against the wind, but the wind will not be able to displace the monolayer, therefore the monolayer will "hold its own" against the wind.

For a wind speed of 3.2 km/hr and opposite to the channel flow, the monolayer will be moved forward by channel flow alone (the wind limiting its ability to expand in the direction of channel flow). The series of diagrams shown in Figure 3.12 describe the monolayer movement pictorially. An example of the time taken for the monolayer to travel the distance between two points where wind is between 0 and 3.2 km/hr and opposite to the channel flow is provided in Example 3.2.

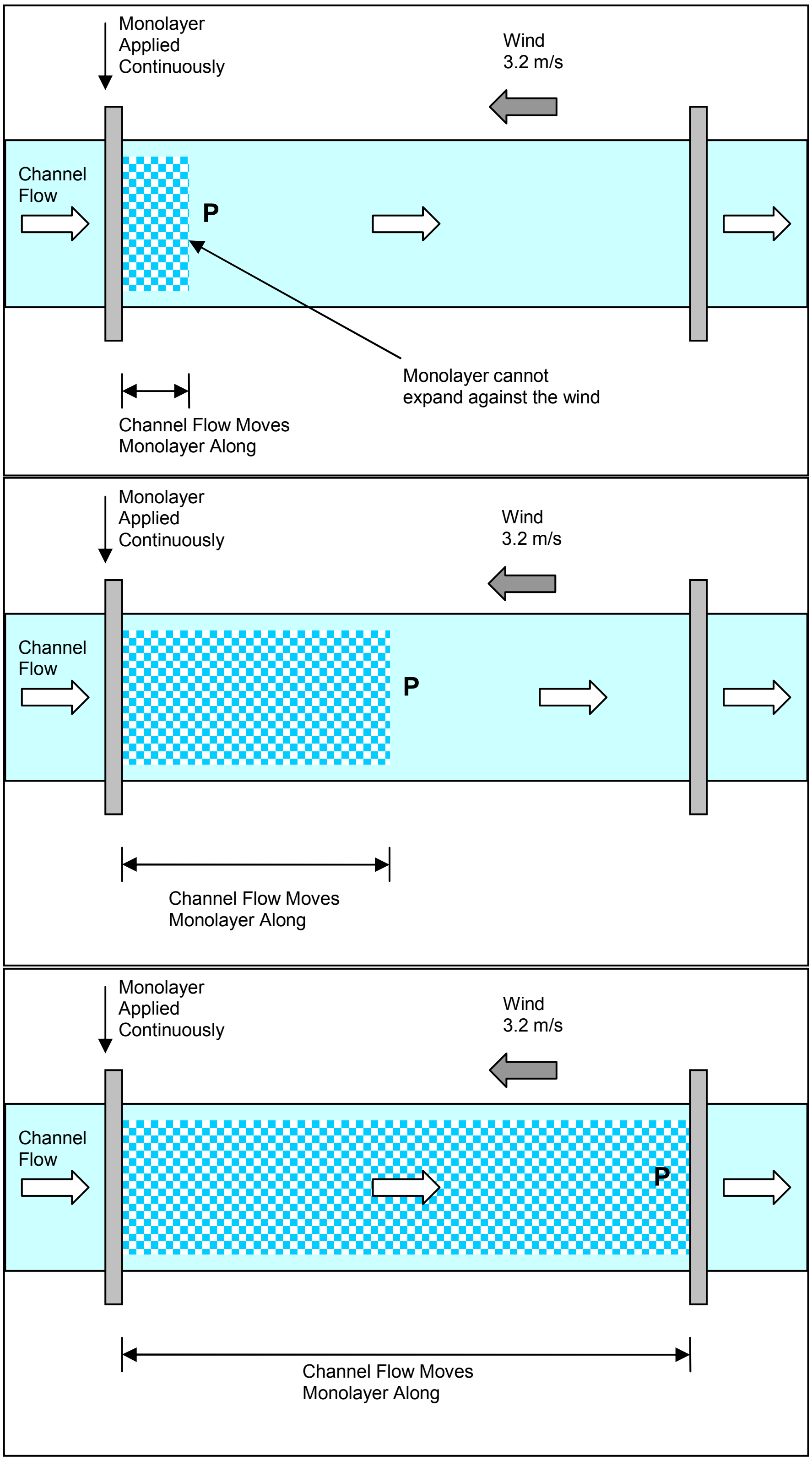


Figure 3.12 Application of monolayer – wind between 0 and 3.2 m/s

Example 3.2 Time taken for monolayer to travel a set distance where wind is between 0 and 3.2 m/s

Example:

Channel type: Trunk
Average velocity = 0.18 m/s
Pool length = 1101 m

1. length between <u>obstacles</u> = 637 m (Table 3.3)

2. distance travelled by leading edge of monolayer between obstacles = 637 m
   637 m = x + y
   where: x = distance covered by channel water in time, t
   y = distance travelled by monolayer in time, t.

3. distance covered by channel water = 0.18t

4. distance covered by monolayer = 0m because wind constrains expansion

5. therefore: 637 = 0.18t
   t = 637 / 0.18 = 3618 seconds or 1 hour[1]

It takes 1 hour for the leading edge of the monolayer to travel from the application point at the first regulator to the obstacle (point "P") on an "average" trunk channel within the GMID when wind is between 0 and 3.2 m/s.

[1] calculated on a computer with all decimals remaining

For a wind speed of 3.2 km/hr and parallel to the channel flow, the monolayer will be moved forward by channel flow and will also be able to expand in the direction of flow. In this instance the time taken for the monolayer to travel the distance between two points would be the same as provided in Example 3.1. For simplicity of calculations within the model it has therefore been assumed that the movement of monolayer for a wind speed of 3.2 km/hr is governed by channel flow alone, which greatly exceeds the impact of the wind allowing or limiting expansion as shown in these two examples.

3.4.3 Monolayer Expansion – Wind > 3.2 km/hr and parallel to channel direction

The results of the different studies generally concur on the rate of monolayer drift in the presence of wind being 0.03 x wind speed, which has been adopted within the model (refer section 2.8.8). Within an irrigation channel with wind parallel to the direction of channel flow, the wind and channel flow can be considered to be adding to the monolayer drift rate. The series of diagrams shown in Figure 3.13 describe the monolayer movement pictorially. An example of the time taken for the monolayer to travel the distance between two points where wind is between 3.2 and 25 km/hr and parallel to the channel is provided in Example 3.3.

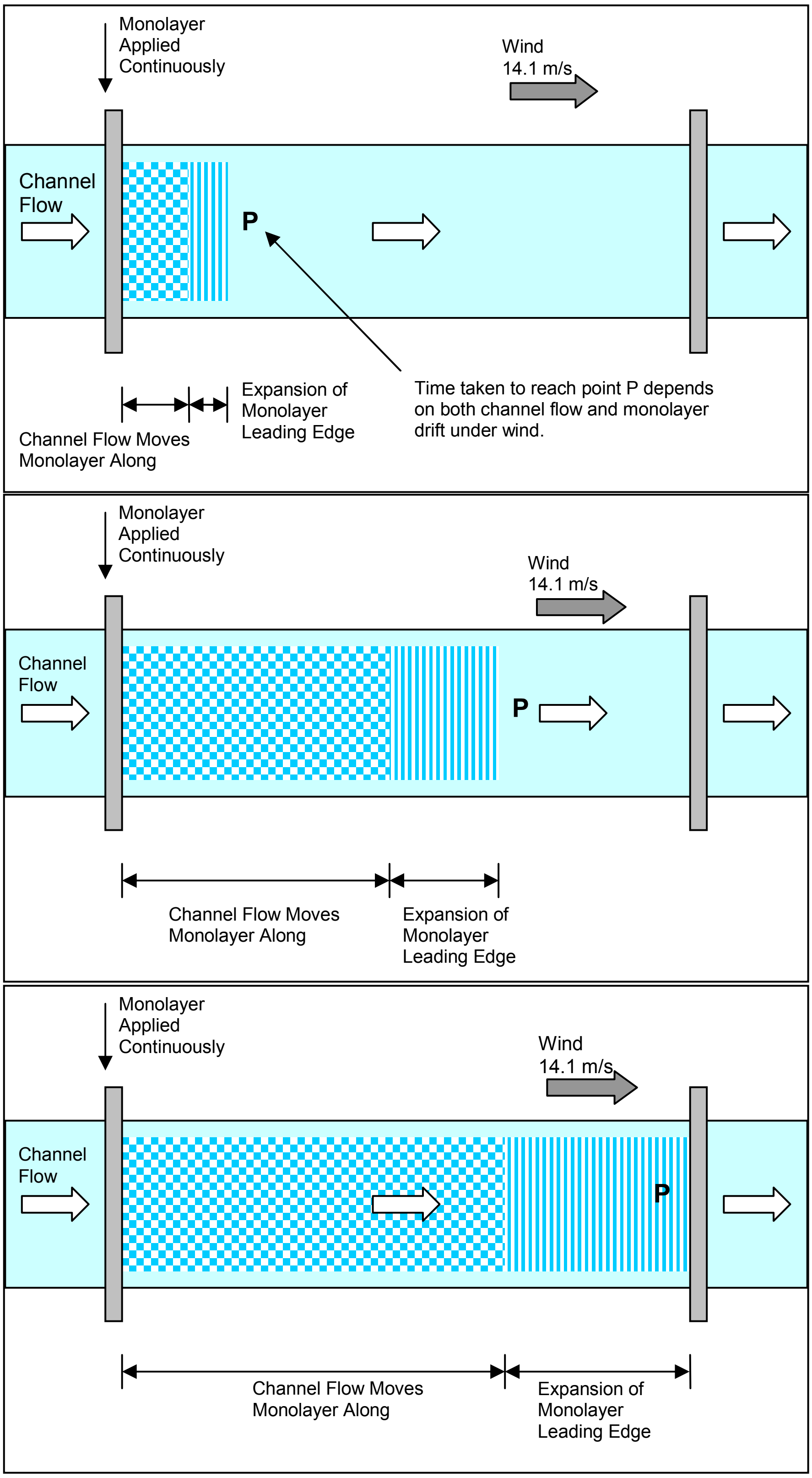


Figure 3.13 Application of monolayer – wind between 3.2 and 25 m/s and parallel to channel flow

Example 3.3 Time for monolayer to travel set distance where between 3.2 and 25 m/s and parallel to channel flow

Example:

Channel type: Trunk
Average velocity = 0.18 m/s
Pool length = 1101 m

1. length between obstacles = 637 m (Table 3.3)

2. distance travelled by leading edge of monolayer between obstacles = 637 m
   637 m = x + y
   where: x = distance covered by channel water in time, t
   y = distance travelled by monolayer in time, t.

3. distance covered by channel water = 0.18t

4. distance covered by monolayer = 0.03 x windspeed x t
   where windspeed is in m/s

5. therefore: 637 = 0.18t + 0.03 x windspeed x t

6. For a windspeed of 14.1 km/hr = 3.92 m/s
   which solved[1] gives t = 2169 seconds or 36 minutes

It takes 36 minutes for the leading edge of the monolayer to travel from the application point at the first regulator to the obstacle (point "P") on an "average" trunk channel within the GMID when the wind is 14.1 km/hr and parallel to the channel flow.

[1] solved on a computer with all decimals remaining

From Table 3.8 it can be seen that GMID channels experience wind between 3.2 and 25 km/hr that is parallel to the channel flow approximately 10-11% of the time.

Table 3.8 Channel characterisation – prevailing weather conditions

Yearly Wind Conditions[1]			
	Channel Type		
Wind Direction	*Carrier*	*Trunk*	*Spur*
Calm	5%	5%	5%
> 0 and < 3.2	6%	3%	3%
>= 3.2 and < 25 and parallel to channel direction	10%	10%	10%
>= 3.2 and < 25 other	67%	71%	71%
>= 25	11%	12%	10%

[1] Weighted average based on segment length

Irrigation Season Wind Conditions[1]			
	Channel Type		
Wind Speed (km/hr)	*Carrier*	*Trunk*	*Spur*
Calm	4%	3%	4%
> 0 and < 3.2	6%	2%	3%
>= 3.2 and < 25 and parallel to channel direction	10%	11%	11%
>= 3.2 and < 25 other	67%	70%	71%
>= 25	12%	14%	12%

[1] Weighted average based on segment length

3.4.4 Monolayer Expansion – Wind > 3.2 km/hr and opposite to channel direction

From section 3.4.3 it follows that within an irrigation channel with wind is opposite to the direction of channel flow, the wind and channel flow are acting against each other. Refer to the series of diagrams shown in Figure 3.14 which describe the monolayer movement pictorially. An example of the time take for the monolayer to travel the distance between two points where wind is between 3.2 and 25 km/hr and parallel to the channel but opposite to the channel flow is provided in Example 3.4.

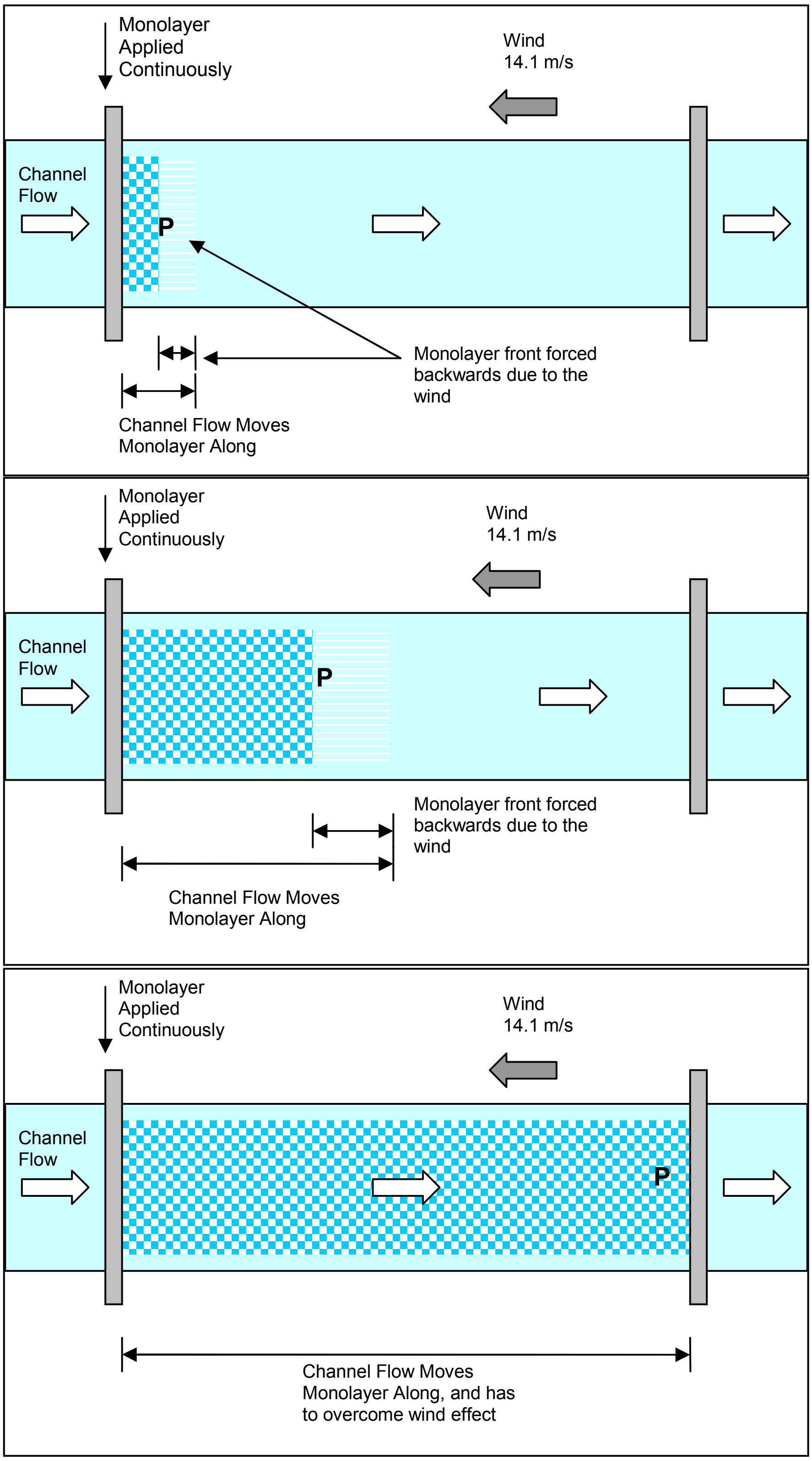


Figure 3.14 Application of monolayer – wind between 3.2 and 25 m/s and opposite to channel flow

Example 3.4 Time for monolayer to travel set distance where between 3.2 and 25 m/s and opposite to channel flow

Example:

Channel type: Trunk
Average velocity = 0.18 m/s
Pool length = 1101 m

1. length between <u>obstacles</u> = 637 m (Table 3.3)

2. distance travelled by leading edge of monolayer between obstacles = 637 m
   637 m = x - y
   where: x = distance covered by channel water in time, t
   y = distance travelled by monolayer in time, t.

3. distance covered by channel water = 0.18t

4. distance covered by monolayer = 0.03 x windspeed x t
   where windspeed is in m/s

5. therefore: 637 = 0.18t - 0.03 x windspeed x t

6. For a windspeed of 14.1 km/hr = 3.92 m/s
   which solved[1] gives t = 10888 seconds or 3 hours.

It takes 3 hours for the leading edge of the monolayer to travel from the application point at the first regulator to the obstacle (point "P") on an "average" trunk channel within the GMID when the wind is 14.1 km/hr and opposite to the direction of channel flow.

[1] solved on a computer with all decimals remaining

In this instance the wind acting against the channel flow has the effect of slowing the travel of the monolayer down the channel.

What happens when the movement of the monolayer under the influence of wind exceeds the channel flow? For example, for the average trunk channel, if the wind was 25 km/hr (6.9 m/s) then the monolayer drift rate is 0.03 x 6.9 = 0.21 m/s which is greater than the channel flow of 0.18 m/s. If the monolayer was applied downstream of the regulator, it theoretically would not be able to move forward due to the wind. If each monolayer application point has a single pump with outlets either side of the regulator or culvert, than depending on the prevailing wind conditions, the monolayer could be applied upstream or downstream of the obstacle. For this example, if the monolayer were applied upstream of the regulator, it would move up the channel at a rate of 0.21 – 0.18 = 0.03 m/s and cover the average length between obstacles (637 m) in a time of 21233 seconds or 5.9 hours. For the purpose of the model, it is assumed that application can occur upstream or downstream of the obstacle, which is the best case scenario for utilisation of the monolayer application points.

From Table 3.9 it can be seen that GMID channels experience wind between 3.2 and 25 km/hr that is opposite to the channel flow approximately 9-11% of the time.

Table 3.9 Channel characterisation – prevailing weather conditions

Yearly Wind Conditions[1]			
	Channel Type		
Wind Direction	*Carrier*	*Trunk*	*Spur*
Calm	5%	5%	5%
> 0 and < 3.2	6%	3%	3%
>= 3.2 and < 25 and parallel to channel direction	10%	10%	10%
>= 3.2 and < 25 and opposite to channel direction	11%	9%	9%
>= 3.2 and < 25 other	57%	61%	62%
>= 25	11%	12%	10%

[1] Weighted average based on segment length

Irrigation Season Wind Conditions[1]			
	Channel Type		
Wind Speed (km/hr)	*Carrier*	*Trunk*	*Spur*
Calm	4%	3%	4%
> 0 and < 3.2	6%	2%	3%
>= 3.2 and < 25 and parallel to channel direction	10%	11%	11%
>= 3.2 and < 25 and opposite to channel direction	10%	9%	9%
>= 3.2 and < 25 other	57%	61%	62%
>= 25	12%	14%	12%

[1] Weighted average based on segment length

3.4.5 Impact on monolayer of wind oblique to channel direction

There is inadequate data to determine the extent of compression a monolayer will experience from a wind that is oblique to the channel. It would depend to some extent on the effect of channel freeboard and surrounding vegetation which are variable across channels within the GMID.

The worst case scenario is that when the portion of wind perpendicular to the channel exceeds 3.2 km/hr the channel would require continued application of the monolayer from the upwind bank in order to maintain complete coverage. Applications points located on either side of the channel along its length would be highly impractical and cost prohibitive. For the purposes of modelling, an oblique wind is assumed to be at 45° to the channel. An oblique wind of 4.5 km/hr would give a perpendicular component of 3.2 km/hr. Therefore, it is assumed that oblique winds exceeding 4.5 km/hr render the monolayer ineffective and result in channel coverage of 0%. Oblique winds between 3.2 and 4.5 km/hr will result in full channel coverage (because the perpendicular component is less than 3.2 km/hr) and downwind movement calculated in the same manner as wind parallel (for that portion of the wind that is "parallel").

Extensive further testing is required to determine what level of protection channel banks provide and whether monolayers are capable of covering a portion of the channel for oblique winds exceeding 4.5 km/hr.

Computational fluid dynamics (CFD) enables modelling of fluids (liquid or air) in different situations. Investigations should be undertaken to determine whether CFD would enable modelling of the wind flow over the channel bank and the resulting turbulent flow over the water surface. The aim would be to establish a function that describes wind velocity at points on the water surface. Variables in the function would be approach wind speed, channel bank height, wind direction relative to the channel and channel width. The wind velocity pattern would be used to determine whether the surface layer will remain in place or be pushed off the surface leaving "holes" in the layer.

From Table 3.10 it can be seen that GMID channels experience wind between 3.2 and 25 km/hr that is oblique but in the same direction as the channel flow approximately 19-22% of the time and oblique and in the opposite direction to channel flow for a similar period of the time. In addition, approximately 28% of the wind between 3.2 and 25 km/hr is less than 4.5 km/hr (for which coverage under an oblique wind will be achieved).

Table 3.10 Channel characterisation – prevailing weather conditions

Yearly Wind Conditions[1]			
	Channel Type		
Wind Direction	*Carrier*	*Trunk*	*Spur*
Calm	5%	5%	5%
> 0 and < 3.2	6%	3%	3%
>= 3.2 and < 25 and parallel to channel direction	10%	10%	10%
>= 3.2 and < 25 and opposite to channel direction	11%	9%	9%
>= 3.2 and < 25 and oblique in direction of channel	19%	20%	21%
>= 3.2 and < 25 and oblique opposite to direction of channel flow	19%	21%	21%
>= 3.2 and < 25 other	18%	20%	20%
>= 25	11%	12%	10%

[1] Weighted average based on segment length

Irrigation Season Wind Conditions[1]			
	Channel Type		
Wind Speed (km/hr)	*Carrier*	*Trunk*	*Spur*
Calm	4%	3%	4%
> 0 and < 3.2	6%	2%	3%
>= 3.2 and < 25 and parallel to channel direction	10%	11%	11%
>= 3.2 and < 25 and opposite to channel direction	10%	9%	9%
>= 3.2 and < 25 and oblique in direction of channel	20%	21%	22%
>= 3.2 and < 25 and oblique opposite to direction of channel flow	19%	20%	20%
>= 3.2 and < 25 other	18%	20%	20%
>= 25	12%	14%	12%

[1] Weighted average based on segment length

3.4.6 Impact on monolayer of wind perpendicular to channel direction

At this stage there is not enough available information to know whether the monolayer is capable of forming a film on the channel when under the influence of a wind perpendicular to the channel direction, or whether it gets compressed against one or the other sides of the channel. As with oblique winds, it would depend to some extent on the effect of channel freeboard and surrounding vegetation.

The worst case scenario is that winds exceeding 3.2 km/hr and perpendicular to the channel would require continued application of the monolayer from the upwind bank in order to maintain complete coverage. For the purpose of the model, it is assumed that perpendicular winds exceeding 3.2 km/hr render the monolayer ineffective and result in channel coverage of 0%. Extensive further testing is required to determine what level of protection channel banks provide and whether monolayers are capable of covering a portion of the channel for perpendicular winds exceeding 3.2 km/hr.

From Table 3.11 it can be seen that GMID channels experience wind between 3.2 and 25 km/hr that is perpendicular to the channel flow approximately 18-20% of the time.

Table 3.11 Channel characterisation – prevailing weather conditions

Yearly Wind Conditions[1]			
	Channel Type		
Wind Direction	*Carrier*	*Trunk*	*Spur*
Calm	5%	5%	5%
> 0 and < 3.2	6%	3%	3%
>= 3.2 and < 25 and parallel to channel direction	10%	10%	10%
>= 3.2 and < 25 and opposite to channel direction	11%	9%	9%
>= 3.2 and < 25 and oblique in direction of channel	19%	20%	21%
>= 3.2 and < 25 and oblique opposite to direction of channel flow	19%	21%	21%
>= 3.2 and < 25 perpendicular	18%	20%	20%
>= 25	11%	12%	10%

[1] Weighted average based on segment length

Irrigation Season Wind Conditions[1]			
	Channel Type		
Wind Speed (km/hr)	*Carrier*	*Trunk*	*Spur*
Calm	4%	3%	4%
> 0 and < 3.2	6%	2%	3%
>= 3.2 and < 25 and parallel to channel direction	10%	11%	11%
>= 3.2 and < 25 and opposite to channel direction	10%	9%	9%
>= 3.2 and < 25 and oblique in direction of channel flow	20%	21%	22%
>= 3.2 and < 25 and oblique opposite to direction of channel flow	19%	20%	20%
>= 3.2 and < 25 perpendicular	18%	20%	20%
>= 25	12%	14%	12%

[1] Weighted average based on segment length

3.4.7 Wind > 25km/hr

Previous studies indicate that the critical wind speed at which monolayers are broken up, cannot reform and become ineffective is 25 km/hr. Therefore, for all winds greater than 25 km/hr, the model assumes the monolayer to be ineffective.

From Table 3.12 it can be seen that GMID channels experience winds greater than 25 km/hr approximately 10-14% of the time.

Table 3.12 Channel characterisation – prevailing weather conditions

Yearly Wind Conditions[1]			
	Channel Type		
Wind Direction	*Carrier*	*Trunk*	*Spur*
Calm	5%	5%	5%
> 0 and < 3.2	6%	3%	3%
>= 3.2 and < 25 and parallel to channel direction	10%	10%	10%
>= 3.2 and < 25 and opposite to channel direction	11%	9%	9%
>= 3.2 and < 25 and oblique in direction of channel flow	19%	20%	21%
>= 3.2 and < 25 and oblique opposite to direction of channel flow	19%	21%	21%
>= 3.2 and < 25 perpendicular	18%	20%	20%
>= 25	11%	12%	10%

[1] Weighted average based on segment length

Irrigation Season Wind Conditions[1]			
	Channel Type		
Wind Speed (km/hr)	*Carrier*	*Trunk*	*Spur*
Calm	4%	3%	4%
> 0 and < 3.2	6%	2%	3%
>= 3.2 and < 25 and parallel to channel direction	10%	11%	11%
>= 3.2 and < 25 and opposite to channel direction	10%	9%	9%
>= 3.2 and < 25 and oblique in direction of channel flow	20%	21%	22%
>= 3.2 and < 25 and oblique opposite to direction of channel flow	19%	20%	20%
>= 3.2 and < 25 perpendicular	18%	20%	20%
>= 25	12%	14%	12%

[1] Weighted average based on segment length

3.4.8 Summary of Wind Conditions Experienced by GMID Channels

The weighted average wind conditions experienced by GMID channels are shown pictorially in Figure 3.15.

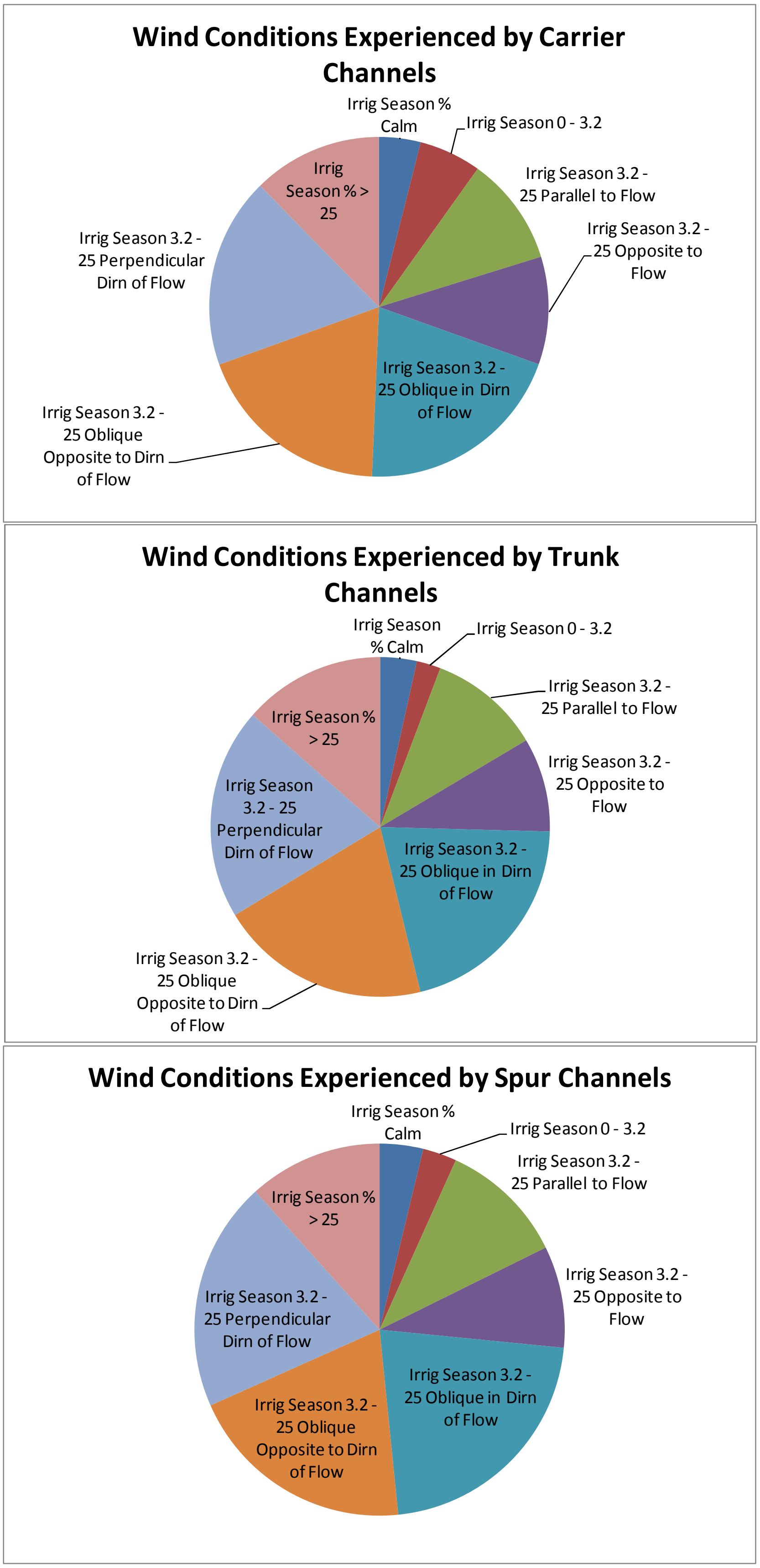


Figure 3.15 Weighted average wind conditions

3.4.9 Summary of Wind Categories Used for Model

The wind speed category of 3.2 km/hr to 25 km/hr is very large and comprises the majority of wind experienced by GMID channels. To model monolayer travel under these wind conditions, a wind speed of 14.1 km/hr can be adopted for this category (as done for Example 3.3 and Example 3.4), however to show a greater range of outcomes this wind category has been broken into smaller divisions. In addition, for wind oblique to the channel, it is necessary to consider that portion of wind that is below 4.5 km/hr which allows full coverage of the channel.

