Improving irrigation efficiency by identifying methods to reduce evaporation losses from on-farm storages in the Granite Belt

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Executive Summary

Evaporation across the Granite Belt is approximately 1,680 mm per year with approximately 66% occurring over the summer period (Oct-March). A total loss of 1,680 mm of evaporation equates to 16.8ML over a 1 ha surface area.

Baillie et al (2010) assessed the likely water losses from storage dams (evaporation and seepage), distribution channels and infield irrigation losses in the Stanthorpe Water Management Area. The assessment suggests 60% of total on farm losses are through storage evaporation which equates to 586 ML/yr[1].

This desktop assessment and review identifies that evaporation losses can be minimized using a range of products and strategies, however not all methods are suitable for widespread use in the Granite Belt. The table below considers the suitability of each evaporation saving method in the context of the type and usage of water storages in the Granite Belt.

Product	***Suitability***
Shade cloth	Highly suitable
Floating covers	Highly suitable
Modular systems	Less suitable owing to high cost
Chemical covers	Not suitable – Reliability and not demonstrated on commercial scale
Raising wall height	Suitable on larger storages and with appropriate soils with low seepage
Cells in storage	Less suitable on small Granite Belt storages
Strategic management	Highly suitable with specific management options to combine water storage

Shade cloth systems have a potential to save between 70% and 85% of evaporation at a cost of between \$675/ML/yr and \$1,252/ML/yr. Floating cover systems have a potential to save between 85% and 100% of evaporation at a cost of between \$787/ML/yr and \$1,515/ML/yr. Modular systems are very expensive, have a potential to save between 75% and 90% of evaporation at a cost of between \$2,745/ML/yr and \$4,118/ML/yr. Monolayer systems (chemical covers) have a potential to save between 0% and 30% of evaporation at a cost from \$123/ML/yr to well in excess of \$6,572/ML/yr. Performance of monolayer systems on a commercial scale is largely unknown and impacted by many factors, hence the wide spread in potential cost. Raising the wall height or incorporating a cell wall has varying cost depending on the proposed design. For a small 1ha dam the strategy of raising the wall will be relatively expensive (\$852-\$1487/ML/yr). For larger dams of 10ha the additional earthwork costs are supported by large evaporation savings at relatively low cost (\$204-\$355/ML/yr).

Baillie et al (2010) shows that generally irrigators are seeking practical and low capital evaporation and seepage mitigation strategies to gain water savings. While the Stanthorpe Water Management Area shows high percentage uptake across all storage management technologies there are still options for savings that should be investigated. A list of research and extension works have been proposed in Section 9 of this report

[1] The estimated losses were based only on fully utilized tradeable entitlements and did not include losses from non-tradeable water entitlements such as overland flow capture or groundwater

1. Introduction

The Stanthorpe Community Reference Panel (SCRP) commissioned the NCEA to undertake a critical investigation and assessment of the evaporation reduction methods that are currently available or are being developed and may be appropriate for the Granite Belt.

The Granite Belt region is indicated in Figure 1 (below) and includes the towns of Stanthorpe and Wallangarra, and the villages and hamlets of Ballandean, Girraween, Wyberba, Greenlands, Eukey, Mt Tully, Glen Aplin, Severnlea, Applethorpe, The Summit, Amiens, Cottonvale, Thulimbah, and Dalveen.

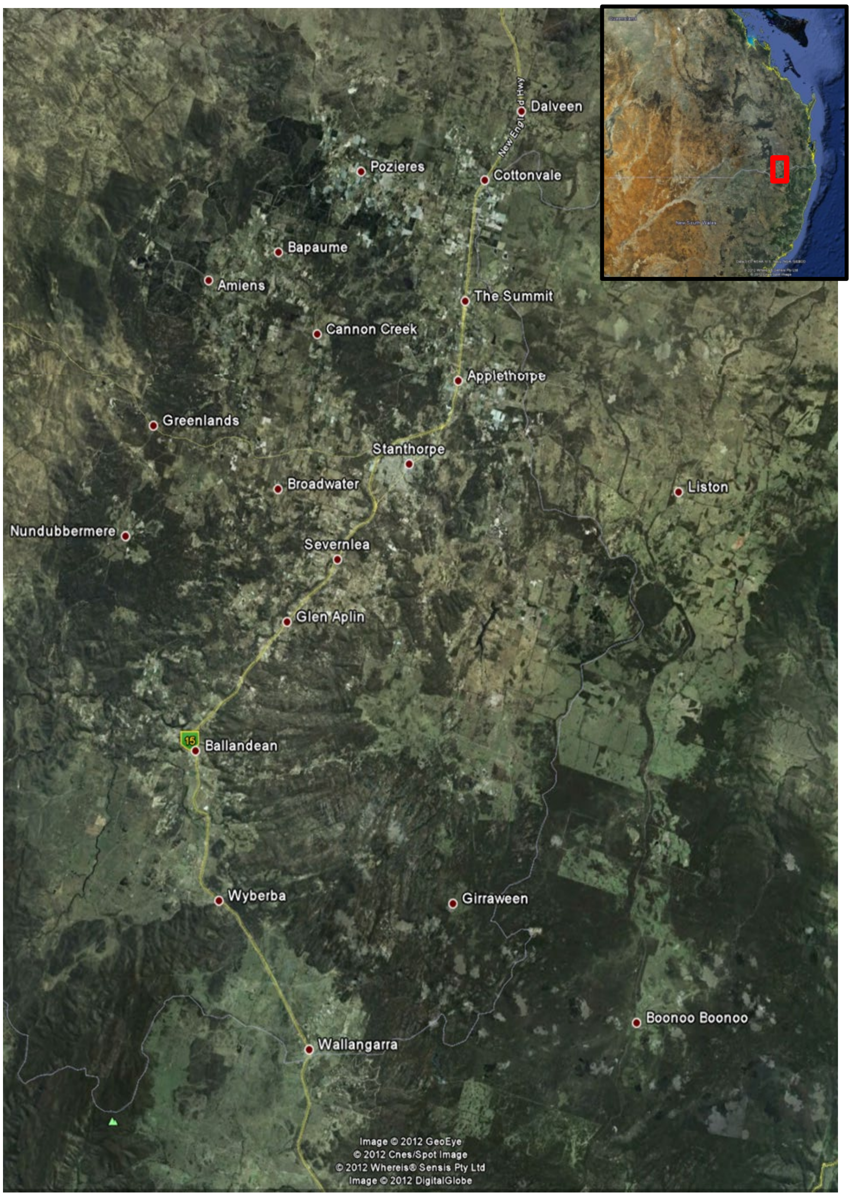

Figure 1 - Location Map – Granite Belt

Most of the Granite Belts crops are irrigated using advanced and efficient systems coupled with soil moisture monitoring. This has enabled producers to maintain and increase crop production whilst using water efficiently. Given this on-farm investment and high level of technology adoption, it is uncertain whether further significant water savings can be achieved by improving irrigation practices. Reduction in water losses from evaporation may be an important strategy allowing producers to maintain their production with reduced water loss.

This project was therefore commissioned to review current best practices in evaporation control and assess their costs, practicalities for the Granite Belt district, predict water savings and likely cost-benefits.

The study provides a desktop assessment of existing evaporation reduction options and technology, likely costs and suitability to local conditions. Basic modelling of economic impacts of possible water savings has been undertaken. The report provides:

1. A review of available technologies including shade cloth, floating covers, modular systems, monolayer systems, earthwork reconfigurations (depth increase and cells) and water management practices.
2. Documentation of the pros and cons and a comparative analysis of available systems and assessment of suitability to Granite Belt.
3. Assessment of potential water savings for each system.
4. Documentation of likely capital and operating costs.
5. Cost- benefit analysis based on discounted cash flow analysis of system costs per unit of water saved ($/ML water saved).
6. Recommendations for further studies.

The study has been based on a literature and commercial review, discussions with suppliers and a desktop technical and economic analysis.

2. Evaporation from Storages in the Granite Belt

2.1. Estimating Evaporation from a Storage

The amount of water lost to evaporation from storages depends on many factors including atmospheric evaporative demand, the size and specific characteristics of the water storage (e.g. geometry and construction) and water management strategies, such as managing the volume and time water is stored. Evapotranspiration comprises the transfer of water, as water vapour, to the atmosphere from both vegetated and un-vegetated land surfaces. It is more common to describe ‘evaporation’ when discussing open water surfaces and bare soil, and ‘evapotranspiration’ when discussing land surfaces with vegetation.

Various methods and complex models can be used to estimate evaporation from a storage dam. In order to accurately estimate evaporation losses from a specific water body, it is necessary to develop and apply a suitable evaporation model. This is generally done using the Penman-Monteith model with modifications to reflect the heat storage and aerodynamic resistance components of the storage dam (McJannett et al, 2008).

Research undertaken by the Cotton Catchment Communities CRC (Cotton Catchment Communities CRC, 2011) has indicated that evaporation from a farm storage dam in the Cotton Industry is likely to range between 67% and 131% (average 97%) of local estimates of evaporation based on the Penman-Monteith model. This was calculated using detailed measurements of seepage and evaporation from 136 storages across the cotton industry ranging in size from 75 ML to 14,000 ML. Similar trends could be anticipated for storages in the Granite Belt. A program measuring actual seepage and evaporation losses from Granite Belt storages using similar methods should considered.

Information available from the Bureau of Meteorology termed ‘Point Potential Evapotranspiration’ is often taken as a preliminary estimate of evaporation from small water bodies such as farm dams and shallow water storages. Point Potential Evapotranspiration represents evapotranspiration that would take place, under the condition of unlimited water supply (such as a dam), from an area so small that the local evapotranspiration effects do not alter local air mass properties. Figure 2 provides a map of Point Potential Evapotranspiration.

Point Potential Evapotranspiration has been used in this report to estimate evaporation from storages in the Granite Belt. Table 1 provides annual and monthly evaporation loss at selected sites (Stanthorpe, Ballandean and Wallangarra). Evaporation does not vary significantly between sites and is around 1680mm per year with approximately 66% occurring over the summer period (Oct-March). It should be noted that 1680mm of evaporation equates to 16.8ML over a 1ha surface area.

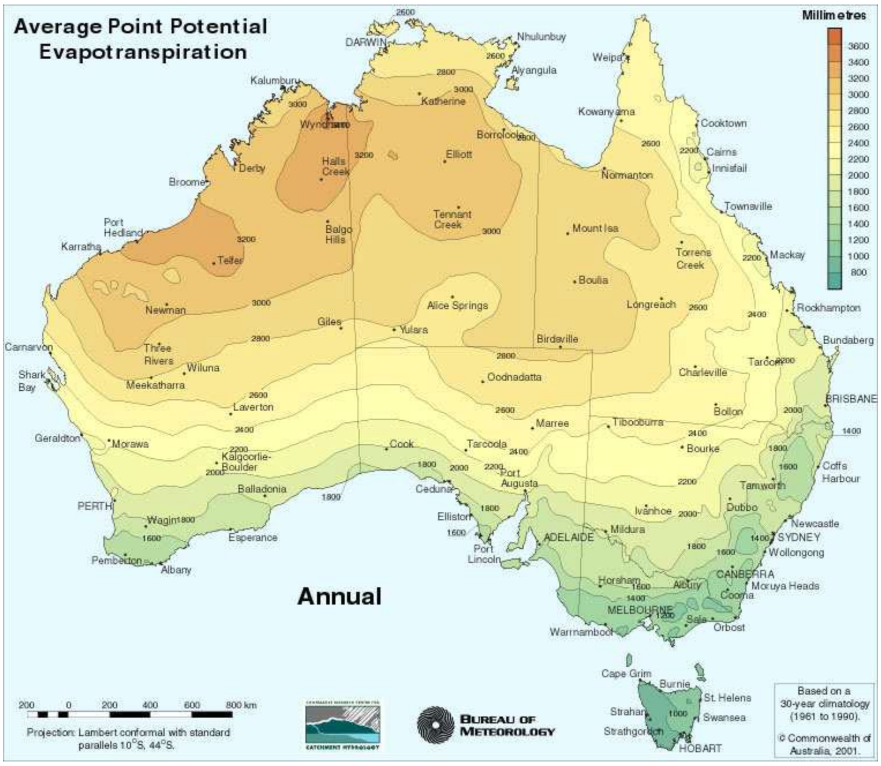

Figure 2 - Annual Point Potential Evapotranspiration (Bureau of Meteorology)

http://www.bom.gov.au/jsp/ncc/climate_averages/evapotranspiration/index.jsp?maptype=6&period=an.

Table 1 - Monthly evaporation figures for selected sites in the Granite Belt based on Bureau of Meteorology Point Potential Evapotranspiration records.

