Evaporation Control Using Rio Tinto's Floating Modules on Northparkes Mine

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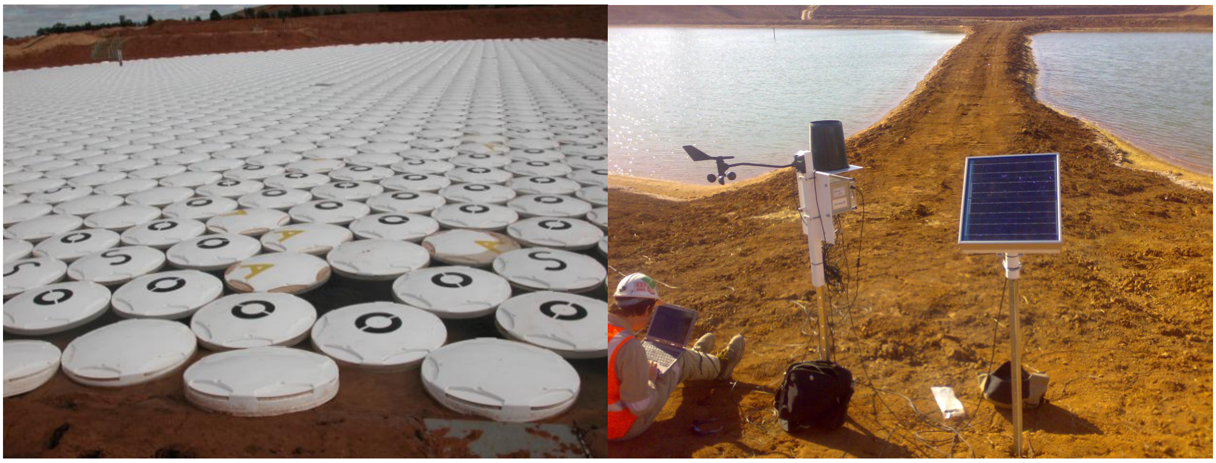

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Executive Summary

Water is essential to the profitable operation of all mine sites. It is essential that minesite water balances be optimised to ensure that losses are reduced and the efficiency of the systems maximised. This is particularly the case for mines where water supply is limited.

In response to the need for continual improvement in the management of water, Rio Tinto has been investigating the use of water storage covers to minimise the loss of water through evaporation. Floating modules designed by Rio Tinto were deployed at Northparkes Mine and their effectiveness in reducing evaporation losses was measured.

Measurement of evaporation losses was achieved by using a mass balance approach to the water balance of an open storage. This required accurate measurement of the change in water level over periods of a day or less and the apportioning of this loss to either evaporation or seepage.

The trial consisted of two storages located adjacent to each other. One of the storages was covered with floating modules while the other remained uncovered (acted as a control). The water levels of both storages were measured using highly accurate pressure sensitive transducers. Seepage was estimated and removed from the water level data for both storages using statistical methods (linear correlations between the change in water level and calculated evapotranspiration), leaving evaporation as the sole cause of changes in water height. The evaporation losses from the covered and control storages were compared to determine the efficiency of the floating modules in reducing evaporation.

Rio Tinto’s floating modules reduced evaporation by 85 %. The floating modules covered approximately 90 % of the surface area of the storage. For the storages located at Northparkes Mine, this was equal to a saving of 3.6 mm/day or 1,235 mm over the 346 day trial period. For every hectare of water surface, this is equivalent to a saving of 12.4 ML. The percentage reduction changed during the year with a maximum reduction of 95 % achieved during winter.

When considering increasing the efficiency of water storages, other options in addition to evaporation covers must also be considered. These include seepage minimisation, storage design and siting, and storage management. In some situations, these options may provide greater gains in efficiency and be more economical.

1. Introduction

Water is essential to the profitable operation of all minesites. It is essential that minesite water balances be optimised to ensure that losses are reduced and the efficiency of the system is maximised. This is particularly the case for mines where water supply is limited or where the volume of supply can vary from year to year via reduced water allocations. It is also important to be able to quantify the losses in a system to ensure that resources can be used in the right areas to bring about improvements in water use efficiency.

Water storages form part of many minesite water balances. They can be used to store water harvested from rivers or floodplains, or they can be used to balance supply from bore fields to the operation's requirements at any one time. Storing water does, however, result in water losses through evaporation and seepage. These losses are rarely, if ever, suitably quantified, making it impossible to improve the efficiency of these structures.

Rio Tinto is investigating ways of reducing losses from water storages, with a strong focus on evaporation losses. As part of this investigation, it has manufactured a floating module designed to reduce evaporation by limiting the surface area of water in contact with the atmosphere.

Trials were undertaken on Northparkes Mine using two specially built storages, each approximately 0.5 ha in surface area,. Northparkes Mine is located approximately 300 km inland of Sydney, New South Wales. The town of Parkes is the closest town to the mine and has an annual rainfall of 584 mm/y and an average annual pan evaporation of 1,570 mm/y (BOM, 2007). Rainfall events are spread evenly through the year, with neither winter or summer rain dominating. Through summer, days are generally less humid and hotter than winter days and are prone to higher evaporation rates. Parkes experiences cold winters with maximum daily temperatures averaging approximately 15°C, and warm to hot summers with average maximum temperatures in excess of 30 °C.

This report outlines the results of the investigation into the efficiency with which Rio Tinto's floating modules reduce evaporation losses. Comparison is made between this product and other products currently available. Consideration is also given to seepage losses and the importance of considering this loss when maximising the efficiency of water storages.

2. Water storage evaporation

2.1 Water storage water balance

The movement of water into and out from a water storage can be described using a water balance. Figure 1 shows a typical water balance for an open water storage.

Components of a water storage water balance include:

- Rainfall;
- Runoff;
- Inflows;
- Outflows, from pumping or via a spillway;
- Evaporation; and
- Seepage.

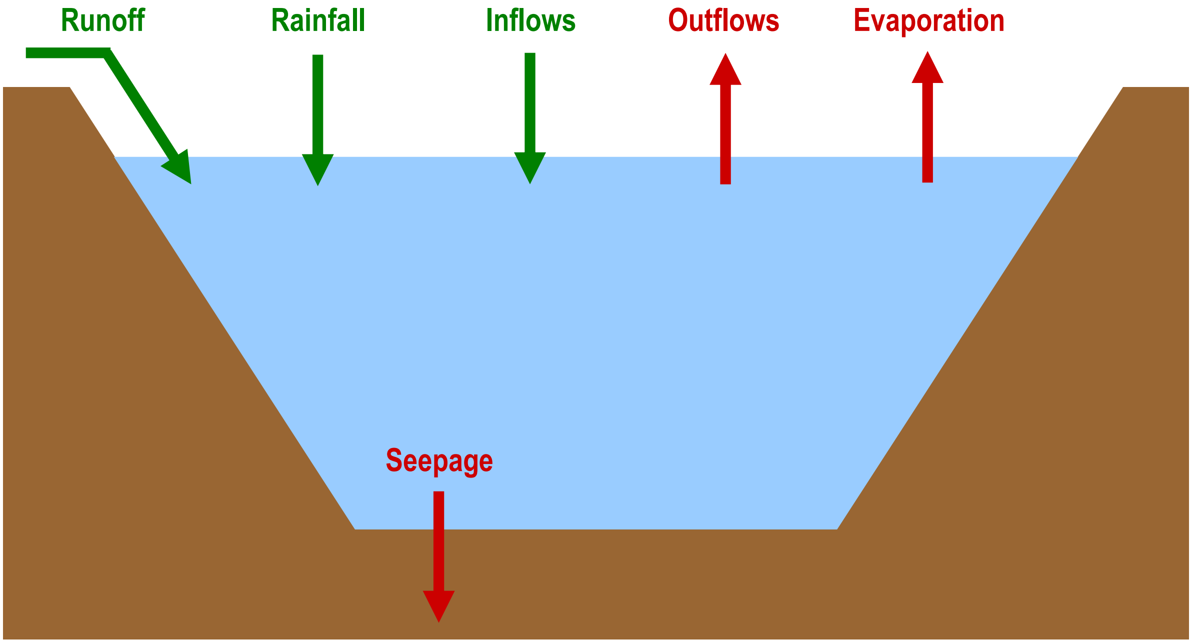

Figure 1: *Water balance for an open water storage. Red arrows indicate losses and green arrows indicate gains in water.*

Seepage and evaporation losses are typically poorly quantified and/or controlled as they are difficult to measure and often considered (falsely in many cases) negligible when compared to inflows and outflows. All water storages will lose water through evaporation and seepage (in the case of PVC-lined storages, seepage can be greatly reduced), and quantifying and minimising these losses can greatly improve the efficiency with which a water storage is operated. Efforts are often made to minimise seepage losses via:

- using suitable materials during construction;
- compacting the base and walls of the storage; or
- using plastic liners.

The quality of the construction is crucial in minimising seepage. Poorly compacted storages or storages made from unsuitable material can have very high seepage losses.