The spread of wind speed within the 3.2 km/hr to 25 km/hr category is shown in Table 3.13. The category of 3.2 km/hr to 4.5 km/hr has been chosen in order to calculate monolayer flow under oblique winds. The remaining categories have been chosen by splitting the range 4.5 km/hr to 25 km/hr into four even divisions. Applying the break-up of the 3.2 km/hr to 25 km/hr wind speed category to Table 3.12 results in the revised Table 3.14. Those instances where monolayers have been assumed to be ineffective are shown in grey.

Table 3.13 Further Refinement of Wind Speed Category ≥ 3.2 km/hr and < 25 km/hr

Model Wind Categories		
Wind Speed Category (km/hr)	*Adopted Speed for Calculations (km/hr)*	*% of Observations (>= 3.2 km/hr and < 25 km/hr)*
>= 3.2 and < 4.5	*3.9*	28%
>= 4.5 and < 9.6	*7.1*	35%
>= 9.6 and < 14.7	*12.2*	8%
>= 14.7 and < 19.8	*17.3*	21%
>= 19.8 and < 25	*22.4*	9%

Table 3.14 Channel characterisation – prevailing weather conditions

Yearly Wind Conditions[1]				
		Channel Type		
Wind Speed	*Wind Direction*	*Carrier*	*Trunk*	*Spur*
Calm		5%	5%	5%
> 0 and < 3.2		6%	3%	3%
>= 3.2 and < 4.5	*Parallel*	3%	3%	3%
	Opposite	3%	3%	3%
	Oblique Parallel	5%	6%	6%
	Oblique Opposite	5%	6%	6%
	Perpendicular	5%	6%	6%
>= 4.5 and < 9.6	*Parallel*	3%	4%	4%
	Opposite	4%	3%	3%
	Oblique Parallel	7%	7%	7%
	Oblique Opposite	7%	7%	7%
	Perpendicular	6%	7%	7%
>= 9.6 and < 14.7	*Parallel*	1%	1%	1%
	Opposite	1%	1%	1%
	Oblique Parallel	2%	2%	2%
	Oblique Opposite	2%	2%	2%
	Perpendicular	1%	2%	2%
>= 14.7 and < 19.8	*Parallel*	2%	2%	2%
	Opposite	2%	2%	2%
	Oblique Parallel	4%	4%	4%
	Oblique Opposite	4%	4%	4%
	Perpendicular	4%	4%	4%
>= 19.8 and < 25	*Parallel*	1%	1%	1%
	Opposite	1%	1%	1%
	Oblique Parallel	2%	2%	2%
	Oblique Opposite	2%	2%	2%
	Perpendicular	2%	2%	2%
>= 25		11%	12%	10%

Irrigation Season Wind Conditions[1]				
		Channel Type		
Wind Speed	*Wind Direction*	*Carrier*	*Trunk*	*Spur*
Calm		4%	3%	4%
> 0 and < 3.2		6%	2%	3%
>= 3.2 and < 4.5	*Parallel*	3%	3%	3%
	Opposite	3%	3%	2%
	Oblique Parallel	6%	6%	6%
	Oblique Opposite	5%	6%	6%
	Perpendicular	5%	6%	6%
>= 4.5 and < 9.6	*Parallel*	4%	4%	4%
	Opposite	4%	3%	3%
	Oblique Parallel	7%	7%	8%
	Oblique Opposite	7%	7%	7%
	Perpendicular	6%	7%	7%
>= 9.6 and < 14.7	*Parallel*	1%	1%	1%
	Opposite	1%	1%	1%
	Oblique Parallel	2%	2%	2%
	Oblique Opposite	1%	2%	2%
	Perpendicular	1%	2%	2%
>= 14.7 and < 19.8	*Parallel*	2%	2%	2%
	Opposite	2%	2%	2%
	Oblique Parallel	4%	4%	5%
	Oblique Opposite	4%	4%	4%
	Perpendicular	4%	4%	4%
>= 19.8 and < 25	*Parallel*	1%	1%	1%
	Opposite	1%	1%	1%
	Oblique Parallel	2%	2%	2%
	Oblique Opposite	2%	2%	2%
	Perpendicular	2%	2%	2%
>= 25		12%	14%	12%

1 Weighted average based on segment length.

3.4.10 Duration of Wind Events and the Possible Impacts

The time for which particular wind conditions exist are not going to align to the time required for the monolayer to travel the length of a pool. The monolayer is likely to experience different speeds and directions which will influence its effectiveness over the course of the day. Figure 3.16 shows actual wind conditions recorded at the G-MW field site (described in Section 2.9) over a sample 5 days during October 2010. Over this period generally low winds were experienced, with the longest continued wind event being approximately 3 m/s from the south-east for approximately 10 hours, although generally even when a wind direction was held for only a short period of time, the wind did not completely change direction, from say north to south. Within the model, the duration of wind events has not been considered, the data used being far too coarse. The concern is whether the monolayer will perform as modelled given that it will not be experiencing continuous wind conditions as it travels down the channel. Further extensive modelling will be required to determine the impact of fluctuating wind conditions. It may be necessary that software used to control the application of the monolayer is programmed not to respond to a wind change unless it lasts for greater than say an hour, which will result in potentially using a greater volume of product and lowering cost effectiveness.

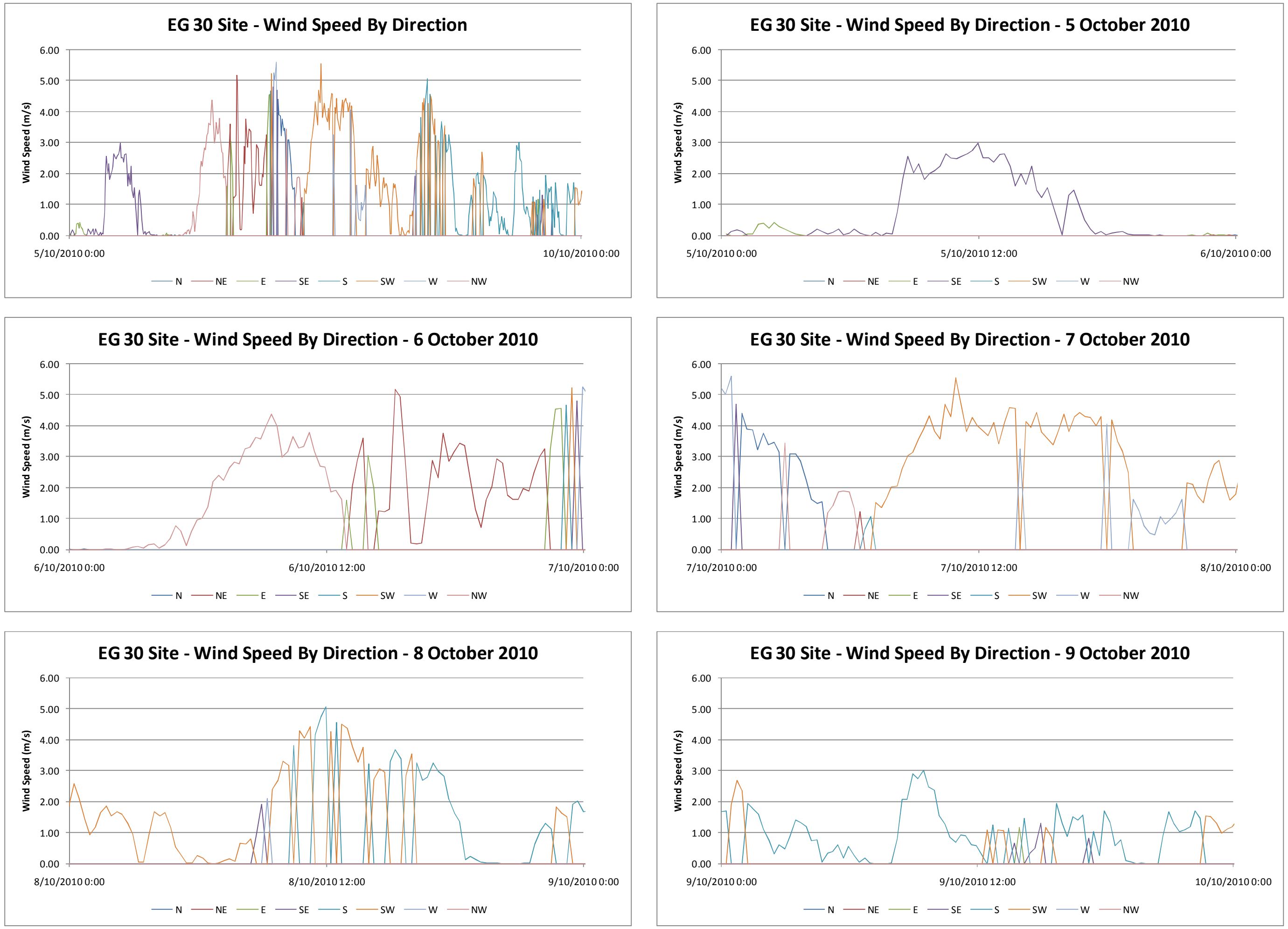


Figure 3.16 Wind Conditions Experienced at Field Trial Site

3.4.11 Channel Characterisation Process – Flow Chart

The overall process of characterising the channel system is detailed below in Figure 3.17.

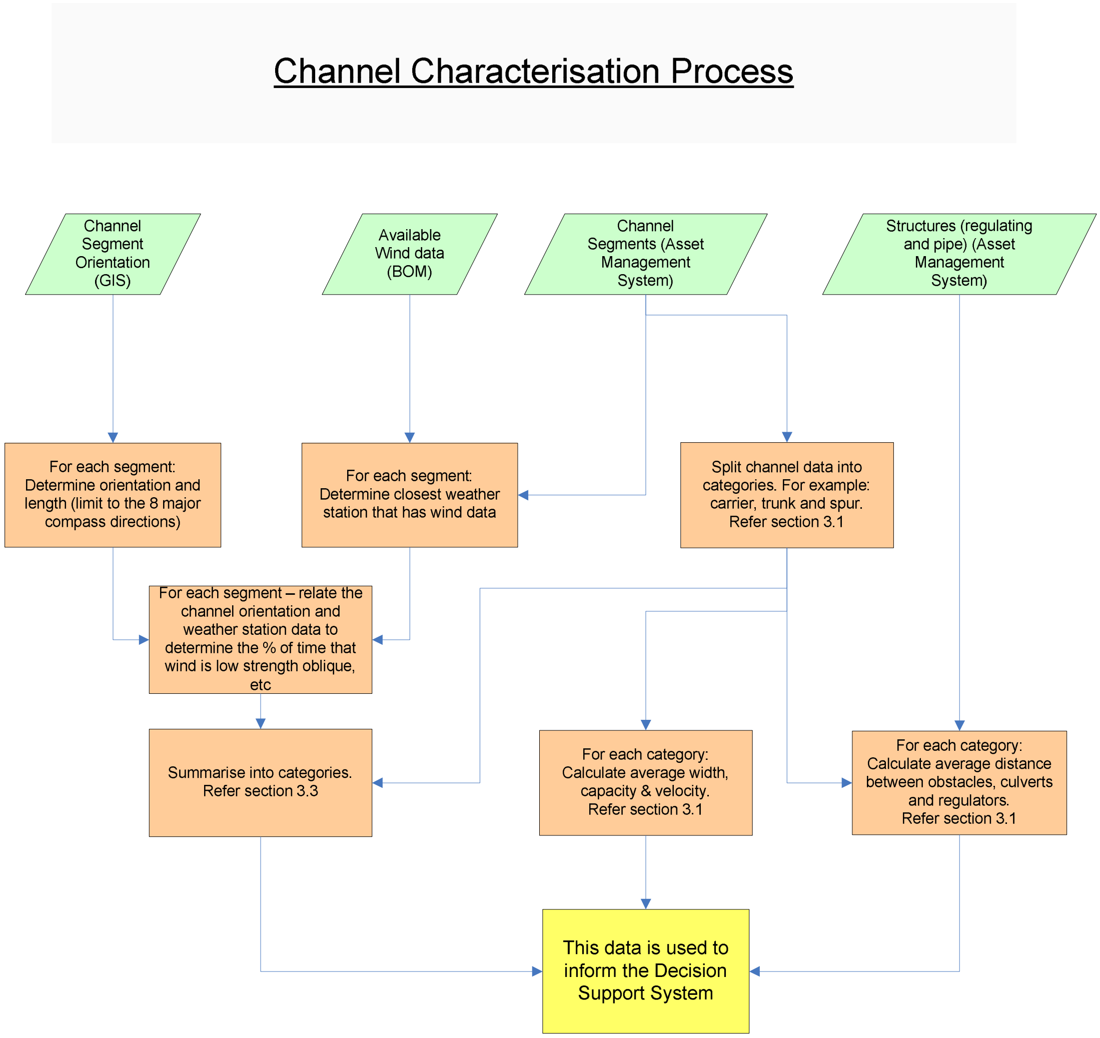


Figure 3.17 Channel Characterisation – Flow Chart

3.5 Impact of Obstacles

The two main types of channel obstacles that will potentially impact monolayer progress are overshot and submerged. As detailed previously, regulating structures (overshot) create turbulence which different monolayer products may or may not withstand, while monolayer products on the surface of the water are unlikely to pass a submerged pipe structure.

Very preliminary laboratory trials undertaken by G-MW indicate that ES300 is potentially capable of passing a regulator structure and reforming (refer Section 2.8.9). Aquatain indicates that it can survive turbulence, but no supporting data has been found. Results of studies into the ability of WaterSavr™ to survive turbulence are conflicting (refer Section 2.8.9). For the purpose of the model the following has been assumed:

- Evaporation suppressing products will generally not be capable of passing submerged pipe structures;
- ES300 will be capable of passing regulators (distance to reform not included); and
- Other products (Aquatain, WaterSavr™) will not be capable of passing regulating structures

Further testing will be required to determine whether the above assumptions are justified.

Therefore, the quantity of monolayer to be applied to the channel surface in a day is proportional to the time taken for the monolayer (being moved by the channel flow and wind) to traverse the length between obstacles to monolayer flow. In the case of ES300, this is the distance between pipe structures, while for the other products this is the distance between obstacles (both pipe structures and regulators).

It is assumed that the monolayer material is replaced in proportion to the amount of channel surfaces that pass in a day. An example of the amount of monolayer material required is provided in Example 3.5 for both WaterSavr and ES300. This example shows the impact of the monolayer resilience to obstacles on the amount of product required. At the end of the calculation, the quantity of product required per CH segment has been provided, in order to show a direct comparison between the products. If only point 5 was compared then the product quantities appear very similar and the resilience of ES300 to regulating structures is not obvious, however, when converted to a "pool" of the same length the quantity of product required is considerably higher for WaterSavr than for ES300.

Example 3.5 Amount of WaterSavr and ES300 material required – average trunk channel, no wind

Example: Product = WaterSavr Channel type: Trunk Average velocity = 0.18 m/s Pool length = 1101 m Weighted average pool width = 10.7m 1. length between <u>obstacles</u> = 637 m (Table 3.3) 2. time for monolayer to cover distance between obstacles = 55 minutes (example 3.1) 3. # times product needs to be applied in a day = 1440 / 51 = 26 times 4. Area monolayer applied to = 637 x 10.7 = 6840 m^2 5. Product quantity to be applied (in ha) = 6840 x 26 = 179 x 10^3 m^2 = 17.9 ha 6. Product quantity applied to "pool" = 17.9 x 1101 / 637 = 30.9 ha The quantity of WaterSavr product that needs to be applied to a trunk channel "pool" is equivalent to 30.1ha. [1] all calculations performed on a computer with all decimals remaining	**Example:** Product = ES300 Channel type: Trunk Average velocity = 0.18 m/s Pool length = 1101 m Weighted average pool width = 10.7m 1. length between <u>pipe structures</u> = 789 m (Table 3.3) 2. time for monolayer to cover distance between obstacles = 69 minutes (following example 3.1) 3. # times product needs to be applied in a day = 1440 / 51 = 21 times 4. Area monolayer applied to = 789 x 10.7 = 8472 m^2 5. Product quantity to be applied (in ha) = 8472 x 21 = 178 x 10^3 m^2 = 17.8 ha 6. Product quantity applied to "pool" = 17.8 x 1101 / 789 = 24.8 ha The quantity of ES300 product that needs to be applied to a trunk channel "pool" is equivalent to 24.8ha. [1] all calculations performed on a computer with all decimals remaining

If monolayer materials were capable of passing all structures, than the quantity of material applied would be dependent on the life of the product only.

Further examples of the difference in quantity of monolayer material required, depending on which structures are boundaries to the monolayer movement, is shown below in Table 3.15

Table 3.15 Monolayer applied to trunk channels – comparison of product quantity required depending on ability to reform after obstacles

Channel Details	
Channel Type	Trunk
Pool Length (m)-> CH Code	1101
Length (m) between Obstacles	637
Length (m) between Regulators	968
Length (m) between Culverts	789
Width (m)	10.7
Velocity (m/s)	0.2

Wind Speed Category (km/hr)	*Wind Direction Category*	*Wind Speed (km/hr)*	*Which side of Regulator to apply monolayer?*	*Time for Monolayer to cover distance (s)*	*# Channel Surfaces that go Past in a day*	*# Channel Surfaces to Apply Monolayer to (If monolayer stripped by regulators **and** culverts)*	*# Channel Surfaces to Apply Monolayer to (If monolayer stripped by culverts **only**)*	*# Channel Surfaces to Apply Monolayer to (If monolayer capable of passing **all** obstacles)*
= 0		0	Downstream	3,310	26.1	26.1	21.0	0.5
> 0 and < 3.2		1.6	Downstream	3,618	23.9	23.9	19.3	0.5
>= 4.5 and < 9.6	*Parallel*	7.1	Downstream	2,708	31.9	31.9	25.8	0.5
>= 4.5 and < 9.6	*Opposite*	7.1	Downstream	5,448	15.9	15.9	12.8	0.5
>= 4.5 and < 9.6	*Oblique Parallel*	7.1	Downstream	2,923	29.6	29.6	23.9	0.5
>= 4.5 and < 9.6	*Oblique Opposite*	7.1	Downstream	4,745	18.2	18.2	14.7	0.5
>= 4.5 and < 9.6	*Perpendicular*	7.1	Downstream	3,618	23.9	23.9	19.3	0.5

1 A two day product lifetime is assumed in the above table

It can be seen that if monolayer products can be created that can withstand the turbulence created by regulating structures, the quantity of monolayer required to be applied will be reduced resulting in a more economical water savings option.

If monolayers were capable of passing culvert structures also then far greater savings could be achieved. It is considered feasible that a pipe located on the channel surface could act as a siphon and move the monolayer from the upstream to the downstream side of the submerged pipe culvert utilising the drop in head across the culvert. This has not been investigated practically in the field, however the potential costs and savings associated with this outcome are presented in the results (Section 3.9) for ES300 only.

3.6 Efficacy of Monolayers in the Field

Based on Sections 2.8.2 and 2.8.8, the adopted average field efficiency for wind speeds of 25 km/hr or less is 30%, while the adopted efficiency for wind speeds greater than 25 km/hr is 1% (ie. Ineffective).

The efficiency of ES300 is potentially greater than that of WaterSavr™. The model can be adjusted if published results become available.

3.7 Additional Product Information

The Additional product information required to determine cost per ML water savings is given in Table 3.16.

Table 3.16 Product information adopted

Product	*Units*	*Quantity/ha*	*Cost/Unit*	*Product Lifetime (days)*	*Efficiency*	*Reapply after regulators*	*Reapply after culverts?*
Aquatain	litre	2	16	10	30%	TRUE	TRUE
ES300	litre	3.6	0.97	2	30%	FALSE	TRUE
ES300 - Assume passes culverts	litre	3.6	0.97	2	30%	FALSE	FALSE
WaterSavr	kg	0.35	10	2	30%	TRUE	TRUE

Product lifetime is only utilised to ensure that the product still remains after it has traversed the available pool length.

Costs for ES300 are not available at this stage, therefore it has been assumed within the model that the cost is equivalent to WaterSavr™. This will require refinement when further information becomes available.

Only product costs have currently been allowed for within the model. Application equipment and maintenance are costs that will be incurred, however it is expected that product usage will be the driving cost. This requires further investigation.

3.8 Model Description

The decision support system essentially consists of a series of tabs within an excel spreadsheet and is the implementation of the data and example calculations provided throughout Chapter 3.

For every unique combination of channel type, monolayer type, wind speed, wind direction (relative to channel direction) and evaporative rate category, the model calculates the quantity of product required in a day and the water savings that can be achieved in a day. This gives the cost of savings in $/ML. In addition the model looks at the percentage of the irrigation season for which the combination of variables exist and provides the total cost and total savings under those conditions.

The output is provided as a series of tables. The tables can be used in different ways:

- To determine the “best” set of conditions that produce the lowest cost ($/ML) of water savings (that is the most cost effective water savings);
- To determine all conditions that will produce savings below a particular $/ML threshold; and
- To determine total savings that could be made when particular conditions exist.

  The tables only need to be updated if the input variables change.

The overall process of using the decision support system is detailed in Figure 3.18.

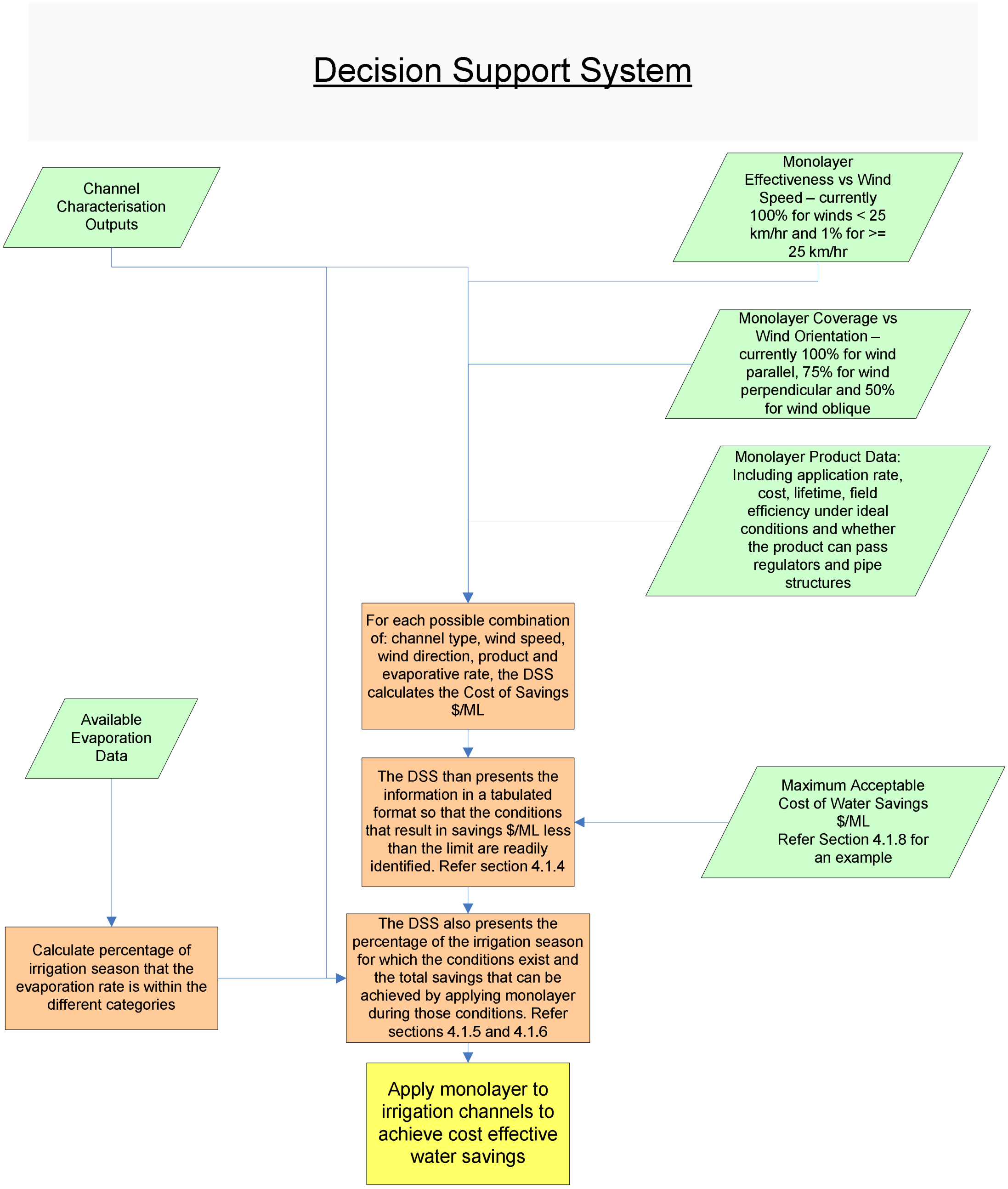


Figure 3.18 Decision Support System – Flow Chart

3.9 Conclusions

The main output of this research has been to establish a decision support system to predict the optimum times, environmental conditions and locations for G-MW to apply monolayers to irrigation channels.

Development of the decision support system has taken into consideration:

- Characterisation of the G-MW channel network;

- Collection of available evaporation & wind data;
- Analysis of monolayer coverage and movement under different wind conditions relative to channel flow and direction;
- Consideration of the effect of the duration of wind events;
- Impact of in-line channel obstacles; and
- Field trials reviewing product effectiveness, obstacle impacts and wind effects.

4 RESULTS & DISCUSSION

The main factor that will determine the future use of monolayers on irrigation channels is the cost per ML of water saved. The water savings projects and measures that provide the greatest water savings at the least cost are the projects that will be implemented first. As water becomes scarcer, the price that investors and users will be willing to pay for water savings will likely increase. Therefore, the two outputs of the decision tool modelling are: cost/ML under certain conditions and volume that can be saved over a year under those same conditions.

4.1 Example Results – Average Trunk Channel

This section details the results of applying monolayer product to the average trunk channel in detail.

4.1.1 Daily Monolayer Material Requirement

Table 4.1 provides the quantity of monolayer material (product) required in a day if particular conditions are maintained for that whole period. Note that the first line in the table reflects the results of Example 3.5.

Table 4.1 Trunk channels – product applied per day

Trunk Channels - Quantity of product required per day									
Wind Speed Category (km/hr)	*Wind Direction Category*	*Wind Speed (km/hr)*	*Which side of Regulator to apply monolayer?*	*Time for Monolayer to cover distance (s)*	*# Channel Surfaces that go Past in a day (**WaterSavr / Aquatain**)*	*Monolayer Surface Area Applied to Pool in Day (Ha)*	*# Channel Surfaces that go Past in a day (ES300)*	*Monolayer Surface Area Applied to Pool in Day (Ha)*	*# Channel Surfaces that go Past in a day (ES300 capable of passing culverts)*	*Monolayer Surface Area Applied to Pool in Day (Ha)*
= 0		0	Downstream	3,310	26.1	30.9	21.0	24.8	0.5	3.0
> 0 and < 3.2		1.6	Downstream	3,618	23.9	28.2	19.3	22.8	0.5	3.0
>= 3.2 and < 4.5	*Parallel*	3.9	Downstream	3,054	28.3	33.5	22.8	27.0	0.5	3.0
>= 3.2 and < 4.5	*Opposite*	3.9	Downstream	4,436	19.5	23.0	15.7	18.6	0.5	3.0
>= 3.2 and < 4.5	*Oblique Parallel*	3.9	Downstream	3,200	27.0	31.9	21.8	25.8	0.5	3.0
>= 3.2 and < 4.5	*Oblique Opposite*	3.9	Downstream	4,161	20.8	24.6	16.8	19.8	0.5	3.0
>= 3.2 and < 4.5	*Perpendicular*	3.9	Downstream	3,618	23.9	28.2	19.3	22.8	0.5	3.0
>= 4.5 and < 9.6	*Parallel*	7.1	Downstream	2,708	31.9	37.7	25.8	30.5	0.5	3.0
>= 4.5 and < 9.6	*Opposite*	7.1	Downstream	5,448	15.9	18.8	12.8	15.1	0.5	3.0
>= 4.5 and < 9.6	*Oblique Parallel*	7.1	Downstream	2,923	29.6	34.9	23.9	28.2	0.5	3.0
>= 4.5 and < 9.6	*Oblique Opposite*	7.1	Downstream	4,745	18.2	21.5	14.7	17.4	0.5	3.0
>= 4.5 and < 9.6	*Perpendicular*	7.1	Downstream	3,618	23.9	28.2	19.3	22.8	0.5	3.0
>= 9.6 and < 14.7	*Parallel*	12.2	Downstream	2,294	37.7	44.5	30.4	36.0	0.5	3.0
>= 9.6 and < 14.7	*Opposite*	12.2	Downstream	8,559	10.1	11.9	8.1	9.6	0.5	3.0
>= 9.6 and < 14.7	*Oblique Parallel*	12.2	Downstream	2,569	33.6	39.8	27.2	32.1	0.5	3.0
>= 9.6 and < 14.7	*Oblique Opposite*	12.2	Downstream	6,113	14.1	16.7	11.4	13.5	0.5	3.0
>= 9.6 and < 14.7	*Perpendicular*	12.2	Downstream	3,618	23.9	28.2	19.3	22.8	0.5	3.0
>= 14.7 and < 19.8	*Parallel*	17.3	Downstream	1,989	43.4	51.4	35.1	41.5	0.5	3.0
>= 14.7 and < 19.8	*Opposite*	17.3	Downstream	19,949	4.3	5.1	3.5	4.1	0.5	3.0
>= 14.7 and < 19.8	*Oblique Parallel*	17.3	Downstream	2,291	37.7	44.6	30.4	36.0	0.5	3.0
>= 14.7 and < 19.8	*Oblique Opposite*	17.3	Downstream	8,590	10.1	11.9	8.1	9.6	0.5	3.0
>= 14.7 and < 19.8	*Perpendicular*	17.3	Downstream	3,618	23.9	28.2	19.3	22.8	0.5	3.0
>= 19.8 and < 25	*Parallel*	22.4	Downstream	1,756	49.2	58.2	39.7	47.0	0.5	3.0
>= 19.8 and < 25	*Opposite*	22.4	Upstream	60,310	1.4	1.7	1.4	1.7	0.5	3.0
>= 19.8 and < 25	*Oblique Parallel*	22.4	Downstream	2,068	41.8	49.4	33.7	39.9	0.5	3.0
>= 19.8 and < 25	*Oblique Opposite*	22.4	Downstream	14,443	6.0	7.1	4.8	5.7	0.5	3.0
>= 19.8 and < 25	*Perpendicular*	22.4	Downstream	3,618	23.9	28.2	19.3	22.8	0.5	3.0
> 25		35	Downstream	3,618	23.9	28.2	19.3	22.8	0.5	3.0

4.1.2 Daily Savings Achieved

Table 4.2 provides an example of the savings achieved (ML/day) and the cost of achieving those savings ($/ML) for a couple of different wind situations on a trunk channel.