	Stanthorpe		Ballandean		Wallangarra	
	Evaporation (mm)	% of Total	Evaporation (mm)	% of Total	Evaporation (mm)	% of Total
Jan	207	8.2%	213	13.1%	203	12.2%
Feb	166	6.8%	172	10.3%	163	10.2%
Mar	163	8.2%	167	9.9%	159	9.1%
Apr	118	7.8%	122	7.1%	116	7.6%
May	81	7.5%	85	4.4%	81	5.1%
Jun	63	6.8%	66	3.2%	62	4.6%
Jul	73	6.8%	76	3.6%	73	4.6%
Aug	101	8.2%	103	5.2%	99	6.1%
Sep	140	9.2%	141	7.5%	137	7.6%
Oct	175	10.9%	177	10.7%	170	10.2%
Nov	189	10.5%	192	11.9%	184	10.7%
Dec	213	9.2%	218	13.1%	209	12.2%
Totals	1686	100.0%	1732	100.0%	1655	100.0%

	Stanthorpe		Ballandean		Wallangarra	
	Evaporation (mm)	% of Total	Evaporation (mm)	% of Total	Evaporation (mm)	% of Total
Apr-Sep	575	34.1%	593	34.2%	568	34.3%
Oct-Mar	1111	65.9%	1139	65.8%	1087	65.7%
Total	1686		1732		1655	

2.2.Farm Storages in the Granite Belt

The Granite Belt is a traditional horticultural area primarily producing vegetables, deciduous fruit production, wine grapes, and some nursery and cut flower production. The Granite Belt is a major warm season production area for both leafy and heading vegetables (lettuce, brassicas, celery), as well as tomatoes and capsicums. Baillie et al (2010) conducted a basin appraisal study and grower / irrigator survey of the Queensland Murray Darling Catchment including the Stanthorpe Water Management Area (SWMA) of which the Granite Belt is the primary sub-area (see Figure 3). The study was undertaken to detail the levels and trends in adoption and use of water use efficiency technology. The results for the SWMA are considered representative of the Granite Belt as all survey respondents were located in the Granite Belt.

There are approximately 240 horticultural farming enterprises in the Stanthorpe Water Management Area. The average horticultural farm size in the region is small (385 ha) compared with an average of 2,600 ha in other parts of the Border Rivers catchment (Murray Darling Basin Commission, 2004).

Figure 3 - Locality map of the Stanthorpe Water management Area (after Baillie et al 2010)

On-farm water supply in the SWMA is derived primarily from water harvesting and overland flow capture into on-farm storages. There is very little underground water supply and no regulated supply (Baillie et al, 2010). Total on-farm storage in the SWMA is 8,779 ML, with storage sizes typically much smaller than most regions with a typical storage size of 160 ML and surface area of 3 ha. Based on an average evaporation rate of 1,680 mm/year, the total evaporation loss from a 3 ha storage in the Granite Belt could be as high as 50.4 ML per year.

2.3 Storage Losses as Part of the Whole Farm Water Balance

Losses from on-farm water storages in the Granite Belt are important since farms are dependent on unsupplemented water supply and reliant on water storage. Storage losses include both evaporation and seepage. Water losses in farming operations will vary depending on a range of factors such as cropping system, irrigation system and management and storage configuration. Whole farm water balance assessments would need to be undertaken for the farming systems of the Granite belt to provide more accurate determination of the relative importance of storage losses in this region.

A large volume of work has been undertaken in the cotton industry to quantify on-farm losses. Cotton production water balance assessments indicate that typically 66% of water losses are from the storage (seepage and evaporation) and only 31% from field application losses (Cotton Catchment Communities CRC, 2011) with evaporation the major component. This will vary widely between farms and across seasons. In the Granite Belt, given the higher technology irrigation systems, it is likely that a greater percentage of losses would be attributable to the storage dam.

Baillie et al (2010) assessed the likely water losses from storage dams (evaporation and seepage), distribution channels and infield irrigation losses in the Stanthorpe Water Management Area. The estimated losses were based only on fully utilized tradeable entitlements and did not include losses from non-tradeable water entitlements such as overland flow capture or groundwater. The figures presented in Table 2 therefore understate total losses but nevertheless give a good indication of relative water losses from farming operations in the Stanthorpe Water Management Area and Granite belt:

Table 2 - Separation of on farm water losses in the Stanthorpe Water Management Area and Granite Belt

	Water Loss (ML/ year)	*Water Loss (% of total)*
Storage evaporation loss	586 ML	60%
Storage seepage loss	98 ML	10%
Distribution loss	117ML	12%
Infield loss	173ML	18%
Total Loss	**974 ML***	

**Based on Volume of Water Storage 8,779ML*

**Tradable Entitlement representing Water at Farm Gate and through storage 1,954ML*

The figures highlight the dominance of evaporation losses (60%). In the Granite Belt irrigation application efficiencies are generally high (85%) given high technology irrigation systems. More detailed assessment of farming systems in the Granite Belt is required to improve our knowledge of aggregate losses.

Technologies are available to directly measure seepage and evaporation losses from farm storage dams. These systems are based on accurate measurement of water level fluctuations using pressure sensitive transducers. A comprehensive program to quantify storage losses was recently completed in the Cotton Industry using these systems (Cotton Catchment Communities CRC, 2011). Consideration should be given to local deployment of the systems in the Granite Belt to raise awareness of seepage and evaporation issues and quantify losses.

3. Review of Technologies for Evaporation Control

Options for reducing evaporation losses from storages include evaporation reduction products and evaporation reduction strategies.

Evaporation reduction products include:

- Shade structures
- Floating covers
- Modular covers , and
- Chemical formulations

Evaporation reduction strategies include:

- Increasing storage depth
- Including storage cells, and
- Strategic management of water

3.1. Evaporation Reduction Products

Various products for evaporation reduction are appropriate in different situations, depending on the surface area, location and storage operational requirements. Potential options for evaporation reduction are described below. Appendix A provides a list of products originally prepared by Craig et al (2005) which has been updated in this project through a commercial review. Appendix B provides details of each product, including supplier contact details, stated performance and costs are also provided.

Appendix C provides information sheets on the various evaporation control products. These information sheets were prepared as part of a farm dam management resources kit which was developed by the NCEA, CRC Irrigation Futures and National Program for Sustainable Irrigation and is accessible at http://ncea-linux.usq.edu.au/farmdammanagement/. The resources kit contains much information relevant to this project including Case Studies, Reports and Calculators to determine the cost effectiveness of various evaporation and seepage remediation options for on-farm storages.

A number of recent studies have reviewed methods for evaporation reduction from storages in Australia. Most significant work has been undertaken by Craig et al (2005), Watts (2005), Scobie et al (2006), Craig (2008), McJannett et al (2008), Yao et al (2008), Baillie et al (2008) and Prime et al (2012a). The summary below is based on these and other reports as referenced.

3.1.1. Shade Cloth

Shade cloth can be suspended above water surfaces by a cable structure (Figure 5) which results in reduced net radiation and wind velocity at the water surface. Given the maximum span that the structure can be suspended over which is around 120-150m storage size is typically limited to under 5 ha. Larger storages (e.g. 25ha) can be covered if support columns are constructed in the storage.

Figure 4 shows Netpro black monofilament shade cloth supported by steel cables over a storage in the Granite Belt. Shade cloth is available in a range of fabric density and percentage-of-UV-reduction ratings. A 95% shading effect can be achieved with 260-500g/m^2 cloth. Lighter material requires less support infrastructure but must not compromise fabric strength. The cable structure should have a design life in excess of 30 years, and the shade cloth itself should have a 15 year life. Replacement and repair may be required during this period, depending on the extent of storm damage and deterioration. Hail shoots or valves can be installed into the cloth to reduce potential damage.

Figure 4 - Shade cloth cover installed near Stanthorpe Qld

Shade cloth is not in contact with the water and is not affected by emptying the dam or changes in water level. Wind blown soil does not collect on the surface of the shade cloth and water cannot seep on top of the cover as is possible in floating covers which could may rise to the growth of weeds or algae on the cover.

Generally, shade structures are not as effective in reducing evaporation as well managed impervious plastic covers. Trials have suggested 70% to 80% evaporation savings (Craig et al, 2005). Newer products with a denser cloth will provide improved shading and greater savings. Shade structures are more economically feasible over small storages (less than 5 hectares in size) where support structures are less complex. The width of the shade cloth panel and grade of material will also impact the number of support cables and capital cost. Consideration needs to be given to the aerodynamics of suspended structures in high wind speeds and anchoring the cables in poor quality soils (Baillie et al, 2010).

Figure 5 - Installation of suspended shade cloth cover

Prototype floating modules supporting shade cloth have been developed for larger storages or as an alternative system for small dams (Figure 6).

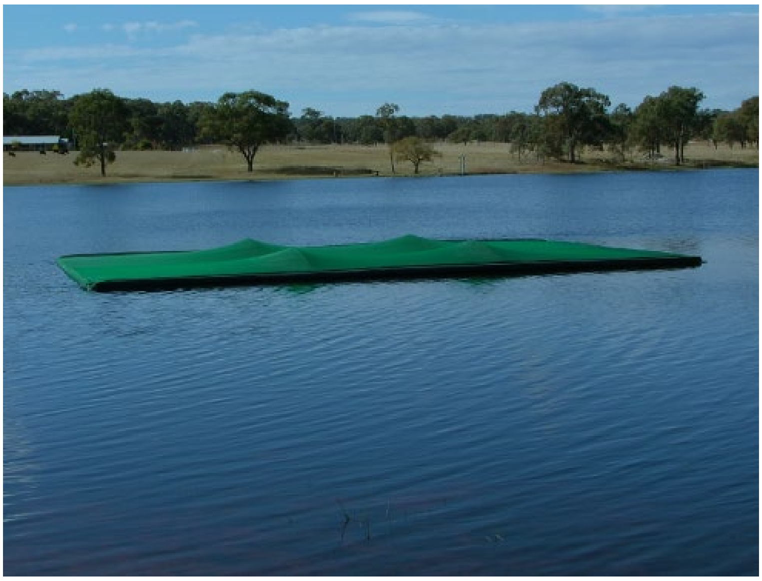

Figure 6 - Shade cloth installed as a series of floating modules to avoid suspension cables

Trials of shade cloth products at the University of Southern Queensland test facility are indicated in Figure 7. Two Sealed Air Australia shade cloth products tested at this site indicated evaporation savings of 85% (Symes, Schmidt and Morrison, 2007).

Figure 7 - Floating Shade cloth being tested at the University of Southern Queensland

Shade cloth systems are thus considered appropriate for small irrigation dams serving high value crops such as those in the Granite Belt. The system is better suited to storages permanently holding water due to the high capital cost.

Installation of hail shoots or valves can extend shade cloth’s lifespan although this adds to the capital cost. Regular inspection of the shade cloth material and prompt maintenance (e.g. repairs to breaks and tears) is critical. Expert advice on shade cloth technologies is available in the Stanthorpe area given widespread use of these systems for orchard and crop protection. No environmental impacts are envisaged with this system. Shade cloth structures will limit algae growth in the storage through a reduction in solar radiation and water temperature.

3.1.2. Floating Covers

Floating covers are a single floating impermeable barrier that generally covers 100% of the water surface and are most commonly made of a plastic material (e.g. polyethylene) although numerous materials have been trialled. Impermeable covers can reduce evaporation from 85 to 100 % and for well-constructed systems saves 90%-95% of evaporation. They are generally suitable for storages of less than 5 ha as a single cover.

Figure 8 - Plastic cover (E-VapCap®) newly installed near St. George, Qld

Figure 8 shows a newly installed Evaporation Control Systems E-VapCap® product a storage dam near St. George. The plastic material consists of a multi-layered, polyethylene membrane with buoyancy cells, similar to bubble wrap or existing swimming pool cover products, but made to resist degradation from sunlight (Craig, 2008). The material is environmentally safe. The polyethylene used is commonly used in food packaging and storing and can be recycled (Craig, 2008). There are a number of covers that have been installed on water storages using specialised equipment designed and built for the installation of covers on water.

The polyethylene is UV stabilised and 10 mm diameter holes are positioned at 1,000 mm centres to allow rainfall penetration and the release of gases from the storage. Consideration needs to be given to the uplift forces on floating covers during strong winds. Accumulation of water and dust on the cover can block drain holes and compromise performance. Cover edges need to be adequately anchored into the embankment. This is generally done by trenching the cover into the soil.

Most of these products have a high capital cost and replacement life varies (typically between 10 and 20 years) although product warranties may be less. The structural integrity of the product under windy conditions and fluctuating water levels is important. Water quality can be impacted by reduced dissolved oxygen, light penetration and change in water temperature. This can have a positive impact in for example, reducing algal growth. However other biota may also be impacted. Significant difficulties can be encountered with installation on large storages above 5 ha. In some cases these covers can be deployed as a series of large rafts tethered in position and covering up to 1ha each (Figure 9). This reduces the risk of structural failure of a large continuous unit and no edge trenching is required.

Other products include standard HDPE sheeting kept buoyant by foam supports. This system does not allow rainfall to enter the storage.

Figure 9 - Deployment of floating cover (E-VapCap®) as a floating raft

Floating covers are frequently used to cover treated waste water to be used for irrigation. Treated waste water generally has a higher cost and also a potential for water quality problems through algal growth. The floating cover reduces sunlight penetration and temperature thereby controlling algal growth and reducing costs of pre-filtration for the irrigation water.

3.1.3. Modular Covers

Modular covers consist of a series of individual floating units which can be constructed from plastic or shade cloth and are often free to distribute across a water surface, although they can be connected together or constrained within specific areas. They act in much the same way as a continuous floating cover, but due to their modular nature, typically cover a smaller proportion of the water surface. Thus the overall effect on evaporation reduction corresponds with the proportion of surface covered.