Although efforts are made to minimise seepage, little effort is made to reduce the amount of water lost through evaporation. A floating module cover is one option which can be used to reduce evaporation. Other options include wind breaks (more effective on small dams), and proper design and management of the storage.

The amount of evaporation from a water storage is dependent on the area of water in contact with the atmosphere, and the climate in which the storage is situated. Storages in hotter climates will evaporate more than in cooler climates. Larger storages will evaporate more than smaller storages in similar climates. Evaporation changes with the seasons (as would be expected) with most of the evaporation occurring during the spring and summer months. Orientation of the storage to prevailing winds also impacts on evaporation losses.

Table 1 shows mean daily evaporation data for Parkes as measured using evaporimeters (evaporation pans). Data collected using evaporimeters often bear little resemblance to the actual evaporation from a water storage, hence the need for this style of trial. However it does allow comparison of the relative differences in evaporation at different times of the year.

Annual pan evaporation for Parkes of 1,570 mm/y is equivalent to 15.7 ML/y for every hectare of water surface in contact with the atmosphere. Of the total annual evaporation occurring at Parkes, 41 % occurs during the summer months (Dec – Feb) and 68 % occurs during spring and summer (Sep – Feb). As a comparison, pan evaporation is 2,000 – 2,500 mm/y for the Bowen Basin in Queensland and 3,500 – 4,000 mm/y for the Pilbara region in Western Australia.

***Table 1**: Mean daily evaporation data for Parkes.*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean daily evaporation (mm)	7.4	6.6	5.2	3.4	2.0	1.4	1.5	2.1	3.2	4.6	5.9	7.9

There is potential to save significant volumes of water through reducing evaporation losses, particularly in climates conducive to high evaporation rates, and on sites where large water storages exist.

2.2 Measuring water storage evaporation

Evaporation from open water storages, interestingly, has rarely been accurately measured due to the difficulty of measuring the movement of water molecules between the surface of the water and the atmosphere (Watts, 2005). The process of evaporation is not covered in this report; however a good summary of the process and the difficulties in accurately measuring it can be found in Craig *et al* (2005).

Due to the difficulty in directly measuring evaporation from a water storage, surrogate (indirect) measures have been developed to gain some understanding of evaporation losses. Historically, the two main methods include evaporimeters, and the use of climate data in evaporation (or more accurately evapotranspiration) equations.

2.2.1 Evaporimeters

The most common evaporimeter is the US Class A pan, which is a metal pan 1.22 m in diameter, 0.25 m deep, and set on a wooden platform so that the base of the tank is 0.15 m above the ground (Figure 2). Evaporimeters are usually (but not always) covered with a wire mesh to exclude birds and other animals. The actual evaporation loss from a water storage is different to that measured from the Class A pan, due predominantly to:

- **Different energy sources.** Heating of the metal pan can accelerate evaporation beyond that occurring in a storage made from soil. The thermal masses of the two different water bodies are also very different as a water storage is very much larger than an evaporimeter.
- **Different conditions at the water/air interface**, resulting in different potentials for water to move from the liquid to vapour state. The banks of a water storage impact on evaporation differently to the sharp lip of an evaporimeter. Waves are more likely to form on large storages, increasing the effective surface area subject to evaporation.
- **Different air movements.** Wind speed is a major factor influencing evaporation as wind is required to move the moisture laden air carrying the evaporated water away from the air/water interface to allow for more evaporation to occur. If the moisture laden air is not removed, evaporation can, in theory, stop.

To account for the differences in evaporation regimes between evaporimeters and *in situ* water storages, an adjustment is sometimes made to the measured pan evaporation to more closely reflect actual evaporation from a water storage. These adjustments are often empirically based and are based on limited data. Horton and Jobling (1984) suggest that Class A pan evaporation should be adjusted by a factor of 0.8 to estimate evaporation from an open body of water. Weeks (1983) found that pan evaporation should be adjusted by 0.75 – 0.85 when he considered it in relation to evaporation from lakes across Queensland. However, these factors were derived using empirical evaporation equations rather than physical measurements of evaporation. Allen *et al* (1998) suggest that differences in pan coefficients occur due to:

- Location of the pan with respect to vegetation,
- Climate conditions such as typical wind speeds, and relative humidity, and
- Maintenance of the pan,

and list pan coefficients varying from 0.40 to 0.85, depending on these factors. Watts (2005) lists pan coefficients varying from 0.4 – 1.2 and suggests that pan coefficients vary with season and locality.

Figure 2: *Typical US Class A evaporimeter installation.*

More uncertainty in the accuracy of evaporation pan data is caused by differences in installation methods. Watts (2005) reports a 7 % reduction in measured evaporation from a Class A pan when wire mesh for exclusion of animals was installed, This detail is rarely (if ever) reported with the evaporimeter data set. This reduction may represent losses due to the influence of the mesh on the atmosphere surrounding the air/water interface or from animals drinking the water from the pan.

With such potential variability in the accuracy of evaporimeter data, and the empirical (and often simplistic) nature of the derivation of factors used to adjust it to represent actual water storage evaporation, it is likely that evaporimeters will give erroneous estimates of evaporation and should therefore not be used when attempting to optimise the water balance of a storage.

2.2.2 Evaporation equations

The advent of computers has reduced the reliance on evaporimeter data when considering evaporation from a water storage.

Many weather stations report reference *evapotranspiration* (ET_o) as one of the output variables; however ET_o is different to *evaporation*. Many people assume that ET_o is a measure of water evaporation, whereas it is actually a measure of the combination of evaporation and transpiration from a reference crop. The definition of the reference crop (Allen *et al*, 1998) is:

> “*a hypothetical reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 s.m and an albedo of 0.23.”*

The reference crop is very similar to a large expanse of actively growing, well watered grass that completely shades the soil surface.

To estimate evapotranspiration for a particular crop other than the reference crop, ET_o is adjusted using a “crop factor”. For the case of a water body, evaporation can be estimated from ET_o using a “storage factor” that relates ET_o to the actual loss in water due to evaporation. Currently, little work has been completed on developing storage factors; this is an outcome of this project. It is likely that storage factors will differ from storage to storage just as crop factors differ from crop to crop, and any storage factor calculated here, if used for another storage, should be used with caution.

Currently ET_o as reported by most weather stations is used erroneously as a measure of evaporation, and this can lead to large errors. To add to the confusion, not all weather stations use the same evapotranspiration equation to calculate ET_o and different equations give different results.

The Penman-Monteith evapotranspiration equation as outlined by Allen *et al* (1998) is generally accepted as the most accurate over a wide range of climate conditions. Allen *et al* (1998) describe the Penman-Monteith method as follows:

> *“The [Penman-Monteith method] is a method with a strong likelihood of correctly predicting ET_o in a wide range of locations and climates and has provision for application in data-short situations. The use of older FAO or other reference ET methods is no longer encouraged”.*

Kashyap and Panda (2001), in their study investigating various evapotranspiration equations, showed that the Penman-Monteith equation was the most accurate equation and gave estimates within 1.36 % of their measured values of evaporation.

Northparkes Mine’s weather station **does not use** the Penman-Monteith equation for calculation of ET_o, and different ET_o values are supplied in the weather station data files to the ones calculated in this project. The equation used to calculate the ET_o reported from Northparkes Mine’s weather station is unknown. For this project, the Penman-Monteith equation was used to calculate ET_o.

3. Water level sensing technology

The National Centre for Engineering in Agriculture (NCEA) has developed technology that enables highly accurate measurement of changes in water levels in storages. Coupled with statistical methods for analysis of water level data sets, the NCEA technology enables separate estimation of the losses from a water storage due to evaporation and seepage.

Figure 3 shows a typical installation of the water level sensors in a water storage. In the case of Northparkes Mine, the sensors were not mounted from a pontoon as shown in the diagram, but rather from the bank of the storages (Figure 4).

The water level sensing technology consists of:

- A pressure sensitive transducer (PST) deployed in the water;
- A vented cable to connect the PST to the atmosphere;
- A high resolution logger that records the data on 15 minute, hourly and daily intervals;
- A solar panel to power the internal battery;
- Cables to transfer the data; and
- Water temperature sensors to enable temperature calibration;

A tipping bucket rain gauge, wind speed, and wind direction sensors were also deployed at the trial site as these factors change over very short distances. All other climate variables used (temperature, relative humidity, and solar radiation) were sourced from Northparkes Mine’s weather station.

The PST measures a gauge pressure by means of a vented cable attached to the sensor that is open to the atmosphere (Figure 3). The vented cable also contains a data cable to convey the signal from the sensor to the logger located on the bank of the storage.