Table 4.2 Example of daily savings achieved and cost/ML

Channel Details	
Channel Type	Trunk
CH Code Length (m)	1101
Width (m)	10.7
CH Code Area (ha)	1.2

Product Applied	*Wind Speed Category*	*# Channel Surfaces to Apply Product to*	*Area to Apply Product to (ha)*	*Quantity Product Applied (kg or l)*	*Cost of Product*
WaterSavr	= 0	26.1	30.9	9	$ 91
WaterSavr	> 0 and < 3.2	23.9	28.2	8	$ 84
Aquatain	= 0	26.1	30.9	52	$ 835
Aquatain	> 0 and < 3.2	23.9	28.2	48	$ 764
ES300	= 0	21.0	24.8	75	$ 73
ES300	> 0 and < 3.2	19.3	22.8	69	$ 67
ES300 - Assume passes culverts	= 0	0.5	0.6	2	$ 2
ES300 - Assume passes culverts	> 0 and < 3.2	0.5	0.6	2	$ 2

				WaterSavr			*Aquatain*			*ES300*			*ES300 - Assume passes culverts*		
Wind Speed Category (km/hr)	*Evaporative Rate Category (mm/day)*	*Evaporative Rate Adopted (mm/day)*	*Losses (ML/day)*	*Effectiveness*	*Savings Achieved (ML/day)*	*Cost of Savings $/ML*	*Effectiveness*	*Savings Achieved (ML/day)*	*Cost of Savings $/ML*	*Effectiveness*	*Savings Achieved (ML/day)*	*Cost of Savings $/ML*	*Effectiveness*	*Savings Achieved (ML/day)*	*Cost of Savings $/ML*
= 0	>= 0 and < 3	1.5	0.02	30%	0.01	$17.2 K	30%	0.01	$157.0 K	30%	0.01	$13.8 K	30%	0.01	$0.3 K
= 0	>= 3 and < 6	4.5	0.05	30%	0.02	$5.7 K	30%	0.02	$52.3 K	30%	0.02	$4.6 K	30%	0.02	$0.1 K
= 0	>= 6 and < 9	7.5	0.09	30%	0.03	$3.4 K	30%	0.03	$31.4 K	30%	0.03	$2.8 K	30%	0.03	$0.1 K
= 0	>= 9	9	0.11	30%	0.03	$2.9 K	30%	0.03	$26.2 K	30%	0.03	$2.3 K	30%	0.03	$0.1 K
> 0 and < 3.2	>= 0 and < 3	1.5	0.02	30%	0.01	$15.7 K	30%	0.01	$143.6 K	30%	0.01	$12.7 K	30%	0.01	$0.3 K
> 0 and < 3.2	>= 3 and < 6	4.5	0.05	30%	0.02	$5.2 K	30%	0.02	$47.9 K	30%	0.02	$4.2 K	30%	0.02	$0.1 K
> 0 and < 3.2	>= 6 and < 9	7.5	0.09	30%	0.03	$3.1 K	30%	0.03	$28.7 K	30%	0.03	$2.5 K	30%	0.03	$0.1 K
> 0 and < 3.2	>= 9	9	0.11	30%	0.03	$2.6 K	30%	0.03	$23.9 K	30%	0.03	$2.1 K	30%	0.03	$0.1 K

<= $1000/ML

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

> $5000/ML

4.1.3 $/ML Cost of Water Savings Achieved – Average Wind Conditions

The results presented in Figure 4.1, Figure 4.2, Figure 4.3 and Figure 4.4 show the cost per ML water savings for the average trunk channel, noting they average the $/ML savings for the different wind directions for the same wind speed. Note that the savings achieved are not in perpetuity, they are for a single irrigation season.

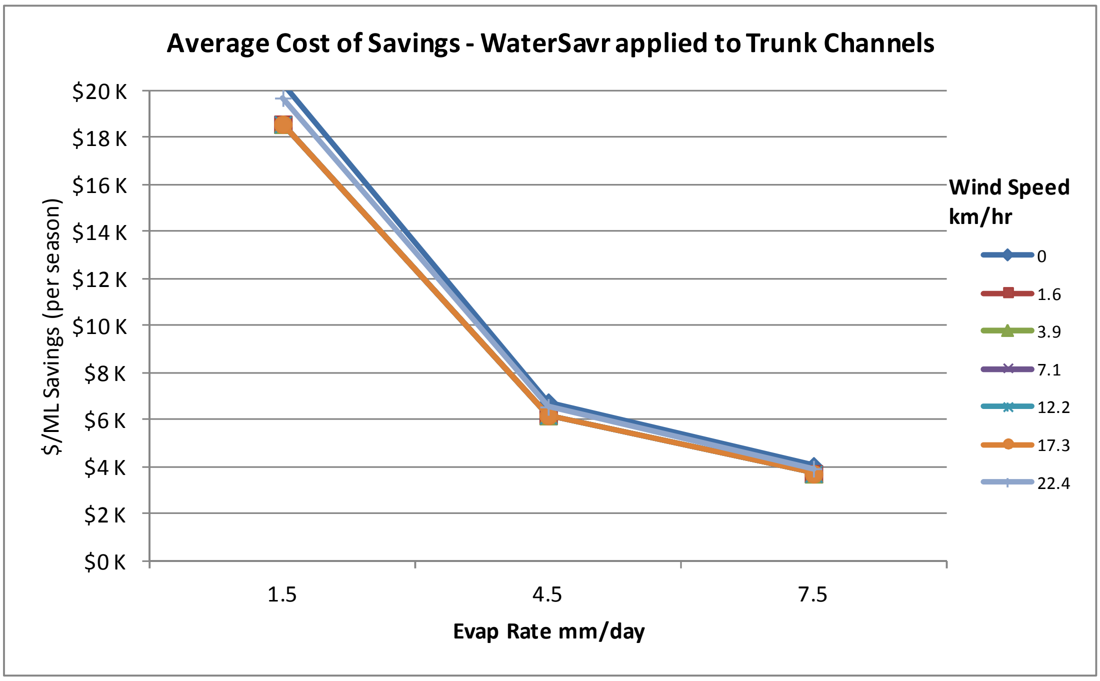


Figure 4.1 Cost per ML savings - WaterSavr™

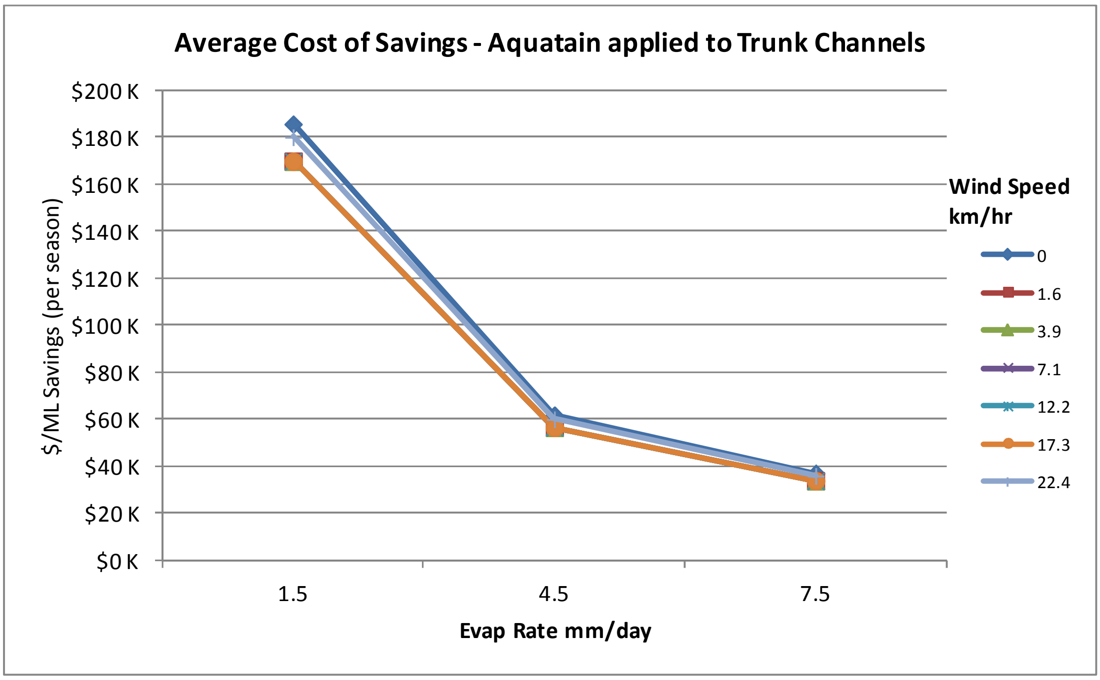


Figure 4.2 Cost per ML savings - Aquatain

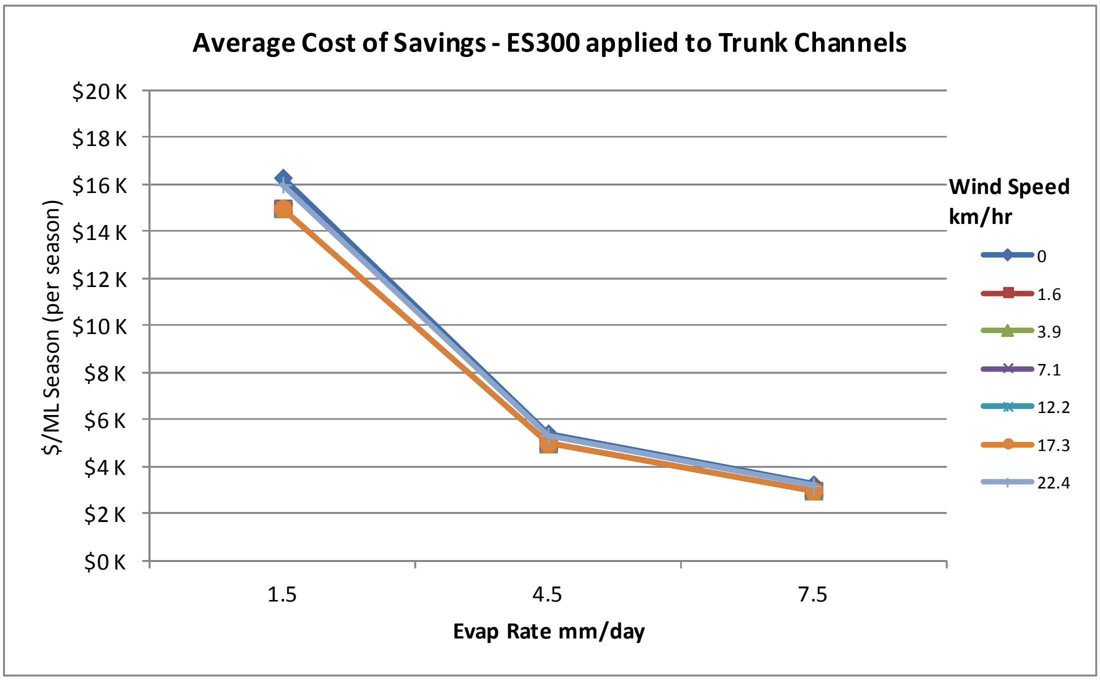


Figure 4.3 Cost per ML savings – ES300

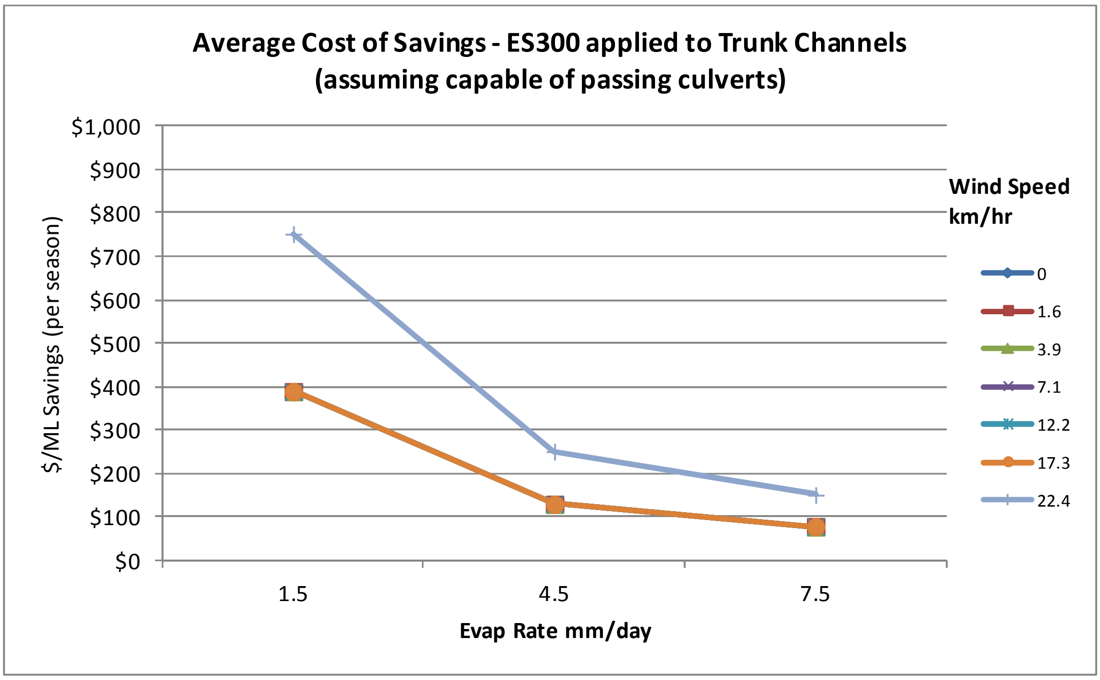


Figure 4.4 Cost per ML savings – ES300 – Assuming Capable of Passing Culverts

The results show that the best $/ML savings are achieved when the evaporation rate is highest (assuming a consistent effectiveness of 30% regardless of temperature).

In this analysis it has been assumed that until test results become available Aquatain has no better ability to pass a regulator or culvert than does WaterSavr™. The cost of the Aquatain product is much higher than WaterSavr™, and therefore the cost of achieving savings is also much higher (a factor of 10 higher considering the graphs above). While Aquatain has a much greater field life than WaterSavr™ or ES300, this advantage will not have the opportunity to be realised when applied to irrigation channels because residence time on the pool surface is typically less than one day.

The cost of ES300 has been assumed to be equivalent to WaterSavr™ (because no further information is yet available on this new product). Because ES300 appears to be capable of passing regulating structures, the amount of product applied is reduced and therefore the cost of savings is also reduced. If a means of getting ES300 to pass submerged pipe structures can be achieved, the $/ML savings will be further reduced.

4.1.4 $/ML Cost of Achieving Water Savings – Detailed Wind Conditions

The previous analysis averaged the $/ML water savings for the different wind directions, however, particular wind conditions may result in more economical savings. Table 4.3, Table 4.4, Table 4.5 and Table 4.6 detail the cost of savings under the different wind conditions. Note: to provide a visual means of seeing the results quickly, the savings have been colour coded into <$1000/ML (green), between $1000 and $5000 ML/year (yellow) and greater than $5000 ML/year (red). Note: where the monolayer has been rendered ineffective due to wind speed and direction, no savings have been shown.

Table 4.3 Cost of Savings ($/ML) - WaterSavr™

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

Table 4.4 Cost of Savings ($/ML) - Aquatain

Product	Aquatain
Channel Type	Trunk
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$185.6 K						$185.6 K
1.6	$169.8 K						$169.8 K
3.9		$201.2 K	$138.5 K	$192.0 K	$147.7 K	N/A	$169.8 K
7.1		$226.9 K	$112.8 K	N/A	N/A	N/A	$169.8 K
12.2		$267.9 K	$71.8 K	N/A	N/A	N/A	$169.8 K
17.3		$308.9 K	$30.8 K	N/A	N/A	N/A	$169.8 K
22.4		$349.9 K	$10.2 K	N/A	N/A	N/A	$180.0 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$61.9 K						$61.9 K
1.6	$56.6 K						$56.6 K
3.9		$67.1 K	$46.2 K	$64.0 K	$49.2 K	N/A	$56.6 K
7.1		$75.6 K	$37.6 K	N/A	N/A	N/A	$56.6 K
12.2		$89.3 K	$23.9 K	N/A	N/A	N/A	$56.6 K
17.3		$103.0 K	$10.3 K	N/A	N/A	N/A	$56.6 K
22.4		$116.6 K	$3.4 K	N/A	N/A	N/A	$60.0 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$37.1 K						$37.1 K
1.6	$34.0 K						$34.0 K
3.9		$40.2 K	$27.7 K	$38.4 K	$29.5 K	N/A	$34.0 K
7.1		$45.4 K	$22.6 K	N/A	N/A	N/A	$34.0 K
12.2		$53.6 K	$14.4 K	N/A	N/A	N/A	$34.0 K
17.3		$61.8 K	$6.2 K	N/A	N/A	N/A	$34.0 K
22.4		$70.0 K	$2.0 K	N/A	N/A	N/A	$36.0 K
35	N/A						

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

Table 4.5 Cost of Savings ($/ML) - ES300

Product	ES300
Channel Type	Trunk
Evaporative Rate	1.5

Wind Speed	Wind Direction Category All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$16.3 K						$16.3 K
1.6	$15.0 K						$15.0 K
3.9		$17.8 K	$12.2 K	$17.0 K	$13.0 K	N/A	$15.0 K
7.1		$20.0 K	$10.0 K	N/A	N/A	N/A	$15.0 K
12.2		$23.7 K	$6.3 K	N/A	N/A	N/A	$15.0 K
17.3		$27.3 K	$2.7 K	N/A	N/A	N/A	$15.0 K
22.4		$30.9 K	$1.1 K	N/A	N/A	N/A	$16.0 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	Wind Direction Category All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$5.4 K						$5.4 K
1.6	$5.0 K						$5.0 K
3.9		$5.9 K	$4.1 K	$5.7 K	$4.3 K	N/A	$5.0 K
7.1		$6.7 K	$3.3 K	N/A	N/A	N/A	$5.0 K
12.2		$7.9 K	$2.1 K	N/A	N/A	N/A	$5.0 K
17.3		$9.1 K	$0.9 K	N/A	N/A	N/A	$5.0 K
22.4		$10.3 K	$0.4 K	N/A	N/A	N/A	$5.3 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	Wind Direction Category All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$3.3 K						$3.3 K
1.6	$3.0 K						$3.0 K
3.9		$3.6 K	$2.4 K	$3.4 K	$2.6 K	N/A	$3.0 K
7.1		$4.0 K	$2.0 K	N/A	N/A	N/A	$3.0 K
12.2		$4.7 K	$1.3 K	N/A	N/A	N/A	$3.0 K
17.3		$5.5 K	$0.5 K	N/A	N/A	N/A	$3.0 K
22.4		$6.2 K	$0.2 K	N/A	N/A	N/A	$3.2 K
35	N/A						

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

Table 4.6 Cost of Savings ($/ML) - ES300 - Assuming Capable of Passing Culverts

Product	ES300 - Assume passes culverts
Channel Type	Trunk
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
12.2		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
17.3		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
22.4		$0.4 K	$1.1 K	N/A	N/A	N/A	$0.8 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.4 K	N/A	N/A	N/A	$0.3 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.2 K	N/A	N/A	N/A	$0.2 K
35	N/A						

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

Evaporation saved depends on the effectiveness of the product and the coverage achieved. The cost of the savings depends on the amount of product applied. Where the product is rendered ineffective if it hits an obstruction (culvert or regulator in the case of WaterSavr™), then the conditions that result in the least amount of product applied are when the channel flow and wind are opposing (therefore slowing the progress of the monolayer down the channel). The tables above indicate that the best value savings are achieved when wind speed is high (but not so high as to destroy the monolayer) and the wind direction is opposing the channel flow. To take advantage of the cost effective water savings under favourable wind conditions, dispensing equipment can be designed to apply material to suit the conditions of wind speed and direction.

Where the product is capable of reforming after an obstacle (and does not need to be reapplied) the most economical savings are achieved where the wind is not compressing the product to one bank or the other (ie, not oblique or perpendicular).

This shows how critical the capability of the monolayer to reform after an obstacle is to the cost effectiveness, due to not having to reapply the monolayer after each obstacle, thereby saving in product cost plus capital and maintenance and taking advantage of the field life of the product.

4.1.5 Period of Time for Which Particular Environmental Conditions Exist

Considering the percentage of the year for which the particular wind conditions are experienced and for which the particular evaporation category is experienced, the tables within Section 4.1.4 can be presented in an alternative format which shows the percentage of the irrigation season for which the particular $/ML savings occur.

The percentage of the irrigation season for which particular combinations of wind speed, wind direction and evaporative rate exist (regardless of product applied) are presented in Table 4.7.

Table 4.7 Percentage of Irrigation Season that Wind & Evaporation rate conditions exist

Product	WaterSavr						
Channel Type	Trunk						
Evaporative Rate	1.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	1.2%						1.2%
1.6	0.8%						0.8%
3.9		1.1%	0.9%	2.1%	2.0%	2.0%	8.0%
7.1		1.3%	1.1%	2.5%	2.5%	2.5%	9.8%
12.2		0.3%	0.2%	0.6%	0.6%	0.6%	2.2%
17.3		0.8%	0.7%	1.5%	1.5%	1.5%	5.9%
22.4		0.3%	0.3%	0.6%	0.6%	0.6%	2.5%
35	4.8%						4.8%
Total	6.8%	3.8%	3.1%	7.3%	7.1%	7.1%	35.3%

Evaporative Rate	4.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	1.3%						1.3%
1.6	0.9%						0.9%
3.9		1.1%	1.0%	2.2%	2.1%	2.1%	8.6%
7.1		1.4%	1.2%	2.7%	2.6%	2.6%	10.6%
12.2		0.3%	0.3%	0.6%	0.6%	0.6%	2.4%
17.3		0.8%	0.7%	1.6%	1.6%	1.6%	6.3%
22.4		0.4%	0.3%	0.7%	0.7%	0.7%	2.7%
35	5.1%						5.1%
Total	7.3%	4.1%	3.4%	7.9%	7.6%	7.6%	37.9%

Evaporative Rate	7.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	0.9%						0.9%
1.6	0.6%						0.6%
3.9		0.8%	0.7%	1.6%	1.5%	1.5%	6.1%
7.1		1.0%	0.8%	1.9%	1.9%	1.9%	7.5%
12.2		0.2%	0.2%	0.4%	0.4%	0.4%	1.7%
17.3		0.6%	0.5%	1.2%	1.1%	1.1%	4.5%
22.4		0.3%	0.2%	0.5%	0.5%	0.5%	1.9%
35	3.6%						3.6%
Total	5.2%	2.9%	2.4%	5.6%	5.4%	5.4%	26.8%

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

For example, for 8.6% of the irrigation season, the wind is between 3.2 and 4.5 km/hr (an average of 3.9 km/hr) and the evaporative rate is between 3 and 6 mm/day (average of 4.5 mm/day).

4.1.6 Total Volume of Saving that Can be Achieved

The total volume of savings that can be achieved under the different wind and evaporative conditions are presented in Table 4.8 assuming that monolayer was used over the irrigation season during those periods. Note that the volumes of savings that can be achieved are the same regardless of product because the model assumes 30% effectiveness for all products.

Table 4.8 Total volume water savings (ML)

Product	WaterSavr
Channel Type	Trunk
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	42						42
1.6	28						28
3.9		37	31	71	69	-	208
7.1		45	38	-	-	-	83
12.2		10	9	-	-	-	19
17.3		27	23	-	-	-	50
22.4		11	10	-	-	-	21
35	-						-
Total	70	131	109	71	69	-	450

Product	WaterSavr
Channel Type	Trunk
Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	137						137
1.6	90						90
3.9		119	99	230	222	-	669
7.1		146	121	-	-	-	267
12.2		33	28	-	-	-	61
17.3		88	73	-	-	-	160
22.4		37	31	-	-	-	68
35	-						-
Total	226	422	351	230	222	-	1,452

Product	WaterSavr
Channel Type	Trunk
Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	161						161
1.6	106						106
3.9		140	116	271	262	-	789
7.1		172	143	-	-	-	315
12.2		39	32	-	-	-	72
17.3		103	86	-	-	-	189
22.4		43	36	-	-	-	80
35	-						-
Total	267	497	413	271	262	-	1,710

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

For example, if monolayer was applied to all trunk channels in the GMID when the wind is between 3.2 and 4.5 km/hr (an average of 3.9 km/hr) and the evaporative rate is between 3 and 6 mm/day (average of 4.5 mm/day), the total volume of savings that could be achieved is 669 ML assuming 30% product effectiveness, and only applying the product when wind speed and direction are favourable.

The total water savings that could be achieved by applying monolayer to all trunk channels during the entire irrigation season is 3,612 ML. The total savings that could be achieved by applying monolayer to all carrier channels during the entire irrigation season is 1,615 ML (not shown in tables above), making a total savings of 5,227 ML for these backbone channels. Referring to Table 2.1, the baseline evaporation loss on backbone channels within the GMID is 44,375 ML. Therefore the effectiveness of applying monolayer to all backbone channels is 5,227/44,375 = 12%. This is considerably less than the 30% average field efficiency of monolayer products, which is logical given that during particular wind conditions, monolayers will be ineffective. Potentially, the savings achieved are understated, because the percentage surface area covered when the wind is oblique or perpendicular needs further investigation and refinement.

4.1.7 Total Cost of Achieving Savings

The total cost of achieving water savings is presented in Table 4.9, Table 4.10, Table 4.11 and Table 4.12. The total cost is dependent of the behaviour of the particular monolayer product.

Table 4.9 Total cost of achieving savings on Average Trunk Channels - WaterSavr™

Product	WaterSavr
Channel Type	Trunk
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	$861.2 K						$861.2 K
1.6	$516.5 K						$516.5 K
3.9		$810.0 K	$463.6 K	$1,497.2 K	$1,115.2 K	$0.0 K	$3,886.0 K
7.1		$1,123.6 K	$464.3 K	$0.0 K	$0.0 K	$0.0 K	$1,587.9 K
12.2		$301.5 K	$67.2 K	$0.0 K	$0.0 K	$0.0 K	$368.7 K
17.3		$917.5 K	$76.1 K	$0.0 K	$0.0 K	$0.0 K	$993.5 K
22.4		$438.1 K	$10.6 K	$0.0 K	$0.0 K	$0.0 K	$448.7 K
35	$0.0 K						$0.0 K
Total	$1,377.7 K	$3,590.6 K	$1,081.8 K	$1,497.2 K	$1,115.2 K	$0.0 K	$8,662.5 K

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	$925.0 K						$925.0 K
1.6	$554.7 K						$554.7 K
3.9		$870.0 K	$498.0 K	$1,608.1 K	$1,197.8 K	$0.0 K	$4,173.9 K
7.1		$1,206.8 K	$498.7 K	$0.0 K	$0.0 K	$0.0 K	$1,705.5 K
12.2		$323.9 K	$72.2 K	$0.0 K	$0.0 K	$0.0 K	$396.0 K
17.3		$985.4 K	$81.7 K	$0.0 K	$0.0 K	$0.0 K	$1,067.1 K
22.4		$470.5 K	$11.4 K	$0.0 K	$0.0 K	$0.0 K	$481.9 K
35	$0.0 K						$0.0 K
Total	$1,479.7 K	$3,856.6 K	$1,162.0 K	$1,608.1 K	$1,197.8 K	$0.0 K	$9,304.2 K

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	$653.9 K						$653.9 K
1.6	$392.1 K						$392.1 K
3.9		$615.0 K	$352.0 K	$1,136.8 K	$846.7 K	$0.0 K	$2,950.5 K
7.1		$853.1 K	$352.6 K	$0.0 K	$0.0 K	$0.0 K	$1,205.6 K
12.2		$228.9 K	$51.0 K	$0.0 K	$0.0 K	$0.0 K	$279.9 K
17.3		$696.6 K	$57.8 K	$0.0 K	$0.0 K	$0.0 K	$754.4 K
22.4		$332.6 K	$8.1 K	$0.0 K	$0.0 K	$0.0 K	$340.7 K
35	$0.0 K						$0.0 K
Total	$1,046.0 K	$2,726.2 K	$821.4 K	$1,136.8 K	$846.7 K	$0.0 K	$6,577.1 K

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

The total cost of applying WaterSavr™ to all trunk channels during the irrigation season (and achieving 3,612 ML savings) is $24.5M or $6,800/ML/yr.

Table 4.10 Total cost of achieving savings on Average Trunk Channels – Aquatain

Product	Aquatain
Channel Type	Trunk
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	$7,874.2 K						$7,874.2 K
1.6	$4,721.8 K						$4,721.8 K
3.9		$7,405.5 K	$4,238.8 K	$13,688.8 K	$10,196.3 K	$0.0 K	$35,529.3 K
7.1		$10,272.6 K	$4,245.4 K	$0.0 K	$0.0 K	$0.0 K	$14,518.0 K
12.2		$2,756.7 K	$614.2 K	$0.0 K	$0.0 K	$0.0 K	$3,371.0 K
17.3		$8,388.4 K	$695.5 K	$0.0 K	$0.0 K	$0.0 K	$9,083.9 K
22.4		$4,005.2 K	$97.0 K	$0.0 K	$0.0 K	$0.0 K	$4,102.2 K
35	$0.0 K						$0.0 K
Total	$12,596.1 K	$32,828.4 K	$9,890.9 K	$13,688.8 K	$10,196.3 K	$0.0 K	$79,200.3 K

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	$8,457.5 K						$8,457.5 K
1.6	$5,071.6 K						$5,071.6 K
3.9		$7,954.0 K	$4,552.8 K	$14,702.7 K	$10,951.5 K	$0.0 K	$38,161.1 K
7.1		$11,033.5 K	$4,559.8 K	$0.0 K	$0.0 K	$0.0 K	$15,593.4 K
12.2		$2,960.9 K	$659.7 K	$0.0 K	$0.0 K	$0.0 K	$3,620.7 K
17.3		$9,009.7 K	$747.0 K	$0.0 K	$0.0 K	$0.0 K	$9,756.7 K
22.4		$4,301.9 K	$104.2 K	$0.0 K	$0.0 K	$0.0 K	$4,406.0 K
35	$0.0 K						$0.0 K
Total	$13,529.1 K	$35,260.1 K	$10,623.6 K	$14,702.7 K	$10,951.5 K	$0.0 K	$85,067.0 K

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	$5,978.6 K						$5,978.6 K
1.6	$3,585.1 K						$3,585.1 K
3.9		$5,622.7 K	$3,218.4 K	$10,393.3 K	$7,741.6 K	$0.0 K	$26,975.9 K
7.1		$7,799.6 K	$3,223.3 K	$0.0 K	$0.0 K	$0.0 K	$11,022.9 K
12.2		$2,093.1 K	$466.4 K	$0.0 K	$0.0 K	$0.0 K	$2,559.4 K
17.3		$6,368.9 K	$528.1 K	$0.0 K	$0.0 K	$0.0 K	$6,897.0 K
22.4		$3,041.0 K	$73.6 K	$0.0 K	$0.0 K	$0.0 K	$3,114.6 K
35	$0.0 K						$0.0 K
Total	$9,563.7 K	$24,925.2 K	$7,509.8 K	$10,393.3 K	$7,741.6 K	$0.0 K	$60,133.6 K

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

The total cost of applying Aquatain to all trunk channels during the irrigation season (and achieving 3,612 ML savings) is $224M or $62k/ML/yr.