The modules can be restrained or tethered to a particular part of the dam or left free to move across the water surface. Existing systems include a prototype circular design (AquaCaps) and a hexagonal design (AquaArmour) which is in commercial production. There is also a prototype rectangular design (Raftex) that has been trialled at USQ.

Figure 10 - AquaArmour – a commercial hexagonal design of modular cover

As each module is small in size, thousands of modules are required to cover a large storage. As modules do not cover 100 per cent of the surface, their evaporation saving performance will be correspondingly less than 100 per cent. However, when they are free floating they will travel with the wind to the downwind margins of the dam and this is often where the warmest water is and where the highest evaporation occurs. AquaArmour generally recommend tethering and booming to aggregate modules in position.

Figure 11 - AquaCaps - a prototype circular design of modular cover

Trials were undertaken by Howard and Schmidt (2008) on behalf of Rio Tinto on prototype AquaCap modules deployed on two specially built storages, each approximately 1 ha in surface area near the town of Parkes. Rio Tinto's floating modules reduced evaporation by 85 % when modules covered approximately 90 % of the surface area of the storage.

Figure 12 - Evaporation trial using (AquaCaps) circular design floating cover near Parkes, NSW

AquaArmour is a floating system of hollow hexagonal pods constructed from High Density Polyethylene (HDPE) and arranged into a free-form floating lattice. The pods are self-anchoring by design in which water is allowed to enter the hollow portion of the pod through vents at the centre of each face, top and bottom (Symes et al, 2009). Water captured in the pod provides a 'water ballast' to anchor the pods in place and reportedly resist against lifting in high winds. AquaArmour pods incorporate flotation chambers at six points around the outer edge and thus eliminates the need for suspension systems to maintain the pods on the surface of the water. Modular systems do not restrict the inflow of rainfall and overland run off to water storages and have a wave calming benefit that may greatly reduce bank erosion in manmade and natural water bodies.

Trials at the University of Southern Queensland in Toowoomba indicated evaporation savings of greater than 73% when deploying AquaArmour pods at a coverage of 81%. Greater savings than those reported here would be expected as total surface area coverage increases towards 100%.

Deployment of modules will result in reduced light penetration and reduced mixing of the water under the modules but has been shown to not adversely affect oxygen levels (Symes et al 2009).

Raftex is a prototype modular cover that floats on the water surface. Each module consists of a fully enclosed rectangular plastic pipe frame with maximum dimensions of 12 m by 2 m. The plastic pipes are 50 or 75mm in diameter. The frames are also strengthened with plastic brace rods every 2m. The frame is wrapped with several layers of UV stabilised adhesive film. Holes in the film and pipe allow the module to partially fill with water to reduce the likelihood of the modules lifting from the water's surface during windy conditions.

Generally modular systems have a very high capital cost (in excess of $20/m2). Repair and replacement of modules is possible and water quality impacts will depend on the relative area covered, and changes in oxygen transfer, light penetration and in water temperature.

Figure 13 - Evaporation trial using prototype Raftex system of floating covers at USQ

The mechanical durability of a modular floating system is also important and will affect cost effectiveness of a product when the cost is amortised over the life of the product. In the context of modular floating systems, the following generalised factors as outlined by Howard and Schmidt (2008) need consideration:

- The product must not bend or twist out of shape, as the module will not sit as designed on the water surface and not provide a barrier between the water and the atmosphere.
- Consideration needs to be given to removal and disposal of modules and material at the end of its design life.
- Untethered floating modules will be moved by surface currents and flows into and out of the storage.
- Potential failures can result from physical breakdown or damage of the material used to construct the floating modules.
- Wind can affect the modules by blowing them out of position or damaging them.
- Limited or difficult access to modules in the centre of storage will hinder access for repairs and maintenance of the storage, pumping infrastructure, and the modules themselves.
- Stability of the modules under wind is critical. Modules that have enough weight in them or are shaped to be stable under windy conditions are preferable. Additional weight makes modules less buoyant and more difficult to handle but provides better protection against wind. Partially filling the module with water will add ballast without making the module any heavier to transport. The size and shape of each module will also have an impact on the ability of wind to disturb the product.
- Water sitting on the cover due to rain events and/or wave action will evaporate much faster than it would if it were with the other water in the storage. It is crucial that any water landing on the modules is quickly shed off the module and into the storage.

3.1.4. Chemical Formulations

Chemical formulations can include monolayers or films which float on the surface of a water storage to create a barrier between the water and atmosphere. Chemical methods are not as effective as other methods in reducing evaporation because they are biodegradable and affected by wind which results in degrading performance over time and a need to reapply frequently (every one to ten days). Potentially monolayers could provide up to 30% evaporation reduction (Craig et al, 2005) although trials on a commercial scale have not demonstrated consistent savings of above 10%.

Commercial monolayer products in Australia have included Water$avr and Aquatain (see Appendix A). Water$avr is comprised of hexadecanol (cetyl alcohol, 'C16'), known to form a mono-molecular layer (a 'monolayer') on a water surface, formulated with hydrated lime as a 'filler' which on dissolving supports ionic repulsion and spreading of the product. Aquatain is a silicone based oil (Si Oil) of unpublished composition and is not a true monolayer (i.e. single molecule layer). Various trials have been conducted to assess the performance of these products (Craig et al, 2005, Morrison et al, 2008, McMahon et al, 2008) and while good savings have been found on small scale tank trials, 0% to 30% (Hancock, et al 2011) on farm dam scale trials savings of between 0% and 10% have been common.

The CRC Polymers are undertaking a large program to develop novel monolayer technologies for evaporation reduction (Prime et al, 2012b). The products can be applied as a suspension in water, dissolved in an organic solvent or applied as a dry solid. CRC Polymers small and medium scale tank and field trials indicated consistent savings of 15% to 60%. Farm dam sized trials are currently being conducted.

Frequent product application is required given the effects of wind, waves, UV radiation, algae and bacteria on product distribution and longevity. Monolayers have a self-spreading property and on small storages the product can be applied by hand from the bank (Figure 14). On larger storages the product can be applied by boat, air or an automated delivery system (Figure 15). The main advantage of monolayers is the low initial setup cost. Additionally, the product need be applied only when it is required, for example when the dam is full and during periods of high evaporation.

Figure 14 - Hand application of Water$avr product near Capella, Qld

Figure 15 - Application of Aquatain through a pipe system on a 120ha storage at Dirranbandi, Qld

Larger storages will require multiple application points. Automated application systems capable of individual dosage from applicators distributed across a dam in response to prevailing wind and weather conditions have been developed (Brink et al,2011) and successfully trialled at a 19ha storage in South East Queensland as illustrated in Figure 16 (Schmidt et al 2011)). While the application technologies effectively deployed the monolayer product, there were problems in ensuring adequate mixing of the water suspension monolayer formulation which compromised evaporation reduction.

Wind and wave action will reduce evaporation savings by causing uneven spreading or washing monolayer onto embankments. Resulting wave action can also cause the surface cover from the monolayer to breakup therefore reducing performance. Floating containment barriers are sometimes used to keep the monolayer from becoming beached on the dam’s embankment.

Variation in product performance is also influenced by naturally occurring microlayers or surface films which: i) degrade the monolayer, ii) accelerate photodegradation and iii) disrupt molecular packing and effective coverage (Pittaway and van den Ancker, 2010). While monolayer technologies are an attractive option there are many complexities in achieving optimum management. Brink et al (2010) provides a useful framework for considering and planning monolayer evaporation strategies.

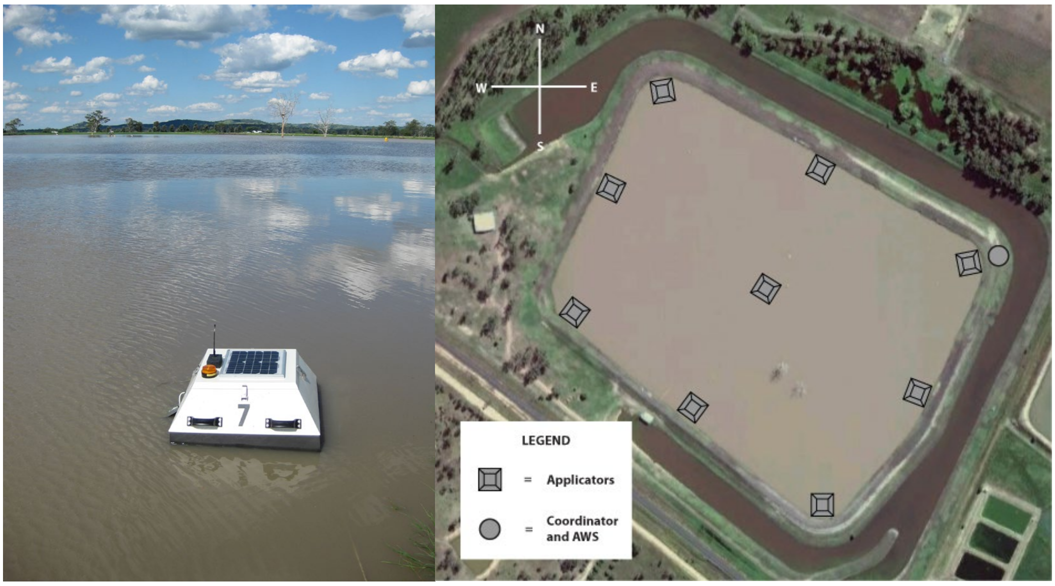

Figure 16 - Monolayer Application Unit with Automated Dosage Control from Central Coordinator and layout on a 16 ha farm dam near Gatton, Qld

Monolayers generally cannot be seen clearly by eye on the surface of a dam limiting confidence in the technology. Increased water surface tension does allow detection under light wind conditions through smoothing of surface wavelets. Various methods for monolayer detection have been researched (Coop et al, 2011) however no commercially viable approach is available. Accurate quantification of water savings is also a challenge. McJannett et al (2011) describe the use of Scintillometry techniques for direct measurement of evaporation off a dam and application to determine evaporation savings when monolayer is applied.

A water balance is a more practical and appropriate method for quantifying evaporation losses and water savings from farm dams. Monitoring water level changes accurately over periods where there is no inflow, outflow or rainfall allows determination of the evaporation and seepage losses. The storage is usually monitored prior to installation of the evaporation mitigation technology to characterize the storage and isolate the seepage and evaporation loss components and then monitored post installation. Equipment used during the monitoring include an automatic weather station and pressure sensitive transducers which can accurately measure changes in storage depth and isolate the evaporation and seepage components . The water balance method is especially useful when two adjacent dams can be monitored simultaneously one as a control and the other as a treated dam and the results compared to determine evaporation savings.

McJannet et al (2008) highlight that long term trials of monolayers have not been conducted and that suppression of evaporation will raise water temperature thereby limiting further evaporation savings.

The main impediment for adoption of monolayer systems is the highly variable performance of chemical barriers and the uncertainty of water savings. Further research and development of products, application and monitoring systems is required for this technology to mature before it becomes a viable option. Technologies associated with the use of monolayers are still relatively immature and the products are not considered market ready until consistent savings of around 30% can be demonstrated at a commercial storage dam scale.

3.2. Evaporation Reduction Strategies

Other approaches for reducing evaporation losses include design and management strategies rather than retrofitted products. These approaches include redesigning the storage to increase depth and reduce surface area, incorporating a cell wall and operating the storage to minimise the volume of water stored during peak evaporation periods. These design and management strategies may prove to be more economical and save more water than installing a cover. However, all options should be considered when looking to optimise the operation of the storage. I.e. deepening the dam and reducing the surface area to be covered can be used in conjunction with covers.

Changes to storage geometry must satisfy any regulatory requirements specified under the respective catchment Resource Operation Plan (Baillie et al, 2010). Strategic management of water in storage can also be used to reduce total evaporation by for example pumping water between storages to minimise surface area per unit volume of water stored.

3.2.1. Increased Wall Height and Storage Cells

Increasing the height of a storage wall can provide evaporation savings by reducing the surface area available for seepage and evaporation for a given volume of water. Resource Operation Plans may require that there is no increase in volume of water collected, therefore a deeper storage would have to replace other separate storage capacity or its footprint reduced (Baillie et al, 2010). Building a new storage to the maximum permissible height is the most appropriate option to minimize evaporation. Water savings are proportional to the reduced surface area of the water in storage. Factors affecting the range of water savings will include the time water is in storage and the potential for higher seepage losses as a result of increased hydraulic head.

The feasibility of raising the wall height for on farm storages will be a function of the earthworks required and the potential water savings which is related to the specific nature of each site. The availability of appropriate construction material will also be an important consideration. The option of excavating deeper to provide wall material will be obvious, however the nature of material to be excavated and the need to provide a sealed base of the storage after excavation is critical and could be an issue in the Granite Belt.

Dividing a storage into two or more cells (through construction of a new earthen embankment) can reduce wind action and minimise the surface area available for evaporation for a given volume of water. Cells give flexibility so that at low storage volumes, water could be concentrated at greater depth in a single cell with a smaller footprint than would be possible if this water was spread across the entire storage area at a smaller depth (Baillie et al 2010). The resulting reduction in seepage and evaporation potential can be of significant benefit, particularly during periods of low water availability. This approach would be more cost effective for larger storages when earthwork volumes would be smaller relative to the volume of water stored.