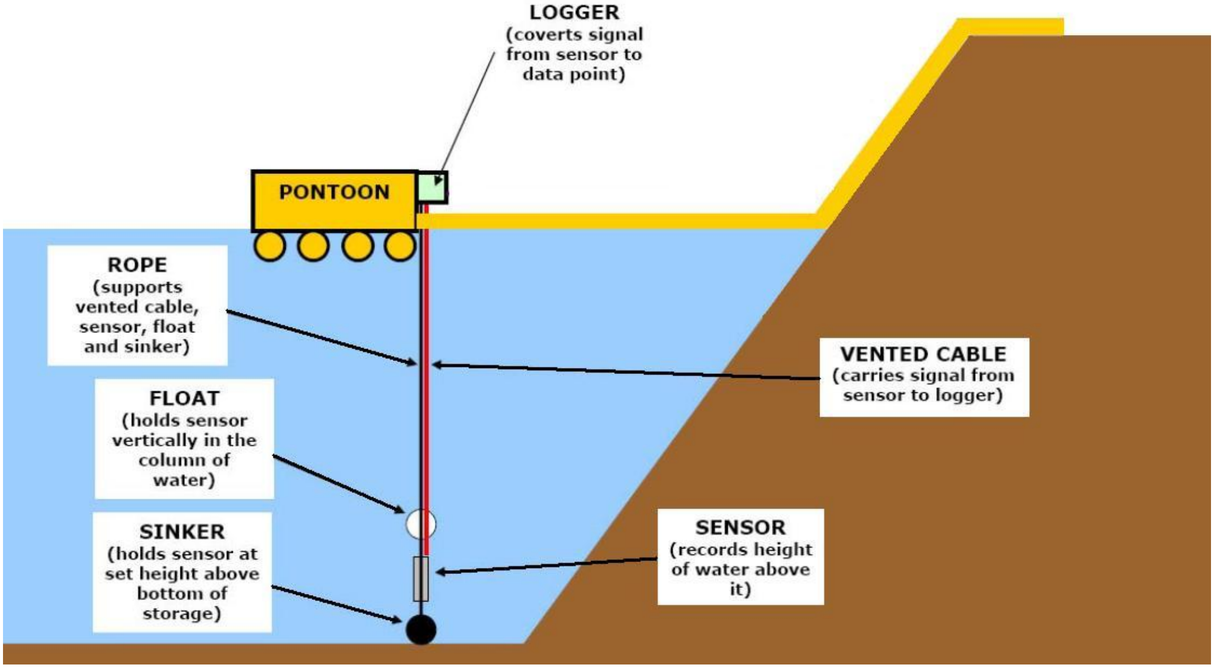

Figure 3: *Typical installation of water depth sensors.*

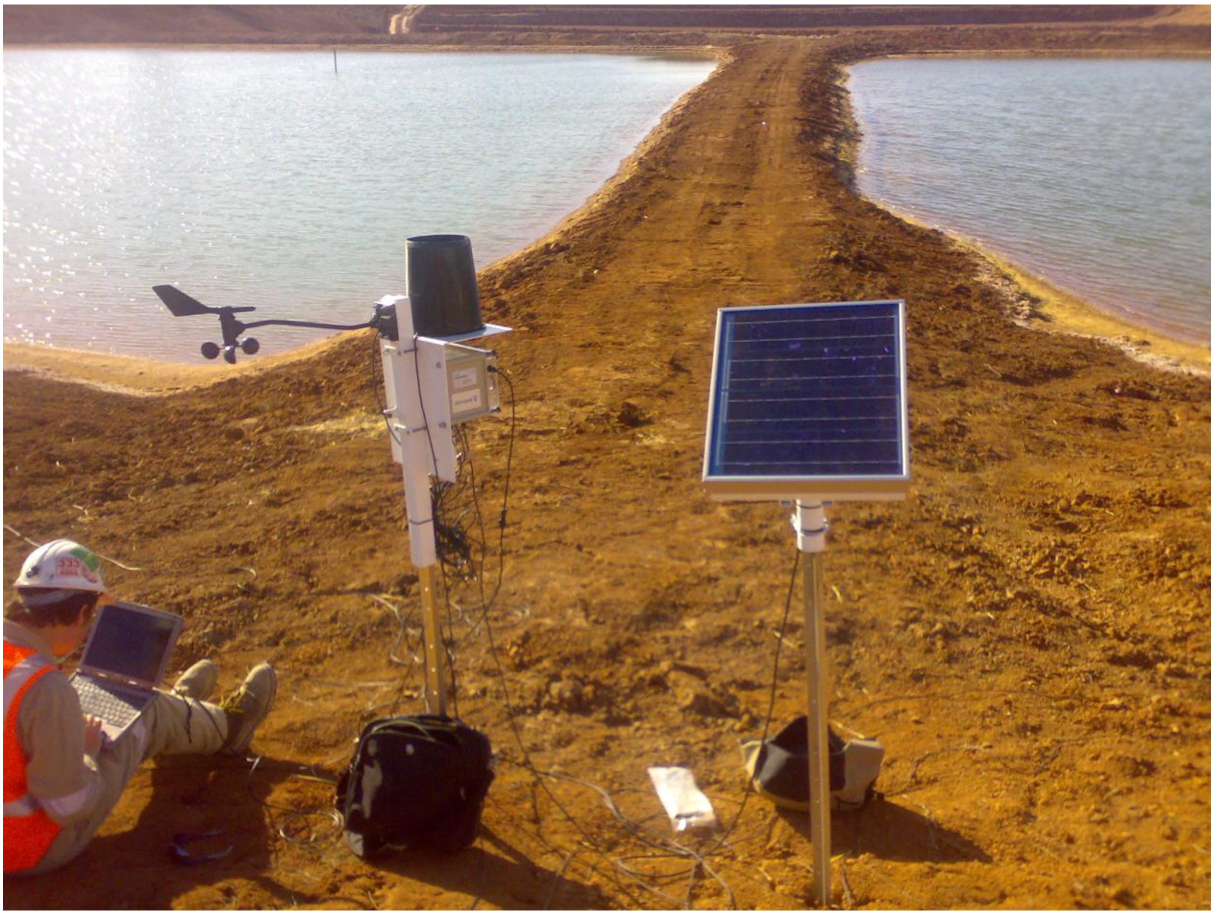

Figure 4: *Logger mounted on a pole collecting data from the PST deployed in the water storage.*

The PST is positioned on a rope between a marine float and sinker. This holds the sensor at a constant height above the bottom of the water storage. The sensor is placed approximately 0.3 m above the bottom of the storage to keep the sensitive equipment out of the soft clay sediment on the bottom. Figure 5 shows the PST located between the float and sinker. The rope also supports the vented cable and is tethered to the bank of the storage.

The vented cable is 10 m long, with the excess cable left in the water to reduce temperature effects on the PST signal.

The high resolution logger converts the electrical signal from the PST into a data point that is recorded every 15 minutes. The logger is powered by a 12 V rechargeable battery connected to a solar panel. The logger stores three data sets, 15 minute data, hourly data and daily data, and these files are downloaded on a weekly basis for processing.

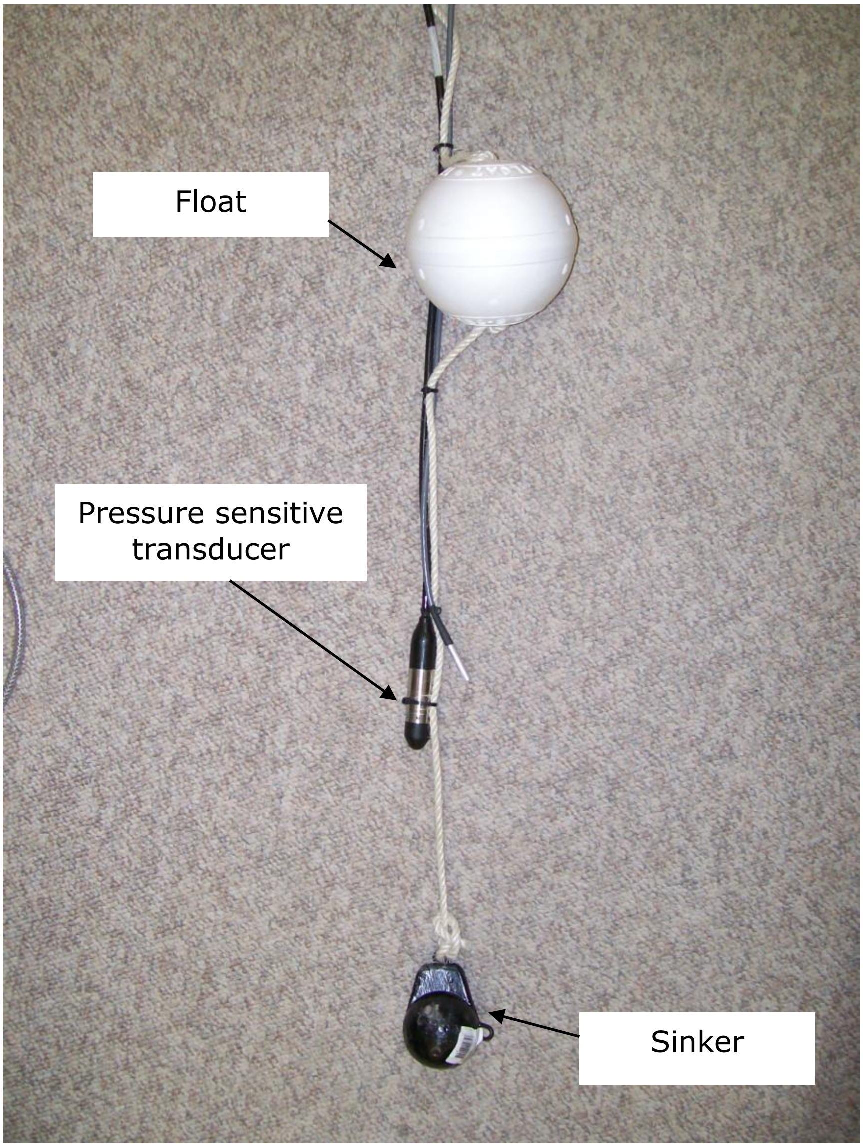

Figure 5: *Pressure sensitive transducer attached to a rope between a marine float and sinker.*