Table 4.11 Total cost of achieving savings on Average Trunk Channels – ES300

Product	ES300						
Channel Type	Trunk						
Evaporative Rate	1.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	$692.0 K						$692.0 K
1.6	$416.9 K						$416.9 K
3.9		$653.9 K	$374.3 K	$1,208.7 K	$900.3 K	$0.0 K	$3,137.2 K
7.1		$907.1 K	$374.9 K	$0.0 K	$0.0 K	$0.0 K	$1,281.9 K
12.2		$243.4 K	$54.2 K	$0.0 K	$0.0 K	$0.0 K	$297.7 K
17.3		$740.7 K	$61.4 K	$0.0 K	$0.0 K	$0.0 K	$802.1 K
22.4		$353.7 K	$10.6 K	$0.0 K	$0.0 K	$0.0 K	$364.3 K
35	$0.0 K						$0.0 K
Total	$1,108.9 K	$2,898.7 K	$875.4 K	$1,208.7 K	$900.3 K	$0.0 K	$6,992.0 K

Evaporative Rate	4.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	$743.2 K						$743.2 K
1.6	$447.8 K						$447.8 K
3.9		$702.3 K	$402.0 K	$1,298.2 K	$967.0 K	$0.0 K	$3,369.5 K
7.1		$974.2 K	$402.6 K	$0.0 K	$0.0 K	$0.0 K	$1,376.9 K
12.2		$261.4 K	$58.3 K	$0.0 K	$0.0 K	$0.0 K	$319.7 K
17.3		$795.5 K	$66.0 K	$0.0 K	$0.0 K	$0.0 K	$861.5 K
22.4		$379.8 K	$11.4 K	$0.0 K	$0.0 K	$0.0 K	$391.2 K
35	$0.0 K						$0.0 K
Total	$1,191.0 K	$3,113.4 K	$940.2 K	$1,298.2 K	$967.0 K	$0.0 K	$7,509.9 K

Evaporative Rate	7.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	$525.4 K						$525.4 K
1.6	$316.6 K						$316.6 K
3.9		$496.5 K	$284.2 K	$917.7 K	$683.6 K	$0.0 K	$2,381.9 K
7.1		$688.7 K	$284.6 K	$0.0 K	$0.0 K	$0.0 K	$973.3 K
12.2		$184.8 K	$41.2 K	$0.0 K	$0.0 K	$0.0 K	$226.0 K
17.3		$562.4 K	$46.6 K	$0.0 K	$0.0 K	$0.0 K	$609.0 K
22.4		$268.5 K	$8.1 K	$0.0 K	$0.0 K	$0.0 K	$276.6 K
35	$0.0 K						$0.0 K
Total	$841.9 K	$2,200.8 K	$664.6 K	$917.7 K	$683.6 K	$0.0 K	$5,308.7 K

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

The total cost of applying ES300 to all trunk channels during the irrigation season (and achieving 3,612 ML savings) is $19.8M or $5,500/ML/yr. This result highlights the cost savings that can be made of monolayer products are capable of withstanding the turbulence caused by regulating structures.

Table 4.12 Total cost of achieving savings on Average Trunk Channels – ES300 – Assuming Capable of Passing Culverts

Product	ES300 - Assume passes culverts						
Channel Type	Trunk						
Evaporative Rate	1.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	$16.5 K						$16.5 K
1.6	$10.8 K						$10.8 K
3.9		$14.3 K	$11.9 K	$27.7 K	$26.9 K	$0.0 K	$80.8 K
7.1		$17.6 K	$14.6 K	$0.0 K	$0.0 K	$0.0 K	$32.2 K
12.2		$4.0 K	$3.3 K	$0.0 K	$0.0 K	$0.0 K	$7.3 K
17.3		$10.6 K	$8.8 K	$0.0 K	$0.0 K	$0.0 K	$19.3 K
22.4		$4.5 K	$10.6 K	$0.0 K	$0.0 K	$0.0 K	$15.1 K
35	$0.0 K						$0.0 K
Total	$27.3 K	$50.9 K	$49.3 K	$27.7 K	$26.9 K	$0.0 K	$182.1 K

Evaporative Rate	4.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	$17.7 K						$17.7 K
1.6	$11.6 K						$11.6 K
3.9		$15.4 K	$12.8 K	$29.8 K	$28.8 K	$0.0 K	$86.8 K
7.1		$18.9 K	$15.7 K	$0.0 K	$0.0 K	$0.0 K	$34.6 K
12.2		$4.3 K	$3.6 K	$0.0 K	$0.0 K	$0.0 K	$7.9 K
17.3		$11.3 K	$9.4 K	$0.0 K	$0.0 K	$0.0 K	$20.8 K
22.4		$4.8 K	$11.4 K	$0.0 K	$0.0 K	$0.0 K	$16.2 K
35	$0.0 K						$0.0 K
Total	$29.3 K	$54.7 K	$52.9 K	$29.8 K	$28.8 K	$0.0 K	$195.6 K

Evaporative Rate	7.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	$12.5 K						$12.5 K
1.6	$8.2 K						$8.2 K
3.9		$10.9 K	$9.0 K	$21.1 K	$20.4 K	$0.0 K	$61.3 K
7.1		$13.4 K	$11.1 K	$0.0 K	$0.0 K	$0.0 K	$24.5 K
12.2		$3.0 K	$2.5 K	$0.0 K	$0.0 K	$0.0 K	$5.6 K
17.3		$8.0 K	$6.7 K	$0.0 K	$0.0 K	$0.0 K	$14.7 K
22.4		$3.4 K	$8.1 K	$0.0 K	$0.0 K	$0.0 K	$11.4 K
35	$0.0 K						$0.0 K
Total	$20.7 K	$38.7 K	$37.4 K	$21.1 K	$20.4 K	$0.0 K	$138.3 K

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

If ES300 was capable of passing culvert structures, the total cost of applying ES300 to all trunk channels during the irrigation season (and achieving 3,612 ML savings) is $516k or $200/ML/yr. This result highlights that substantial cost savings could be achieved if monolayer passing of submerged culvert structures could be achieved.

4.1.8 Achieving Savings at Required $/ML Threshold

If G-MW set a threshold for which savings using monolayers would be considered viable, then the tables presented within Sections 4.1.4, 4.1.5, 4.1.6 and 4.1.7 could be used to inform the percentage of the year for which these savings could be achieved and the total cost of achieving the water savings.

The threshold set in any particular year will depend on the climatic conditions, water trading costs and the cost investors are willing to pay to achieve water savings.

As an example, if a threshold of $1000/ML was chosen as the maximum acceptable cost of achieving water savings, and assuming that WaterSavr™ was the chosen monolayer product to be applied to trunk channels:

- The threshold of $1000/ML reflects the highest peak cost in temporary trade during drought conditions.
- Considering Table 4.3, only three sets of environmental conditions exist that will achieve water savings below the threshold on trunk channels:
    - Wind that is opposite and between 19.8 and 25 km/hr and evaporation between 3 and 6 mm/day will achieve water savings of $400/ML;
    - Wind that is opposite and between 14.7 and 19.8 km/hr and evaporation between 6 and 9 mm/day will achieve water savings of $700/ML; and
    - Wind that is opposite and between 19.8 and 25 km/hr and evaporation between 6 and 9 mm/day will achieve water savings of $200/ML.
- Considering Table 4.7, these conditions exist for 0.3%, 0.5% and 0.2% of the irrigation season, respectively.
- Considering Table 4.8, the total volume of savings that could be achieved by applying monolayer during these conditions is 31, 86 and 36 ML, respectively
- Considering Table 4.9, the cost of achieving the water savings is $11.4k, $57.8k and $8.1k respectively.

The total volume of water that can be achieved by applying WaterSavr™ to trunk channels during these conditions is 153 ML at a total cost of $77.3k. That is, only 153 ML water savings can be achieved by applying WaterSavr™ to trunk channels at periods when the cost per megalitre savings is below $1000. Refer to Table 4.8. The average cost of these savings is $500/ML/yr.

4.2 Results – Other Channel Types

4.2.1 Summary of Results – Trunk, Carrier & Spur Channels

Section 4.1 showed the various sections within the model in considerable detail for the example case of an average Trunk channel. A summary of the $/ML to achieve water savings and the total savings possible for the Trunk, Carrier and Spur channels (using average pool length in the calculations) is provided in Appendix A to Appendix F.

4.2.2 Summary of Results – 25% Longest Carrier, Trunk & Spur Channels

A summary of the $/ML to achieve water savings and the total savings possible for the 25% longest Carrier, Trunk and Spur channels is provided in Appendix G to Appendix L.

4.2.3 Summary of Results – 10% Longest Carrier, Trunk & Spur Channels

A summary of the $/ML to achieve water savings and the total savings possible for the 10% longest Carrier, Trunk and Spur channels is provided in Appendix M to Appendix R.

4.2.4 Summary of Results – 1% Longest Carrier, Trunk & Spur Channels

A summary of the $/ML to achieve water savings and the total savings possible for the 10% longest Carrier, Trunk and Spur channels is provided in Appendix S to Appendix X.

4.3 Summary of Results – All Channel Types

A summary of all results are presented graphically within the following figures. Note that for conditions where monolayer products are ineffective, no $/ML values are shown on the graphs.

