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Evaporation mitigation using floating modular devices

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SUMMARY

Reducing evaporation losses from open water storages is of paramount importance in the improvement of water security in arid countries, including Australia. Widespread adoption of evaporation mitigation techniques has been prevented by their high capital and maintenance or operating costs. The use of clean, floating recycled materials to mitigate evaporation technique has been investigated systematically at sites within both the coastal and semi-arid zones of Australia. Evaporation reduction systematically increases with the proportion of covered surface. Evaporation is reduced by 43% at coastal site and 37% at arid zone site at the maximum packing densities achievable for a single layer of floating devices. The study highlights the importance of both long-term investigations and the climatic influences in the robust quantification of evaporation mitigation. The effects of solar radiation, temperature, wind speed and relative humidity on the evaporation rate at both study sites have been determined in terms of both the classical Penman model and FAO Penman Monteith model with corresponding pan coefficients quantified. FAO Penman Monteith model better estimates evaporation from the open reference tank.

1. Introduction

Climate change is now recognised as one of the greatest potential challenges to human society and industry (Pachauri and Reisinger, 2007).Water security is under threat in the arid and semi-arid regions during drought due to changes in precipitation or evaporation from open water bodies (Bennett and Peirson, 2007). For example, it is recognised that the eastern half of Australia was systematically drier from 1895–1948 and wetter from 1948–1976. However, rainfall has been below long term averages across much southeast Australia since 1997 (Murphy and Timbal, 2008).

In many arid and semi-arid regions, a primary source of water is from large numbers of small farm dams. Consequently, minimising water losses from such dams is fundamental to the ongoing economic viability of farm production. Construction costs and the energy intensity of pumping water long distances make supply of water from more well-watered regions infeasible. Weeks (1983) stated, "Considering the importance of evaporation in the water balance of reservoirs, it is surprising that so few detailed research projects have studied the problem."

The principal strategies in evaporation reduction are the minimization of the water surface area that is in contact with the air and protection of water surface from the solar radiation (Pereira et al., 2002, p. 235) whilst noting that effective economic ways to reduce evaporation from large water bodies are yet to be developed (Pereira et al., 2002).

Proposed open water evaporation mitigation techniques include wind sheltering by trees (Hipsey, 2002) [although to our knowledge effectiveness has never been quantified]; reservoir deepening (Pereira et al., 2002) [unquantified]; sand storage dams/ managed aquifer recharge (Wipplinger, 1958); chemical monolayers (Barnes, 1986); continuous coverings of the entire reservoir (Finn and Barnes, 2007) and floating modular devices (Burston, 2002). Quantitative investigations are summarised in Table 1.

Use of sand storage dams for conserving water has been one of the successful methods in mitigating evaporation (Hellwig (1973), Wipplinger (1953, 1958), Peirson et al. (2010)). Although evaporation is higher from wet sand than plain water (Pavia, 2008), measurements shows that evaporation can be eliminated if the water level is kept below 1 m (Wipplinger, 1958) from top of sand surface. However, the main limitation of this method has been the yield from the aquifer (Lee, 2009). Although attempts to increase the specific yield by improving gradation have been made by Peirson et al. (2010), specific yield never exceeds 47%. In addition,

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Table 1
Summary of evaporation mitigation investigations.

Study	Type	Material	Mean mitigation	Duration	Cost	Comments
Wipplinger (1958)	Field	Sand	100%	10 years	N.S.	Specific yield is low (25–35%)
Vines and La Mer (1962)	Field	Chemical films	0–40%	3 years	N.S.	40% when the wind speed is below 5 mph and 0% if wind exceeds 15 mph
Hellwig (1973)	Field	Sand	10–100%	1.5 years	N.S.	Mitigation depends on the water level below the surface. Specific yield is low
Cooley (1983)	Field	Foamed wax block	36%	8 years	US$ 0.18/kl	Efficiency is quite low comparing to other measures and the unit cost at 1968 year rate
Cooley (1983)	Field	Continuous wax	80%	7 years	US$ 0.10/kl	Heavily affected by cold temperature and cost is 1970 rate
Cooley (1983)	Field	Foamed Rubber	84%	4 years	US$ 0.17/kl	Mitigation deteriorated as days progressed (1974 year rate)
Craig (2005)	Field	Raftex (modules)	56%	3–5 days	N.S.	They become ineffective when subject to high winds or rain
Craig (2005)	Field	Polyacrylamaide	37%	2–3 weeks	N.S.	Monolayer, weather sensitive
Cited at Craig (2005)	Field	Aquaguard	Up to 90%	N.S.	AU$ 6.5/m^2	Floating covers; expensive
Cited at Craig (2005)	N.S.	C.W. NEAL	Up to 95%	N.S.	AU$ 30/m^2	Crop defined sump floating cover; Storage cannot be recharged and not applicable for large storages
Cited at Craig (2005)	N.S.	Evap-mat (Shade covers)	Up to 90%	N.S.	AU$ 3.5/m^2	Not applicable for very large dams and risks involved in installation
Cited at Craig (2005)	N.S.	REVOC floating cover	Up to 95%	N.S.	AU$ 30/m^2	For installation, the storage needs to be empty
Cited at Craig (2005)	N.S.	Aquaspan	76–84%	N.S.	AU$ 33/m^2	Shade structure; not applicable for the larger area and very labour-intensive to install
Burston (2002)	Field	Aquacap	65–70%	4–6 months	AU$ 17/m^2	Supported by Burston and Akbarzadeh (1995)
ECC	Field	Bird Balls	Up to 90%.	N.S.	US$ 23/m^2	Manufacturer product with no known independent evaluation
Cited at Craig (2005)	Field	Layfield Modular Cover	N.S.	N.S.	N.S.	Manufacturer product with no known independent evaluation
Cited at Craig (2005)	N.S.	HexDome	Up to 90%	N.S.	AU$ 4.5–8/m^2	Recycled material but expensive measure
Craig (2005)	Field	NetPro	60–80%	3–5 days	AU$ 9/m^2	Unit cost excludes operating and maintenance costs
Finn and Barnes (2007)	Field	SuperSpan	90%	1 year	N.S.	Suspended covers and Impermeable; hard to recharge; least oxygen transfer to water
Cited at Craig (2005)	Field	QUIT	85–90%	N.S.	AU$ 6–8/m^2	Evap Modular Floating Cover; cost excludes transport and installation cost
Alvarez et al. (2006)	Field	D.L.B.P	80–85%	5–8 days	N.S.	Double layered polyethylene, floated cover
Segal and Burstein (2010)	Lab	Protective float	50%	7-day	US$ 5.5/m^2	Availability an issue; expensive measure
Peirson et al. (2010)	Lab	Sand and rock	30%	28 days	N.S.	Rock has higher specific yield than sand but specific yield is limited up to 47%
Busuttil et al. (2011)	Lab	Plastic Balls	65%	35 days	N.S.	
This Present Study	Field	PET Bottles	42%	5–8 months	Nil	

N.S. = Not Specified