Given the duration of data collection during this project, it was possible to use daily data in the analysis. Daily data are typically more accurate than hourly or 15 minute data as:

- the potential measurement errors are smaller in relation to the measured change in water level at this time scale;
- diurnal changes in water level due to temperature changes are largely compensated for; and
- short term impacts due to wave action in windy weather are largely removed.

The PSTs used are highly accurate, with a maximum error of ± 0.04 %. Errors in measured water level can be expected to be less than 1 mm based on a water height of 2.5 m.

4. Methodology

4.1 Trial site

Two storages were constructed side by side for this trial and are shown in Figure 6. The base and walls of the storage were lined with 350 mm of expansive clay and compacted to 98.5 % maximum dry density to ensure as little water was lost through seepage as possible. The gradient of the storage banks was 1V:3H and the storages could hold up to 3 m depth of water. The two storages were both approximately 70 m wide and 90 m long when full, giving a maximum surface area for each storage of 0.63 ha. The two storages were separated by a highly compacted clay wall with a crest width of approximately 4 m and a bank gradient of 1V:3H.

Figure 6: *Trial storages at Northparkes Mine, showing one storage covered and the other uncovered.*

4.2 Data collection, and floating module design and deployment

One PST was deployed in each water storage for the duration of the trial. A manual gauge plate was also installed in each storage as a manual check on the data (Figure 7).

Water level data were collected from both storages for a period of 18 days prior to deploying the floating modules on one of the storages. Data for a further 30 day period were collected at the end of the trial after the modules had been removed. These data were used to assist with the seepage analysis. Water level data were collected for each storage during the trial period and analysed for seepage and evaporation losses.

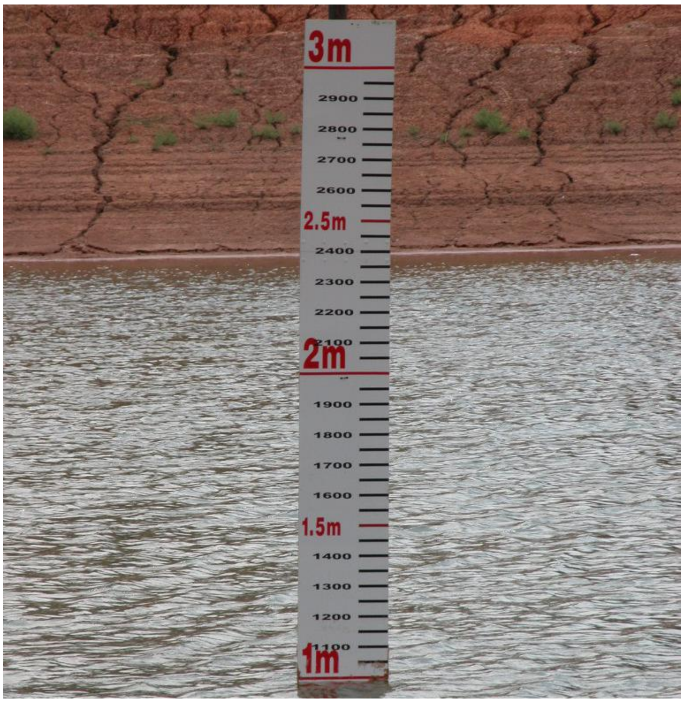

Figure 7: *Gauge plate used to manually check water level data recorded by logger.*

Floating modules were deployed by Rio Tinto and Northparkes Mine staff on one of the storages. Their design is described by Takos *et al* (2006). Briefly, the floating modules are 1.15 m in diameter and are made from polypropylene. They are designed to pack together and cover 80 - 90 % of the surface area of the storage (Figure 6) depending on how closely they pack. The floating modules have been designed to be partially submerged, increasing their stability in high winds and minimising the risk of modules lifting from the water surface.

4.3 Statistical analysis of data

Water level data collected from both storages were analysed and seepage and evaporation losses were calculated. Analysis involved the use of the water level and climate data collected at the trial site and from Northparkes Mine's weather station. Climate data were used to calculate Penman-Monteith ET_o on a daily basis. The ET_o equation used is outlined in Allen *et al* (1998). Climate data required for this included:

- Wind speed;
- Air temperature;
- Relative humidity;
- Solar radiation; and
- Rainfall.

ET_o calculated by the Penman-Monteith equation was compared to the measured change in water level. A linear regression analysis was performed using these data. Figure 8 is an example of the analysis performed.

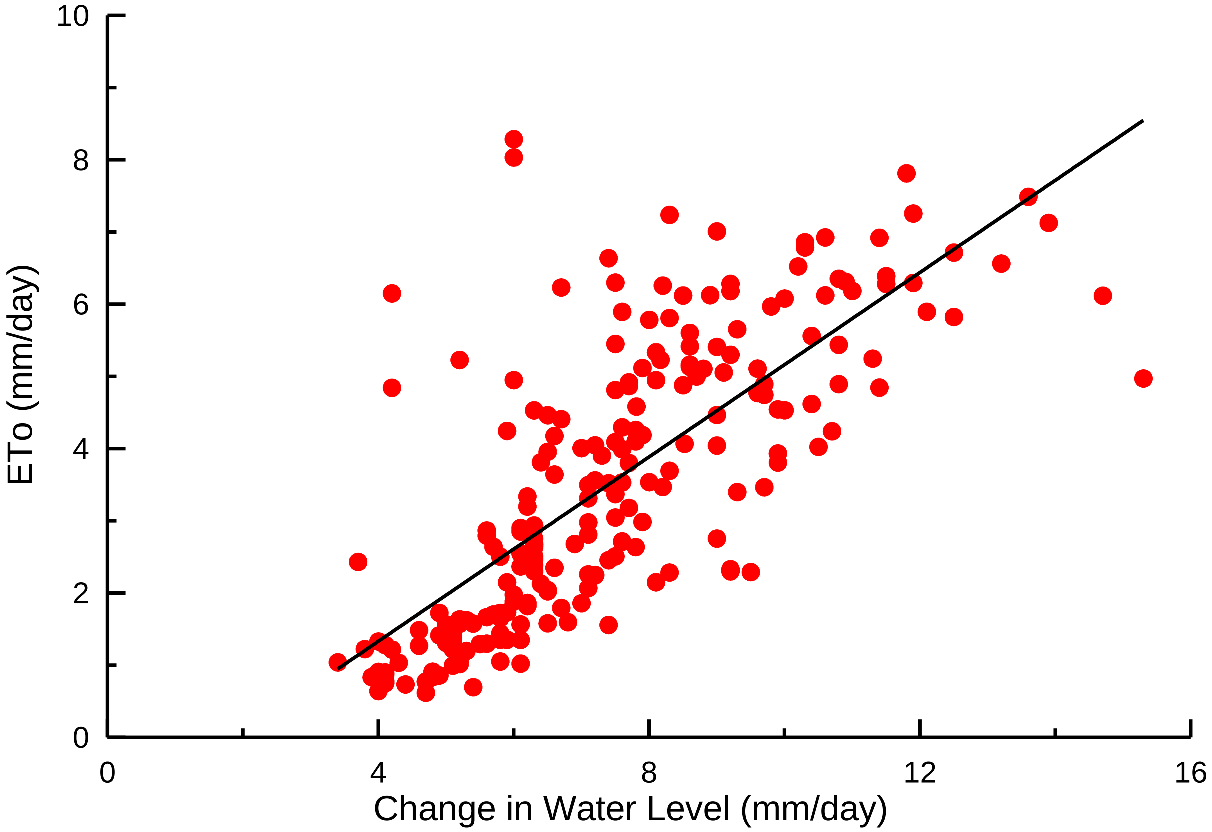

Figure 8: *Example linear regression analysis of calculated* ET_o *(mm/day) and the change in water level (mm/day).*

Linear regression analysis assumes that there is a relationship between the change in water level of the storage and the sum of the calculated evapotranspiration and seepage. This assumption is valid as the same principles used to derive the Penman-Monteith equation for a reference crop also apply to evaporation from an open water storage.