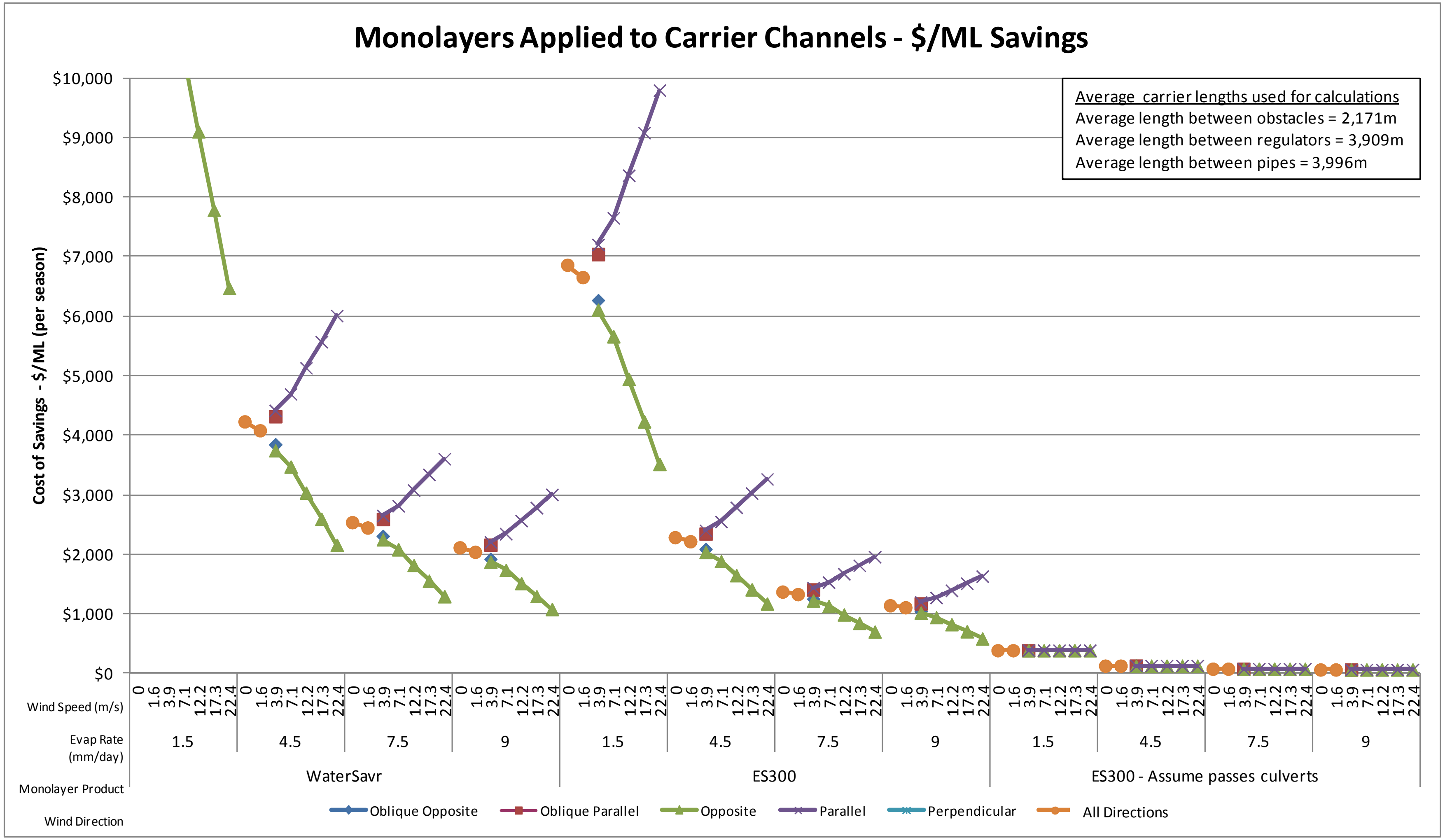


Figure 4.5 Cost per ML savings – Carrier Channels

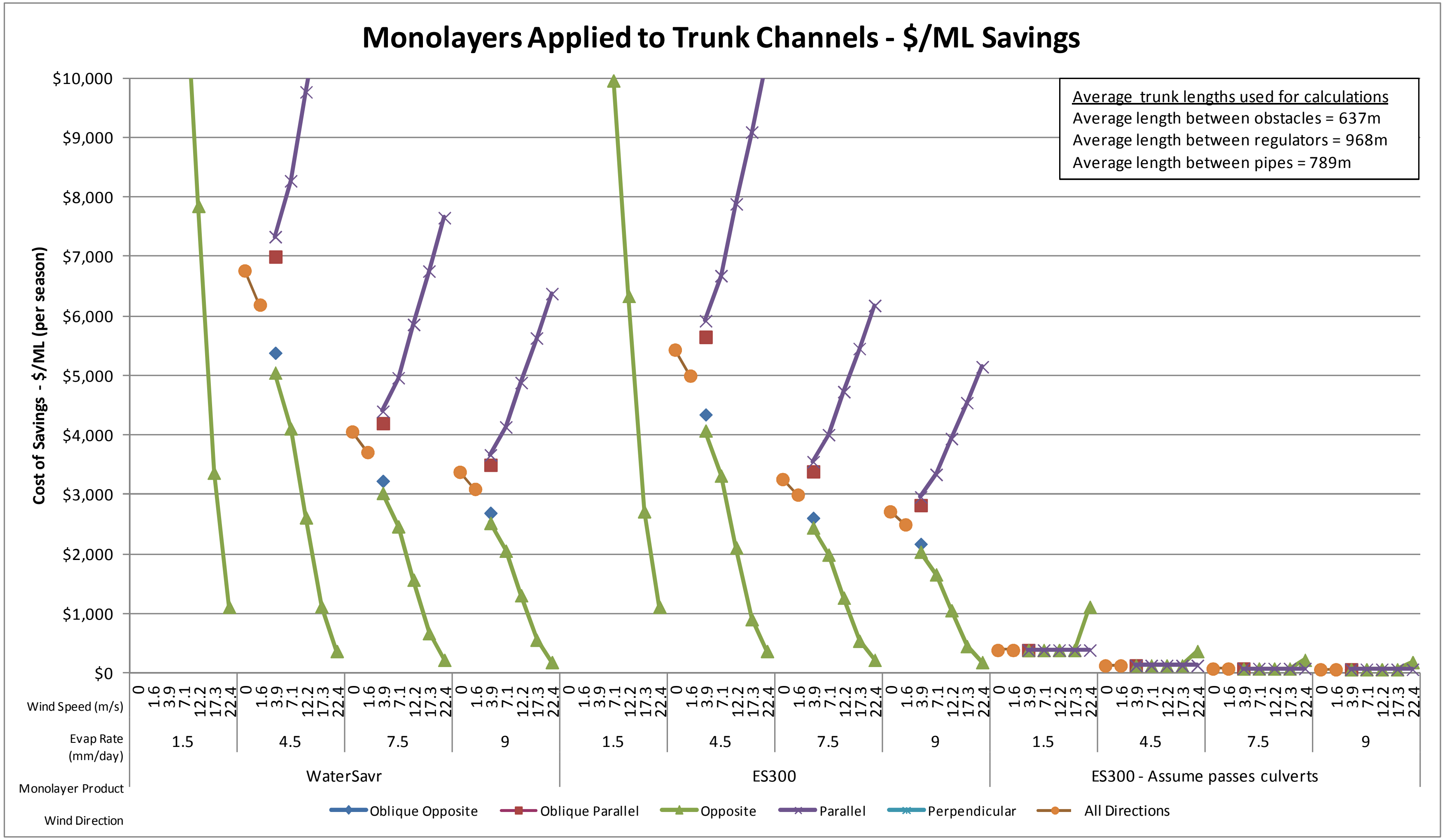


Figure 4.6 Cost per ML savings – Trunk Channels

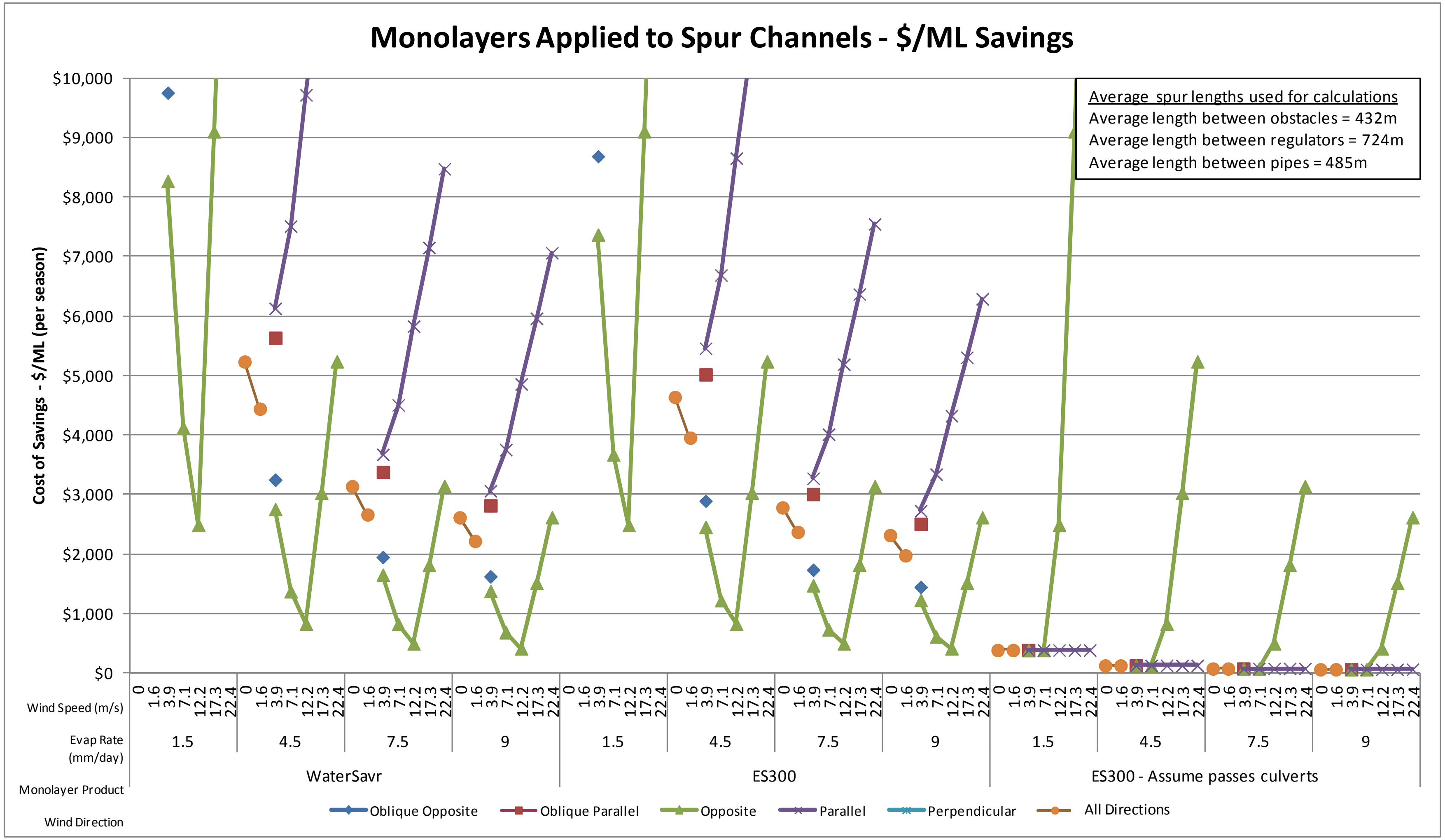


Figure 4.7 Cost per ML savings – Spur Channels

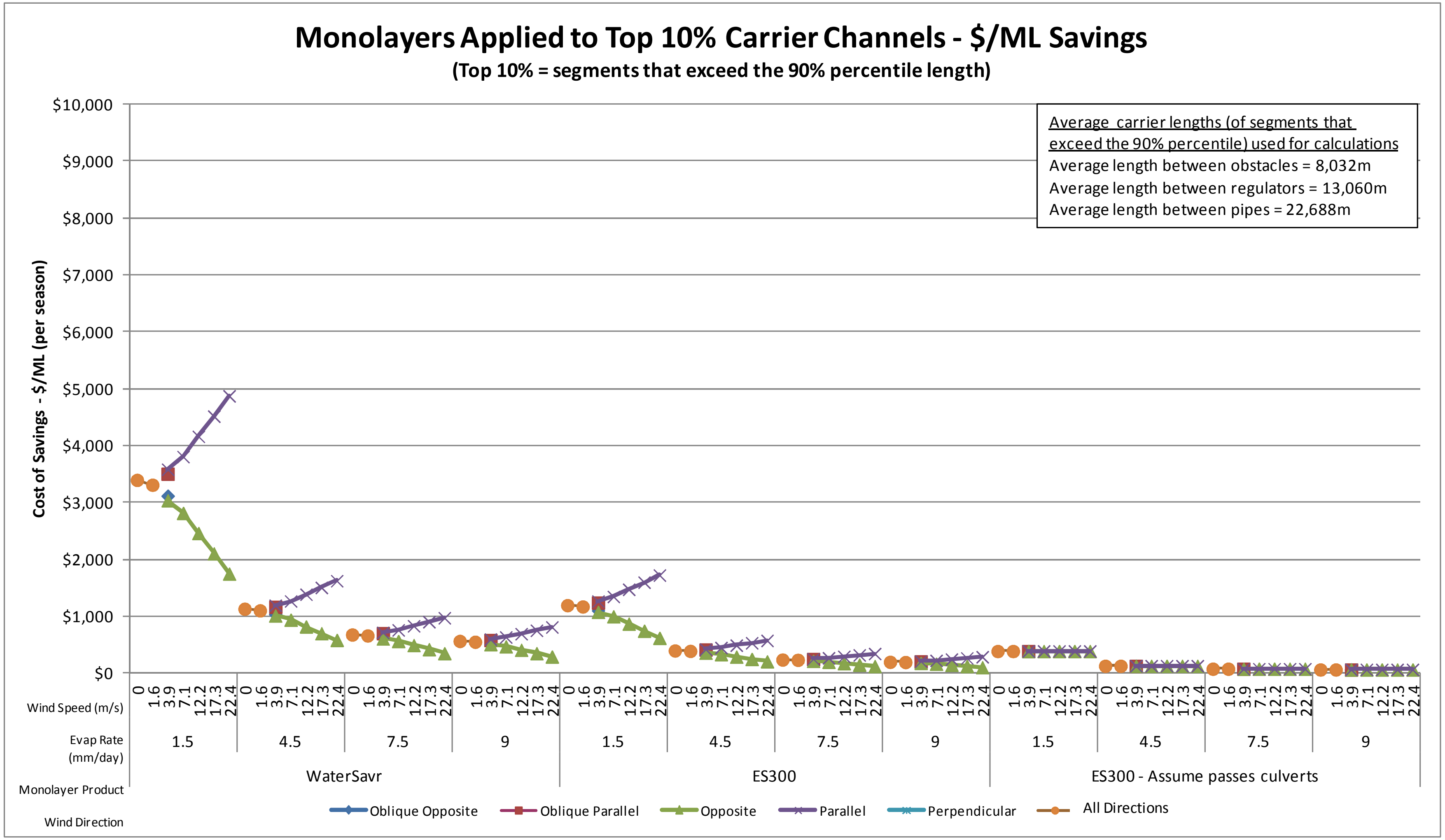


Figure 4.8 Cost per ML savings – Top 10% Carrier Channels

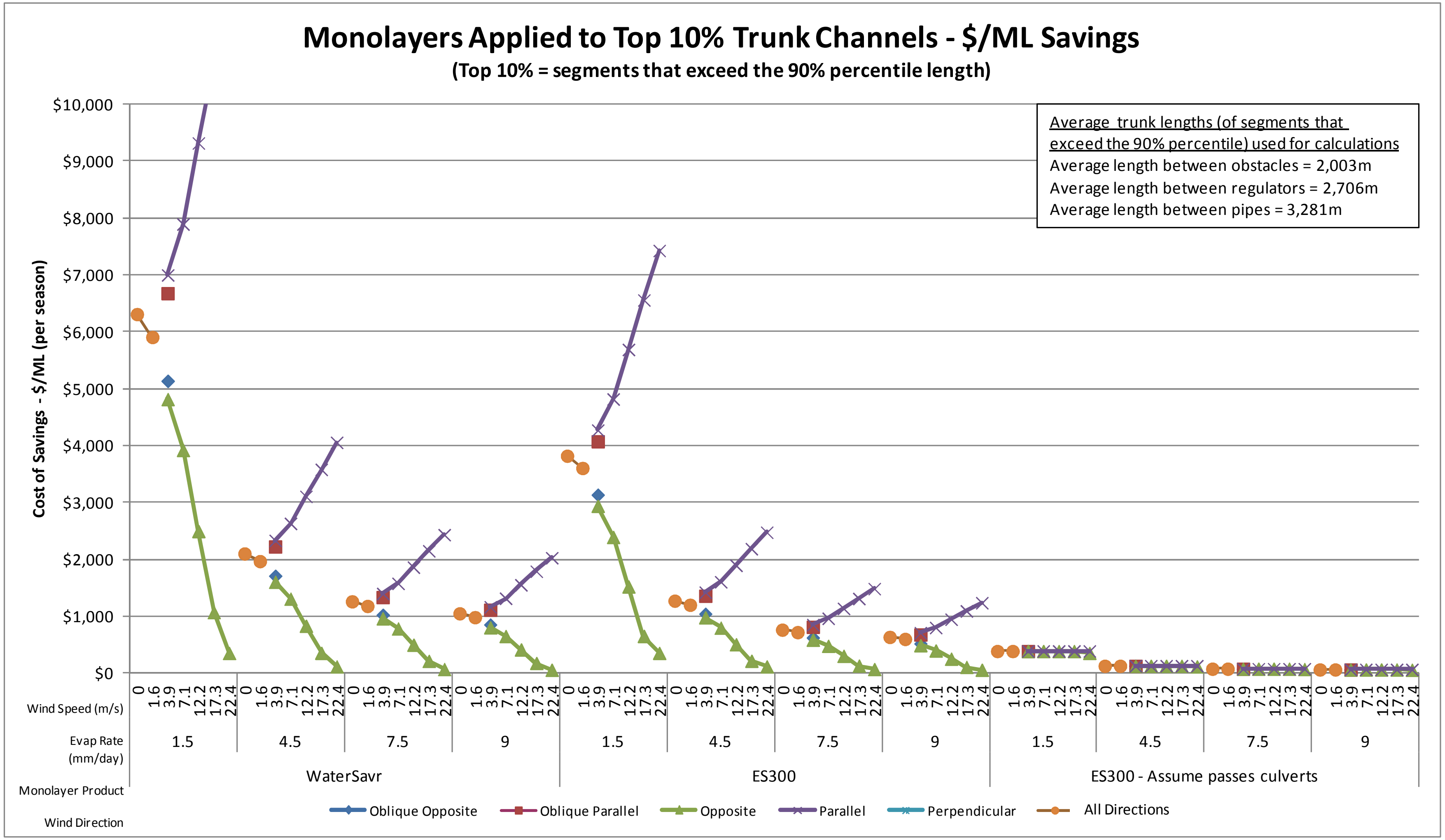


Figure 4.9 Cost per ML savings – Top 10% Trunk Channels

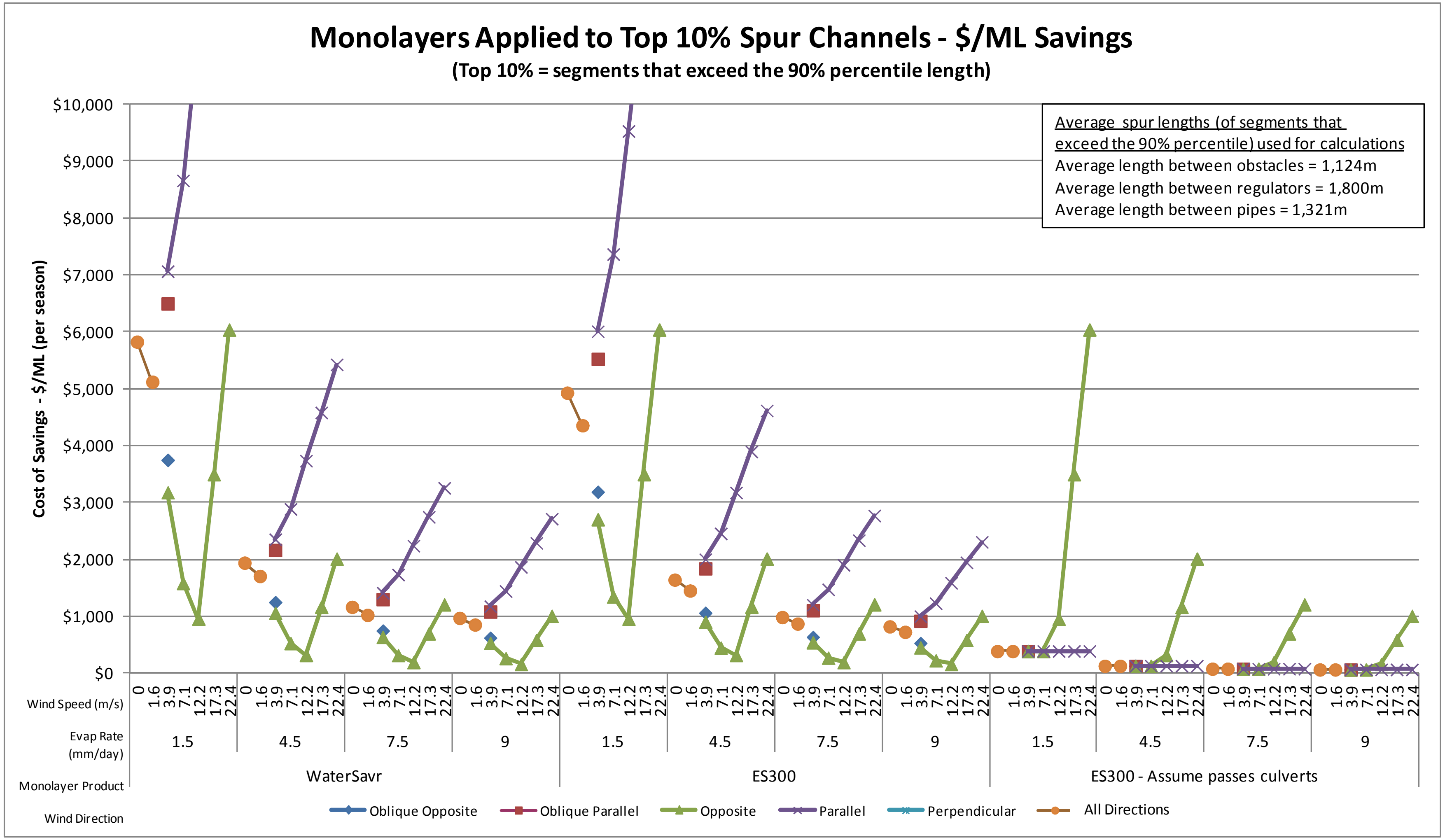


Figure 4.10 Cost per ML savings – Top 10% Spur Channels

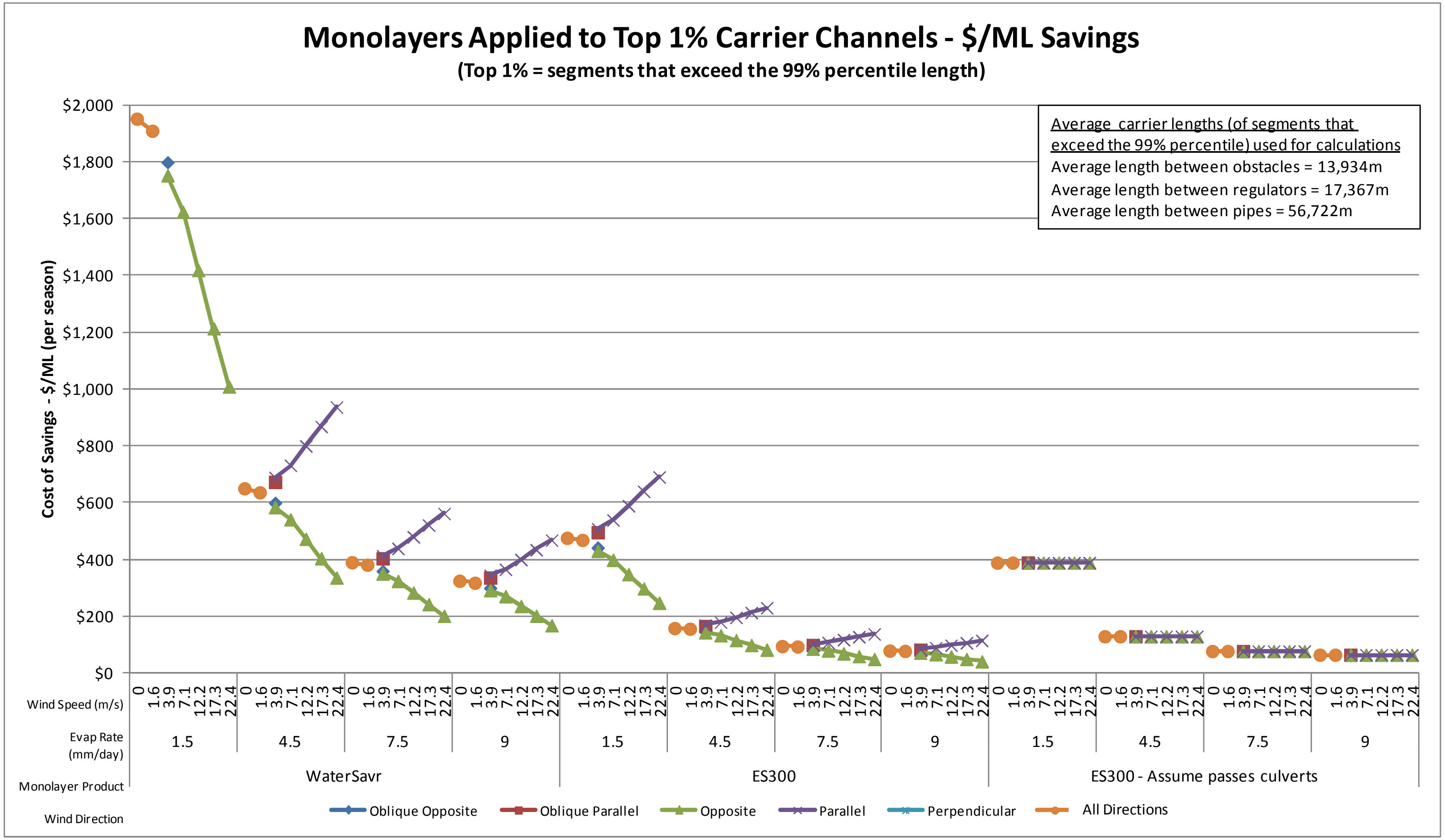


Figure 4.11 Cost per ML savings – Top 1% Carrier Channels

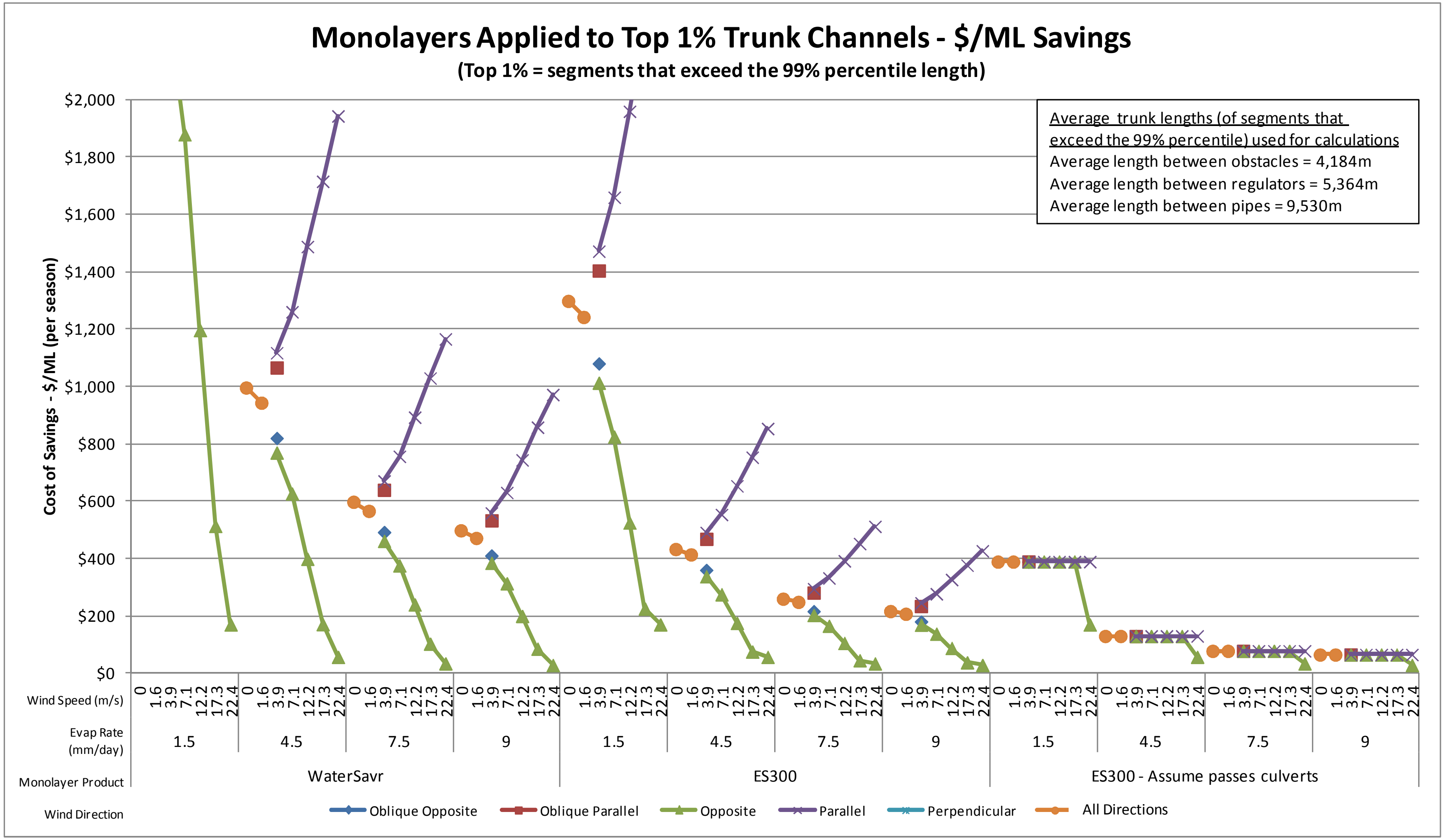


Figure 4.12 Cost per ML savings – Top 1% Trunk Channels

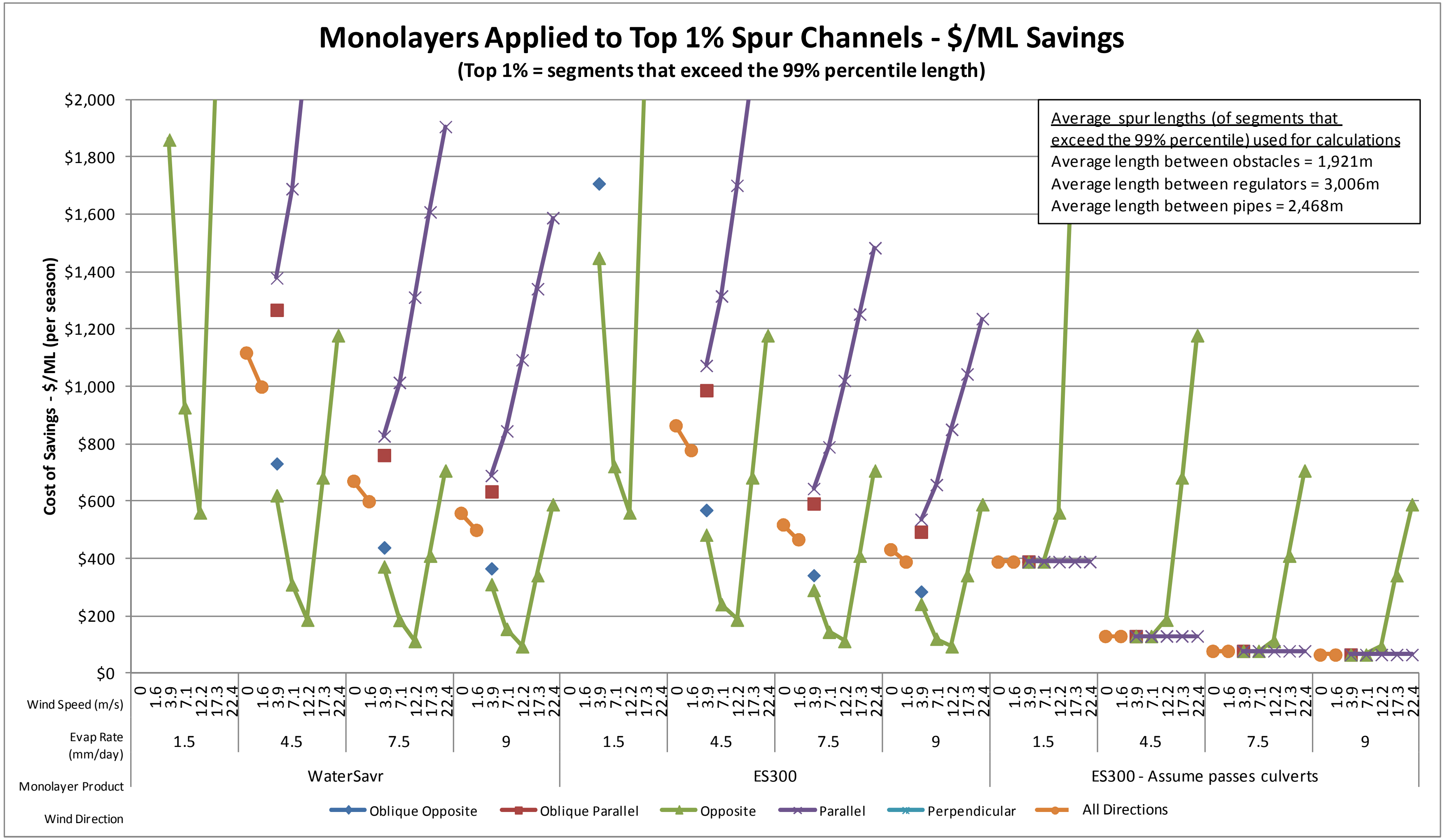


Figure 4.13 Cost per ML savings – Top 1% Spur Channels

The series of graphs display the following trends:

- Longer channel pools result in the most cost effective savings (decreasing $/ML);
- Increased evaporative rates result in increased cost effectiveness (decreasing $/ML);
- From least cost effective to most cost effective, the products are: Aquatain (not shown on the graphs), WaterSavr™ and ES300. The assumptions behind this are:
    - Aquatain and WaterSavr™ assumed incapable of passing regulating structures;
    - ES300 assumed capable of passing regulating structures (distance to reform and attain pressure not included); and
    - Cost of ES300 assumed equivalent to WaterSavr™.
- If a method can be devised to allow ES300 to pass culverts, it will further increase cost effectiveness;
- When wind is in the same direction as channel flow, increasing wind speed results in decreased cost effectiveness (increasing $/ML);
- Generally, when wind opposes channel flow, increasing wind speed results in increased cost effectiveness (decreasing $/ML); and
- In the cases of spur channels, when wind opposes channel flow; increasing wind speed results in increased cost effectiveness (decreasing $/ML) up to wind speeds of 12.2 km/hr. Further increasing wind speed results in decreased cost effectiveness (increasing $/ML). This occurs because the average spur velocity (0.09m/s) is very low compared to the wind speed. At low speeds, the opposite wind acts against the channel flow and ensures that the monolayer stays on the channel longer as the wind speed increases. As the wind speed continues to increase the movement of the monolayer due to wind far exceeds the movement due to the channel flow. Even if the monolayer is applied upstream of the regulator and moved up the channel (refer to the discussion following Example 3.4), it is moved so quickly that it requires a much greater volume of product to be applied (at the higher wind speeds) resulting in a decreased cost effectiveness (increasing $/ML).

4.4 Monolayers compared to other techniques of saving evaporation

Monolayers differ from other evaporation savings techniques in that they are an ongoing operational activity, rather than one off capital works (although some capital works will be required to install the pumps when/where required). They can be targeted for use on those channels and times that represent the biggest savings and best conditions for the use of monolayers. They can also be targeted for periods when additional water is highly sought after. However, although monolayers come at a low capital cost, the potential savings is lower than other evaporation reduction techniques, and the cost per megalitre of savings can still be quiet high. The two most important issues that need to be resolved in order to accurately compare monolayer use to other techniques for saving evaporation are: can monolayers pass over regulating structures and remain effective; and can a technique be devised to allow monolayers to pass culvert structures. For monolayers capable of passing regulating structures, the $/ML varies from $100/ML to well over $10,000/ML. However, if the monolayer is also capable of passing a culvert structure, the cost generally remains below $1000/ML, and depending on the conditions can be quiet low, for example when evaporation is 4.5 mm/day on the average carrier channel, the cost is approximately $130/ML.

Referring to Table 2.6, the cost of the other techniques ranged from $130/ML for Evap-Mat to $1110/ML for Defined Sump.

Monolayers will be a more attractive option for saving evaporation losses from irrigation channels if a technique can be devised to enable them to pass culvert structures.

Further cost effectiveness could then be obtained if the life of the product in the environment could be increased, however the potential environmental implications of a longer life product would need to be investigated.

5 Conclusions and Recommendations

To date, research into evaporation suppression using monolayers has focused on storages or dams with minimal research having been done into reducing evaporation losses from irrigation channels. This research project concentrated on the application of monolayers to irrigation channels in the GMID in Northern Victoria where evaporative losses are a major component of the total yearly water losses (approximately 70 GL/year).

One of the main drivers for this research was the record number of drought years in the GMID irrigation region and the record high prices achieved for both temporary and permanent water sales. Water is a scarce commodity that is integral for the viability of the irrigation sector. Water savings makes available for irrigation water that would have otherwise been lost.

5.1 Summary of Work Undertaken

The work undertaken during the course of this research is summarised in the sections following.

The contributions to the subject of monolayer use on irrigation channels as a result of this thesis are as follows:

- Review of the available literature as it applies to irrigation channels;
- Investigation into the effect of regulator turbulence on monolayer efficacy; and
- Determination of the $/ML that can be achieved on various channel types and the volume of water that can be saved.

5.1.1 Literature Survey

The volume of evaporation lost from channels in the GMID was reviewed and found to be in the order of 70 GL annually. A number of ways to assess the value of the lost water were reviewed and ranged from a maximum of \$4,500/ML for the NVIRP Stage 1 water savings initiative, a gross value of \$270M (\$744/ML), \$60-\$80/ML on the temporary trade market or \$1000/ML on the permanent trade market to \$18-\$33/ML for pumping the dead storage of Waranga Basin. Monolayers are an operational investment or procedure, and can be utilised when and where required and only achieve the savings in a single irrigation season, not in perpetuity.

The process of evaporation and different methods of suppressing evaporation were reviewed, including shading and floating covers & objects, with effectiveness ranging from 70% to 95% and installation prices ranging from $3.50/m^2 to $30/m^2. This equates to net present value per megalitre of water saved of between $130 and $1110 (@ 6% over 30 years).

Commercially available evaporation suppressant products WaterSavr™ and Aquatain were reviewed in addition to the monolayer product ES300 being developed by CRC Polymers. The literature reports a range of different values for effectiveness of monolayers in the laboratory, generally in the order of 70%. The manufacturers state field effectiveness of up to 30% for WaterSavr™ and 50% for Aquatain, although the literature generally reported much lower values of monolayer field effectiveness. Orica (Craig Clarke, pers. comm.) reported a field efficiency of 60% for ES300 under “ideal” conditions.

There do not appear to be any notable adverse impacts to the environment or human health from monolayers, however the literature does report that further investigation is required. The literature reports that monolayers are adversely affected by turbulence.

The natural expansion rate of monolayers is approximately 0.1 km/hr, with recent investigations by Brink (2010) concurring with past research. The critical wind speed that limits monolayer expansion is 3.2 km/hr and the limiting wind speed to applying monolayers is approximately 25 km/hr. Between 3.2 and 25 km/hr, the rate of monolayer movement is approximately 3% of the wind speed. These results are believed to be independent of temperature.

5.1.2 Laboratory & Field Trials

Goulburn-Murray Water undertook laboratory trials of the different monolayer products and generally achieved an effectiveness in the order of 70%.

Laboratory tests of ES300 following shaking indicated that it was capable of suppressing evaporation when compared to the control clean water. However, similar tests on WaterSavr™ also indicated evaporation savings was possible following shaking, which is not in accordance with the literature. Further testing should be undertaken to verify these results.

Closed channel trials were conducted indicating that using monolayers on irrigation channels could result in potential savings between 10% and 30%, however, the tests were not able to show consistent results and further testing is required.

Flowing channel trials were conducted which give promising preliminary results into the ability of ES300 to pass a regulating structure and reform with surface pressure adequate to suppress evaporation. It took approximately 100 m downstream of the regulating structure for the required surface pressure to be achieved. Further testing is required to substantiate this result.

5.1.3 Model Development

The main output of this research project has been the development of a model to determine in what situations, if any, it is cost effective for G-MW to apply monolayers to irrigation channels in order to save evaporation.

Developing the model consisted of:

- Characterising the irrigation network, considering the variation in pool lengths across the three main types of channel (carrier, trunk and spur). The average length between regulating structures varied from 724 m for a spur channel to 3,909 m for a carrier channel. In comparison the 90% percentile length between regulators was found to be 1,344 m for a spur channel to 9,883 m for a carrier channel. There is a large variation in length of irrigation channel pools. The model does not calculate savings for a "specific" channel pool, rather it looks at a range of channel pools, for example the 10% longest pools (that is segments that exceed the 90% percentile length);

- Review of available evaporation data from the Kyabram weather station found that evaporation varies day to day, month to month and year to year, with an average daily evaporation during the irrigation season of 4.24 mm based on 10 years of records. Actual evaporation measurements at a trial site yielded a similar value. A range of evaporation rates were considered in the model;

- Wind data across the GMID (from approximately 20 weather stations) was reviewed and related to individual channel segments (based on the closest weather station with wind data). This data was built up to determine the period of time that channels experienced wind of different speeds and from different directions (in relation to the channel flow). It was found that channels generally experience calm conditions with wind speed less than 3.2 k/hr for 8% of the year. Winds greater than 25 km/hr are generally experienced for approximately 12% of the year. The remaining 80% of the time, irrigation channels are experiencing winds of between 3.2 and 25 km/hr, 10%

being parallel to the direction of channel flow, 10% opposite, 20% perpendicular and 40% oblique;

- Additional inputs to the model included monolayer costs, efficacy and ability to withstand turbulence.
- Monolayer expansion under different combinations of wind and channel flow was built into the model in order to calculate the quantity of product required and the savings achieved; and
- Consideration of the duration of wind events and the potential impact to the modelled results.

The modelling has produced a series of graphs and tables to indicate the $/ML savings on different channels under different conditions.

The model is specific to the G-MW channel system, however flow charts have been developed to enable other irrigation authorities to characterise their irrigation network in order to apply the model to their situation.

In order to use the model, G-MW needs to ensure all costs and variables are up to date, set the maximum $/ML that it is willing to pay at that particular time and then review the model output to determine where to apply monolayers to achieve that result.

5.2 Conclusions

Review of the available literature found that the use of monolayers on large water bodies has been investigated since the 1960s, however there is very little research into the use of monolayers on irrigation channels or other situations with flowing water.

Field and laboratory work gave positive preliminary results into the ability of ES300 to reform following the turbulence caused by regulating structures.

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. In addition, the following generalisations can be made from the modelling results:

- Longer channel pools result in the most cost effective savings (decreasing $/ML);
- Increased evaporative rates result in increased cost effectiveness (decreasing $/ML);

- Generally, when wind opposes channel flow, increasing wind speed results in increased cost effectiveness (decreasing $/ML); and
- When wind is in the same direction as channel flow, increasing wind speed results in decreased cost effectiveness (increasing $/ML).

Depending on the drivers to save water, it would appear that monolayers would be most suited to application on the longest pools. Savings at well below $200/ML can be achieved by applying ES300 to the 1% longest carrier channels (segments that exceed the 99% percentile length) when evaporation is 4.5 mm/day or greater, however the total volume that could be expected to be saved under these conditions is only 70 ML or 0.1% of the current total losses due to channel evaporation. The cost quoted is for product only and for a single irrigation season only.

Greater volumes of water could be saved at greater cost per megalitre, for example applying ES300 to the 25% longest carrier channels (segments that exceed the75% percentile length) could achieve savings of 640 ML at a cost of approximately $600/ML (product only and savings achieved for a single irrigation season). This shows that the total savings achieved and the average cost of achieving those savings are intrinsically related and an improvement in one will detrimentally affect the other.

If monolayers were capable of passing both regulator and culvert structures, than the length of the pool would not be critical to the $/ML achieved, and a far greater volume of water could be saved. If monolayers can be made to pass culvert structures than they will provide a low cost water savings solution which can be targeted for use at high evaporation periods and is more cost effective than the other options to save evaporation.

If no technique can be found to allow monolayers to pass culvert structures then this technique remains a costly method of saving evaporation water, despite that they can be targeted for high loss periods. Its main attractiveness for use is that it can be used when and where required without large capital investment and at times when the cost can be warranted by the value of water.

5.3 Recommendations

5.3.1 Areas of Further Research

In order to fully determine the benefits of applying monolayers to irrigation channels to save evaporation, the following research needs to be undertaken:

- Testing to determine how coverage is reduced when wind is oblique or perpendicular to the channel flow;
- Testing to determine what level of protection channel banks provide;
- Investigations to determine whether CFD would enable modelling of the wind flow over the channel bank and the resulting turbulent flow over the water surface;
- Testing to determine whether “beaching” of the monolayer material is applicable to irrigation channel banks;
- Testing to determine the level of “stripping” of the monolayer product by weeds at the edge of the channel;
- Testing to determine how fluctuating wind conditions affect the monolayer performance and whether the duration of different wind events is critical to the cost effectiveness;
- Testing to confirm that the monolayer does not pass through submerged irrigation outlets;
- Further testing to confirm the average field efficiency of ES300;
- Further testing to validate that ES300 can pass a regulating structure;
- Further testing to confirm how long it takes ES300 to achieve the pressure required to suppress evaporation after passing a regulating structure;
- Further testing to determine whether WaterSavr™ and Aquatain are capable of passing regulating structures also;
- Confirmation of the actual cost of ES300;
- Investigations into the capital cost of application equipment, including linkage into the SCADA system;
- Investigations into the cost of maintenance and filling for all products;
- Investigations into the effectiveness and cost of using a siphon pipe to transfer monolayer from one side to the other side of a submerged pipe culvert;

- Investigations into a method of bunding to ensure that the monolayer does not pass overshot irrigation outlets;
- Investigations into the impact of resolution of the wind and channel data on the model outputs;
- Refinement of the model to take into consideration the distance taken to achieve the pressure required to suppress evaporation after passing a regulating structure; and
- Refinement of channel characterisation within the model to take into account variation in width, flow, etc of 10% longest and 25% longest channels.

5.3.2 Application by Goulburn-Murray Water

In order for G-MW to consider the application of monolayers to irrigation channels as an operational means of saving water, G-MW will need a good understanding of:

- Long term cost effectiveness of monolayers as a water savings technique including: actual water savings, initial establishment costs and ongoing costs to operate, maintain, monitor and report;
- Potential negative impacts on the channel assets including: clay bank structure, HDPE lining, concrete structures and aluminium regulating gates;
- Environmental impacts in particular if the product was to be applied to natural carriers (although not included within the model) and where the channel outfall is to a river or other environmental feature;
- On-farm impacts including the impact to organic certification, potential negative impacts to on-farm assets such as pumps, and stock and human health impacts;
- Community perception and how to manage potentially negative views of the application of a chemical monolayer on irrigation channels; and
- Changes to the DSE water savings technical manual to enable use of the technique as a “water savings” measure.

There are two ways in which G-MW can approach the application of monolayers to irrigation channels:

- As a water savings measure that is funded by an external investor. This would involve a permanent change to the bulk entitlement and G-MW would need to apply monolayers on a permanent basis to ensure ongoing savings are achieved; or

- As a method of "water creation" within an irrigation season when the environmental conditions and requirement for water would benefit from saving evaporative water losses in that year.

Section 5.3.1 details the technical issues that need to be addressed to fully determine the cost effectiveness of the monolayer technique. However, as detailed above, significant other work will be required before G-MW could consider ongoing use of monolayers.

6 REFERENCES

Al-Hassoun, S, Mohammed, T and Nurdin, J, 2099, 'Evaporation Reduction from Impounding Reservoirs in Arid Areas Using Palm Leaves', *Journal of Engineering and Applied Sciences*, vol. 4, no. 4, pp.247-250

Albrecht, B 2011, Evaporation Mitigation Project – Closed & Flowing Channel Trials, Goulburn-Murray Water, Tatura, Vic

Aquatain Products Pty Ltd, n.d(a), *Save Evaporation,* Aquatain ProductsPty Ltd, Dandenong South, Vic, viewed 5 October 2001 <http://www.aquatain.com/index.php/evaporation-savings/>

Aquatain Products Pty Ltd, n.d(b), *Environment & Safety,* Aquatain ProductsPty Ltd, Dandenong South, Vic, viewed 5 October 2001 <http://www.aquatain.com/index.php/environmental-and-safety-aspects/>

Australian Bureau of Statistics 2006, *4610.0 – Water Account, Australia, 2004-05*, Australian Bureau of Statistics, Canberra, ACT, viewed 5 October 2009, <http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4610.0Main+Features12004-05?OpenDocument>

Brink, G, Symes, T, Pittaway, P, Hancock N, Pather, S, Schmidt, E, 2009b, *'Smart' Monolayer Application and Management to Reduce Evaporation on Farm Dams – Formulation of a Universal Design Framework,* Proceedings of the Environmental Research Event 2009, Noosa, QLD

Brink, G, Wandel, A, Hancock, N, Herzig, M and Pather, S, 2010, Spreading rate and dispersion pattern of a C18OH water-emulsion spread in round laboratory water tanks, University of Southern Queensland, Toowoomba, Qld

Bureau of Meteorology n.d(a), *Victorian Weather Observation Stations*, Bureau of Meteorology, Melbourne, Vic, viewed 5 October 2009, <http://reg.bom.gov.au/vic/vic-observations-map.shtml>

Bureau of Meteorology n.d(b), *New South Wales Weather Observation Stations*, Bureau of Meteorology, Melbourne, Vic, viewed 5 October 2009, < http://reg.bom.gov.au/nsw/observations/map.shtml>

Coliban Regional Water Corporation, 2007, *Annual Report 2007,* Coliban Regional Water Corporation, Bendigo, Vic, viewed 1 February 2011, <http://www.coliban.com.au/DE7D8CA9-97A2-4549-9E13-

0AF3C989A049/FinalDownload/DownloadId-52E6F012456D05098F6C1FA233D57724/DE7D8CA9-97A2-4549-9E13-0AF3C989A049/about/media_and_public_affairs/publications/documents/CWAR07Complete.pdf>

Community Education and Extension Support Unit and Rural Water Use Efficiency Initiative Department of Natural Resources and Mines, Queensland 2002, Current knowledge and developing technology for controlling evaporation from on-farm storage, Department of Environment and Resources Management, Qld, viewed 6 October 2010, <http://www.derm.qld.gov.au/rwue/pdf/evaporation_report.pdf>

Craig, I 2005, *Loss of storage water due to evaporation – a literature review*, NCEA publication, University of Southern Queensland, Toowoomba, Qld

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

Craig, I, Aravinthan, V, Baillie, C, Beswick, A, Barnes, G, Bradbury, R, Connell, L, Coop, P, Fellows, C, Fitzmaurice, L, Foley, J, Hancock, N, Lamb, D, Morrison, P, Misra, R, Mossad, R, Pittaway, P, Prime, E, Rees, S, Schmidt, E, Dolomon, D, Symes, T & Turnbull, D 2007, 'Evaporation, Seepage and Water Quality Management in Storage Dams: A Review of Research Methods', *Environmental Health,* vol. 7, no. 3, pp. 84-97

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

Crow, F, and Sattler, H, 1958, *'The influence of wind on chemical films for reservoir evaporation retardation.',* Paper presented at the meeting of the Southwest-Southeast Sections of the American Society of Agricultural Engineers at Little Rock, Arkansas, 1958.