Most likely application of this approach would be dividing the storage into two equal sized cells by constructing a new internal wall. Variations include dividing the storage into unequal sized cells. Similarly an additional cell might be added by constructing new embankments outside of the existing storage, however this would obviously increase the total on farm storage capacity with may contradict the Resource Operation Plan (Baillie et al 2010).

The main operational consideration by the irrigator is the transfer of water between cells. How well the storage is managed to reduce the surface area of water in storage will influence losses and water savings. Incorporating cells will require technical expertise and skilled contractors to design and construct the new embankments.

The feasibility of incorporating cells for on farm storages will be a function of the earthworks required, the infrastructure required (i.e. pumping and pipe work to be retro fitted to the storage for transferring water) and potential water savings.

Case Studies undertaken on behalf of the National Water Commission (Cotton Catchment Communities CRC, 2011b) indicated the cost of water saved through storage modifications. The results indicated that the cost of water saved was often attractive when compared with the value of water available from temporary transfer markets (Table 3 and Table 4). However, only individual growers will be able to determine an acceptable cost for water saved under their particular conditions. The average cost of water saved for both cell division and wall height strategies was around 150/ML/year. Whilst the maximum cost of water saved was $350/ML/year for cell division strategies and $300/ML/year for wall height strategies, the cheapest savings were only $15/ ML/year and $59/ML/year respectively. This range of results demonstrates the importance of analysing individual storages to determine where particular solutions can be most cost effectively applied.

Table 3 - Case studies of the cost of saved water by introducing cells

Cell Division Strategies						
Farm Number	Cell Split Ratio	Storage Volume (ML)	Storage Area (ha)	Water Saved (ML)	Capital Cost	Cost of Saved Water ($/ML/year)
1	50:50	1200	22	31.8	$162,150	$285
2	50:50	3963	130	1011	$278,050	$15
3	25:75	350	7.5	37.7	$111,780	$170
4	50:50	1000	34.5	52.3	$161,595	$173
5	50:50	1100	29.4	40.1	$161,595	$225
6	50:50	1500	27	234.8	$269,541	$63
7	50:50	350	11.5	15.5	$93,150	$350
8	25:75	450	10.7	94.3	$123,750	$75
13	50:50	3000	97.3	201	$547,000	$143
14	50:50	963	25.7	98.8	$105,450	$56
15	50:50	12000	337	1404	$390,000	$15
Average		2352	67	293	$218,551	$143

(Cotton Catchment Communities CRC, 2011b)

Table 4 - Case studies of the cost of saved water by increasing wall height

Wall Height Strategies					
Farm Number	Storage Volume (ML)	Storage Area (ha)	Water Saved (ML)	Capital Cost	Cost of Saved Water ($/ML/year)
9	780	29.9	549	$1,685,000	$161
10	3850	74	2065	$6,252,756	$159
11	900	23.1	585	$1,800,000	$163
12	265	6.5	611.8	$3,499,500	$302
14	963	25.7	211.7	$234,838	$59
15	12000	337	2929	$3,412,500	$62
Average	**3126**	**82.7**	**1159**	**$2,814,099**	**$151**

(Cotton Catchment Communities CRC, 2011b)

Generally the smaller the storage the higher the relative cost of earthworks as an evaporation control strategy. This is evident in Table 3 and Table 4. For typical Granite Belt storages of less than 5 ha surface area, introducing cells is less likely to be viable. Availability of suitable borrow material to increase wall height and ensure the base of the storage does not leak could be a limiting factor on many Granite Belt soils.

3.2.2. Strategic Management of Water

Strategically managing storages can provide significant water savings for very little cost. Depending on the different situations that growers might face, this could include, storing water for the shortest period of time possible; identifying storages with higher seepage or evaporation and using water from these storages first; combining water into a single dam and using the smallest or deepest storage possible. It is important to limit removal of water from sources that evaporate less (such as deep dams and ground water supplies) and reduce the time that the water is retained in a storage and hence the time that evaporation can occur.

4. Comparative Analysis of Technologies and Likely Adoption

4.1. Comparative and SWOT Analysis

A comparative analysis and SWOT analysis of water saving options was presented by Baillie et al (2010) and is provided below (Table 5). Interpretation of the SWOT analysis in the context of small Granite Belt storages irrigating typically high value crops, the following conclusions can be reached for currently available solutions:

Table 5 - Summary of evaporation saving products and strategies and suitability to the Granite Belt

Product	***Suitability***
Shade cloth	Highly suitable
Floating covers	Highly suitable
Modular systems	Less suitable owing to high cost
Chemical covers	Not suitable – Reliability and not demonstrated on commercial scale
Raising wall height	Suitable on larger storages and with appropriate soils with low seepage
Cells in storage	Less suitable on small Granite Belt storages
Strategic management	Highly suitable with specific management options to combine water storage

Table 6 - SWOT analysis of evaporation management options for on-farm storages, (Baillie et al 2010)

	Strengths	Weaknesses	Opportunities	Threats
Evaporation Reduction Products				
Floating Covers	• Highest average evaporation reduction of EMTs • Lowest variability in performance • Long lasting • Relatively easy to install	• High capital and maintenance costs • Dust build-up and the growth of weeds on top of the cover • Disruption to surface wildlife and change in the environment and water quality beneath the cover • High winds may cause damage and removal of cover • Use of cover limited to storages<5 ha.	• Potentially reduces algal growth – advantage in areas that use micro irrigation systems • Potentially improves water quality and reduces salinity. • Low level of expertise required • Easy to determine the likely water saving with a high degree of confidence	• Environmental impact concerns • Water saving may not be realised during dry periods
Suspended shade cloth	• High evaporation reduction • Permeability of cover allows direct rain entry and prevents debris build up • Enables entry of wildlife onto storage • Not affected by changing water levels • Allows easy access to the storage for maintenance operations • Low ongoing running costs.	• High capital outlay and maintenance costs • Limited applicability • Use of cover limited to storages with a surface area less than <5ha. • Satisfactory anchoring in some poor soils may be difficult	• Familiarity in the Granite Belt due to common use for hail and bird damage prevention in tree crops. • Existing expertise for installations. • Appropriate sized storages in some areas (ie Granite Belt)	• Specialist skills and significant engineering design required (footings and high tensile cables) • Can only be installed under low wind conditions.

	Strengths	*Weaknesses*	*Opportunities*	*Threats*
Modular covers	• Individual modules can be repaired or replaced • Virtually maintenance free • Progressive purchase enables initial cost to be spread out over longer period of time • Lightweight, quick and easy to install	• High variability in performance between commercial covers available • Very high capital cost • Disruption to surface wildlife • Difficult to cover 100% of storage • Modular cover may not refloat if left in a muddy storage	• Improved water quality through reduced algae • Low level of expertise required • Easy to install and maintain by irrigator.	• High winds may cause movement and loss of covers, especially on dry storages.
Chemical barriers	• Low initial setup cost • Low risk investment for ephemeral storages • Suitable for storages in dry periods • Flexibility and ease in application of cover • Can be applied only when needed • Suitable for large storages • Can use automatic applications • Potentially viable system for large (>10 ha) storages based on capital outlay for other systems. • Biodegradable product should limit potential environmental	• Low evaporative reduction • Highly variableperformance • Biodegradable product means longevity is affected • Monitoring and measurement of covers presence/thickness difficult • Not suitable in windy locations.	• Can potentially be applied by aircraft. • Applicable to a large number of storages in the Granite Belt	• Environmental and water quality concerns • Actual resulting performance and watersaving is less certain.

	Strengths	*Weaknesses*	**Opportunities**	*Threats*
Evaporation Reduction Strategies				
Increased wall height	• Easy to determine likely water saving – robust calculation • No additional ongoing maintenance.	• Working with a Greenfield site is easier. • Easier to build a new storage with smaller surface area and same volume • Cost of construction increases rapidly with embankment height. • May increase seepage rate	• Access to earthmoving equipment and design expertise - Same expertise required as per the initial construction	• Regulatory limitations.
Storage cells	• Allows water depth to be maximised while reducing surface area • Reduced wind action • Easy to quantify water saving based on reduced area • Particularly useful for reducing losses during periods of low water availability.	• Lose volume (unless combined with increased wall height or external cells) • Effective if each cell is emptied completely • System has additional operational costs (labour, energy).	• Access to earthmoving equipment and design expertise - Same expertise required as per the initial construction	•
Strategic management	• Quantifiable water savings • Simple strategy • Low cost.	• System has additional operational costs (labour, energy) • Additional infrastructure (pipes, pumps, etc) to allow management of the storages • Require some storages to be completely emptied (part full –same losses).	• Opportunity for farms with multiple storages	• May be limited by farm distribution layout • Significant conveyancing losses could undermine thewater saving.

4.2.Adoption of Evaporation Saving Solutions

A grower / irrigator survey was completed in January and February 2010 by Baillie et al (2010) to quantify the potential for water savings across the Queensland Murray Darling Basin (QMDB). The survey included the Stanthorpe Water Management Area (SWMA). All 6 survey respondents from the SWMA are located in the Granite Belt. They had a combined water storage volume of 510ML and the average storage dam surface area was 3 ha. While the survey number is small it provides valuable insight into likely adoption of methods to reduce evaporation losses.

The summary statistics below identify the percentage of survey respondents who have either adopted a water use saving technology or indicated they would consider uptake. The following categories of storage water use efficiency improvements were surveyed.

- Measurement of storage dams,
- Use of advanced monitoring and record keeping systems,
- Installation of water meters and evaporation and seepage control systems,
- Modified design of the storage,
- Improved management of water resources.

Table 7 suggests there is already widespread adoption of storage volume and inflow outflow measurement and record keeping in the Granite Belt. There is significant potential for and interest in the uptake of more sophisticated water budget software to better account for water resource.

Table 7 - Adoption and potential uptake of measurement and monitoring water efficiency options in storages in the Granite Belt (% of 6 respondents)

	Measurement					Monitoring	
	Volume	Evaporation	Seepage	Inflow&Outflow	EM Survey	Water budget software	Record keeping
Adoption	50%	0%	17%	50%	0%	17%	50%
Potential Uptake	17%	17%	17%	17%	17%	50%	17%

Table 8 indicates there is already widespread adoption of compaction to reduce seepage from the base of the dam. There is significant interest in and potential uptake in evaporation mitigation products. This is likely due to the smaller storages combined with a higher value crop grown. In particular there is greater interest in shade and floating covers than in any other area of the QMDB but none of the respondents had installed such systems as yet although there have been some trials of monolayers.

Table 8 - Adoption and potential uptake of installed water efficiency options in storages in the Granite Belt (% of 6 respondents)

	Installation							
		Evaporation				Seepage		
	Volume Meters	Monolayers	Shadecloth	Floating Cover	Wind barrier	Clay lining	Base compaction	Plastic lining
Adoption	0%	33%	0%	0%	17%	33%	50%	33%
Potential Uptake	33%	50%	83%	67%	33%	0%	0%	17%

Table 9 indicates there is already significant management of water resource through use of leaky storages first. There is some interest in increasing depth to improve evaporation savings but less for introducing cells. This is to be expected given the generally small storages in the area.

Table 9 - Adoption and potential uptake of design and management water efficiency options in storages in the Granite Belt (% of 6 respondents)

	Design		Management		
	Cells	Increase Depth	Weed Control	Use Leaky Dam 1st	Combine into single dam
Adoption	0%	17%	17%	50%	50%
Potential Uptake	17%	33%	0%	0%	0%

Baillie et al (2010) also surveyed barriers to adoption of water use efficiency technologies. Some of these barriers are specific to investment in water saving technology as part of the Federal Governments Sustainable Water Use Infrastructure Program (SWUIP). This program offers a co-sharing/co-investment scheme whereby the government helps pay the cost of water saving infrastructure in return for a share of the water saved being returned to the Commonwealth. These barriers would be less relevant to farmers investing personally for productivity gains, but still provide some insight into the issues faced.

The following barriers are important in the Granite Belt

Technical Barriers

- Lack of confidence in water saving technologies and stated water savings, uncertainty in life expectancy of technologies,
- Lack of assessment tools to quantify savings and uncertainty over savings,
- Unconvinced that that benefits exceeded costs,
- Gap between scientific research and practical demonstration of benefits.

Financial Barriers

- Lack of cash flow due to a run of poor seasons,
- Total cost to the irrigator of investing in water saving technology is difficult to determine and a feasibility study would be required to determine total cost prior to participation,
- Perception that $/ML invested by Government through SWUIP will be lower than current market value of water,
- Exchanging an appreciating asset (water) for a depreciating asset (water saving technology) through participation in SWUIP.

Biophysical Barriers

- Climate variability – in high rainfall years there would be no benefit through savings, in low rainfall years and persistent drought there is no water to save,
- Difficulties to reconfigure storages (raised height) etc when storages are located against property boundaries and a significantly broader wall base is required and the location of power lines and other infrastructure in the field.