Seepage from each storage is determined as the X-axis intercept.

Days with large residual errors (as highlighted during the regression analysis) were omitted. These days corresponded to days where the following occurred:

- Rainfall;
- Surface runoff from rainfall events;
- Inflows; and/or
- Sustained windy weather or highly variable wind gusts.

The Beaufort Wind Speed Scale defines wind speeds of 3.4 m/s as “wind felt on the face, leaves rustle, and ordinary vane moved by the wind” (BOM, 1975). Crested wavelets (waves that break) are evident on inland waters (such as lakes) at speeds greater than 8 m/s. For the purpose of the analysis, it appeared prudent that days with periods of sustained winds greater than 3.4 m/s not be used in the analysis.

5. Results

5.1 Comparison of gauge plate and PST data

Gauge plate data were collected by Northparkes Mine staff and compared with data collected from the PST to ensure that the PST data were consistent with what was measured manually. Gauge plate data were collected on a weekly (or as close to that as practicable) basis. Figures 9 and 10 show the comparison of gauge plate (blue dots) and PST data (red line) for the covered and the control (uncovered) storage respectively. The data were normalised by brought both sets to an arbitrary starting water level of 2,000 mm.

The gauge plate and PST data for both storages correspond very closely and the PST data can be used with a high degree of confidence as an accurate measure of the actual change in water level.

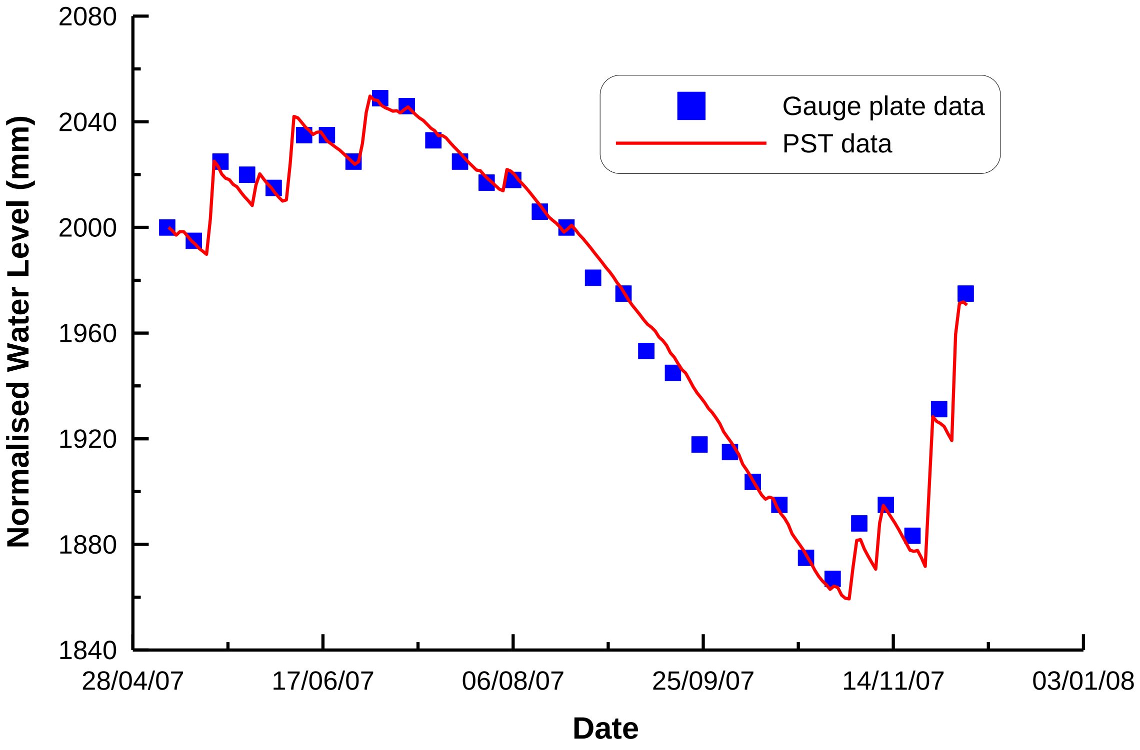

Figure 9: *Comparison of gauge plate and PST data for the covered storage.*

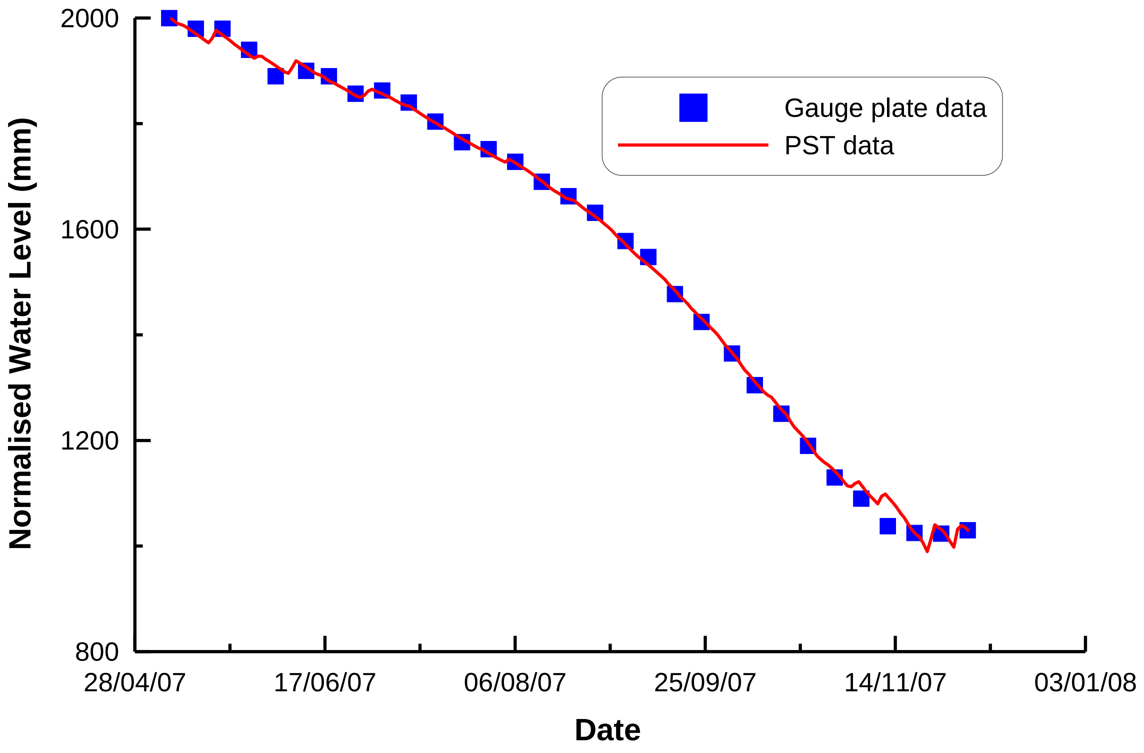

Figure 10: *Comparison of gauge plate and PST data for the control storage.*

5.2 Water level data

Water level was recorded for both the covered and the control storage, and the data are shown in Figures 11 and 12. Increases in water level from both storages were caused by rainfall events and pumping events. No outflows via pumping occurred during the trial period. Neither storage had a spillway.

It is clear that the covered storage lost considerably less water than the control storage during the trial period.