Crow, FR, 1963, The effect of wind on evaporation suppressing films and methods of modification, in 'International Union of Geodesy and Geophysics. International association of scientific hydrology. General Assembly of Berkeley', California, pp. 26-37.

Department of Sustainability and Environment n.d, *Water Shares, Delivery Shares and Water Use Licences*, Department of Sustainability and Environment, Melbourne, Vic, viewed 21 November 2011, <http://www.water.vic.gov.au/allocation/water_allocation_framework/water_shares>

Department of Sustainability and Environment, 2010, *Water Savings Protocol – Technical Manual for the Quantification of Water Savings*, Department of Sustainability and Environment, Melbourne, Vic, viewed 21 November 2011, <http://www.water.vic.gov.au/__data/assets/pdf_file/0005/53528/Water-Savings-Protocol-Technical-Manual.pdf>

Evaporation Control Systems Pty Ltd n.d., *E-VapCap Evaporation Control,* Evaporation Control Systems Pty Ltd, Australia, viewed 6 October 2010, <http://www.evaporationcontrol.com.au/aboutecsproduct.htm>

Fitzgerald, LM, & Vines, RG, 1963. 'Retardation of evaporation by monolayers: practical aspects of the treatment of large water storages', *Australian Journal of Applied Science*, vol 14, pp. 340-346

Fitzgerald, LM, 1964, 'The Effect of Wave-Damping on the Surface Velocity of Water in a Wind Tunnel', *Australian Journal of Physics,* vol. 17, pp. 184-188

Flexible Solutions International Inc n.d., *WaterSavr™*, Flexible Solutions International Inc, viewed 6 October 2010, <http://www.flexiblesolutions.com/products/WaterSavr™/default.shtml>

Flexible Solutions Internation Inc, 2006, *Coliban Water Evaporation Reduction Trial Using WaterSavr™ – Case Study,* Flexible Solutions International Inc, viewed 6 October 2010, <http://www.flexiblesolutions.com/products/WaterSavr™/documents/TheColibanTrial-WaterSavr™CaseStudy.pdf>

F Cubed (Australia) Pty Ltd n.d., *Raftex – Evaporation Mitigation Panel,* F Cubed (Australia) Pty Ltd, Somerton, Victoria, viewed 6 October 2010, < http://www.fcubed.com.au/products/Raftex/Water-Evaporation-Mitigation-Panel-Dams-Lakes>

Gladyshev, M, 2002, *Biophysics of the Surface Microlayer of Aquatic Ecosystems,* IWA Publishing 528 London, United Kingdom

Goldacre, R, 1949, 'Surface Films on Natural Bodies of Water', *J.Animal Ecology,* vol 18, no. 1, pp. 36-39

Goulburn-Murray Water n.d, *Goulburn-Murray Water Region Map*, Goulburn-Murray Water, Tatura, Vic, viewed 5 October 2009, < http://www.g-mwater.com.au/about/regionalmap>

Goulburn-Murray Water 2010, Docs # 2828686 Baseline Year Water Balance – Draft, Goulburn-Murray Water, Tatura, Vic

Gowen, T, Karantonis, P & Rofail, T, 2004, *'Converting Bureau of Meteorology Wind Speed Data to Local Wind Speeds at 1.5m Above Ground Level',* Paper presented at the Acoustics Proceedings, Gold Coast, Australia, 2004.

Gugliotta, M, Baptista, MS & Politi, MJ, 2005, 'Reduction of Evaporation of Natural Water Samples by Monomolecular Films', *J. Braz. Chem. Soc,* vol 16, no. 6A, pp. 1186-1190

Hancock, N, Pittaway, P & Symes, T, 2011, 'Assessment of the Performance of Evaporation Suppressant Films – Analysis and Limitations of Simple Trialling Methods', *Aust J. Multidisc Eng* (In press)

Hexa-Cover Aps n.d., *Hexa-Cover,* Hexa-Cover Aps, Thisted, Denmark, viewed 6 October 2010, < http://www.hexa-cover.com/>

Hightower, M & Brown, G, 2004, 'Evaporation Suppression Research and Applications for Water Management', *Identifying Technologies to Improve Regional Water Stewardship: North-Middle Rio Grande Corridor,* pp. 76-83

Hsin, Y-LL, 2002, *Feasibility Experiments into the Use of Hexadecanol for Hurricane Mitigation and the Planning and Construction of the Monolayer Evaporation Retardation Laboratory,* Massachusetts Institute of Technology, USA

Lange, P & Huhnerfuss H, 1977, 'Drift Response of Monomolecular Slicks to Wave and Wind Action', Journal of Physical Oceanography, vol. 8, pp. 142-150

Martinez Alvarez, V, Baille, A, Molina Martinez, JM & Gonzales-Real, MM 2006, 'Efficiency of shading materials in reducing evaporation from free water surfaces', Agricultural Water Management, no. 84, pp. 229-239

McJannet, D, Cook, F, Knight, J and Burn, S, 2008, Evaporation reduction by monolayers: overview, modelling and effectiveness, Urban Water Security Research Alliance, City East, Qld

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>

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>

NVIRP 2010, *Business Case for Northern Victoria Irrigation Renewal Project Stage 1,* NVIRP, Shepparton, Victoria, viewed January 2011, <http://www.nvirp.com.au/downloads/Communications/Business_case-Stage_1_for_public_release_3_February10_FINAL.pdf>

O'Brien, RN, Feher, AI, Li, KL & Tan, WC, 1976, 'The effect of monolayers on the rate of evaporation of H2O and solution of O2 in H2O', *Canadian Journal of Chemistry,* no. 54, pp. 2739-2744

Pittaway, P & Ancker T, 2010, Microbial and Environmental Implications for Use of Monolayers to Reduce Evaporative Loss from Water Storages, Cooperative Research Centre for Irrigation Futures, Australia

Polarity 2008, *Nylex caps water losses for industry sectors,* Polarity, Richmond, Vic, viewed 6 October 2010, <http://www.polarity.com.au/userfiles/file/AquaCap.pdf>

Plastipack Limited n.d., *VapourGuard,* Plastipack Limited, UK, viewed 6 October 2010, <http://www.plastipack.co.uk/trans-ENGLISH/vapourguard.html>

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

Sahoo, B, Panda S and Panigrahi, B, 2010, 'Modelling Evaporative Water Loss from the On-Farm Reservoir with Biological Shading', *Journal of Hydrologic Engineering,* vol. 15, no. 7, pp. 544-553

Seidl, M, Laouali, S, Idder, T and Mouchel, J, n.d., 'Duckweed – Tilapia System: A Possible Way of Ecological Sanitation for Developing Countries', *Seminario Internacional sobre Metodos Naturales para el Tratamiento de Aguas Residuales*, pp. 140-148

Skillicorn, P, Spira, W and Journey, W, n.d., *Technical Working Paper, Duckweed Aquaculture,* Europe, Middle East, and North Africa Regional Office of the World Bank, Washington, USA, viewed 6 October 2010, http://www.p2pays.org/ref/09/08875.htm

SKM 2009, Kerang Lakes Water Savings Project – Review of Ecological Character and Identification of Watering Regimes, Sinclair Knight Merz, Tatura, Victoria

Subramanya, K, 2009, Flow in Open Channels, Tata McGraw-Hill, New Delhi

Vines, R, 1962, Evaporation Control: A Method of Treating Large Water Storages. In: La Mer, V.K. (Ed.), Retardation of Evaporation by Monolayers: Transport Processes. Academic Press, New York, USA, pp. 137-160

Water Innovations n.d., *AquaArmour*, Water Innovations, Australia, viewed 6 October 2010, <http://www.waterinnovations.com.au/>

Walter, J, 1963, The Use of Monomolecular Films to Reduce Evaporation, *In: General Assembly of Berkeley. Gentbrugge, Belgium, International Association of Scientific Hydrology,* no. 62, pp. 39-48.

Watts, P, 2005, *Scoping Study – Reduction of Evaporation from Farm Dams. Final Report to the National Program for Sustainable Irrigation,* Feedlot Services Australia Pty Ltd, Toowoomba, Qld

Weekly Times Now, 2009, *Aqua Armour Plates to Save Water*, Weekly Times Now, Australia, viewed 6 October 2010, <http://www.weeklytimesnow.com.au/article/2009/03/06/59465_water.html>

Winter, M, 2011, Evaporation Mitigation Project – Application Equipment Report, Goulburn-Murray Water, Tatura, Victoria

Wixon, B, 1966, Studies on the Ecological Impact of Evaporation Retardation Monolayers, Water Resources Institute, Texas A&M University

7 BIBLIOGRAPHY

Barnes, GT 2008, 'The potential for monolayers to reduce the evaporation of water from large water storages', *Agricultural Water Management,* no. 95, pp. 339-353

Brink, G, Wandel, A, Pittaway, P, Hancock, N and Pather, S, n.d, *A 'Universal Design Framework' for installation planning and operational management of evaporation-suppressing films on agricultural reservoirs,* to be presented at conference AgEng 2010, Clermond-Ferrand, France, September 2010

Brink, G, Symes, T and Hancock, N, 2009a, *'Development of a 'Smart' Monolayer Application System for Reducing Evaporation from Farm Dams – Introductory Paper',* In "The 2009 CIGR International Symposium of the Australian Society for Engineering in Agriculture 'Agricultural Technologies in a Changing Climate'". Brisbane, Australia

Brink, G, 2011, *Universal Design Framework for optimal application of chemical monolayer to open water surfaces*, University of Southern Queensland, Toowoomba, Qld

Bureau of Meteorology 2009, *Living with Drought*, Bureau of Meteorology, Melbourne, Vic, viewed 5 October 2009, <http://www.bom.gov.au/climate/drought/livedrought.shtml>

Craig, I & Hancock, N 2004, *Methods for Assessing Dam Evaporation – An Introductory Paper*, NCEA

publication, University of Southern Queensland, Toowoomba, Qld

Dressler, RG & Guinat, E, 1973, 'Evaporation Control on Water Reservoirs', *Industrial & Engineering Chemistry Product Research and Development,* vol. 12, no. 1, pp. 80-82

GHD, 2003, *Methods for Reducing Evaporation from Storages used for Urban Water Supplies – Final Report,* Department of Natural Resources and Mines, QLD

Goulburn-Murray Water c.2009, *Irrigation Renewal – How we share water in northern Victoria*, Goulburn-Murray Water, Tatura, Vic, viewed 5 October 2009, <http://www.g-mwater.com.au/downloads/Current_Projects/irrigation_renewal.pdf>

Heinrich, N & Schmidt, E 2006, *Final Report - Economic Ready Reckoner for Evaporation Mitigation Systems – Reference Manual',* National Program for Sustainable Irrigation , Canberra, ACT

TenCate Australia c.2008, *Anti-Evaporation Covers*, TenCate Australia, North Albury, NSW, viewed 5 October 2009, <http://www.tencate.com.au/wawcs0136912/anti-evaporation-covers.html>

Willet, D, 2005, *Duckweed-based wastewater treatment systems: design aspects and integrated reuse options for Queensland conditions,* Department of Primary Industries and Fisheries, Qld

8 GLOSSARY OF TERMS

Allocation	The percentage of water shares that are available for use by irrigators within an irrigation season
Bacterial/Microbial Degradation	The breakup of monolayers by bacterial and/or microbial action
Baseline Year	The historic irrigation season that is used to measure water losses or savings against – assumed to representative of losses within an "average" irrigation season
CH	Method of referencing individual channel segments within the asset management system
CRCIF	The Cooperative Research Centre for Irrigation Futures
CRC Polymers	The Cooperative Research Centre for Polymers
Capillary Waves	Very small waves travelling on the water surface often referred to as ripples
DSS	Decision Support System
Delivery Share	"a share of the available flow in a delivery system: a share in terms of unit volume per unit of time of the total amount of water that can be drawn from a water system at a certain point" (Department of Sustainability and Environment n.d)
Effectiveness	The performance measure of a technique in reducing evaporation. If a technique has an effectiveness of 20%, this means that it has the potential to save 20% of the total evaporation, therefore reducing the evaporation to 80% of its original value.
Evaporation	Transformation of water from the liquid state to the gas state
GMID	Goulburn-Murray Irrigation District
G-MW	Goulburn-Murray Water
Gross Value of Water	The production achieved from water use (without considering costs)

Heterogeneities	Not consistent or homogenous. In reference to a monolayer applied to the water surface: when there are holes (areas not covered by monolayer) in the monolayer surface
ML	Mega litre. One million litres of water
Median Price	Determined by arranging all trade prices into an ordered list and finding the middle value. The median price is the value quoted by Water Moves as representing the price of permanent water
Monolayer	Consists of a one molecule thick film of a water insoluble organic compound spread across the water surface.
NPSI	National Program for Sustainable Irrigation
NVIRP	Northern Victoria Infrastructure Renewal Project
Net Evaporation	Total evaporation – rainfall (net loss of water from the water surface)
Operational Investment	A method of achieving water savings within a single irrigation season, not in perpetuity
Orica	Manufacturer and distributor of chemicals to industry; working with CRC Polymers on the development of improved monolayer materials including ES300
PAM	Polyacrylamide . Product that is mixed into water to increase the viscosity
Permanent Trade	Trade of water shares in perpetuity
Permanent Water Savings	A savings that is made in-perpetuity without continued investment each year
Pool	Alternate name for CH, method of referencing individual channel segments within the channel system
SCADA	Supervisory Control and Data Acquisition
SP	Service point

System losses	Volume of water lost from the system and not available to be supplied for the purpose of irrigation. Includes: meter error, outfalls, evaporation, leakage, seepage and theft
Temporary Trade	Trade of water shares within one irrigation season
Total Evaporation	The total evaporation from a water surface
Water Savings	The reduction of system losses; an additional quantity of water that can be delivered and used for irrigation which would otherwise have been "lost" from the irrigation system
Water Share	"a secure share of the water available to be taken from a defined water system; a water share is specified as a maximum volume of seasonal allocation that may be made against that share" (Department of Sustainability and Environment n.d)
$/ML	The cost of one megalitre of water. May be used to describe the cost of purchasing one megalitre of water on the trade market or the cost of achieving one megalitre of water savings

9 APPENDICES

Appendix A $/ML Savings for Average Carrier Channels

Product	WaterSavr						
Channel Type	Carrier						
Evaporative Rate	1.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$12.7 K						$12.7 K
1.6	$12.2 K						$12.2 K
3.9		$13.3 K	$11.2 K	$13.0 K	$11.5 K	N/A	$12.2 K
7.1		$14.1 K	$10.4 K	N/A	N/A	N/A	$12.2 K
12.2		$15.4 K	$9.1 K	N/A	N/A	N/A	$12.2 K
17.3		$16.7 K	$7.8 K	N/A	N/A	N/A	$12.2 K
22.4		$18.0 K	$6.5 K	N/A	N/A	N/A	$12.2 K
35	N/A						

Evaporative Rate	4.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$4.2 K						$4.2 K
1.6	$4.1 K						$4.1 K
3.9		$4.4 K	$3.7 K	$4.3 K	$3.8 K	N/A	$4.1 K
7.1		$4.7 K	$3.5 K	N/A	N/A	N/A	$4.1 K
12.2		$5.1 K	$3.0 K	N/A	N/A	N/A	$4.1 K
17.3		$5.6 K	$2.6 K	N/A	N/A	N/A	$4.1 K
22.4		$6.0 K	$2.2 K	N/A	N/A	N/A	$4.1 K
35	N/A						

Evaporative Rate	7.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$2.5 K						$2.5 K
1.6	$2.4 K						$2.4 K
3.9		$2.7 K	$2.2 K	$2.6 K	$2.3 K	N/A	$2.4 K
7.1		$2.8 K	$2.1 K	N/A	N/A	N/A	$2.4 K
12.2		$3.1 K	$1.8 K	N/A	N/A	N/A	$2.4 K
17.3		$3.3 K	$1.6 K	N/A	N/A	N/A	$2.4 K
22.4		$3.6 K	$1.3 K	N/A	N/A	N/A	$2.4 K
35	N/A						

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

Product	Aquatain						
Channel Type	Carrier						
Evaporative Rate	1.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$116.1 K						$116.1 K
1.6	$112.0 K						$112.0 K
3.9		$121.2 K	$102.8 K	$118.5 K	$105.5 K	N/A	$112.0 K
7.1		$128.7 K	$95.2 K	N/A	N/A	N/A	$112.0 K
12.2		$140.7 K	$83.2 K	N/A	N/A	N/A	$112.0 K
17.3		$152.8 K	$71.2 K	N/A	N/A	N/A	$112.0 K
22.4		$164.8 K	$59.2 K	N/A	N/A	N/A	$112.0 K
35	N/A						

Evaporative Rate	4.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$38.7 K						$38.7 K
1.6	$37.3 K						$37.3 K
3.9		$40.4 K	$34.3 K	$39.5 K	$35.2 K	N/A	$37.3 K
7.1		$42.9 K	$31.7 K	N/A	N/A	N/A	$37.3 K
12.2		$46.9 K	$27.7 K	N/A	N/A	N/A	$37.3 K
17.3		$50.9 K	$23.7 K	N/A	N/A	N/A	$37.3 K
22.4		$54.9 K	$19.7 K	N/A	N/A	N/A	$37.3 K
35	N/A						

Evaporative Rate	7.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$23.2 K						$23.2 K
1.6	$22.4 K						$22.4 K
3.9		$24.2 K	$20.6 K	$23.7 K	$21.1 K	N/A	$22.4 K
7.1		$25.7 K	$19.0 K	N/A	N/A	N/A	$22.4 K
12.2		$28.1 K	$16.6 K	N/A	N/A	N/A	$22.4 K
17.3		$30.6 K	$14.2 K	N/A	N/A	N/A	$22.4 K
22.4		$33.0 K	$11.8 K	N/A	N/A	N/A	$22.4 K
35	N/A						

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

Product	ES300
Channel Type	Carrier
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$6.9 K						$6.9 K
1.6	$6.7 K						$6.7 K
3.9		$7.2 K	$6.1 K	$7.0 K	$6.3 K	N/A	$6.7 K
7.1		$7.7 K	$5.7 K	N/A	N/A	N/A	$6.7 K
12.2		$8.4 K	$4.9 K	N/A	N/A	N/A	$6.7 K
17.3		$9.1 K	$4.2 K	N/A	N/A	N/A	$6.7 K
22.4		$9.8 K	$3.5 K	N/A	N/A	N/A	$6.7 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$2.3 K						$2.3 K
1.6	$2.2 K						$2.2 K
3.9		$2.4 K	$2.0 K	$2.3 K	$2.1 K	N/A	$2.2 K
7.1		$2.6 K	$1.9 K	N/A	N/A	N/A	$2.2 K
12.2		$2.8 K	$1.6 K	N/A	N/A	N/A	$2.2 K
17.3		$3.0 K	$1.4 K	N/A	N/A	N/A	$2.2 K
22.4		$3.3 K	$1.2 K	N/A	N/A	N/A	$2.2 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.4 K						$1.4 K
1.6	$1.3 K						$1.3 K
3.9		$1.4 K	$1.2 K	$1.4 K	$1.3 K	N/A	$1.3 K
7.1		$1.5 K	$1.1 K	N/A	N/A	N/A	$1.3 K
12.2		$1.7 K	$1.0 K	N/A	N/A	N/A	$1.3 K
17.3		$1.8 K	$0.8 K	N/A	N/A	N/A	$1.3 K
22.4		$2.0 K	$0.7 K	N/A	N/A	N/A	$1.3 K
35	N/A						

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

Product	ES300 - Assume passes culverts
Channel Type	Carrier
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
12.2		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
17.3		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
22.4		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
35	N/A						

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

Appendix B Total ML Savings for Average Carrier Channels

Product	All
Channel Type	Carrier
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	19						19
1.6	29						29
3.9		14	14	28	26	-	81
7.1		17	17	-	-	-	35
12.2		4	4	-	-	-	8
17.3		10	10	-	-	-	21
22.4		4	4	-	-	-	9
35	-						-
Total	48	50	50	28	26	-	201

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	62						62
1.6	93						93
3.9		46	45	89	83	-	262
7.1		56	55	-	-	-	112
12.2		13	13	-	-	-	25
17.3		34	33	-	-	-	67
22.4		14	14	-	-	-	28
35	-						-
Total	155	162	161	89	83	-	649

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	73						73
1.6	109						109
3.9		54	53	104	98	-	309
7.1		66	65	-	-	-	131
12.2		15	15	-	-	-	30
17.3		40	39	-	-	-	79
22.4		17	17	-	-	-	33
35	-						-
Total	182	191	189	104	98	-	764

Appendix C $/ML Savings for Average Trunk Channels

Product	WaterSavr
Channel Type	Trunk
Evaporative Rate	1.5

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 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 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

Product	Aquatain
Channel Type	Trunk
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$185.6 K						$185.6 K
1.6	$169.8 K						$169.8 K
3.9		$201.2 K	$138.5 K	$192.0 K	$147.7 K	N/A	$169.8 K
7.1		$226.9 K	$112.8 K	N/A	N/A	N/A	$169.8 K
12.2		$267.9 K	$71.8 K	N/A	N/A	N/A	$169.8 K
17.3		$308.9 K	$30.8 K	N/A	N/A	N/A	$169.8 K
22.4		$349.9 K	$10.2 K	N/A	N/A	N/A	$180.0 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$61.9 K						$61.9 K
1.6	$56.6 K						$56.6 K
3.9		$67.1 K	$46.2 K	$64.0 K	$49.2 K	N/A	$56.6 K
7.1		$75.6 K	$37.6 K	N/A	N/A	N/A	$56.6 K
12.2		$89.3 K	$23.9 K	N/A	N/A	N/A	$56.6 K
17.3		$103.0 K	$10.3 K	N/A	N/A	N/A	$56.6 K
22.4		$116.6 K	$3.4 K	N/A	N/A	N/A	$60.0 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$37.1 K						$37.1 K
1.6	$34.0 K						$34.0 K
3.9		$40.2 K	$27.7 K	$38.4 K	$29.5 K	N/A	$34.0 K
7.1		$45.4 K	$22.6 K	N/A	N/A	N/A	$34.0 K
12.2		$53.6 K	$14.4 K	N/A	N/A	N/A	$34.0 K
17.3		$61.8 K	$6.2 K	N/A	N/A	N/A	$34.0 K
22.4		$70.0 K	$2.0 K	N/A	N/A	N/A	$36.0 K
35	N/A						

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

Product	ES300
Channel Type	Trunk
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$16.3 K						$16.3 K
1.6	$15.0 K						$15.0 K
3.9		$17.8 K	$12.2 K	$17.0 K	$13.0 K	N/A	$15.0 K
7.1		$20.0 K	$10.0 K	N/A	N/A	N/A	$15.0 K
12.2		$23.7 K	$6.3 K	N/A	N/A	N/A	$15.0 K
17.3		$27.3 K	$2.7 K	N/A	N/A	N/A	$15.0 K
22.4		$30.9 K	$1.1 K	N/A	N/A	N/A	$16.0 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$5.4 K						$5.4 K
1.6	$5.0 K						$5.0 K
3.9		$5.9 K	$4.1 K	$5.7 K	$4.3 K	N/A	$5.0 K
7.1		$6.7 K	$3.3 K	N/A	N/A	N/A	$5.0 K
12.2		$7.9 K	$2.1 K	N/A	N/A	N/A	$5.0 K
17.3		$9.1 K	$0.9 K	N/A	N/A	N/A	$5.0 K
22.4		$10.3 K	$0.4 K	N/A	N/A	N/A	$5.3 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$3.3 K						$3.3 K
1.6	$3.0 K						$3.0 K
3.9		$3.6 K	$2.4 K	$3.4 K	$2.6 K	N/A	$3.0 K
7.1		$4.0 K	$2.0 K	N/A	N/A	N/A	$3.0 K
12.2		$4.7 K	$1.3 K	N/A	N/A	N/A	$3.0 K
17.3		$5.5 K	$0.5 K	N/A	N/A	N/A	$3.0 K
22.4		$6.2 K	$0.2 K	N/A	N/A	N/A	$3.2 K
35	N/A						

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

Product	ES300 - Assume passes culverts
Channel Type	Trunk
Evaporative Rate	1.5

Wind Speed	Wind Direction Category All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
12.2		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
17.3		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
22.4		$0.4 K	$1.1 K	N/A	N/A	N/A	$0.8 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	Wind Direction Category All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.4 K	N/A	N/A	N/A	$0.3 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	Wind Direction Category All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.2 K	N/A	N/A	N/A	$0.2 K
35	N/A						

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

Appendix D Total ML Savings for Average Trunk Channels

Product	All
Channel Type	Trunk
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	42						42
1.6	28						28
3.9		37	31	71	69	-	208
7.1		45	38	-	-	-	83
12.2		10	9	-	-	-	19
17.3		27	23	-	-	-	50
22.4		11	10	-	-	-	21
35	-						-
Total	70	131	109	71	69	-	450

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	137						137
1.6	90						90
3.9		119	99	230	222	-	669
7.1		146	121	-	-	-	267
12.2		33	28	-	-	-	61
17.3		88	73	-	-	-	160
22.4		37	31	-	-	-	68
35	-						-
Total	226	422	351	230	222	-	1,452

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	161						161
1.6	106						106
3.9		140	116	271	262	-	789
7.1		172	143	-	-	-	315
12.2		39	32	-	-	-	72
17.3		103	86	-	-	-	189
22.4		43	36	-	-	-	80
35	-						-
Total	267	497	413	271	262	-	1,710

Appendix E $/ML Savings for Average Spur Channels

Product	WaterSavr
Channel Type	Spur
Evaporative Rate	1.5

Wind Speed	Wind Direction Category All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$15.7 K						$15.7 K
1.6	$13.3 K						$13.3 K
3.9		$18.4 K	$8.3 K	$16.9 K	$9.8 K	N/A	$13.3 K
7.1		$22.5 K	$4.1 K	N/A	N/A	N/A	$13.3 K
12.2		$29.1 K	$2.5 K	N/A	N/A	N/A	$15.8 K
17.3		$35.8 K	$9.1 K	N/A	N/A	N/A	$22.4 K
22.4		$42.4 K	$15.7 K	N/A	N/A	N/A	$29.0 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	Wind Direction Category All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$5.2 K						$5.2 K
1.6	$4.4 K						$4.4 K
3.9		$6.1 K	$2.8 K	$5.6 K	$3.3 K	N/A	$4.4 K
7.1		$7.5 K	$1.4 K	N/A	N/A	N/A	$4.4 K
12.2		$9.7 K	$0.8 K	N/A	N/A	N/A	$5.3 K
17.3		$11.9 K	$3.0 K	N/A	N/A	N/A	$7.5 K
22.4		$14.1 K	$5.2 K	N/A	N/A	N/A	$9.7 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	Wind Direction Category All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$3.1 K						$3.1 K
1.6	$2.7 K						$2.7 K
3.9		$3.7 K	$1.7 K	$3.4 K	$2.0 K	N/A	$2.7 K
7.1		$4.5 K	$0.8 K	N/A	N/A	N/A	$2.7 K
12.2		$5.8 K	$0.5 K	N/A	N/A	N/A	$3.2 K
17.3		$7.2 K	$1.8 K	N/A	N/A	N/A	$4.5 K
22.4		$8.5 K	$3.1 K	N/A	N/A	N/A	$5.8 K
35	N/A						

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

Product	Aquatain
Channel Type	Spur
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$143.6 K						$143.6 K
1.6	$121.9 K						$121.9 K
3.9		$168.1 K	$75.6 K	$154.6 K	$89.2 K	N/A	$121.9 K
7.1		$206.0 K	$37.7 K	N/A	N/A	N/A	$121.9 K
12.2		$266.5 K	$22.8 K	N/A	N/A	N/A	$144.6 K
17.3		$326.9 K	$83.2 K	N/A	N/A	N/A	$205.1 K
22.4		$387.4 K	$143.7 K	N/A	N/A	N/A	$265.5 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$47.9 K						$47.9 K
1.6	$40.6 K						$40.6 K
3.9		$56.0 K	$25.2 K	$51.5 K	$29.7 K	N/A	$40.6 K
7.1		$68.7 K	$12.6 K	N/A	N/A	N/A	$40.6 K
12.2		$88.8 K	$7.6 K	N/A	N/A	N/A	$48.2 K
17.3		$109.0 K	$27.7 K	N/A	N/A	N/A	$68.4 K
22.4		$129.1 K	$47.9 K	N/A	N/A	N/A	$88.5 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$28.7 K						$28.7 K
1.6	$24.4 K						$24.4 K
3.9		$33.6 K	$15.1 K	$30.9 K	$17.8 K	N/A	$24.4 K
7.1		$41.2 K	$7.5 K	N/A	N/A	N/A	$24.4 K
12.2		$53.3 K	$4.6 K	N/A	N/A	N/A	$28.9 K
17.3		$65.4 K	$16.6 K	N/A	N/A	N/A	$41.0 K
22.4		$77.5 K	$28.7 K	N/A	N/A	N/A	$53.1 K
35	N/A						

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

Product	ES300
Channel Type	Spur
Evaporative Rate	1.5

Wind Speed	Wind Direction Category: All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$13.9 K						$13.9 K
1.6	$11.9 K						$11.9 K
3.9		$16.4 K	$7.4 K	$15.1 K	$8.7 K	N/A	$11.9 K
7.1		$20.1 K	$3.7 K	N/A	N/A	N/A	$11.9 K
12.2		$26.0 K	$2.5 K	N/A	N/A	N/A	$14.2 K
17.3		$31.8 K	$9.1 K	N/A	N/A	N/A	$20.5 K
22.4		$37.7 K	$15.7 K	N/A	N/A	N/A	$26.7 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	Wind Direction Category: All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$4.6 K						$4.6 K
1.6	$4.0 K						$4.0 K
3.9		$5.5 K	$2.5 K	$5.0 K	$2.9 K	N/A	$4.0 K
7.1		$6.7 K	$1.2 K	N/A	N/A	N/A	$4.0 K
12.2		$8.7 K	$0.8 K	N/A	N/A	N/A	$4.7 K
17.3		$10.6 K	$3.0 K	N/A	N/A	N/A	$6.8 K
22.4		$12.6 K	$5.2 K	N/A	N/A	N/A	$8.9 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	Wind Direction Category: All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$2.8 K						$2.8 K
1.6	$2.4 K						$2.4 K
3.9		$3.3 K	$1.5 K	$3.0 K	$1.7 K	N/A	$2.4 K
7.1		$4.0 K	$0.7 K	N/A	N/A	N/A	$2.4 K
12.2		$5.2 K	$0.5 K	N/A	N/A	N/A	$2.8 K
17.3		$6.4 K	$1.8 K	N/A	N/A	N/A	$4.1 K
22.4		$7.5 K	$3.1 K	N/A	N/A	N/A	$5.3 K
35	N/A						