Motivational Barriers

- Recent good rains which have reduced interest in water saving,
- Negative mind set over participation in government water saving programs such as SWUIP and skepticism over political motivation,
- SWUIP program seems complex and risky and skepticism whether the volumes saved will make any difference, considering the extractions downstream.

Regulatory Barriers

- Uncertainty over regulatory changes and impacts. Examples include certification of works, Resource Operation Plans, water trading, changing entitlements, impact of Sustainable Diversion Limits and impact on those who had already implemented water saving programs.

Generally irrigators are seeking practical and low capital evaporation and seepage mitigation strategies to gain water savings. While the Stanthorpe Water Management Area shows high percentage uptake across all storage management technologies, the savings would be small at a whole of basin level when considering the low total volume of water in farm storages.

5. Assessment of Water Saving Potential

Table 10 gives an indication of expected water saving potential of specific evaporation control products. This information is based on a literature and commercial review of products and results of trials conducted by the NCEA. These results vary slightly from figures previously published, reflecting more recent results and experience. Actual water saving will be site dependent and will reflect the quality of the installation and ongoing management. The figures assume 100% cover of the water surface and water held in the storage all year. Losses are also given in megalitres (ML) for a 1 ha storage in the Granite Belt based on 1,686mm average annual evaporation loss (Table 1). During dry years evaporation is likely to increase.

Table 10 - Expected annual evaporation water savings for a range of products as a percentage and in ML for a 1ha storage in the Granite Belt (Evaporation 1686mm/yr)

Product	Evaporation reduction (%) Range in Performance			Evaporation Saving (ML) 1ha Storage - Granite Belt (Stanthorpe)		
	High	Medium	Low	High	Medium	Low
Floating Cover	100%	90%	85%	16.9	15.2	14.3
Modules	90%	85%	75%	15.2	14.3	12.6
Shadecloth	85%	80%	70%	14.3	13.5	11.8
Monolayer	30%	10%	0%	5.1	1.7	0.0

When water is not stored all year the evaporation savings will be reduced and the benefits of installing a cover will also decline. Table 11 indicates the water saving of various products for different months of assumed water storage assuming 'Medium' evaporation reduction performance. Similarly if a dam only holds water 5 years in 10, the long term average evaporation saving will be 50% of the figures provided.

Table 11 indicates that for the Granite Belt, 15.2 ML/yr of water would be saved off a 1 ha storage when using a floating cover providing 90% evaporating saving performance when water is held all year. This would reduce to 10 ML/yr if water is only held from October to March. Should the dam be dry 5 years in 10 this would reduce to an average 5ML/yr saving.

Table 11 - Annual evaporation savings for different periods of water storage, based on medium product performance

	Evaporation Saving (ML) 1ha Storage Granite Belt			
No Months Water in Storage	12	8	6	4
Months Water in Storage	Jan-Dec	Sep-Apr	Oct-Mar	Nov-Feb
Days Water in Storage	365	242	182	120
Evaporation Loss from Storage (mm)	1686	1369	1111	774
Floating Cover (90%)	15.2	12.3	10.0	7.0
Modules (85%)	14.3	11.6	9.4	6.6
Shadecloth (80%)	13.5	11.0	8.9	6.2
Monolayer (10%)	1.7	1.4	1.1	0.8

Evaporation mitigation strategies such as introducing cells or raising the wall height to increase water depth will reduce evaporation loss by decreasing the surface area of water exposed per unit of water volume stored. Doubling storage depth will not decrease surface area and evaporation loss, unless another dam is decommissioned. It will however result in a similar evaporation loss from twice the volume of water stored.

Splitting a dam into two equal cells will allow all water to be consolidated into one cell when the dam is 50% full, thereby halving water surface area.

6. Capital and Operating Costs

Typical installation, operating and maintenance costs of evaporation control products are provided in Table 12.

Table 12 - Evaporation product capital and operating costs

Product	Evaporation reduction %	Installation Cost ($/m^2)	Operating & Maintenance Cost $/ha/yr	Monolayer Cost $/ha/yr
	High - Med - Low	Low - High	Low - High	Low - High
Floating Cover	100% - 90% - 85%	$11.00 - $18.00	$550 - $900	
Modules	90% - 85% - 75%	$40.00 - $50.00	$2000- $2500	
Shadecloth	85% - 80% - 70%	$12.00 - $19.00	$600 - $950	
Monolayer	30% - 10% - 0%	$0.072 - $0.24	$36 - $120	$547 - $10,950

6.1. Capital Costs

Capital costs provided above do not represent a specific product and are based on information from a range of suppliers. Actual costs will be site specific and relate to the specific material used, installation arrangement and costs. Costs would vary depending on site location (freight distance), weather conditions (e.g. wind load), product specification, installation detail and size and geometric arrangement of the storage. A range of costs has thus been provided. Actual costs would need to be obtained from a supplier to accurately determine system costs.

The capital costs are based on a 12 year life of the floating cover and modular systems and a 15 year life of the shade cloth fabric with 30year life of the shade cloth suspension structure. No residual value was assumed at the end of the product life.

Monolayer capital costs are based on a monolayer applicator system and containment grid to reduce monolayer wash up on the embankment. Costs are based on a containment grid installation cost of $3.5/m and one applicator costing $1,000 serving between 1 ha and 4 ha. Hand application is also possible however an automated dosage system allows optimal dosing in accordance with weather conditions (e.g. wind) without need for labour intervention. The life of the application and containment system is assumed to be 10 years.

6.2. Operating and Maintenance Costs

Operating and maintenance costs of floating covers, modular systems and shade cloth systems include maintenance and repair after storm damage, removal of debris, repairs of tears, replacement of modules, repair of tethering and foundations. This has been assumed to be 0.05% of capital cost for all products.

Annual maintenance and operating costs for monolayer systems will include labour for refilling hoppers and repair and maintenance of the application system and containment grid. These have been assumed at 5% of the systems capital cost.

6.2.1. Chemical Product Cost

Cost of monolayer itself will vary depending on the specific chemical product used ($/l), frequency of application (days) and dosage rate (l/ha). Based on NCEA experience with a range of products a product cost of $15/l has been assumed with a dosage of between $1l/ha and $2l/ha at a frequency of application varying between every 1 day and 10 days.

A major advantage of chemical application is the potential to apply the product only during periods of high evaporation loss that is when water is stored in summer, thereby reducing application costs.

7. Economic Analysis

The economic feasibility of deploying an evaporation control product will vary and the decision to install a system will depend on the value of water to the irrigator. High capital cost systems are best suited to storages holding water all year every year to spread the high initial investment costs over a greater volume of water saved. The potential cost of installing and operating an evaporation cover will be a function of:

- Annual and seasonal evaporation losses from storage at the location,
- Installation and maintenance costs and replacement period, which are very dependent on site situation and installation specifics,
- Efficiency of the product in mitigating evaporation, and
- Storage operating conditions, in particular months of the year the storage holds water and how many years out of ten the storage is empty.

A 'Ready Reckoner' developed by the CRC for Irrigation Futures (http://www.readyreckoner.ncea.biz) to undertake an economic analysis for evaporation control products has been used in this study. The calculator allows site-specific assessment of evaporation control systems. The 'Ready Reckoner' returns the volume of water saved (in ML) and the cost of the evaporation control system used per ML of water saved (i.e $/ML saved/year). Inputs include:

- Site location (Latitude and Longitude) to estimate monthly evaporation loss
- Storage dam size and shape
- Storage operating conditions in terms of years out of ten the dam is expected to hold water and typical percentage full each month of the year.
- Anticipated seepage losses.
- Evaporation control technology to be used, water saving potential and costing assumptions.

The analysis below is based on Stanthorpe evaporation information (Table 1). A regular square storage (ring tank) of area 1 ha has been used to compare different products. Comparing system economics on a $/ML saved/year basis makes the choice of area largely irrelevant when doing a comparative analysis between evaporation control systems. A site specific analysis would need to be undertaken to determine the absolute cost of a particular system which is area dependent.

The analysis includes a discounted cash flow analysis for the selected product to determine the net present value (NPV) of the investment and annuity to finance this investment. A real discount rate of 5% was assumed. The dollar value of the annuity per megalitre (ML) water saved ($/ML/yr) can then be determined to allow comparison between systems. This is the best way to determine relative costs of various evaporation mitigation systems.

Capital, operating, maintenance and repair costs of the systems have been discussed in Section 6. It should be recognised that capital costs can vary markedly depending on site and product specifics including product specification, site location, access, installation specifics, wind, storage geometry and surface area. A site and installation specific assessment is always recommended.

A representative range of cost scenarios (low and high) was used to represent the likely spread in capital, operating and operating/maintenance costs (see Table 12) and a range in evaporation reduction performance was considered.

Table 13 summarises for each product:

- The range in expected evaporation reduction performance (from Table 10)
- A low cost and high cost scenario of the capital cost ($/ha), operating and maintenance cost of all systems as well as the chemical cost of the monolayer systems ($/ha/yr) (Table 12)
- An appropriate replacement life for each system (Section 6)
- The water saved by the system (ML/yr) (Table 10)
- The annual cost of the system per unit of water saved ($/ML/yr).

Table 13 - Economic analysis for various evaporation control technologies in the Granite Belt

					Granite Belt - Stanthorpe		
Floating Cover					Evaporation Reduction (%)		
					85%	90%	100%
				Water Saved (ML/yr)	14.3	15.2	16.9
Cost Scenario	Capital Cost ($/ha)	Op & Maint ($/ha/yr)		Cost of Product $/ML/yr	$/ML/yr	$/ML/yr	$/ML/yr
Low	$110,000	$550			$925	$874	$787
High	$180,000	$900			$1,515	$1,431	$1,278
Modules					Evaporation Reduction (%)		
					75%	85%	90%
				Water Saved (ML/yr)	12.6	14.3	15.2
Cost Scenario	Capital Cost ($/ha)	Op & Maint ($/ha/yr)		Cost of Product $/ML/yr	$/ML/yr	$/ML/yr	$/ML/yr
Low	$400,000	$2,000			$3,294	$2,907	$2,745
High	$500,000	$2,500			$4,118	$3,633	$3,431
ShadeCloth					Evaporation Reduction (%)		
					70%	80%	85%
				Water Saved (ML/yr)	11.8	13.5	14.3
Cost Scenario	Capital Cost ($/ha)	Op & Maint ($/ha/yr)		Cost of Product $/ML/yr	$/ML/yr	$/ML/yr	$/ML/yr
Low	$120,000	$600			$820	$717	$675
High	$190,000	$950			$1,252	$1,096	$1,031
Monolayer					Evaporation Reduction (%)		
					70%	80%	85%
				Water Saved (ML/yr)	0.0	1.7	5.1
Cost Scenario	Capital Cost ($/ha)	Op & Maint ($/ha/yr)	Chemical Cost ($/ha/yr)	Cost of Product $/ML/yr	$/ML/yr	$/ML/yr	$/ML/yr
Low	$720	$36	$547		Infinity	$370	$123
High	$2,400	$120	$10,950		Infinity	$6,572	$2,190

The results indicate the following:

- Floating cover systems have a potential to save between 85% and 100% of evaporation at a cost of between $787/ML/yr and $1,515/ML/yr.
- Modular systems are very expensive, have a potential to save between 75% and 90% of evaporation at a cost of between $2,745/ML/yr and $4,118/ML/yr.

- Shade cloth systems have a potential to save between 70% and 85% of evaporation at a cost of between $675/ML/yr and $1,252/ML/yr.
- Monolayer systems have a potential to save between 0% and 30% of evaporation at a cost from $123/ML/yr to well in excess of $6,572/ML/yr. Performance of monolayer systems on a commercial scale is largely unknown and impacted by many factors, hence the wide spread in potential cost. The frequency of application, dosage rate and evaporation reduction can vary enormously. These systems cannot be recommended commercially at this stage. Successful development of products providing consistent evaporation saving of above 30% with dosage every 5-10 days would provide an attractive option.

The above indicates that floating cover systems and shade cloth systems are likely to be the preferred systems for the Granite Belt. The cost of saving evaporation water ($/ML/yr) should be compared with the gross margin that can be generated from additional irrigation water, or the cost of purchasing additional water. For high value crops in the Granite Belt this could make deployment of shade cloth and floating cover systems viable. If a farmer has ready access to a range of water supplies at costs lower than indicated in Table 13, there will be little incentive to install a cover.

Table 13 assumes that the storage is full all months of every year. Recalculation assuming the dam is 50% full in the summer months (Oct-Mar) when irrigation is underway and that 5 years out of 10 the storage is empty would increase the cost/ML for shade cloth, modular and floating cover systems by 237%. Installation of these systems is only viable when water is held in storage the majority of the time.

Consideration was also given to the economics of raising the dam wall to effect evaporation savings. As stated earlier raising the dam will not in itself reduce evaporation. It will however reduce evaporation per unit volume stored. Assuming the farmer can withdraw other storages to maintain the same volume of water stored, but in a deeper dam, evaporation savings will be realised. This is the basis of calculations below.

Increasing wall height and storage volume may be illegal in terms of local resource operation plans. Increasing wall should also only be considered when appropriate embankment material is available and seepage is minimal. Deepening the dam can sometimes increase seepage losses. This has not been factored into the results below.