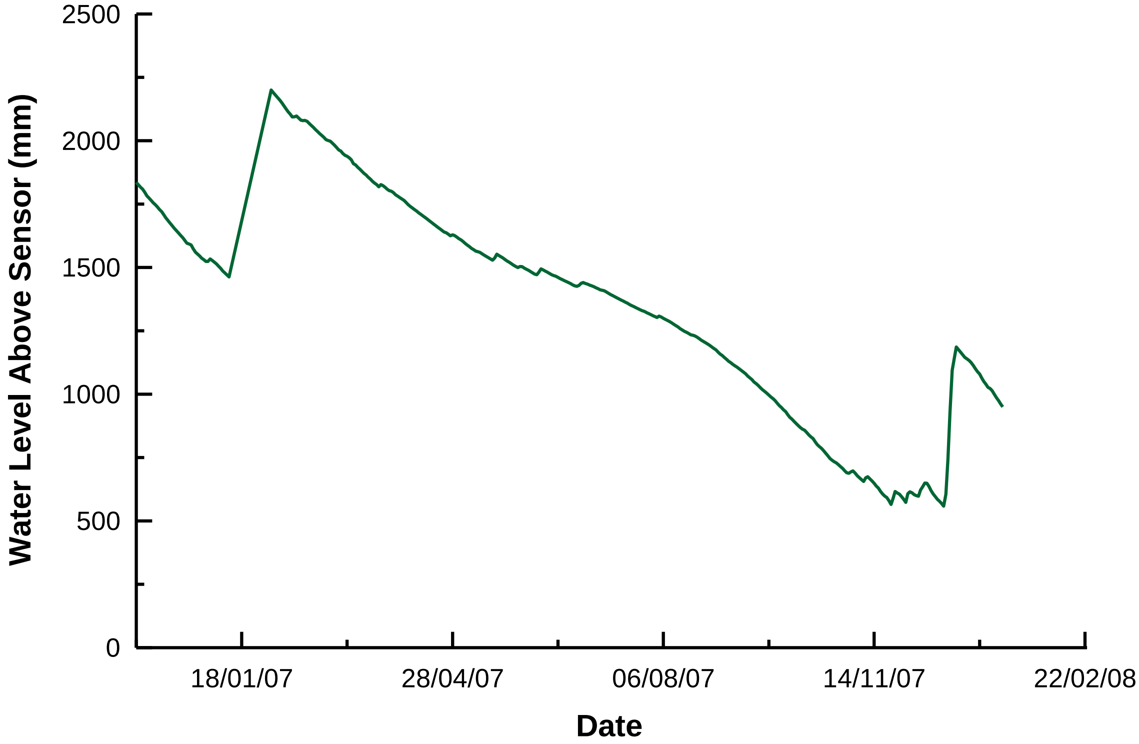

__Figure 11:__ Water level data for the control storage.

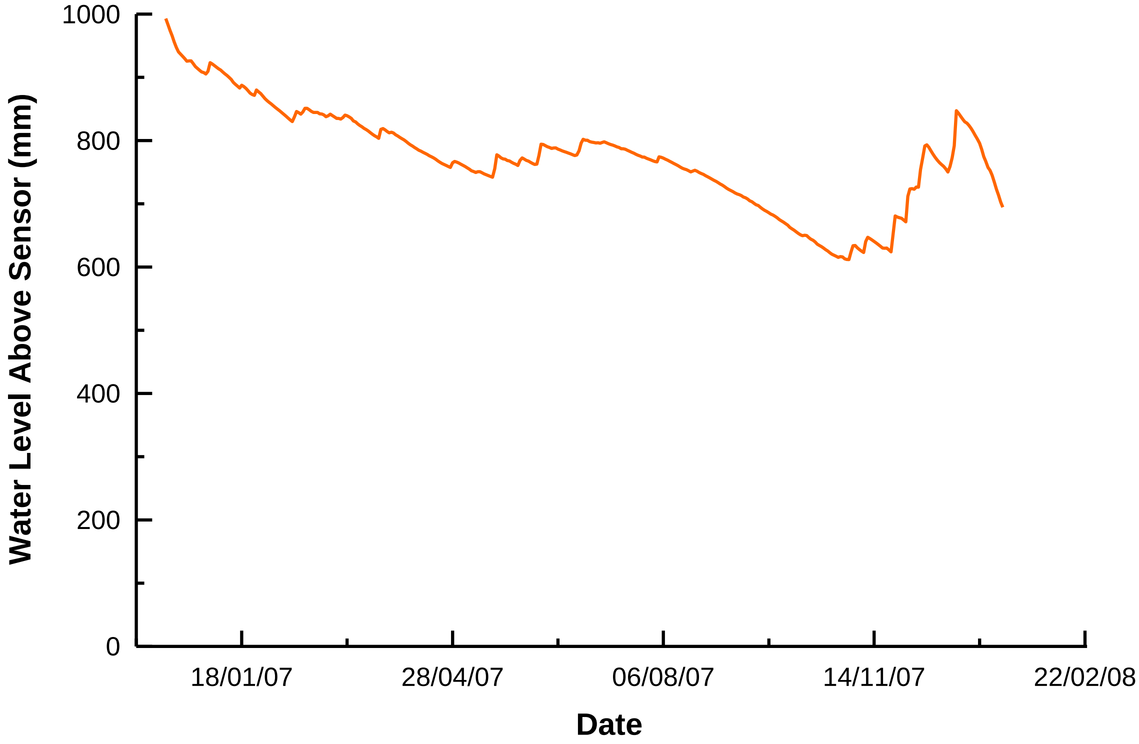

__Figure 12:__ Water level data for the covered storage.

5.3 Seepage analysis

Seepage was estimated using a linear regression analysis of the ET_o calculated using climate data from Northparkes Mine and the change in water level for each storage. Figures 13 and 14 show the linear regression analysis of the control and covered storages, and Table 2 lists the results of the regression analysis.

Both linear regressions are statistically significant, indicating a strong relationship between the daily change in water level and the calculated daily ET_o.

The estimated daily seepage rate for the control storage was 2.4 mm/day and 1.3 mm/day for the storage covered with floating modules.

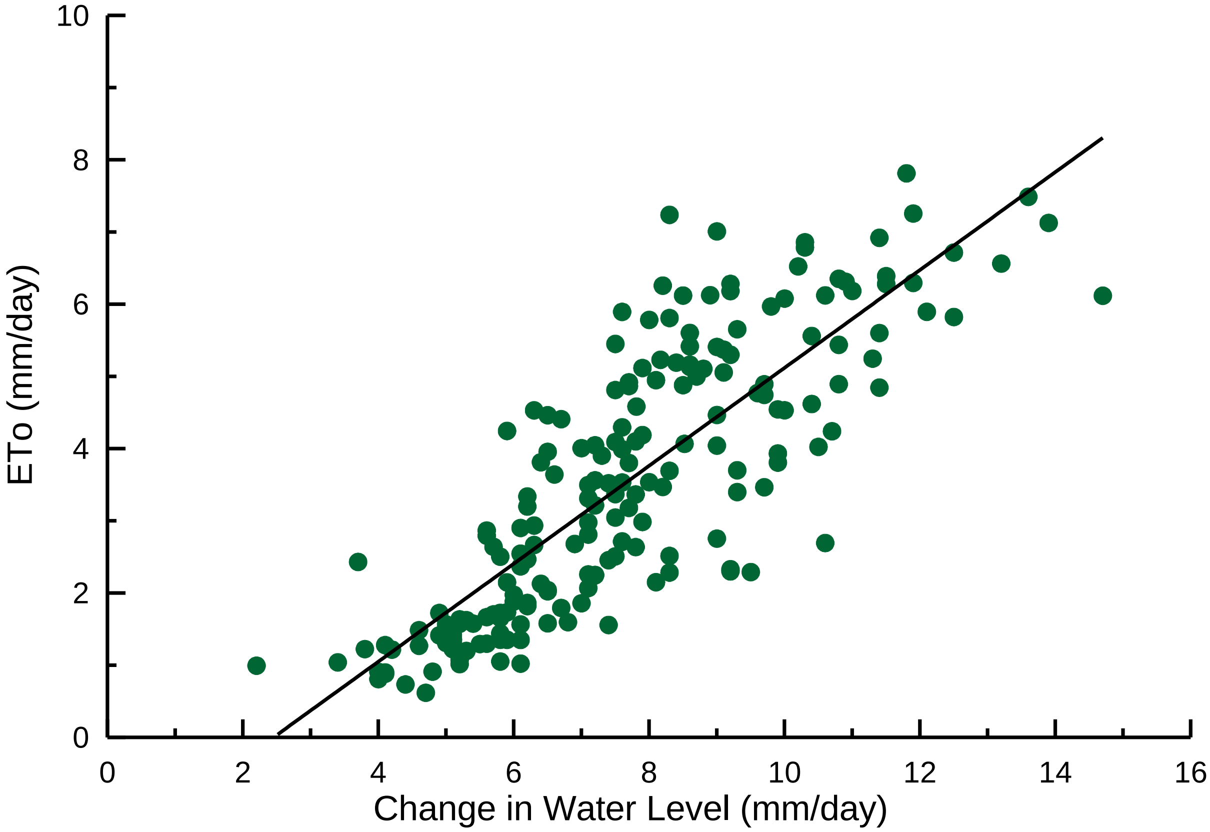

Figure 13: *Linear regression analysis of ET_o (mm/day) and change in water level (mm/day) for the control storage. Seepage (X-axis intercept) is 2.4 mm/day.*