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

Product	ES300 - Assume passes culverts						
Channel Type	Spur						
Evaporative Rate	1.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
12.2		$0.4 K	$2.5 K	N/A	N/A	N/A	$1.4 K
17.3		$0.4 K	$9.1 K	N/A	N/A	N/A	$4.7 K
22.4		$0.4 K	$15.7 K	N/A	N/A	N/A	$8.1 K
35	N/A						

Evaporative Rate	4.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.8 K	N/A	N/A	N/A	$0.5 K
17.3		$0.1 K	$3.0 K	N/A	N/A	N/A	$1.6 K
22.4		$0.1 K	$5.2 K	N/A	N/A	N/A	$2.7 K
35	N/A						

Evaporative Rate	7.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.5 K	N/A	N/A	N/A	$0.3 K
17.3		$0.1 K	$1.8 K	N/A	N/A	N/A	$0.9 K
22.4		$0.1 K	$3.1 K	N/A	N/A	N/A	$1.6 K
35	N/A						

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

Appendix F Total ML Savings for Average Spur Channels

Product	All
Channel Type	Spur
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	39						39
1.6	31						31
3.9		32	26	63	58	-	178
7.1		39	32	-	-	-	71
12.2		9	7	-	-	-	16
17.3		23	19	-	-	-	42
22.4		10	8	-	-	-	18
35	-						-
Total	69	113	91	63	58	-	395

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	125						125
1.6	98						98
3.9		102	83	204	186	-	575
7.1		126	102	-	-	-	228
12.2		29	23	-	-	-	52
17.3		75	61	-	-	-	137
22.4		32	26	-	-	-	58
35	-						-
Total	224	364	294	204	186	-	1,272

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	148						148
1.6	116						116
3.9		121	97	240	219	-	677
7.1		148	120	-	-	-	268
12.2		34	27	-	-	-	61
17.3		89	72	-	-	-	161
22.4		37	30	-	-	-	68
35	-						-
Total	264	429	347	240	219	-	1,498

Appendix G $/ML Savings for 25% Longest Carrier Channels

Product	WaterSavr
Channel Type	Carrier-Top 25%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$5.2 K						$5.2 K
1.6	$5.0 K						$5.0 K
3.9		$5.4 K	$4.6 K	$5.3 K	$4.7 K	N/A	$5.0 K
7.1		$5.8 K	$4.3 K	N/A	N/A	N/A	$5.0 K
12.2		$6.3 K	$3.7 K	N/A	N/A	N/A	$5.0 K
17.3		$6.8 K	$3.2 K	N/A	N/A	N/A	$5.0 K
22.4		$7.4 K	$2.6 K	N/A	N/A	N/A	$5.0 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.7 K						$1.7 K
1.6	$1.7 K						$1.7 K
3.9		$1.8 K	$1.5 K	$1.8 K	$1.6 K	N/A	$1.7 K
7.1		$1.9 K	$1.4 K	N/A	N/A	N/A	$1.7 K
12.2		$2.1 K	$1.2 K	N/A	N/A	N/A	$1.7 K
17.3		$2.3 K	$1.1 K	N/A	N/A	N/A	$1.7 K
22.4		$2.5 K	$0.9 K	N/A	N/A	N/A	$1.7 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.0 K						$1.0 K
1.6	$1.0 K						$1.0 K
3.9		$1.1 K	$0.9 K	$1.1 K	$0.9 K	N/A	$1.0 K
7.1		$1.2 K	$0.9 K	N/A	N/A	N/A	$1.0 K
12.2		$1.3 K	$0.7 K	N/A	N/A	N/A	$1.0 K
17.3		$1.4 K	$0.6 K	N/A	N/A	N/A	$1.0 K
22.4		$1.5 K	$0.5 K	N/A	N/A	N/A	$1.0 K
35	N/A						

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

Product	Aquatain
Channel Type	Carrier-Top 25%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$47.1 K						$47.1 K
1.6	$45.8 K						$45.8 K
3.9		$49.6 K	$42.1 K	$48.5 K	$43.2 K	N/A	$45.8 K
7.1		$52.7 K	$39.0 K	N/A	N/A	N/A	$45.8 K
12.2		$57.6 K	$34.1 K	N/A	N/A	N/A	$45.8 K
17.3		$62.5 K	$29.1 K	N/A	N/A	N/A	$45.8 K
22.4		$67.4 K	$24.2 K	N/A	N/A	N/A	$45.8 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$15.7 K						$15.7 K
1.6	$15.3 K						$15.3 K
3.9		$16.5 K	$14.0 K	$16.2 K	$14.4 K	N/A	$15.3 K
7.1		$17.6 K	$13.0 K	N/A	N/A	N/A	$15.3 K
12.2		$19.2 K	$11.4 K	N/A	N/A	N/A	$15.3 K
17.3		$20.8 K	$9.7 K	N/A	N/A	N/A	$15.3 K
22.4		$22.5 K	$8.1 K	N/A	N/A	N/A	$15.3 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$9.4 K						$9.4 K
1.6	$9.2 K						$9.2 K
3.9		$9.9 K	$8.4 K	$9.7 K	$8.6 K	N/A	$9.2 K
7.1		$10.5 K	$7.8 K	N/A	N/A	N/A	$9.2 K
12.2		$11.5 K	$6.8 K	N/A	N/A	N/A	$9.2 K
17.3		$12.5 K	$5.8 K	N/A	N/A	N/A	$9.2 K
22.4		$13.5 K	$4.8 K	N/A	N/A	N/A	$9.2 K
35	N/A						

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

Product	ES300
Channel Type	Carrier-Top 25%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$2.3 K						$2.3 K
1.6	$2.2 K						$2.2 K
3.9		$2.4 K	$2.0 K	$2.3 K	$2.1 K	N/A	$2.2 K
7.1		$2.5 K	$1.9 K	N/A	N/A	N/A	$2.2 K
12.2		$2.8 K	$1.6 K	N/A	N/A	N/A	$2.2 K
17.3		$3.0 K	$1.4 K	N/A	N/A	N/A	$2.2 K
22.4		$3.3 K	$1.2 K	N/A	N/A	N/A	$2.2 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.8 K						$0.8 K
1.6	$0.7 K						$0.7 K
3.9		$0.8 K	$0.7 K	$0.8 K	$0.7 K	N/A	$0.7 K
7.1		$0.8 K	$0.6 K	N/A	N/A	N/A	$0.7 K
12.2		$0.9 K	$0.5 K	N/A	N/A	N/A	$0.7 K
17.3		$1.0 K	$0.5 K	N/A	N/A	N/A	$0.7 K
22.4		$1.1 K	$0.4 K	N/A	N/A	N/A	$0.7 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.5 K						$0.5 K
1.6	$0.4 K						$0.4 K
3.9		$0.5 K	$0.4 K	$0.5 K	$0.4 K	N/A	$0.4 K
7.1		$0.5 K	$0.4 K	N/A	N/A	N/A	$0.4 K
12.2		$0.6 K	$0.3 K	N/A	N/A	N/A	$0.4 K
17.3		$0.6 K	$0.3 K	N/A	N/A	N/A	$0.4 K
22.4		$0.7 K	$0.2 K	N/A	N/A	N/A	$0.4 K
35	N/A						

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

Product	ES300 - Assume passes culverts
Channel Type	Carrier-Top 25%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
12.2		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
17.3		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
22.4		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
35	N/A						

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

Appendix H Total ML Savings for 25% Longest Carrier Channels

Product	All
Channel Type	Carrier-Top 25%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	9						9
1.6	13						13
3.9		6	6	12	12	-	37
7.1		8	8	-	-	-	16
12.2		2	2	-	-	-	4
17.3		5	5	-	-	-	9
22.4		2	2	-	-	-	4
35	-						-
Total	22	23	22	12	12	-	91

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	28						28
1.6	42						42
3.9		21	20	40	37	-	118
7.1		25	25	-	-	-	50
12.2		6	6	-	-	-	11
17.3		15	15	-	-	-	30
22.4		6	6	-	-	-	13
35	-						-
Total	70	73	72	40	37	-	293

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	33						33
1.6	49						49
3.9		24	24	47	44	-	139
7.1		30	29	-	-	-	59
12.2		7	7	-	-	-	13
17.3		18	18	-	-	-	36
22.4		8	7	-	-	-	15
35	-						-
Total	82	86	85	47	44	-	345

Appendix I $/ML Savings for 25% Longest Trunk Channels

Product	WaterSavr
Channel Type	Trunk-Top 25%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$9.1 K						$9.1 K
1.6	$8.5 K						$8.5 K
3.9		$10.1 K	$6.9 K	$9.6 K	$7.4 K	N/A	$8.5 K
7.1		$11.4 K	$5.6 K	N/A	N/A	N/A	$8.5 K
12.2		$13.4 K	$3.6 K	N/A	N/A	N/A	$8.5 K
17.3		$15.5 K	$1.5 K	N/A	N/A	N/A	$8.5 K
22.4		$17.5 K	$0.5 K	N/A	N/A	N/A	$9.0 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$3.0 K						$3.0 K
1.6	$2.8 K						$2.8 K
3.9		$3.4 K	$2.3 K	$3.2 K	$2.5 K	N/A	$2.8 K
7.1		$3.8 K	$1.9 K	N/A	N/A	N/A	$2.8 K
12.2		$4.5 K	$1.2 K	N/A	N/A	N/A	$2.8 K
17.3		$5.2 K	$0.5 K	N/A	N/A	N/A	$2.8 K
22.4		$5.8 K	$0.2 K	N/A	N/A	N/A	$3.0 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.8 K						$1.8 K
1.6	$1.7 K						$1.7 K
3.9		$2.0 K	$1.4 K	$1.9 K	$1.5 K	N/A	$1.7 K
7.1		$2.3 K	$1.1 K	N/A	N/A	N/A	$1.7 K
12.2		$2.7 K	$0.7 K	N/A	N/A	N/A	$1.7 K
17.3		$3.1 K	$0.3 K	N/A	N/A	N/A	$1.7 K
22.4		$3.5 K	$0.1 K	N/A	N/A	N/A	$1.8 K
35	N/A						

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

Product	Aquatain						
Channel Type	Trunk-Top 25%						
Evaporative Rate	1.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$83.6 K						$83.6 K
1.6	$77.8 K						$77.8 K
3.9		$92.2 K	$63.4 K	$87.9 K	$67.6 K	N/A	$77.8 K
7.1		$103.9 K	$51.7 K	N/A	N/A	N/A	$77.8 K
12.2		$122.7 K	$32.9 K	N/A	N/A	N/A	$77.8 K
17.3		$141.5 K	$14.1 K	N/A	N/A	N/A	$77.8 K
22.4		$160.3 K	$4.7 K	N/A	N/A	N/A	$82.5 K
35	N/A						

Evaporative Rate	4.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$27.9 K						$27.9 K
1.6	$25.9 K						$25.9 K
3.9		$30.7 K	$21.1 K	$29.3 K	$22.5 K	N/A	$25.9 K
7.1		$34.6 K	$17.2 K	N/A	N/A	N/A	$25.9 K
12.2		$40.9 K	$11.0 K	N/A	N/A	N/A	$25.9 K
17.3		$47.2 K	$4.7 K	N/A	N/A	N/A	$25.9 K
22.4		$53.4 K	$1.6 K	N/A	N/A	N/A	$27.5 K
35	N/A						

Evaporative Rate	7.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$16.7 K						$16.7 K
1.6	$15.6 K						$15.6 K
3.9		$18.4 K	$12.7 K	$17.6 K	$13.5 K	N/A	$15.6 K
7.1		$20.8 K	$10.3 K	N/A	N/A	N/A	$15.6 K
12.2		$24.5 K	$6.6 K	N/A	N/A	N/A	$15.6 K
17.3		$28.3 K	$2.8 K	N/A	N/A	N/A	$15.6 K
22.4		$32.1 K	$0.9 K	N/A	N/A	N/A	$16.5 K
35	N/A						

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

Product	ES300
Channel Type	Trunk-Top 25%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$6.5 K						$6.5 K
1.6	$6.1 K						$6.1 K
3.9		$7.2 K	$4.9 K	$6.8 K	$5.3 K	N/A	$6.1 K
7.1		$8.1 K	$4.0 K	N/A	N/A	N/A	$6.1 K
12.2		$9.6 K	$2.6 K	N/A	N/A	N/A	$6.1 K
17.3		$11.0 K	$1.1 K	N/A	N/A	N/A	$6.1 K
22.4		$12.5 K	$0.5 K	N/A	N/A	N/A	$6.5 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$2.2 K						$2.2 K
1.6	$2.0 K						$2.0 K
3.9		$2.4 K	$1.6 K	$2.3 K	$1.8 K	N/A	$2.0 K
7.1		$2.7 K	$1.3 K	N/A	N/A	N/A	$2.0 K
12.2		$3.2 K	$0.9 K	N/A	N/A	N/A	$2.0 K
17.3		$3.7 K	$0.4 K	N/A	N/A	N/A	$2.0 K
22.4		$4.2 K	$0.2 K	N/A	N/A	N/A	$2.2 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.3 K						$1.3 K
1.6	$1.2 K						$1.2 K
3.9		$1.4 K	$1.0 K	$1.4 K	$1.1 K	N/A	$1.2 K
7.1		$1.6 K	$0.8 K	N/A	N/A	N/A	$1.2 K
12.2		$1.9 K	$0.5 K	N/A	N/A	N/A	$1.2 K
17.3		$2.2 K	$0.2 K	N/A	N/A	N/A	$1.2 K
22.4		$2.5 K	$0.1 K	N/A	N/A	N/A	$1.3 K
35	N/A						

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

Product	ES300 - Assume passes culverts					
Channel Type	Trunk-Top 25%					
Evaporative Rate	1.5					

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
12.2		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
17.3		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
22.4		$0.4 K	$0.5 K	N/A	N/A	N/A	$0.4 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.2 K	N/A	N/A	N/A	$0.1 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
35	N/A						

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

Appendix J Total ML Savings for 25% Longest Trunk Channels

Product	All
Channel Type	Trunk-Top 25%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	21						21
1.6	14						14
3.9		19	15	36	35	-	105
7.1		23	19	-	-	-	42
12.2		5	4	-	-	-	10
17.3		14	11	-	-	-	25
22.4		6	5	-	-	-	11
35	-						-
Total	35	66	55	36	35	-	228

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	69						69
1.6	45						45
3.9		60	50	116	112	-	338
7.1		74	61	-	-	-	135
12.2		17	14	-	-	-	31
17.3		44	37	-	-	-	81
22.4		19	15	-	-	-	34
35	-						-
Total	114	213	177	116	112	-	733

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	81						81
1.6	53						53
3.9		71	59	137	132	-	398
7.1		87	72	-	-	-	159
12.2		20	16	-	-	-	36
17.3		52	43	-	-	-	95
22.4		22	18	-	-	-	40
35	-						-
Total	135	251	209	137	132	-	864

Appendix K $/ML Savings for 25% Longest Spur Channels

Product	WaterSavr
Channel Type	Spur-Top 25%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$7.8 K						$7.8 K
1.6	$6.8 K						$6.8 K
3.9		$9.4 K	$4.2 K	$8.7 K	$5.0 K	N/A	$6.8 K
7.1		$11.6 K	$2.1 K	N/A	N/A	N/A	$6.8 K
12.2		$14.9 K	$1.3 K	N/A	N/A	N/A	$8.1 K
17.3		$18.3 K	$4.7 K	N/A	N/A	N/A	$11.5 K
22.4		$21.7 K	$8.1 K	N/A	N/A	N/A	$14.9 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$2.6 K						$2.6 K
1.6	$2.3 K						$2.3 K
3.9		$3.1 K	$1.4 K	$2.9 K	$1.7 K	N/A	$2.3 K
7.1		$3.9 K	$0.7 K	N/A	N/A	N/A	$2.3 K
12.2		$5.0 K	$0.4 K	N/A	N/A	N/A	$2.7 K
17.3		$6.1 K	$1.6 K	N/A	N/A	N/A	$3.8 K
22.4		$7.2 K	$2.7 K	N/A	N/A	N/A	$5.0 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.6 K						$1.6 K
1.6	$1.4 K						$1.4 K
3.9		$1.9 K	$0.8 K	$1.7 K	$1.0 K	N/A	$1.4 K
7.1		$2.3 K	$0.4 K	N/A	N/A	N/A	$1.4 K
12.2		$3.0 K	$0.3 K	N/A	N/A	N/A	$1.6 K
17.3		$3.7 K	$0.9 K	N/A	N/A	N/A	$2.3 K
22.4		$4.3 K	$1.6 K	N/A	N/A	N/A	$3.0 K
35	N/A						

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

Product	Aquatain
Channel Type	Spur-Top 25%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$71.7 K						$71.7 K
1.6	$62.5 K						$62.5 K
3.9		$86.2 K	$38.8 K	$79.2 K	$45.7 K	N/A	$62.5 K
7.1		$105.6 K	$19.3 K	N/A	N/A	N/A	$62.5 K
12.2		$136.6 K	$11.7 K	N/A	N/A	N/A	$74.1 K
17.3		$167.6 K	$42.7 K	N/A	N/A	N/A	$105.1 K
22.4		$198.6 K	$73.6 K	N/A	N/A	N/A	$136.1 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$23.9 K						$23.9 K
1.6	$20.8 K						$20.8 K
3.9		$28.7 K	$12.9 K	$26.4 K	$15.2 K	N/A	$20.8 K
7.1		$35.2 K	$6.4 K	N/A	N/A	N/A	$20.8 K
12.2		$45.5 K	$3.9 K	N/A	N/A	N/A	$24.7 K
17.3		$55.9 K	$14.2 K	N/A	N/A	N/A	$35.0 K
22.4		$66.2 K	$24.5 K	N/A	N/A	N/A	$45.4 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$14.3 K						$14.3 K
1.6	$12.5 K						$12.5 K
3.9		$17.2 K	$7.8 K	$15.8 K	$9.1 K	N/A	$12.5 K
7.1		$21.1 K	$3.9 K	N/A	N/A	N/A	$12.5 K
12.2		$27.3 K	$2.3 K	N/A	N/A	N/A	$14.8 K
17.3		$33.5 K	$8.5 K	N/A	N/A	N/A	$21.0 K
22.4		$39.7 K	$14.7 K	N/A	N/A	N/A	$27.2 K
35	N/A						

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

Product	ES300
Channel Type	Spur-Top 25%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$6.8 K						$6.8 K
1.6	$6.0 K						$6.0 K
3.9		$8.2 K	$3.7 K	$7.6 K	$4.4 K	N/A	$6.0 K
7.1		$10.1 K	$1.8 K	N/A	N/A	N/A	$6.0 K
12.2		$13.0 K	$1.3 K	N/A	N/A	N/A	$7.2 K
17.3		$16.0 K	$4.7 K	N/A	N/A	N/A	$10.3 K
22.4		$18.9 K	$8.1 K	N/A	N/A	N/A	$13.5 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$2.3 K						$2.3 K
1.6	$2.0 K						$2.0 K
3.9		$2.7 K	$1.2 K	$2.5 K	$1.5 K	N/A	$2.0 K
7.1		$3.4 K	$0.6 K	N/A	N/A	N/A	$2.0 K
12.2		$4.3 K	$0.4 K	N/A	N/A	N/A	$2.4 K
17.3		$5.3 K	$1.6 K	N/A	N/A	N/A	$3.4 K
22.4		$6.3 K	$2.7 K	N/A	N/A	N/A	$4.5 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.4 K						$1.4 K
1.6	$1.2 K						$1.2 K
3.9		$1.6 K	$0.7 K	$1.5 K	$0.9 K	N/A	$1.2 K
7.1		$2.0 K	$0.4 K	N/A	N/A	N/A	$1.2 K
12.2		$2.6 K	$0.3 K	N/A	N/A	N/A	$1.4 K
17.3		$3.2 K	$0.9 K	N/A	N/A	N/A	$2.1 K
22.4		$3.8 K	$1.6 K	N/A	N/A	N/A	$2.7 K
35	N/A						

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

Product	ES300 - Assume passes culverts
Channel Type	Spur-Top 25%
Evaporative Rate	1.5

Wind Speed	Wind Direction Category: All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
12.2		$0.4 K	$1.3 K	N/A	N/A	N/A	$0.8 K
17.3		$0.4 K	$4.7 K	N/A	N/A	N/A	$2.5 K
22.4		$0.4 K	$8.1 K	N/A	N/A	N/A	$4.2 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	Wind Direction Category: All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.4 K	N/A	N/A	N/A	$0.3 K
17.3		$0.1 K	$1.6 K	N/A	N/A	N/A	$0.8 K
22.4		$0.1 K	$2.7 K	N/A	N/A	N/A	$1.4 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	Wind Direction Category: All	Parallel	Opposite	Oblique Parallel	Oblique Opposite	Perpendicular	Average
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.3 K	N/A	N/A	N/A	$0.2 K
17.3		$0.1 K	$0.9 K	N/A	N/A	N/A	$0.5 K
22.4		$0.1 K	$1.6 K	N/A	N/A	N/A	$0.8 K
35	N/A						

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

Appendix L Total ML Savings for 25% Longest Spur Channels

Product	All
Channel Type	Spur-Top 25%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	20						20
1.6	16						16
3.9		16	13	32	29	-	91
7.1		20	16	-	-	-	36
12.2		5	4	-	-	-	8
17.3		12	10	-	-	-	22
22.4		5	4	-	-	-	9
35	-						-
Total	35	57	46	32	29	-	200

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	64						64
1.6	50						50
3.9		52	42	103	94	-	292
7.1		64	52	-	-	-	116
12.2		15	12	-	-	-	26
17.3		38	31	-	-	-	69
22.4		16	13	-	-	-	29
35	-						-
Total	114	185	149	103	94	-	646

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	75						75
1.6	59						59
3.9		61	49	122	111	-	344
7.1		75	61	-	-	-	136
12.2		17	14	-	-	-	31
17.3		45	37	-	-	-	82
22.4		19	15	-	-	-	34
35	-						-
Total	134	218	176	122	111	-	761

Appendix M $/ML Savings for 10% Longest Carrier Channels

Product	WaterSavr
Channel Type	Carrier-Top 10%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$3.4 K						$3.4 K
1.6	$3.3 K						$3.3 K
3.9		$3.6 K	$3.0 K	$3.5 K	$3.1 K	N/A	$3.3 K
7.1		$3.8 K	$2.8 K	N/A	N/A	N/A	$3.3 K
12.2		$4.2 K	$2.5 K	N/A	N/A	N/A	$3.3 K
17.3		$4.5 K	$2.1 K	N/A	N/A	N/A	$3.3 K
22.4		$4.9 K	$1.7 K	N/A	N/A	N/A	$3.3 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.1 K						$1.1 K
1.6	$1.1 K						$1.1 K
3.9		$1.2 K	$1.0 K	$1.2 K	$1.0 K	N/A	$1.1 K
7.1		$1.3 K	$0.9 K	N/A	N/A	N/A	$1.1 K
12.2		$1.4 K	$0.8 K	N/A	N/A	N/A	$1.1 K
17.3		$1.5 K	$0.7 K	N/A	N/A	N/A	$1.1 K
22.4		$1.6 K	$0.6 K	N/A	N/A	N/A	$1.1 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.7 K						$0.7 K
1.6	$0.7 K						$0.7 K
3.9		$0.7 K	$0.6 K	$0.7 K	$0.6 K	N/A	$0.7 K
7.1		$0.8 K	$0.6 K	N/A	N/A	N/A	$0.7 K
12.2		$0.8 K	$0.5 K	N/A	N/A	N/A	$0.7 K
17.3		$0.9 K	$0.4 K	N/A	N/A	N/A	$0.7 K
22.4		$1.0 K	$0.3 K	N/A	N/A	N/A	$0.7 K
35	N/A						

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

Product	Aquatain						
Channel Type	Carrier-Top 10%						
Evaporative Rate	1.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$31.1 K						$31.1 K
1.6	$30.3 K						$30.3 K
3.9		$32.8 K	$27.8 K	$32.0 K	$28.5 K	N/A	$30.3 K
7.1		$34.8 K	$25.7 K	N/A	N/A	N/A	$30.3 K
12.2		$38.1 K	$22.5 K	N/A	N/A	N/A	$30.3 K
17.3		$41.3 K	$19.2 K	N/A	N/A	N/A	$30.3 K
22.4		$44.6 K	$16.0 K	N/A	N/A	N/A	$30.3 K
35	N/A						

Evaporative Rate	4.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$10.4 K						$10.4 K
1.6	$10.1 K						$10.1 K
3.9		$10.9 K	$9.3 K	$10.7 K	$9.5 K	N/A	$10.1 K
7.1		$11.6 K	$8.6 K	N/A	N/A	N/A	$10.1 K
12.2		$12.7 K	$7.5 K	N/A	N/A	N/A	$10.1 K
17.3		$13.8 K	$6.4 K	N/A	N/A	N/A	$10.1 K
22.4		$14.9 K	$5.3 K	N/A	N/A	N/A	$10.1 K
35	N/A						

Evaporative Rate	7.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$6.2 K						$6.2 K
1.6	$6.1 K						$6.1 K
3.9		$6.6 K	$5.6 K	$6.4 K	$5.7 K	N/A	$6.1 K
7.1		$7.0 K	$5.1 K	N/A	N/A	N/A	$6.1 K
12.2		$7.6 K	$4.5 K	N/A	N/A	N/A	$6.1 K
17.3		$8.3 K	$3.8 K	N/A	N/A	N/A	$6.1 K
22.4		$8.9 K	$3.2 K	N/A	N/A	N/A	$6.1 K
35	N/A						

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

Product	ES300
Channel Type	Carrier-Top 10%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.2 K						$1.2 K
1.6	$1.2 K						$1.2 K
3.9		$1.3 K	$1.1 K	$1.2 K	$1.1 K	N/A	$1.2 K
7.1		$1.3 K	$1.0 K	N/A	N/A	N/A	$1.2 K
12.2		$1.5 K	$0.9 K	N/A	N/A	N/A	$1.2 K
17.3		$1.6 K	$0.7 K	N/A	N/A	N/A	$1.2 K
22.4		$1.7 K	$0.6 K	N/A	N/A	N/A	$1.2 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.3 K	N/A	N/A	N/A	$0.4 K
12.2		$0.5 K	$0.3 K	N/A	N/A	N/A	$0.4 K
17.3		$0.5 K	$0.2 K	N/A	N/A	N/A	$0.4 K
22.4		$0.6 K	$0.2 K	N/A	N/A	N/A	$0.4 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.2 K						$0.2 K
1.6	$0.2 K						$0.2 K
3.9		$0.3 K	$0.2 K	$0.2 K	$0.2 K	N/A	$0.2 K
7.1		$0.3 K	$0.2 K	N/A	N/A	N/A	$0.2 K
12.2		$0.3 K	$0.2 K	N/A	N/A	N/A	$0.2 K
17.3		$0.3 K	$0.1 K	N/A	N/A	N/A	$0.2 K
22.4		$0.3 K	$0.1 K	N/A	N/A	N/A	$0.2 K
35	N/A						

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

Product	ES300 - Assume passes culverts
Channel Type	Carrier-Top 10%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
12.2		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
17.3		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
22.4		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
35	N/A						

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

Appendix N Total ML Savings for 10% Longest Carrier Channels

Product	All
Channel Type	Carrier-Top 10%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	5						5
1.6	7						7
3.9		3	3	7	6	-	20
7.1		4	4	-	-	-	9
12.2		1	1	-	-	-	2
17.3		3	3	-	-	-	5
22.4		1	1	-	-	-	2
35	-						-
Total	12	12	12	7	6	-	50

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	15						15
1.6	23						23
3.9		11	11	22	20	-	65
7.1		14	14	-	-	-	28
12.2		3	3	-	-	-	6
17.3		8	8	-	-	-	17
22.4		3	3	-	-	-	7
35	-						-
Total	38	40	40	22	20	-	160

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	18						18
1.6	27						27
3.9		13	13	26	24	-	76
7.1		16	16	-	-	-	32
12.2		4	4	-	-	-	7
17.3		10	10	-	-	-	19
22.4		4	4	-	-	-	8
35	-						-
Total	45	47	47	26	24	-	189

Appendix O $/ML Savings for 10% Longest Trunk Channels

Product	WaterSavr
Channel Type	Trunk-Top 10%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$6.3 K						$6.3 K
1.6	$5.9 K						$5.9 K
3.9		$7.0 K	$4.8 K	$6.7 K	$5.1 K	N/A	$5.9 K
7.1		$7.9 K	$3.9 K	N/A	N/A	N/A	$5.9 K
12.2		$9.3 K	$2.5 K	N/A	N/A	N/A	$5.9 K
17.3		$10.7 K	$1.1 K	N/A	N/A	N/A	$5.9 K
22.4		$12.2 K	$0.4 K	N/A	N/A	N/A	$6.3 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$2.1 K						$2.1 K
1.6	$2.0 K						$2.0 K
3.9		$2.3 K	$1.6 K	$2.2 K	$1.7 K	N/A	$2.0 K
7.1		$2.6 K	$1.3 K	N/A	N/A	N/A	$2.0 K
12.2		$3.1 K	$0.8 K	N/A	N/A	N/A	$2.0 K
17.3		$3.6 K	$0.4 K	N/A	N/A	N/A	$2.0 K
22.4		$4.1 K	$0.1 K	N/A	N/A	N/A	$2.1 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.3 K						$1.3 K
1.6	$1.2 K						$1.2 K
3.9		$1.4 K	$1.0 K	$1.3 K	$1.0 K	N/A	$1.2 K
7.1		$1.6 K	$0.8 K	N/A	N/A	N/A	$1.2 K
12.2		$1.9 K	$0.5 K	N/A	N/A	N/A	$1.2 K
17.3		$2.1 K	$0.2 K	N/A	N/A	N/A	$1.2 K
22.4		$2.4 K	$0.1 K	N/A	N/A	N/A	$1.3 K
35	N/A						