Table 14 summarises the cost of effecting evaporation savings by increasing embankment height. Calculations are based on both a 1 ha storage and 10ha storage and raising wall height by one, two and three meters. It is assumed the storage is a square ring tank with original wall height of 4m, crest with 3m, embankment batters 4:1 (inside) and 3:1 (outside) and freeboard of 0.5m. Earthwork costs are assumed to be $\$3/m^3$. Table 11 provides:

- Required earthworks (m^3)
- Increase in water storage resulting from raising the dam (ML)
- Evaporation saved (ML/yr)
- Capital cost of earthworks ($)
- Cost of water saving strategy ($/ML/yr)

Table 14 indicates that for a small 1ha dam the strategy of raising the wall will be relatively expensive ($852-$1,487/ML/yr). For larger dams of 10ha the additional earthwork costs are supported by large evaporation savings at relatively low cost ($204-$355/ML/yr). Again these savings will only be realised if the farmer can withdraw other storages to maintain the same volume of water stored, but in a deeper dam.

For large storages with appropriate soils that limit seepage increasing wall height offers an attractive option.

Table 14 - Economic analysis for increasing storage depth

Raise Embankment						Storage Area (ha)
						1ha
Increase Wall (m)	Earthworks (m3)	Increase in Storage (ML)	Evaporation Saved (ML/yr)	Capital Cost ($)	Cost of Strategy $/ML/yr	$/ML/yr
1m	14,700	5.1	2.7	$44,100		$852
2m	33,000	9.5	4.5	$99,000		$1,152
3m	53,000	13.4	5.7	$159,000		$1,487
						10ha
Increase Wall (m)	Earthworks (m3)	Increase in Storage (ML)	Evaporation Saved (ML/yr)	Capital Cost ($)	Cost of Strategy $/ML/yr	$/ML/yr
1m	45,000	84	35	$135,000		$204
2m	99,300	163	57.2	$297,900		$275
3m	162,500	238	72.5	$487,500		$355

8. Discussion and Conclusion

Evaporation loss from storages in the Granite Belt is likely to be of the order of 1,650mm to 1,750mm per year. For example evaporation losses at Stanthorpe are estimated to be 1686mm/year of which 66% occurs in the months October to March.

Storages in the Granite Belt are typically small (<10ha) and water is derived from water harvesting and overland flow capture with limited underground water supply and no regulated water supply. High value crops are irrigated with generally efficient irrigation systems. Water losses from storages (evaporation and seepage) are likely to represent 70% of the total on farm water loss with the remainder being distribution losses and infield irrigation system losses.

There is already widespread adoption of measurement and monitoring water efficiency options by Granite Belt irrigators and there is significant interest in potential for evaporation covers and reconfiguring and managing dams to effect water saving. Barriers to invest in these systems are likely to include lack of finances, low confidence in water saving technologies and cost-benefit, practical difficulties related to the specific storage. Recent good rains have also reduced the likely uptake.

Evaporation control technologies have been shown to be potentially viable to reduce evaporation and save water. The decision to install a system will depend on the value of water to the landowner in terms of increased crop production and the cost of alternative water supplies.

Feasible systems for the Granite Belt are likely to include shade cloth, floating covers and possibly increasing wall height. While a generalised assessment of comparative costs has been provided in this report a detailed site specific assessment is required to evaluate actual system costs.

Suspended shade cloth systems reducing evaporation by 80% could potentially save a Granite Belt farmer 13.5ML of water per year per hectare of storage dam at a cost of around $720/ML water saved/yr. Shade cloth systems are widely used in the Granite Belt for crop protection and there is an existing site in the area which demonstrates the system for evaporation water saving.

Floating covers reducing evaporation by 90%-95% could save Granite Belt farmers between 15.2 ML and 16.9 ML of water per year per hectare of storage dam at a cost of around $790/ML to $870/ML water saved/yr. On larger storages (>3ha) tethered floating raft systems would be more appropriate than trenched systems anchored into the dam embankment. This would increase costs to around $1,200/ML to

$1,400/ML water saved/yr. Floating cover systems have been deployed in Stanthorpe, specifically at the Stanthorpe school to cover treated waste water storage where additional benefits of maintaining water quality and odour control arise.

Increasing wall height provides an opportunity to reduce the surface area per unit of water stored. Savings will only be realised if the farmer can withdraw other storages to maintain the same volume of water stored, but in a deeper dam. Catchment resource operation plans may limit an irrigator's ability to increase storage volume on the property. Increasing depth on inferior soils with high seepage will result in higher seepage which would negate evaporation savings. The cost of increasing wall height would be between $850/ML and $1,490/ML water saved/yr on a small 1 ha ringtank. This reduces to between $200/ML and $350/ML water saved on larger 10 ha storages. The economics on gully dams would be very different and generally a lot cheaper owing to less earthworks.

Monolayer systems have not demonstrated consistent performance and until new products are developed that can generate consistent 30% savings they are unlikely to be adopted.

Modular systems are very expensive and are unlikely to be economically feasible for agriculture in the Granite Belt. However, they do offer much potential in locations where water is very valuable such as in mining operations and treated wastewater.

Introducing cells into dams becomes more feasible when storages are large, earthwork volumes are small in proportion to the water volume and there is appropriate pumping infrastructure to transfer water between cells to minimize exposed water surfaces. In cases where there are nested gulley dams on a creek, release of water to maximise water levels in the bottom dam is a sensible water management strategy.

The cost per ML water saved will be influenced by the amount of time the storage holds water. Evaporation saving products are not recommended unless there is a high assurance of water being held most of the year and in most years.

9. Recommendations for Further Studies

This desktop assessment has highlighted the magnitude of losses and assessed the costs and benefit of using a variety of evaporation mitigation products and management strategies. This work will be further refined and become more specific to the Granite Belt through the following works

- Collection of site specific storage usage patterns to characterise how water is stored and used for a series of farms. This data can then be used to develop specific case studies using the evaporation and seepage 'Ready Reckoner'
- A program measuring actual seepage and evaporation losses from Granite Belt storages using similar methods to those used to quantify losses in the cotton industry should considered.
- Development of a series demonstration sites of water saving technology and case studies for water management.
- Undertaking whole farm water balance assessments to assess relative water losses in storages, channels and field applications.
- Public forums or workshops to raise awareness of losses and potential mitigation products and strategies

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Appendix A – Summary of Commercially Available Evaporation Control Products

Cover Type	*Cover Name*	*Manufacture*	*Reference Site*
Floating Modular	Aqua Armour	AQUA Guardian Group	http://www.aquaguardiangroup.com/
	Aquacap	Nylex, Royal Melbourne Institute of Technology	http://www.aquacap.com.au/specs.asp → site no longer exists
	Aquaguard	Fabric Solutions International	http://www.fabricsolutions.com.au/evaporative_covers.htm
	BirdBalls	Environmental Controls Company (USA)	http://www.eccllc.us/
	CURV	Propex	http://www.curvonline.com/
	E-VapCap	Evaporation Control Systems	http://www.evaporationcontrol.com.au/ http://www.evaporationcontrol.com.au/aboutecsproduct.htm
	Euro-matic Bird Balls	Euro-Matic	http://www.euro-matic.com/birdb.html
	Fabtech	Fabtech	http://www.fabtech.com.au/
	HexDome	Indusium	NA
	Layfield Modular Cover	Layfield	http://www.layfieldgeosynthetics.com/
	LemTec Modular Single Sheet Cover System	Lemna Technologies (USA)	http://www.lemnatechnologies.com/
	MOD-E-VAP	Merit Lining Systems	http://www.merit-linings.com.au/
	Polynet	Designed by Ken Gordon, Tel/Fax: (02) 6847 1381 (NSW)	NA
	Raftex	F Cubed Australia	http://www.fcubed.com.au/pdf/RAFTEX-InfoSheet.pdf http://www.fcubed.com.au/aspx/home.aspx --> product not mentioned on current website

Floating Covers	RTD Enterprises	RTD En terprises	http://www.rtd-enterprises.com/index.html --> site no longer exists http://www.rtdenterprises.com/
	QUIT Evap	SMEC Australia	Peter.Chapman@smec.com.au
	Water Innovations Modular Covers	Water Innovations	http://www.waterinnovations.com.au/
	Defined Sump floating cover	Layfield (C. W. Neal Corporation)	http://www.cwneal.com/floatingcover.htm
	Enviro Dam Covers	Dam Covers Now	http://www.damcoversnow.com.au/
	Evap-Mat	DeVere Mining Technologies	http://www.deveremining.com/final-web-pages/dam-cover.html → website no longer exists
	REVOC – Floating Covers	Layfield (USA)	http://www.layfieldenvironmental.com/ http://www.layfieldgroup.com/pages/home/default.aspx http://www.cwneal.com/floatingcover.htm
Shade Structures	Aquaspan	Aquaspan (UK)	NA
	MuzCov	Designed at the Dalby Agricultural College	NA
	NetPro	NetPro Protective Canopies	http://www.netprocanopies.com
	NICOSUN®	Maccaferri	http://www.tencate.com/ http://www.maccaferri.com.au/afawcs0150039/CATID=6/ID=28/SID=1039373700/Nicosun%C2%AE-Anti-Evaporation-Covers.html → current site
	Superspan	TechSpan	http://www.superspan.com.au/

Monolayer Covers	*Aquatain*	*Aquatain Products*	**http://www.aquatain.com/**
	CIBA PAM	Ciba Specialty Chemicals Pty Limited	http://www.cibasc.com/ind-agr.htm
	Hydrotect	Swift and Co Ltd	www.swiftco.com.au → website no longer exists
	Water$avr	Flexible Solutions	http://www.flexiblesolutions.com/

(Note information provided below is based on the promotion material provided for each product).

Appendix B – Detail of Commercially Available Evaporation Control Products

Aqua Armour

Description: AquaArmour is an evaporation algal contral mitigation system which can be deployed on any large water storage or major dam. Proven to reduce evaporation by up to 94% (Aust Water Quality Testing) and to significantly decrease algal growth, it provides a twofold benefit to water storages. Designed and made in Australia, constructed of HDPE it has no significant impact water quality or aqua culture.

Manufacturer/Supplier: The AquaArmour™ modules are being manufactured by Venture DMG in

Campbellfield, Victoria, Australia.

Address: Level 9, 175 Collins St, Melbourne VIC 3000, Australia

Phone: + 61 3 8530 2000

Fax: + 61 3 8530 2020

Email: info@aquaguardiangroup.com

Website: http://www.aquaguardiangroup.com/

Performance as stated by the manufacturer: 80% to 90% depending on area covered.

Costs: $46/sq m including all costs for installation, freighting and tethering.

Durability: It is expected to have a 20 year lifespan. Rotation of modules every 5 years

Installation: As each AquaArmour™ module is assembled, they are deployed into the water storage and take approximately three minutes to take in ballast water. The modules naturally self-tessellate and are not tethered together. Booming options are available if required.

Advantages: Minimal bank erosion and turbidity due to reduced wave action; there will also be a reduced concentration of nutrients and salts in the water and possibly a reduction in algal blooms.

Aquacap

Description: Aquacap is a free-standing floating modular cover using individual modules with a diameter of approximately 1 m. These modules have specific design attributes to maximise their effectiveness in reducing evaporation loss from open water storages. The modules are used to cover up to 90 per cent of the surface area of a water body. Aquacap modules have unique suction properties that make them stable on a water surface.

Manufacturer/Supplier: The product was designed by Ian Burston. –

Performance as stated by the manufacturer: Field studies have shown that Aquacap reduces evaporation by an average of 70% when 80% of the water surface is covered.

Costs: The estimated cost is $17/m^2 installed.

Durability: It is expected to have a long lifespan. Installation: The cover may be easily installed by the owner.

Advantages: Minimal bank erosion and turbidity due to reduced wave action; there will also be a reduced concentration of nutrients and salts in the water and possibly a reduction in algal blooms.

Aquaguard Evaporation Cover

Description: The cover is manufactured from a laminated polyethylene bubble with a beige/white top and black underside; the light top reflects heat while the black underside eliminates light. The material has positive buoyancy due to the "bubble" material and so floats on the water surface.

Manufacturer/Supplier: Fabric Solutions by PyramidDOME Australia Pty Ltd.Fabric Solutions International

Address: 21-23 Access Ave Yatala QLD 4207

Phone: (07) 3807 0200

Fax: (07) 3807 8217

Email: info@fabricsolutions.com.au

Website: http://www.fabricsolutions.com.au/evaporative_covers.htm

Performance as stated by the manufacturer: Up to a 90 per cent reduction in evaporation.

Costs: The estimated cost is \$6.00–6.60/m^2 installed. Cost subject to site location.

Durability: UV resistant long life material.

Installation: The cover is installed by Fabric Solutions and the ease of installation is related to the site conditions, size and weather conditions.

Advantages: Significantly reduces algal growth, allows rainwater to enter the storage, slows salt build up and reduces erosion from wind and wave action.

BirdBalls

Description: ECC floating ball blankets provide highly effective solutions to difficult water storage problems for Municipal Utilities. By placing a sufficient quantity of hollow plastic balls onto the surface of a liquid, the balls automatically arrange themselves into a close packed formation over 91% of the surface area. This high surface coverage provides an extremely effective barrier and significantly reduces the mass and heat transfer mechanisms operating between the liquid and surrounding environment.