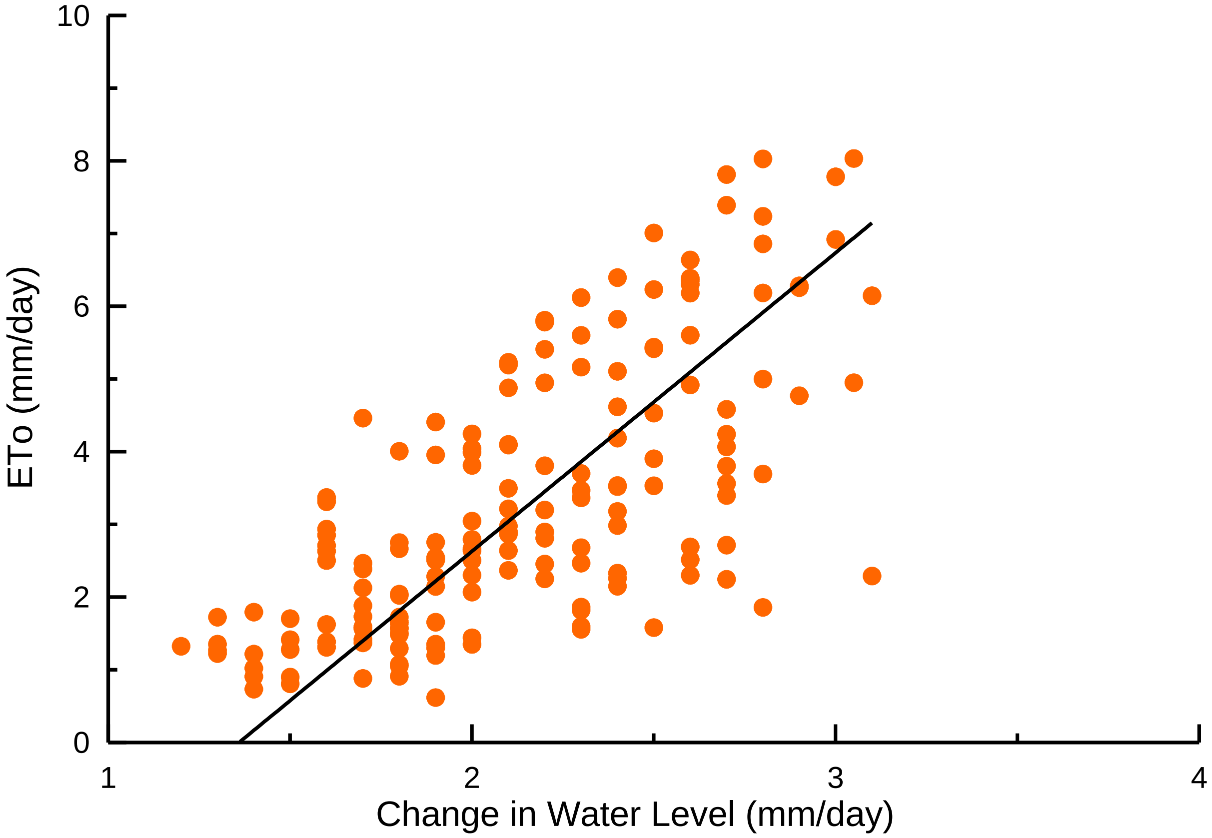

Figure 14: *Linear regression analysis of ET_o (mm/day) and change in water level (mm/day) for the covered storage. Seepage is 1.3 mm/day.*

Table 2: *Results of linear regression analysis*

Parameter	**Covered Storage**	**Control Storage**
Seepage	1.3	2.4
Coefficient of determination, R	0.625	0.829
Significance, P	$P < 0.001$	$P < 0.001$

The highly significant linear regressions for the two storages indicate a difference between them in seepage rates of 1.1 mm/day.

Difference in seepage rates were estimated for two other time periods:

(a) an 18 day period prior to deployment of the modules at the start of the project, and
(b) a 40 day period after the trial period when the modules were removed.

The difference in seepage rates between the two storages was assumed to be the difference in the change in water levels over the period. It is assumed that the two storages evaporate at the same rate (storages were sited side by side, the same shape and the same size). For the 18 day period, the difference between seepage rates was 1.1 mm/day. The difference between seepage rates for the 40 days after the trial period was 1.5 mm/day. Seepage differences calculated using the linear regression, the data prior to deployment, and the data after removal of the covers are all in good agreement. The linear regression method allows for estimation of actual seepage (rather than just seepage differences as is the case for the periods prior to deployment and after removal) and was used to estimate actual evaporation losses from the storages. Therefore, the seepage values obtained for the trial period, derived from statistically highly significant relationships were used.

5.4 Evaporation losses

Evaporation losses from the control and covered storage were measured for a 346 day period. This period is known as the trial period.

Figure 15 shows cumulative evaporation loss from both the control and covered storages. Periods prior to and after the trial period – when both storages were uncovered – is also included.

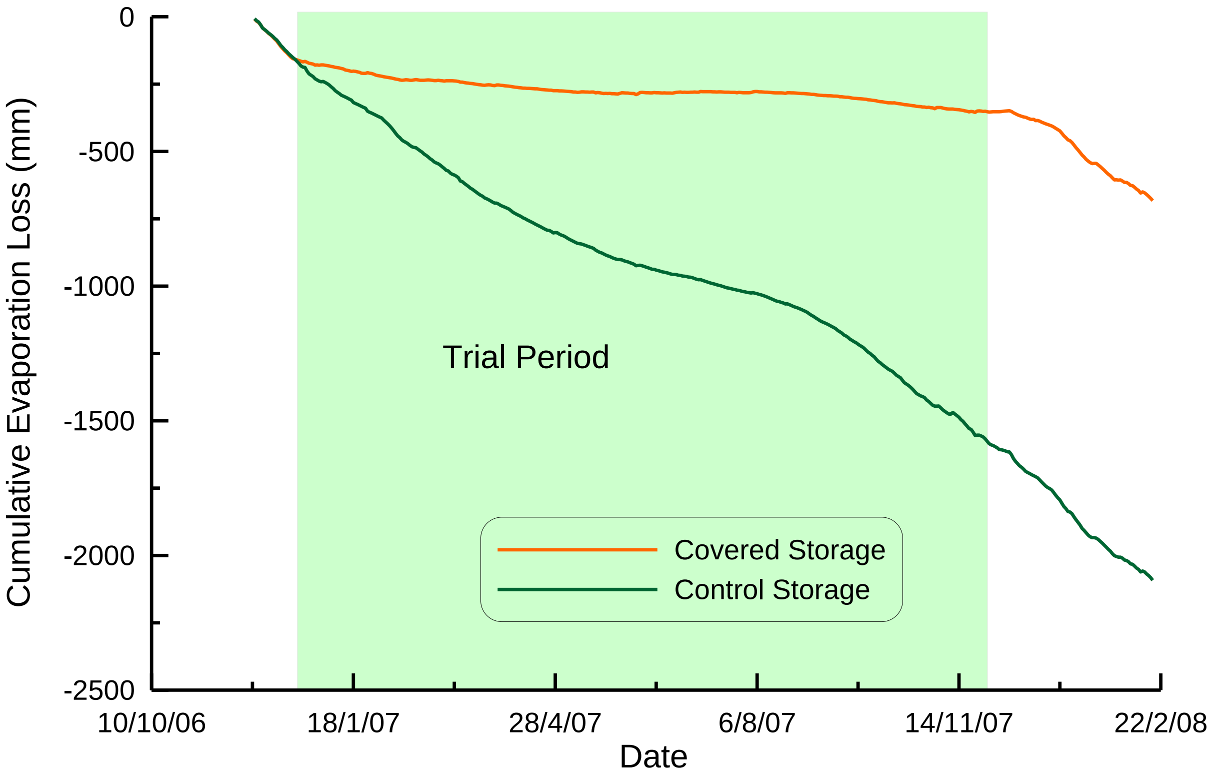

Figure 15: *Evaporation losses from the control and covered storages.*

During the trial period the covered storage lost 210 mm in evaporation and the control storage lost 1,445 mm, resulting in a saving of 1,235 mm or an 85 % reduction in evaporation loss. On a daily basis, this equates to an average evaporation reduction of approximately 3.6 mm/day over the trial period. A reduction in evaporation loss of 1,235 mm is equal to 12.4 million litres (ML) for every hectare of water storage surface area. If the average evaporation reduction is assumed to be 3.6 mm/day over a full year rather than the trial period (346 days), 13.0 ML of evaporation for every hectare of water storage surface area would be saved.

The rate of evaporation loss changed during the year, and hence the amount of water saved by deploying the floating modules also changed. Table 3 shows the reduction in evaporation for the different seasons during the trial period.

Table 3: *Evaporation reduction for the seasons during the trial periods*

Year	Month	Number of days recorded (days)	Evaporation from covered storage (mm)	Evaporation from control storage (mm)	Volume of water saved (mm)	Saving due to modules (%)
2006/07	Dec-Feb	72	92	394	302	77
2007	Mar-May	92	45	363	318	88
	Jun –Aug	92	9	198	189	95
	Sep-Nov	90	64	490	426	87

The average daily evaporation loss during the winter months (June – August) was 0.1 mm/day for the covered storage and 2.2 mm/day for the control storage, a saving of 95 % (Table 3). In contrast, during the summer months (December – February), the average daily evaporation loss for the covered storage was 1.3 mm/day and 5.5 mm/day, a saving of 77 %.

Water saved through reduction in evaporation loss can be used to increase the certainty of water supply, particularly in areas where water is derived from highly variable water sources such as river or dam allocations. In the case of Northparkes Mine, with a daily water requirement of 8.75 ML/day (Northparkes Mine, 2006) and storages with a total surface area of 18 ha (pers comm. Stephen Raal), deployment of floating modules on the entire water surface would save enough water to provide the site with an additional 26 days of water per year. This saving is cumulative (assuming sufficient storage capacity) and if not used one year, can be used the next if water supply is limited.