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

Product	Aquatain
Channel Type	Trunk-Top 10%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$57.7 K						$57.7 K
1.6	$54.0 K						$54.0 K
3.9		$64.0 K	$44.1 K	$61.1 K	$47.0 K	N/A	$54.0 K
7.1		$72.2 K	$35.9 K	N/A	N/A	N/A	$54.0 K
12.2		$85.2 K	$22.8 K	N/A	N/A	N/A	$54.0 K
17.3		$98.2 K	$9.8 K	N/A	N/A	N/A	$54.0 K
22.4		$111.3 K	$3.2 K	N/A	N/A	N/A	$57.3 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$19.2 K						$19.2 K
1.6	$18.0 K						$18.0 K
3.9		$21.3 K	$14.7 K	$20.4 K	$15.7 K	N/A	$18.0 K
7.1		$24.1 K	$12.0 K	N/A	N/A	N/A	$18.0 K
12.2		$28.4 K	$7.6 K	N/A	N/A	N/A	$18.0 K
17.3		$32.7 K	$3.3 K	N/A	N/A	N/A	$18.0 K
22.4		$37.1 K	$1.1 K	N/A	N/A	N/A	$19.1 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$11.5 K						$11.5 K
1.6	$10.8 K						$10.8 K
3.9		$12.8 K	$8.8 K	$12.2 K	$9.4 K	N/A	$10.8 K
7.1		$14.4 K	$7.2 K	N/A	N/A	N/A	$10.8 K
12.2		$17.0 K	$4.6 K	N/A	N/A	N/A	$10.8 K
17.3		$19.6 K	$2.0 K	N/A	N/A	N/A	$10.8 K
22.4		$22.3 K	$0.6 K	N/A	N/A	N/A	$11.5 K
35	N/A						

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

Product	ES300						
Channel Type	Trunk-Top 10%						
Evaporative Rate	1.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$3.8 K						$3.8 K
1.6	$3.6 K						$3.6 K
3.9		$4.3 K	$2.9 K	$4.1 K	$3.1 K	N/A	$3.6 K
7.1		$4.8 K	$2.4 K	N/A	N/A	N/A	$3.6 K
12.2		$5.7 K	$1.5 K	N/A	N/A	N/A	$3.6 K
17.3		$6.6 K	$0.7 K	N/A	N/A	N/A	$3.6 K
22.4		$7.4 K	$0.4 K	N/A	N/A	N/A	$3.9 K
35	N/A						

Evaporative Rate	4.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.3 K						$1.3 K
1.6	$1.2 K						$1.2 K
3.9		$1.4 K	$1.0 K	$1.4 K	$1.0 K	N/A	$1.2 K
7.1		$1.6 K	$0.8 K	N/A	N/A	N/A	$1.2 K
12.2		$1.9 K	$0.5 K	N/A	N/A	N/A	$1.2 K
17.3		$2.2 K	$0.2 K	N/A	N/A	N/A	$1.2 K
22.4		$2.5 K	$0.1 K	N/A	N/A	N/A	$1.3 K
35	N/A						

Evaporative Rate	7.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.8 K						$0.8 K
1.6	$0.7 K						$0.7 K
3.9		$0.9 K	$0.6 K	$0.8 K	$0.6 K	N/A	$0.7 K
7.1		$1.0 K	$0.5 K	N/A	N/A	N/A	$0.7 K
12.2		$1.1 K	$0.3 K	N/A	N/A	N/A	$0.7 K
17.3		$1.3 K	$0.1 K	N/A	N/A	N/A	$0.7 K
22.4		$1.5 K	$0.1 K	N/A	N/A	N/A	$0.8 K
35	N/A						

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

Product	ES300 - Assume passes culverts
Channel Type	Trunk-Top 10%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
12.2		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
17.3		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
22.4		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
35	N/A						

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

Appendix P Total ML Savings for 10% Longest Trunk Channels

Product	All
Channel Type	Trunk-Top 10%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	12						12
1.6	8						8
3.9		10	8	20	19	-	57
7.1		13	10	-	-	-	23
12.2		3	2	-	-	-	5
17.3		7	6	-	-	-	14
22.4		3	3	-	-	-	6
35	-						-
Total	19	36	30	20	19	-	124

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	38						38
1.6	25						25
3.9		33	27	63	61	-	185
7.1		40	33	-	-	-	74
12.2		9	8	-	-	-	17
17.3		24	20	-	-	-	44
22.4		10	8	-	-	-	19
35	-						-
Total	62	117	97	63	61	-	401

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	44						44
1.6	29						29
3.9		39	32	75	72	-	218
7.1		47	39	-	-	-	87
12.2		11	9	-	-	-	20
17.3		28	24	-	-	-	52
22.4		12	10	-	-	-	22
35	-						-
Total	74	137	114	75	72	-	472

Appendix Q $/ML Savings for 10% Longest Spur Channels

Product	WaterSavr
Channel Type	Spur-Top 10%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$5.8 K						$5.8 K
1.6	$5.1 K						$5.1 K
3.9		$7.1 K	$3.2 K	$6.5 K	$3.7 K	N/A	$5.1 K
7.1		$8.7 K	$1.6 K	N/A	N/A	N/A	$5.1 K
12.2		$11.2 K	$1.0 K	N/A	N/A	N/A	$6.1 K
17.3		$13.7 K	$3.5 K	N/A	N/A	N/A	$8.6 K
22.4		$16.3 K	$6.0 K	N/A	N/A	N/A	$11.2 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.9 K						$1.9 K
1.6	$1.7 K						$1.7 K
3.9		$2.4 K	$1.1 K	$2.2 K	$1.2 K	N/A	$1.7 K
7.1		$2.9 K	$0.5 K	N/A	N/A	N/A	$1.7 K
12.2		$3.7 K	$0.3 K	N/A	N/A	N/A	$2.0 K
17.3		$4.6 K	$1.2 K	N/A	N/A	N/A	$2.9 K
22.4		$5.4 K	$2.0 K	N/A	N/A	N/A	$3.7 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.2 K						$1.2 K
1.6	$1.0 K						$1.0 K
3.9		$1.4 K	$0.6 K	$1.3 K	$0.7 K	N/A	$1.0 K
7.1		$1.7 K	$0.3 K	N/A	N/A	N/A	$1.0 K
12.2		$2.2 K	$0.2 K	N/A	N/A	N/A	$1.2 K
17.3		$2.7 K	$0.7 K	N/A	N/A	N/A	$1.7 K
22.4		$3.3 K	$1.2 K	N/A	N/A	N/A	$2.2 K
35	N/A						

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

Product	Aquatain
Channel Type	Spur-Top 10%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$53.3 K						$53.3 K
1.6	$46.8 K						$46.8 K
3.9		$64.6 K	$29.1 K	$59.4 K	$34.3 K	N/A	$46.8 K
7.1		$79.2 K	$14.5 K	N/A	N/A	N/A	$46.8 K
12.2		$102.4 K	$8.7 K	N/A	N/A	N/A	$55.6 K
17.3		$125.7 K	$32.0 K	N/A	N/A	N/A	$78.8 K
22.4		$148.9 K	$55.2 K	N/A	N/A	N/A	$102.1 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$17.8 K						$17.8 K
1.6	$15.6 K						$15.6 K
3.9		$21.5 K	$9.7 K	$19.8 K	$11.4 K	N/A	$15.6 K
7.1		$26.4 K	$4.8 K	N/A	N/A	N/A	$15.6 K
12.2		$34.1 K	$2.9 K	N/A	N/A	N/A	$18.5 K
17.3		$41.9 K	$10.7 K	N/A	N/A	N/A	$26.3 K
22.4		$49.6 K	$18.4 K	N/A	N/A	N/A	$34.0 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$10.7 K						$10.7 K
1.6	$9.4 K						$9.4 K
3.9		$12.9 K	$5.8 K	$11.9 K	$6.9 K	N/A	$9.4 K
7.1		$15.8 K	$2.9 K	N/A	N/A	N/A	$9.4 K
12.2		$20.5 K	$1.7 K	N/A	N/A	N/A	$11.1 K
17.3		$25.1 K	$6.4 K	N/A	N/A	N/A	$15.8 K
22.4		$29.8 K	$11.0 K	N/A	N/A	N/A	$20.4 K
35	N/A						

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

Product	ES300
Channel Type	Spur-Top 10%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$4.9 K						$4.9 K
1.6	$4.4 K						$4.4 K
3.9		$6.0 K	$2.7 K	$5.5 K	$3.2 K	N/A	$4.4 K
7.1		$7.4 K	$1.3 K	N/A	N/A	N/A	$4.4 K
12.2		$9.5 K	$1.0 K	N/A	N/A	N/A	$5.2 K
17.3		$11.7 K	$3.5 K	N/A	N/A	N/A	$7.6 K
22.4		$13.9 K	$6.0 K	N/A	N/A	N/A	$9.9 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.6 K						$1.6 K
1.6	$1.5 K						$1.5 K
3.9		$2.0 K	$0.9 K	$1.8 K	$1.1 K	N/A	$1.5 K
7.1		$2.5 K	$0.4 K	N/A	N/A	N/A	$1.5 K
12.2		$3.2 K	$0.3 K	N/A	N/A	N/A	$1.7 K
17.3		$3.9 K	$1.2 K	N/A	N/A	N/A	$2.5 K
22.4		$4.6 K	$2.0 K	N/A	N/A	N/A	$3.3 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.0 K						$1.0 K
1.6	$0.9 K						$0.9 K
3.9		$1.2 K	$0.5 K	$1.1 K	$0.6 K	N/A	$0.9 K
7.1		$1.5 K	$0.3 K	N/A	N/A	N/A	$0.9 K
12.2		$1.9 K	$0.2 K	N/A	N/A	N/A	$1.0 K
17.3		$2.3 K	$0.7 K	N/A	N/A	N/A	$1.5 K
22.4		$2.8 K	$1.2 K	N/A	N/A	N/A	$2.0 K
35	N/A						

<= $1000/ML

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

> $5000/ML

Product	ES300 - Assume passes culverts
Channel Type	Spur-Top 10%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
12.2		$0.4 K	$1.0 K	N/A	N/A	N/A	$0.7 K
17.3		$0.4 K	$3.5 K	N/A	N/A	N/A	$1.9 K
22.4		$0.4 K	$6.0 K	N/A	N/A	N/A	$3.2 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.3 K	N/A	N/A	N/A	$0.2 K
17.3		$0.1 K	$1.2 K	N/A	N/A	N/A	$0.6 K
22.4		$0.1 K	$2.0 K	N/A	N/A	N/A	$1.1 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.2 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.7 K	N/A	N/A	N/A	$0.4 K
22.4		$0.1 K	$1.2 K	N/A	N/A	N/A	$0.6 K
35	N/A						

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

Appendix R Total ML Savings for 10% Longest Spur Channels

Product	All
Channel Type	Spur-Top 10%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	11						11
1.6	8						8
3.9		9	7	17	16	-	49
7.1		11	9	-	-	-	19
12.2		2	2	-	-	-	4
17.3		6	5	-	-	-	12
22.4		3	2	-	-	-	5
35	-						-
Total	19	31	25	17	16	-	108

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	34						34
1.6	27						27
3.9		28	23	56	51	-	157
7.1		34	28	-	-	-	62
12.2		8	6	-	-	-	14
17.3		21	17	-	-	-	37
22.4		9	7	-	-	-	16
35	-						-
Total	61	100	81	56	51	-	348

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	40						40
1.6	32						32
3.9		33	27	66	60	-	185
7.1		41	33	-	-	-	73
12.2		9	7	-	-	-	17
17.3		24	20	-	-	-	44
22.4		10	8	-	-	-	19
35	-						-
Total	72	117	95	66	60	-	410

Appendix S $/ML Savings for 1% Longest Carrier Channels

Product	WaterSavr
Channel Type	Carrier-Top 1%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$2.0 K						$2.0 K
1.6	$1.9 K						$1.9 K
3.9		$2.1 K	$1.8 K	$2.0 K	$1.8 K	N/A	$1.9 K
7.1		$2.2 K	$1.6 K	N/A	N/A	N/A	$1.9 K
12.2		$2.4 K	$1.4 K	N/A	N/A	N/A	$1.9 K
17.3		$2.6 K	$1.2 K	N/A	N/A	N/A	$1.9 K
22.4		$2.8 K	$1.0 K	N/A	N/A	N/A	$1.9 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.7 K						$0.7 K
1.6	$0.6 K						$0.6 K
3.9		$0.7 K	$0.6 K	$0.7 K	$0.6 K	N/A	$0.6 K
7.1		$0.7 K	$0.5 K	N/A	N/A	N/A	$0.6 K
12.2		$0.8 K	$0.5 K	N/A	N/A	N/A	$0.6 K
17.3		$0.9 K	$0.4 K	N/A	N/A	N/A	$0.6 K
22.4		$0.9 K	$0.3 K	N/A	N/A	N/A	$0.6 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.3 K	N/A	N/A	N/A	$0.4 K
12.2		$0.5 K	$0.3 K	N/A	N/A	N/A	$0.4 K
17.3		$0.5 K	$0.2 K	N/A	N/A	N/A	$0.4 K
22.4		$0.6 K	$0.2 K	N/A	N/A	N/A	$0.4 K
35	N/A						

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

Product	Aquatain
Channel Type	Carrier-Top 1%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$17.8 K						$17.8 K
1.6	$17.5 K						$17.5 K
3.9		$18.9 K	$16.0 K	$18.5 K	$16.4 K	N/A	$17.5 K
7.1		$20.1 K	$14.8 K	N/A	N/A	N/A	$17.5 K
12.2		$21.9 K	$13.0 K	N/A	N/A	N/A	$17.5 K
17.3		$23.8 K	$11.1 K	N/A	N/A	N/A	$17.5 K
22.4		$25.7 K	$9.2 K	N/A	N/A	N/A	$17.5 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$5.9 K						$5.9 K
1.6	$5.8 K						$5.8 K
3.9		$6.3 K	$5.3 K	$6.2 K	$5.5 K	N/A	$5.8 K
7.1		$6.7 K	$4.9 K	N/A	N/A	N/A	$5.8 K
12.2		$7.3 K	$4.3 K	N/A	N/A	N/A	$5.8 K
17.3		$7.9 K	$3.7 K	N/A	N/A	N/A	$5.8 K
22.4		$8.6 K	$3.1 K	N/A	N/A	N/A	$5.8 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$3.6 K						$3.6 K
1.6	$3.5 K						$3.5 K
3.9		$3.8 K	$3.2 K	$3.7 K	$3.3 K	N/A	$3.5 K
7.1		$4.0 K	$3.0 K	N/A	N/A	N/A	$3.5 K
12.2		$4.4 K	$2.6 K	N/A	N/A	N/A	$3.5 K
17.3		$4.8 K	$2.2 K	N/A	N/A	N/A	$3.5 K
22.4		$5.1 K	$1.8 K	N/A	N/A	N/A	$3.5 K
35	N/A						

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

Product	ES300
Channel Type	Carrier-Top 1%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.5 K						$0.5 K
1.6	$0.5 K						$0.5 K
3.9		$0.5 K	$0.4 K	$0.5 K	$0.4 K	N/A	$0.5 K
7.1		$0.5 K	$0.4 K	N/A	N/A	N/A	$0.5 K
12.2		$0.6 K	$0.3 K	N/A	N/A	N/A	$0.5 K
17.3		$0.6 K	$0.3 K	N/A	N/A	N/A	$0.5 K
22.4		$0.7 K	$0.2 K	N/A	N/A	N/A	$0.5 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.2 K						$0.2 K
1.6	$0.2 K						$0.2 K
3.9		$0.2 K	$0.1 K	$0.2 K	$0.1 K	N/A	$0.2 K
7.1		$0.2 K	$0.1 K	N/A	N/A	N/A	$0.2 K
12.2		$0.2 K	$0.1 K	N/A	N/A	N/A	$0.2 K
17.3		$0.2 K	$0.1 K	N/A	N/A	N/A	$0.2 K
22.4		$0.2 K	$0.1 K	N/A	N/A	N/A	$0.2 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.0 K	N/A	N/A	N/A	$0.1 K
35	N/A						

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

Product	ES300 - Assume passes culverts
Channel Type	Carrier-Top 1%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
12.2		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
17.3		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
22.4		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
35	N/A						

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

Appendix T Total ML Savings for 1% Longest Carrier Channels

Product	All
Channel Type	Carrier-Top 1%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	1						1
1.6	1						1
3.9		1	1	1	1	-	4
7.1		1	1	-	-	-	2
12.2		0	0	-	-	-	0
17.3		1	1	-	-	-	1
22.4		0	0	-	-	-	0
35	-						-
Total	2	2	2	1	1	-	10

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	3						3
1.6	4						4
3.9		2	2	4	4	-	13
7.1		3	3	-	-	-	5
12.2		1	1	-	-	-	1
17.3		2	2	-	-	-	3
22.4		1	1	-	-	-	1
35	-						-
Total	8	8	8	4	4	-	31

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	4						4
1.6	5						5
3.9		3	3	5	5	-	15
7.1		3	3	-	-	-	6
12.2		1	1	-	-	-	1
17.3		2	2	-	-	-	4
22.4		1	1	-	-	-	2
35	-						-
Total	9	9	9	5	5	-	37

Appendix U $/ML Savings for 1% Longest Trunk Channels

Product	WaterSavr
Channel Type	Trunk-Top 1%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$3.0 K						$3.0 K
1.6	$2.8 K						$2.8 K
3.9		$3.4 K	$2.3 K	$3.2 K	$2.5 K	N/A	$2.8 K
7.1		$3.8 K	$1.9 K	N/A	N/A	N/A	$2.8 K
12.2		$4.5 K	$1.2 K	N/A	N/A	N/A	$2.8 K
17.3		$5.1 K	$0.5 K	N/A	N/A	N/A	$2.8 K
22.4		$5.8 K	$0.2 K	N/A	N/A	N/A	$3.0 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.0 K						$1.0 K
1.6	$0.9 K						$0.9 K
3.9		$1.1 K	$0.8 K	$1.1 K	$0.8 K	N/A	$0.9 K
7.1		$1.3 K	$0.6 K	N/A	N/A	N/A	$0.9 K
12.2		$1.5 K	$0.4 K	N/A	N/A	N/A	$0.9 K
17.3		$1.7 K	$0.2 K	N/A	N/A	N/A	$0.9 K
22.4		$1.9 K	$0.1 K	N/A	N/A	N/A	$1.0 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.6 K						$0.6 K
1.6	$0.6 K						$0.6 K
3.9		$0.7 K	$0.5 K	$0.6 K	$0.5 K	N/A	$0.6 K
7.1		$0.8 K	$0.4 K	N/A	N/A	N/A	$0.6 K
12.2		$0.9 K	$0.2 K	N/A	N/A	N/A	$0.6 K
17.3		$1.0 K	$0.1 K	N/A	N/A	N/A	$0.6 K
22.4		$1.2 K	$0.0 K	N/A	N/A	N/A	$0.6 K
35	N/A						

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

Product	Aquatain						
Channel Type	Trunk-Top 1%						
Evaporative Rate	1.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$27.3 K						$27.3 K
1.6	$25.9 K						$25.9 K
3.9		$30.6 K	$21.1 K	$29.2 K	$22.5 K	N/A	$25.9 K
7.1		$34.6 K	$17.2 K	N/A	N/A	N/A	$25.9 K
12.2		$40.8 K	$10.9 K	N/A	N/A	N/A	$25.9 K
17.3		$47.0 K	$4.7 K	N/A	N/A	N/A	$25.9 K
22.4		$53.3 K	$1.6 K	N/A	N/A	N/A	$27.4 K
35	N/A						

Evaporative Rate	4.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$9.1 K						$9.1 K
1.6	$8.6 K						$8.6 K
3.9		$10.2 K	$7.0 K	$9.7 K	$7.5 K	N/A	$8.6 K
7.1		$11.5 K	$5.7 K	N/A	N/A	N/A	$8.6 K
12.2		$13.6 K	$3.6 K	N/A	N/A	N/A	$8.6 K
17.3		$15.7 K	$1.6 K	N/A	N/A	N/A	$8.6 K
22.4		$17.8 K	$0.5 K	N/A	N/A	N/A	$9.1 K
35	N/A						

Evaporative Rate	7.5						
	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$5.5 K						$5.5 K
1.6	$5.2 K						$5.2 K
3.9		$6.1 K	$4.2 K	$5.8 K	$4.5 K	N/A	$5.2 K
7.1		$6.9 K	$3.4 K	N/A	N/A	N/A	$5.2 K
12.2		$8.2 K	$2.2 K	N/A	N/A	N/A	$5.2 K
17.3		$9.4 K	$0.9 K	N/A	N/A	N/A	$5.2 K
22.4		$10.7 K	$0.3 K	N/A	N/A	N/A	$5.5 K
35	N/A						

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

Product	ES300
Channel Type	Trunk-Top 1%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$1.3 K						$1.3 K
1.6	$1.2 K						$1.2 K
3.9		$1.5 K	$1.0 K	$1.4 K	$1.1 K	N/A	$1.2 K
7.1		$1.7 K	$0.8 K	N/A	N/A	N/A	$1.2 K
12.2		$2.0 K	$0.5 K	N/A	N/A	N/A	$1.2 K
17.3		$2.3 K	$0.2 K	N/A	N/A	N/A	$1.2 K
22.4		$2.6 K	$0.2 K	N/A	N/A	N/A	$1.4 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.5 K	$0.3 K	$0.5 K	$0.4 K	N/A	$0.4 K
7.1		$0.6 K	$0.3 K	N/A	N/A	N/A	$0.4 K
12.2		$0.7 K	$0.2 K	N/A	N/A	N/A	$0.4 K
17.3		$0.8 K	$0.1 K	N/A	N/A	N/A	$0.4 K
22.4		$0.9 K	$0.1 K	N/A	N/A	N/A	$0.5 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.3 K						$0.3 K
1.6	$0.2 K						$0.2 K
3.9		$0.3 K	$0.2 K	$0.3 K	$0.2 K	N/A	$0.2 K
7.1		$0.3 K	$0.2 K	N/A	N/A	N/A	$0.2 K
12.2		$0.4 K	$0.1 K	N/A	N/A	N/A	$0.2 K
17.3		$0.5 K	$0.0 K	N/A	N/A	N/A	$0.2 K
22.4		$0.5 K	$0.0 K	N/A	N/A	N/A	$0.3 K
35	N/A						

<= $1000/ML

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

> $5000/ML

Product	ES300 - Assume passes culverts
Channel Type	Trunk-Top 1%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
12.2		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
17.3		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
22.4		$0.4 K	$0.2 K	N/A	N/A	N/A	$0.3 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
22.4		$0.1 K	$0.0 K	N/A	N/A	N/A	$0.1 K
35	N/A						

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

Appendix V Total ML Savings for 1% Longest Trunk Channels

Product	All
Channel Type	Trunk-Top 1%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	2						2
1.6	1						1
3.9		2	2	4	3	-	11
7.1		2	2	-	-	-	4
12.2		1	0	-	-	-	1
17.3		1	1	-	-	-	3
22.4		1	0	-	-	-	1
35	-						-
Total	4	7	6	4	3	-	23

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	7						7
1.6	5						5
3.9		6	5	12	11	-	34
7.1		7	6	-	-	-	14
12.2		2	1	-	-	-	3
17.3		4	4	-	-	-	8
22.4		2	2	-	-	-	3
35	-						-
Total	11	21	18	12	11	-	74

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	8						8
1.6	5						5
3.9		7	6	14	13	-	40
7.1		9	7	-	-	-	16
12.2		2	2	-	-	-	4
17.3		5	4	-	-	-	10
22.4		2	2	-	-	-	4
35	-						-
Total	14	25	21	14	13	-	87

Appendix W $/ML Savings for 1% Longest Spur Channels

Product	WaterSavr
Channel Type	Spur-Top 1%
Evaporative Rate	1.5

Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
	Wind Direction Category						
0	$3.4 K						$3.4 K
1.6	$3.0 K						$3.0 K
3.9		$4.1 K	$1.9 K	$3.8 K	$2.2 K	N/A	$3.0 K
7.1		$5.1 K	$0.9 K	N/A	N/A	N/A	$3.0 K
12.2		$6.6 K	$0.6 K	N/A	N/A	N/A	$3.6 K
17.3		$8.0 K	$2.0 K	N/A	N/A	N/A	$5.0 K
22.4		$9.5 K	$3.5 K	N/A	N/A	N/A	$6.5 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
	Wind Direction Category						
0	$1.1 K						$1.1 K
1.6	$1.0 K						$1.0 K
3.9		$1.4 K	$0.6 K	$1.3 K	$0.7 K	N/A	$1.0 K
7.1		$1.7 K	$0.3 K	N/A	N/A	N/A	$1.0 K
12.2		$2.2 K	$0.2 K	N/A	N/A	N/A	$1.2 K
17.3		$2.7 K	$0.7 K	N/A	N/A	N/A	$1.7 K
22.4		$3.2 K	$1.2 K	N/A	N/A	N/A	$2.2 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
	Wind Direction Category						
0	$0.7 K						$0.7 K
1.6	$0.6 K						$0.6 K
3.9		$0.8 K	$0.4 K	$0.8 K	$0.4 K	N/A	$0.6 K
7.1		$1.0 K	$0.2 K	N/A	N/A	N/A	$0.6 K
12.2		$1.3 K	$0.1 K	N/A	N/A	N/A	$0.7 K
17.3		$1.6 K	$0.4 K	N/A	N/A	N/A	$1.0 K
22.4		$1.9 K	$0.7 K	N/A	N/A	N/A	$1.3 K
35	N/A						

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

Product	Aquatain
Channel Type	Spur-Top 1%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$30.7 K						$30.7 K
1.6	$27.4 K						$27.4 K
3.9		$37.8 K	$17.0 K	$34.8 K	$20.1 K	N/A	$27.4 K
7.1		$46.3 K	$8.5 K	N/A	N/A	N/A	$27.4 K
12.2		$59.9 K	$5.1 K	N/A	N/A	N/A	$32.5 K
17.3		$73.5 K	$18.7 K	N/A	N/A	N/A	$46.1 K
22.4		$87.1 K	$32.3 K	N/A	N/A	N/A	$59.7 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$10.2 K						$10.2 K
1.6	$9.1 K						$9.1 K
3.9		$12.6 K	$5.7 K	$11.6 K	$6.7 K	N/A	$9.1 K
7.1		$15.4 K	$2.8 K	N/A	N/A	N/A	$9.1 K
12.2		$20.0 K	$1.7 K	N/A	N/A	N/A	$10.8 K
17.3		$24.5 K	$6.2 K	N/A	N/A	N/A	$15.4 K
22.4		$29.0 K	$10.8 K	N/A	N/A	N/A	$19.9 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$6.1 K						$6.1 K
1.6	$5.5 K						$5.5 K
3.9		$7.6 K	$3.4 K	$7.0 K	$4.0 K	N/A	$5.5 K
7.1		$9.3 K	$1.7 K	N/A	N/A	N/A	$5.5 K
12.2		$12.0 K	$1.0 K	N/A	N/A	N/A	$6.5 K
17.3		$14.7 K	$3.7 K	N/A	N/A	N/A	$9.2 K
22.4		$17.4 K	$6.5 K	N/A	N/A	N/A	$11.9 K
35	N/A						

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

Product	ES300
Channel Type	Spur-Top 1%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$2.6 K						$2.6 K
1.6	$2.3 K						$2.3 K
3.9		$3.2 K	$1.4 K	$3.0 K	$1.7 K	N/A	$2.3 K
7.1		$3.9 K	$0.7 K	N/A	N/A	N/A	$2.3 K
12.2		$5.1 K	$0.6 K	N/A	N/A	N/A	$2.8 K
17.3		$6.3 K	$2.0 K	N/A	N/A	N/A	$4.2 K
22.4		$7.4 K	$3.5 K	N/A	N/A	N/A	$5.5 K
35	N/A						

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.9 K						$0.9 K
1.6	$0.8 K						$0.8 K
3.9		$1.1 K	$0.5 K	$1.0 K	$0.6 K	N/A	$0.8 K
7.1		$1.3 K	$0.2 K	N/A	N/A	N/A	$0.8 K
12.2		$1.7 K	$0.2 K	N/A	N/A	N/A	$0.9 K
17.3		$2.1 K	$0.7 K	N/A	N/A	N/A	$1.4 K
22.4		$2.5 K	$1.2 K	N/A	N/A	N/A	$1.8 K
35	N/A						

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.5 K						$0.5 K
1.6	$0.5 K						$0.5 K
3.9		$0.6 K	$0.3 K	$0.6 K	$0.3 K	N/A	$0.5 K
7.1		$0.8 K	$0.1 K	N/A	N/A	N/A	$0.5 K
12.2		$1.0 K	$0.1 K	N/A	N/A	N/A	$0.6 K
17.3		$1.3 K	$0.4 K	N/A	N/A	N/A	$0.8 K
22.4		$1.5 K	$0.7 K	N/A	N/A	N/A	$1.1 K
35	N/A						

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

Product	ES300 - Assume passes culverts
Channel Type	Spur-Top 1%
Evaporative Rate	1.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.4 K						$0.4 K
1.6	$0.4 K						$0.4 K
3.9		$0.4 K	$0.4 K	$0.4 K	$0.4 K	N/A	$0.4 K
7.1		$0.4 K	$0.4 K	N/A	N/A	N/A	$0.4 K
12.2		$0.4 K	$0.6 K	N/A	N/A	N/A	$0.5 K
17.3		$0.4 K	$2.0 K	N/A	N/A	N/A	$1.2 K
22.4		$0.4 K	$3.5 K	N/A	N/A	N/A	$2.0 K
35	N/A						

Evaporative Rate	4.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.2 K	N/A	N/A	N/A	$0.2 K
17.3		$0.1 K	$0.7 K	N/A	N/A	N/A	$0.4 K
22.4		$0.1 K	$1.2 K	N/A	N/A	N/A	$0.7 K
35	N/A						

Evaporative Rate	7.5

Wind Speed	*Wind Direction Category* *All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Average*
0	$0.1 K						$0.1 K
1.6	$0.1 K						$0.1 K
3.9		$0.1 K	$0.1 K	$0.1 K	$0.1 K	N/A	$0.1 K
7.1		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
12.2		$0.1 K	$0.1 K	N/A	N/A	N/A	$0.1 K
17.3		$0.1 K	$0.4 K	N/A	N/A	N/A	$0.2 K
22.4		$0.1 K	$0.7 K	N/A	N/A	N/A	$0.4 K
35	N/A						

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

Appendix X Total ML Savings for 1% Longest Spur Channels

Product	All
Channel Type	Spur-Top 1%
Evaporative Rate	1.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	2						2
1.6	2						2
3.9		2	1	3	3	-	10
7.1		2	2	-	-	-	4
12.2		0	0	-	-	-	1
17.3		1	1	-	-	-	2
22.4		1	0	-	-	-	1
35	-						-
Total	4	6	5	3	3	-	21

Evaporative Rate	4.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	7						7
1.6	5						5
3.9		5	4	11	10	-	31
7.1		7	5	-	-	-	12
12.2		2	1	-	-	-	3
17.3		4	3	-	-	-	7
22.4		2	1	-	-	-	3
35	-						-
Total	12	20	16	11	10	-	68

Evaporative Rate	7.5

	Wind Direction Category						
Wind Speed	*All*	*Parallel*	*Opposite*	*Oblique Parallel*	*Oblique Opposite*	*Perpendicular*	*Total*
0	8						8
1.6	6						6
3.9		6	5	13	12	-	36
7.1		8	6	-	-	-	14
12.2		2	1	-	-	-	3
17.3		5	4	-	-	-	9
22.4		2	2	-	-	-	4
35	-						-
Total	14	23	19	13	12	-	80