Manufacturer/Supplier:

Address: ECC, LLC., P.O Box 1325, Vass NC 28394 USA

Phone: 910-245-2241

Fax: 910-245-2821

Email: sales@eccllc.us

Website: http://www.eccllc.us/

Performance as stated by
the manufacturer: Up to a 90 per cent reduction in evaporation.

Costs:

Durability: 10 year warranty.

Installation: With levels always moving the ECC floating ball covers will rise and fall with fluctuating water levels in tanks and reservoirs. When water levels fall the balls will double stack until the level rises again and the cover will automatically spread into a single layer of coverage.

Advantages: No Maintenance, no vegetation growth on cover, easy to move through for pump repair, 10 year warranty, less expensive.

CURV

Description: A new form of polypropylene sheet made in a patented process: the sheets are 0.3 mm thick and they are attached to cables on either side of the storage. Smaller strips of the product can then be interwoven for stability. The product floats on the surface and is kept in tension by the cables.

Manufacturer/Supplier:

Germany:

Propex Fabrics GmbH, Düppelstrasse 16, D - 48599 Gronau,

Phone: +49 2562 77471

Fax: +49 2562 777471

E-Mail: info@curvonline.com

Website: http://www.curvonline.com/

North America:

Propex Operating Company, LLC, 14460 Muscadine Ln, Chino Hills, CA 91709

Contact: Mr Bill Bumstead

Phone: +1 (951) 961-5166

E-Mail: Bill.Bumstead@propexglobal.com

Performance as stated
by the manufacturer: Unknown at this stage.

Costs: The estimated cost is around \$3.50/m^2 or more.

Durability: It is expected to be highly durable and long lasting. Installation: Not known at this

stage.

Advantages: The product is relatively cheap and long lasting.

Evaporation Control System E-VapCap

Description: E-VapCap is a heavy duty polyethylene ‘bubble wrap’ style product with a white surface to reflex heat and a black bubble underside which provide flotation and stops light penetration. Both of the layers are UV stabilised and 10mm diameter holes are positioned at 1000mm centres to allow rainfall penetration and the release of gases from the storage.

Manufacturer/Supplier: Sealed Air Australia Pty Ltd (SAA), Evaporation Control Systems Pty Ltd (ECS) and Darling Downs Tarpaulins Pty Ltd (DDT)

Address: Evaporation Control Systems Pty Ltd (ECS)

Phone: (07) 4665 6144

Fax: (07) 4665 6395

Website: http://www.evaporationcontrol.com.au/

Approved installers:

Darling Downs Tarpaulins Pty Ltd:

Website: http://www.ddt.com.au/

C E Bartlett Pty Ltd:

Website: http://www.bartlett.net.au/

Ertech Pty Ltd. Western Australia:

Website: http://www.ertech.com.au/

Sealed Air Australia:

Website: http://www.sealedair.com/ap/en/default.aspx

Performance as stated by the manufacturer: E-VapCap has been shown to reduce evaporation by as much as 90–95%.

Costs: \$11 to \$18/m^2 but these costs are dependant on transport costs and may be site specific. Higher costs reflect tethered systems and lower costs trenched systems.

Durability: E-VapCap offers a 5 year warranty and expected life of 10 or more years for polyethylene membrane 540 microns in thickness. Optional thicker material up to 1000 microns gives a greater warranty and a design life of 20 years.

Installation: The ease of installing this product is site specific and also dependant on the weather conditions as wind can create problems during installation.

Advantages: Reduction of salt build up, improved water quality, reduction in algal growth, reduction in wave action and reduced bank erosion.

Euro-matic Bird Balls

Description: Bird balls are hollow black balls that form a floating cover; they are made of high density polyethylene (HDPE) or polyethylene and come in a range of sizes from10 to150mm in diameter.

Manufacturer/Supplier: Euro-Matic Ltd - Contact: Adrian Wilkes (Director)

Address: Clausen House
Perivale Industrial Park
Horsenden Lane South
Greenford Middlesex UB6 7QE UK

Phone: + 44 20 8991 2211

Fax: + 44 20 8997 5074

Email: sales@euro-matic.com

Website: http://www.enquip.com/BirdBalls.html

Performance as stated by the manufacturer: They may reduce evaporation by up to 90 per cent. Costs: The approximate cost is $22.80/m^2$.

Installation: Installation of bird balls is very easy and may be carried out by the owner.

Durability: The balls are UV stabilised and are long lasting.

Advantages: Reduce light penetration (and therefore algal growth) and are virtually maintenance free. They allow rainfall to penetrate the storage and adjust with changing water levels.

Fabtech

Description: Floating covers must function correctly at all operational water levels, hence their oscillating design. The key to achieving a well-balanced, oscillating floating cover is to ensure that the tension of the cover is maintained at all times. Ballast lines bordered by floats must be configured correctly so that as the reservoir fills, the ballast lines the excess material and forms rainwater sumps. Rainwater which collects in these sumps is then pumped away.

Manufacturer/Supplier: Fabtech SA Pty Ltd

Address: 53 South Terrace Winfield SA 5013

Phone: 1300 664 776 (general enquires); +61 8 8347 3111 (SA offices);
+61 7 4662 2919 (QLD offices)

Fax: (08) 8347 3729 (general enquires)

Email: reception@fabtech.com.au

Website: http://www.fabtech.com.au/products/covers

Performance as stated by the manufacturer: Estimated to reduce evaporation by up to 95 per cent.

Costs: $7.00/m^2 but this price does not include any earthworks required for the installation.

Durability: Design life a minimum of 15 years, with QA/QC ISO9001:2000 accreditation.

Installation: The storage is required to be empty.

Advantages: No light passes through the cover so it reduces algal growth in the storage (which can cause problems with irrigation sprinkler blockages).

HexDome

Description: An independent modular system made from UV resistant recycled plastic – each module covers one square metre.

Manufacturer/Supplier: Indusium Pty Ltd and tested by the Queensland University of Technology. Stoph Vanwensveen

Email: stvn@bigpond.com

Performance as stated by the manufacturer: Reduce evaporation by up to 90%

Costs: The anticipated cost is $4.50–8.00/m^2

Durability: Expected life of more than 25 years.

Installation: This cover may be easily installed by the owner.

Advantages: It has been shown to greatly reduce the effects of wave action, and is easily installed by the customer.

Layfield Modular Cover

Description: A typical floating module measures 15.24 x 15.24 m (50 x 50 feet) or 30.48 x 30.48 m (100 x 100 feet). The modules are floated out onto the storage and then lashed together by ropes or webbing. In storages with fluctuating levels, special panels can be made to take up slack around the perimeter.

Manufacturer/Supplier: Layfield Plastics Inc.

Address: Head Office in Seattle, Washington USA

Phone: +1 425-254-1075

Email: seattle@layfieldgroup.com

Website: http://www.layfieldgeosynthetics.com/

Performance as stated by the manufacturer: Unavailable

Costs: Unavailable

Durability: The modules are made from long lasting material and are expected to have a long working life.

Installation: Modules are manufactured in ideal conditions in the factory and then installation is easily carried out by floating the modules into position on the storage. Installation does not necessarily require a trained professional.

Advantages: Maintenance on the cover is easy to carry out as damaged modules may be removed independently and with ease.

LemTec Modular Single Sheet Cover System

Description: The LemTec modular cover system uses 10 year UV resistant, High Density Polyethylene (HDPE) geomembrane sheets with encapsulated, closed-cell, lateral extruded-polystyrene insulation for flotation. These sheets are laced together during installation to form a complete cover. The edges of the cover are anchored to the perimeter of the storage with LemTec's unique anchoring system.

Manufacturer/Supplier: Lemna Technologies, Inc.

Address: 2445 Park Avenue South Minneapolis, Minnesota USA 55404-3790

Phone: (612) 253-2000

Fax: (612) 253-2003

Email: techsales@lemnatechnologies.com

Website: http://www.lemnatechnologies.com/

Performance as stated by the manufacturer: Information unavailable.

Costs: Information unavailable.

Durability: Made from long lasting HDPE material which is 10 year UV resistant.

Installation: For installation of this cover fewer people are required than other products on the market. No heavy equipment is needed and the storage does not need to be empty.

Advantages: Reduces algae and also the amount of total suspended solids in the storage, product is relatively easy to install.

MOD-E-VAP

Description: This product consists of a simple and easy to install modular plate system of polyethylene pipe, fittings and sheeting. Each module has a rigid framework of high density polyethylene (HDPE) pipe and fittings restraining, via plastic sheet clips, linear low density polyethylene sheets (LLDPE). The individual plates are then inter- connected utilising manufactured polyvinyl chloride 'nuckle joints'.

Manufacturer/Supplier: Merit Lining Systems Pty Ltd

Address: 6 Lombark Street Acacia Ridge Qld 4110

Phone: (07) 3275 3950

Fax: (07) 3275 3960

Performance as stated by the manufacturer: Not known at this stage.

Costs: The product has an estimated cost of $3.00–3.50/m^2 depending on the catchment area shape.

Durability: It is expected to be long lasting. Installation: The modular cover is easy to

install.

Advantages: Easy to install by the land owner and easy to remove the cover if necessary. There is no need for an anchor trench and maintenance costs are expected to be minimal.

Polynet

Description: Polynet is a floating modular product that is comprised of expanded 20mm thick polystyrene sheets wrapped in a net and secured into pockets in the net in sections. Each section is prefabricated into 50 m x 5 m units which can then be floated out onto the storage.

Manufacturer/Supplier: Product designed by Ken Gordon but still in concept stage.

Address: 1 Euro Street PO Box 33 Gilgandra N.S.W 2827

Phone/Fax: (02) 6847 1381

Performance as stated by the manufacturer: Not known at this stage.

Costs: The anticipated cost is $2.50/m$^{2.}$

Durability: It is expected to be long lasting.

Installation: Installation of this product is relatively easy and could be done by the owner.

Advantages: It has been shown to greatly reduce the effects of wave action – easily installed by the customer.

Raftex

Description: Raftex modules comprise a fully enclosed rectangular plastic pipe frame with maximum dimensions of 12m x 2m. The plastic pipes are 50 or 75 mm (2" or 3") diameter and are joined using force fit right angle joiners. The frames are also strengthened with plastic brace rods every 2 metres. The frame is easily assembled on site with the pre- drilled holes for the brace rods. Once the frame is assembled it is then machine wrapped in multiple layers of UV stabilised adhesive film which totally encloses the frame to form a raft. Holes are then drilled through the film and pipe to allow the raft to partially fill with water and so act as an anchor for the raft in windy conditions.

Manufacturer/Supplier: IPEX Bulk Systems International Pty Ltd, trading as F Cubed (F^3).
Peter Johnstone

Address: 35 Robins Avenue Humevale VIC. 3757

Phone: (03) 9716 1195

Mob: 0413 949 007

Fax: (03) 9716 1541

Email: pjjohnstone@ipstretch.com

Performance as stated by the manufacturer: This product is still in its trial stage.

Costs: The anticipated cost of this product is $\$4.00–5.00/m^2$.

Durability: The product is UV stabilised and the film has an anticipated life of 5 years. At the end of this time F^3 will provide complete refurbishment. The frame is expected to have a much longer working life than the film.

Installation: Installation of this cover is easy and may be carried out by the owner. Advantages:

Easy to install and remove from the storage.

RTD Enterprises

Description: This floating cover is made from reinforced products such as Hypalon or polypropylene. This cover is typically incorporated with a liner to totally seal the storage.

Manufacturer/Supplier: RTD Enterprises

Address: 196 Old Point Avenue Madison, Maine 04950 USA

Phone: +1 207 696 3964

Fax: +1 207 696 0815

Email: info@rtdenterprises.com (general enquires)

Website: http://www.rtdenterprises.com/index.html

Performance as stated by the manufacturer: No information available.

Costs as at Dec 04: $\$28.38–63.86/m^2$ ($US\$21.53–48.44/m^2$).(The cost of this product is site specific and therefore may vary.)

Durability: The cover is made from long lasting product. Installation: Not available.

Advantages: Not available.

QUIT Evap Modular Floating Cover

Description: Quit Evap is a rectangular modular floating cover, manufactured from 0.5–0.75 mm thick polypropylene sheet with polystyrene floats. The modules are interconnected by Velcro straps. The full scale modules are up to 5 m x 25–30 m.

Manufacturer/Supplier: SMEC Australia Pty Ltd. (Contact: Peter Chapman)

Address: 1st floor, 105 Denham Street Townsville Qld 4810

Phone: (07) 4771 6119

Fax: (07) 4771 6120

Email: Peter.Chapman@smec.com.au

Performance as stated by the manufacturer: Can effectively achieve 90–95 per cent coverage of the water surface and reduce evaporation by 85–90 per cent.

Costs: The estimated cost is around $6.00–8.00/m^2 plus transport and installation.

Durability: The cover has a minimum life span of 5 years with a potential life of 8–10 years – the cover is also UV stabilised.

Installation: Installation of this product is easy and may be done by the owner. Advantages:

Lightweight and easy to install.

Water Innovations Modular Covers

Description: Opaque covers will exclude light and therefore control algae incubation. Our modular cover is a revolutionary evaporation and hydrological control system. It is designed to prevent up to 95 percent of evaporation on water storage surfaces, with the added advantage of inhibiting the incubation of algae growth within the storage, while being aquaculture friendly.

Manufacturer/Supplier: Water Innovations

Address:

Phone: 619 435 8991 (Ross Woodfield , Sales and Marketing)

E-Mail: ross@waterinnovations.com.au

Website: http://www.waterinnovations.com.au/

Performance as stated by the manufacturer: Reduces evaporation by up to 95%

Costs : Unknown

Durability: Unknown

Installation: Unknown

Advantages: Cover is suitable for all size water storages and uses free floating modules.

Defined sump floating cover

Description: The defined sump style cover is constructed with a polyester fabric reinforced geomembrane such as Hypalon or polypropylene with thicknesses ranging from 0.91mm to 1.14mm.The cover uses ballast tubes in the centre to keep it taught. The cover is also impermeable, so storm water collects in the ballast lines and is removed through a network of hoses either via gravity or electric pumps.

Manufacturer/Supplier: C. W. Neal Corporation

Address: 8625 Argent St Santee, CA 92071 USA Phone: +1 619 562-1200 (800) 377-8404

Fax: (619) 562-1150

E-Mail: info@cwneal.com

Website: http://www.cwneal.com/floatingcover.htm

Performance as stated by the manufacturer: Reduces evaporation by up to 95%

Costs as at Dec 04: The anticipated cost is $30/m^2 but this price is subject to size of site and site conditions.

Durability: This product has a 30 year warranty.

Installation: To install this product the storage is required to be empty and the cover is installed by C.W. Neal Corp.

Advantages: The cover is long lasting and prevents light from entering the storage, eliminating algal growth and therefore increasing water quality.

Enviro Dam Covers

Description: The cover is comprised of laminated 20 micron, stainless steel mesh and 0.4mm bubble HDPE sheet. The cover is anchored to the storage floor by cables attached to a buried polyethylene pipe. It is designed to only cover 90% of the water surface area.

Manufacturer/Supplier: Reservoir Covers Australia (Pty Ltd proposed extension). Performance as stated by the manufacturer: May reduce evaporation by up to 80 per cent.

Costs: $8.00/m^2 , DIY installation.

Durability: Life expectancy of 10 or more years – guarantee for 3 years from UV damage.

Installation: 65 m rolls 2m wide. The material can be installed in layers to cover the dam. These layers can be secured and connected together using rope or the supplied nuts and bolts. The Enviro Dam Cover sheets have pre-cut, high strength holes to facilitate for easy assembly.

Advantages: Hampers bacterial growth, suitable for still and running water.

Evap-Mat

Description: The cover is comprised of laminated 20 micron, stainless steel mesh and 0.4mm bubble HDPE sheet. The cover is anchored to the storage floor by cables attached to a buried polyethylene pipe. It is designed to only cover 90% of the water surface area.

Manufacturer/Supplier: Reservoir Covers Australia (Pty Ltd proposed extension). Performance as stated by the manufacturer: May reduce evaporation by up to 90 per cent depending on the water level of the storage.

Costs: $3.50/m^2$ for complete installation.

Durability: Life expectancy of 30 or more years – resistant to UV light and oxidation.

Installation: Not available.

Advantages: It is simple and easy to install, heat reflective and self-protecting in high winds (up to 150 kph) whether empty or full. The cover is also suitable for all storage sizes, shapes and profiles up to 2 km wide.

REVOC floating cover

Description: REVOC floating covers use patented tensioners attached around the perimeter of the cover system to prevent undue cover movement and wrinkling regardless of the reservoir's water level fluctuation. Tensioners also serve to retain slack cover material in a defined peripheral sump. Cover drains conduct storm water into a drainage system. The floating cover is typically fabricated of reinforced Hypalon or polypropylene geomembranes. Floats and weights are encapsulated in geomembrane for maximum longevity. REVOC floating covers offer lower maintenance and lower replacement cost than other floating cover type.

Manufacturer/Supplier: Layfield Environmental Systems Corp (which acquired C. W. Neal Corporation)

Corporate Office and International Contacts:

Address: 11120 Silversmith Place, Richmond, British Columbi, Canada V7A 5E4

Phone: 604-275-5588; 800-558-8275 (toll free)

Fax: 604-275-5589

E-Mail: international@layfieldgroup.com

Website: http://www.cwneal.com/floatingcover.htm

Performance as stated by the manufacturer: Reduce evaporation by up to 95 per cent

Costs as at Dec 04: The anticipated cost is $30/m^2$ but this price is subject to size of site and site conditions.

Durability as stated
by the manufacturer: The Hypalon cover has 30 year warranty.

Installation: The storage is required to be empty.

Advantages: The cover is able to be inflated for maintenance and inspection of the storage.

Aquaspan

Description: Aquaspan is comprised of a patented polymer fabric which is suspended above the water storage via the use of steel support posts and cable. The fabric used is purpose designed and blocks 98% of light and reduces temperatures beneath by 31%. The fabric is a densely knitted membrane which reduces and stabilises the water temperature reducing vapour pressure adjacent to the surface and effectively insulating the water.

Manufacturer/Supplier: Aquaspan Pty Ltd and Gale Pacific Limited.

Address: Aquaspan Pty Ltd (Gary Gale), P.O. Box 367 Braeside Vic. 3195

Performance as stated
by the manufacturer: Evaporation is reduced by 76–84%.

Costs: The cover costs approximately $33.00/m^2$.

Durability: The fabric is UV stabilised and supported by a 20 year warranty against UV breakdown.

Installation: The cover is able to be installed regardless of the water level in the storage.

Advantages: The structure is long lasting and the cover is not affected by changing water levels.

MuzCov

Description: The cover is comprised of high tension cables supported by poles with shade cover panels attached to the cables. The high tension cables give the structure stability while still allowing some natural movement. The structure is designed to allow heavy machinery access to the storage for maintenance and operational activities with minimal disruption.

Manufacturer/Supplier: Designed at the Dalby Agricultural College and still in initial concept stage. Murray Choat. Dalby Agricultural College

Address: PO Box 398 Dalby Qld 4405

Phone: (07) 4672 3100

Performance as stated
by the manufacturer: Unknown at this stage.

Costs: The anticipated costs are $7.50/m^2$

Durability: Unknown at this stage but it is expected to have a long life span. Installation:

Unknown at this stage.

Advantages: The cover allows easy access to the storage for maintenance operations.

NetPro cabled shade cover

Description: High tension cable, incorporating long life 260-500g/m^2 90+% black monofilament shade cloth. In essence the cable design acts as a giant spider web, with all cables spliced at crossover points to disperse the load evenly and to eliminate product creep due to wind.

Manufacturer/Supplier: NetPro Pty Ltd.

Address: Lot 1 Sullivan Drive, Stanthorpe, Queensland, Australia

Lot 1 Sullivan Drive Stanthorpe, Qld 4380

Free Call: 1300 638 776

Phone: +61 7 4681 6666

Fax: +61 7 4681 6600
Email: sales@netprocanopies.com

Website: http://www.netprocanopies.com/

Performance as stated by the manufacturer: It has been shown to reduce evaporation by 70 to 85%

Costs: \$12.50–19.00/m^2. Lower costs typically relates to larger storages.

Durability: The support structure has an expected lifespan of 30 years; canopy lifespan expected to exceed 15 years.

Installation: The storage is required to be empty for the installation of support columns.

Advantages: The cover does not float on the water so there are no problems with changing water levels.

NICOSUN®

Description: NICOSUN® Anti-Evaporation covers comprise of a double layer, woven mesh, supported by a system of posts and cables threaded though the mesh. This allows the shade system to lay flat above the surface, giving extreme stability in the wind. The mesh itself gives a high percentage of shade, while still allowing rainwater to penetrate through to the reservoir below.

Manufacturer/Supplier : Maccaferri Australia Pty Ltd
Address: Unit 7/237 Fleming Road, Hemmant, QLD 4174 (Brisbane Office)

Phone: +61 7 3890 3820

Fax: +61 7 3890 3393

Email: sales@maccaferri.com.au

Website: http://www.maccaferri.com.au/wawcs0137304/Home.html

Performance as stated by the manufacturer: Reduce evaporation by 60 to 80%

Costs:

Durability: 5.10m width 100% HDPE

Installation: Self supporting, no poles or pillars in the reservoir

Advantages: Reduces: algae growth, concentration of salts in water, wind and rain effects including erosion, weathering of reservoir liner.

Superspan

Description: SuperSpan was the first membrane construction company to use knitted shade cloth and saw the potential for this niche market of construction. Two years were spent perfecting patterns and structural methods and those methods and patterns still exceed the standards of all others.

Manufacturer/Supplier : SuperSpan

Address: 272 Meakins Rd., Flinders 3929, Victoria Australia

Phone: 03 5989 0046

Fax: 03 5989 0097

Email: enquiry@superspan.info

Website: www.superspan.com.au

Performance as stated by the manufacturer:

Costs:

Durability: Made from knitted shade cloth.

Installation: Requires tension of 3kg per square meter. E.g. 100 square meters requires a tension of 300kg to stay flat during high wind speed.

Advantages: Large shade cloth is more economical and prevents light getting through gaps present if smaller sails were used.

Aquatain

Description: Aquatain is a unique silicone-based liquid which spreads across the water surface, forming a very thin film and greatly reducing evaporation.The concept of a monolayer is not new – it's been known for many years that some industrial alcohols can reduce evaporation in this way, but alcohols degrade very quickly and must be re-applied every couple of days. Aquatain uses the same concept, but with advanced materials to greatly improve its performance and longevity.

Manufacturer/Supplier: Aquatain ProductsPty Ltd

Address: 9-13 Villas Road, Dandenong South VIC 3175, Australia

Phone: +61 3 9768 3052

Fax: +61 3 9768 3059

Email: info@aquatain.com

Website: http://www.aquatain.com/

Performance as stated

by the manufactuer: No information is available

Costs: Initial application of 8L/ha and followed by 3L/ha every week.

Durability: Breaks down after several days

Installation: Application directly from drum onto water surface, Dosing unit DS-1 up to 1ha, DS-2 for larger area. For areas greater than 20 ha, aerial application is recommended.

Advantages: Very low setup costs with low ongoing costs.

CIBA PAM

Description: PAM stands for polyacrylamide, which is a chemical that is added to water in low concentrations to thicken it and therefore reduce evaporation.

Manufacturer/Supplier: Ciba Specialty Chemicals Pty Limited

Address: 235 Settlement Road PO Box 332 Thomastown VIC. 3074

Phone: +61 3 9282 0600

Fax: +61 3 9465 9070

Email: customerservice.au@cibasc.com

Website: http://www.cibasc.com/ind-agr.htm

Performance as stated
by the manufacturer: Not known at this stage.

Costs: It is expected to cost $25/ML. Durability: Not available.

Installation: Very easy to apply to the water.

Advantages: PAM can reduce erosion and nutrient runoff in the field and also reduce seepage from the water storage.

Hydrotect → website no longer exists

Description: Hydrotect is a water-evaporation retardant which is an emulsion of 60 per cent water and 40 per cent aliphatic alcohols. This product is claimed to be non-toxic, biodegradable and suitable for application to drinking water.

Manufacturer/Supplier: Swift and Co Ltd. Neil Clifford (Business Manager)

Phone: +61 3 8544 3159

Fax: +61 3 8544 3259

Mob: 0425 724 085

Email: nclifford@im.aust.com

Website: www.swiftco.com.au

Performance as stated by the manufacturer: Hydrotect is claimed to reduce evaporation in larger storages by 25–35 per cent.

Costs: $5.00/kg with an application rate of 1.5kg/ha. Durability: The product has to be reapplied daily.

Installation: Very easy to apply by machine or by hand with a boat. The wind direction must be taken into consideration when applying the product so as to gain an effective unbroken film.

Advantages: Very low initial setup costs requiring minimal capital expenditure.

Water$avr

Description*:* Water$avr is a white powdered product which is comprised of hydrated lime with a cetyl/stearyl alcohol flow aid which forms a film on the water surface. This product is made of food grade chemicals which are biodegradable in 2 ½ to 3 days and it is permeable to oxygen.

Manufacturer/Supplier: ONDEO Nalco Australia Pty Ltd. and Flexible Solutions Int. Inc. Flexible Solutions International Ltd.

Address: 615 Discovery Street Victoria, BC Canada V8T 5G4

Phone: +1 250 477 9969

Fax: +1 250 477 9912

Email: infowatersavr@flexiblesolutions.com

Website: http://www.flexiblesolutions.com/products/watersavr/

Performance as stated by the manufacturer: Reduces evaporation by up to 50 per cent and on average 35 per cent.

Costs: $18.00/kg with an application rate of 0.5–1kg/ha. Durability: Breaks down in 2 ½ to 3 days.

Installation: Very easy to apply with a patented self applicator, by hand or with a boat. The wind direction must be taken into consideration when applying the product so as to gain an effective unbroken film.

Advantages: Very low initial setup costs and relatively low ongoing maintenance costs.

Appendix C – Evaporation Control Information Sheets