6. Comparison with other evaporation control products

6.1 Product comparison

The results of the Rio Tinto floating modules project can be compared with the performance of other evaporation control products. The National Centre for Engineering in Agriculture (NCEA) has recently completed an evaluation of various evaporation control products (Craig *et al*. 2005). The project assessed the effectiveness of different products in reducing evaporation from a range of storages, as well as assessing practical and technical limitations to their use and a comparison of the economics of different products.

The products evaluated included:

- Water$avr (a chemical monolayer);
- E-VapCap (a floating cover);
- NetPro shade cloth (suspended cover); and
- Raftex (modular floating cover).

Descriptions of these products and other products also available including advantages and disadvantages of each product, can be found in Craig *et al* (2005)[1]. Figures 16 – 19 show the different products installed on a water surface. Rio Tinto's floating module would be most similar to the Raftex product tested.

Source: http://www.flexiblesolutions.com/products/watersavr/documents/TheColibanTrial-WaterSavrCaseStudy.pdf

Figure 16: *Water$avr is spread on the surface of the water to form a layer between the water and the air one molecule thick.*

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[1] This report can be found at http://www.ncea.org.au/Evaporation%20Resources/Downloads/Contolling%20 Evaporation20Loss%20from%20Water%20Storages%20final%20report.pdf

Figure 17: *E-VapCap is a floating cover constructed as a single piece with holes spread evenly over the surface to allow rain to enter the storage.*

Source: http://www.netprocanopies.com/npcpp.php

Figure 18*: Netpro shade cloth is suspended above the surface of the water using poles and high tension cable.*

Source: Craig *et al*, 2005

Figure 19: *Raftex is a floating module similar in concept (though not design) to Rio Tinto's floating modules.*

Water$avr consists of a cetyl/stearyl alcohol which forms a one molecule thick film (monolayer) on the water surface. The Water$avr product takes the form of a white powder as the alcohol is combined with a hydrated lime carrier which acts as a bulking agent and aids flow of the product over the water surface. The product is made of food grade chemicals which are biodegradable in 2.5 to 3 days and it is permeable to oxygen. It requires frequent reapplication. The product tends to break up on larger storages due to wind.

E-VapCap is a floating cover made from heavy duty polyethylene and looks like 'bubble wrap', with a white upper surface to reflect heat and a black bubble underside that provides flotation and stops light penetration. 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.

NetPro provides a shade cloth structure made using high tension cable, incorporating black monofilament shade cloth (300 g/m^2 – blocking 90 % of UV light). The cable design acts to support the shade cloth above the surface of the storage, with all cables spliced at crossover points to disperse the load evenly and also to stop the shade cloth moving during windy conditions.

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.

6.2 Evaporation reduction

Table 4 lists the evaporation reduction of the four products tested by NCEA. The evaporation reductions expressed as a percentage were **produced from trials performed in shallow galvanised tanks**, 10 m in diameter. Seepage was eliminated by lining the storages.

Table 4: *Performance of different evaporation control products in shallow galvanised lined tanks.*

Product	Average Evaporation Reduction (% of total evaporation)
Monolayer (Water$avr)	26
Floating cover (E-VapCap)	96
Suspended cover (NetPro shade cloth)	70
Modular cover (Raftex)	87

Evaporation reduction on larger *in situ* storages was generally less successful due to the practical challenges of using these products on much larger areas. The Raftex product was, unfortunately, only evaluated in the shallow tanks, and no data from *in situ* storages is available for comparison with Rio Tinto's floating modules. Table 5 lists indicative evaporation reduction results collected from *in situ* storages.

Rio Tinto's floating modules compare favourably with other evaporation control products previously tested. When compared with other products tested on large *in situ* storages, Rio Tinto's floating modules out-perform all other products.

Table 5: *Performance of evaporation products installed on large in situ storages*

Product	Average Evaporation Reduction (% of total evaporation)
Monolayer - Water$avr (Dirranbandi)	19
Monolayer - Water$avr (Capella)	0
Floating cover - E-VapCap (St George)[2]	-
Suspended cover - NetPro shade cloth (Stanthorpe)	68
Rio Tinto's floating modules	**85**

6.3 Other considerations

The mechanical durability of an evaporation control product 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 need consideration:

- The product must not bend or twist out of shape. If they do the module will not sit as designed on the water surface and not provide a barrier between the water and the atmosphere. Rio Tinto's floating modules were structurally sound and kept their shape during the trials period.
- Consideration needs to be given to removal and disposal of modules and material at the end of its design life. They are made from recyclable materials and hence can be recycled at the end of their life (design life of 10 years).
- Untethered floating modules will be moved by surface currents and flows into and out of the storage. Rio Tinto's floating modules can be tethered if the total surface area of the water storage is not covered.
- 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. This was seen at Northparkes during a severe storm where winds in excess of 130 km/h were recorded. When modules are lifted off the surface, they have to be physically put back into place. Figure 20 shows the floating modules having been lifted from the trial storages after the storm.
- Limited or difficult access to modules in the centre of storage will hinder access for repairs and maintenance of both 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.

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[2] No reliable estimate available as continual pumping from the storage made assessment of evaporation losses impossible.

- 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.

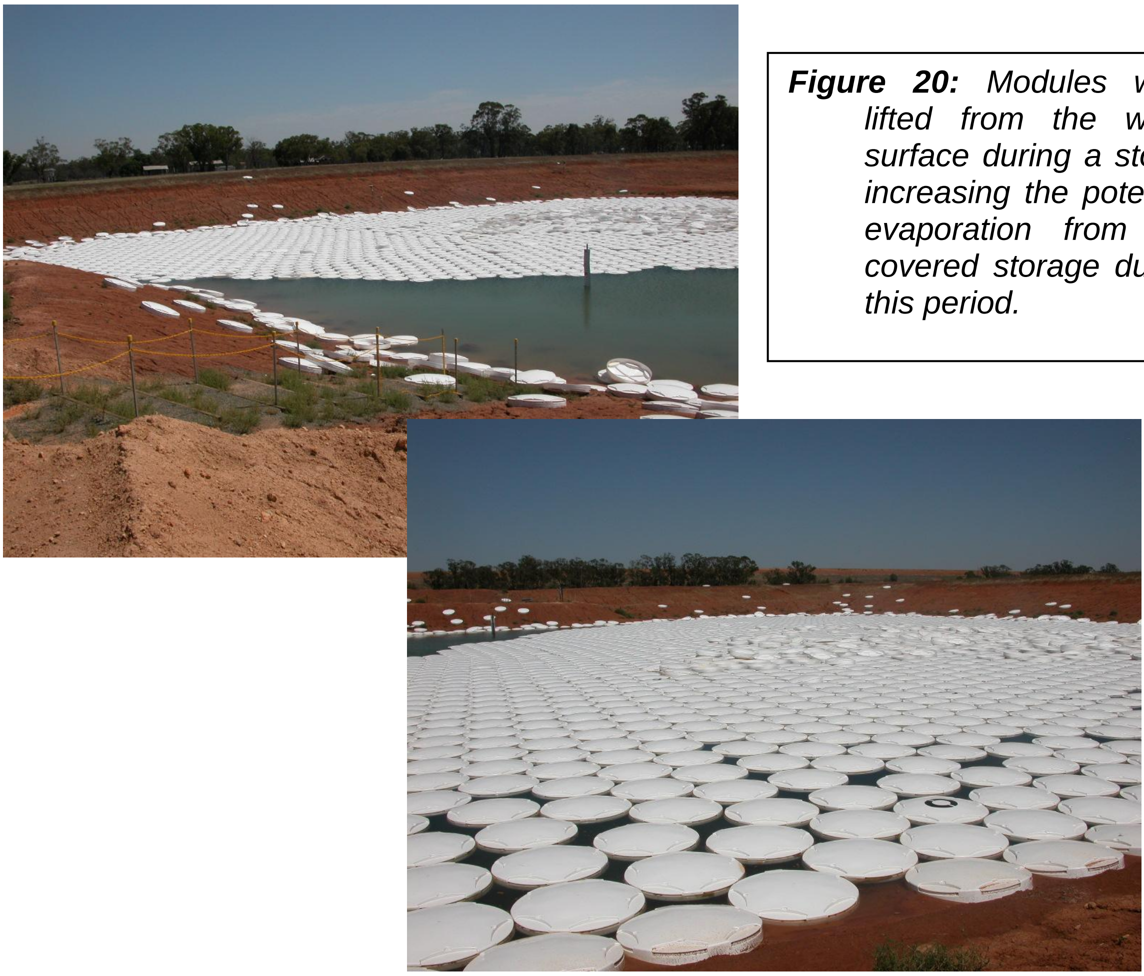

Figure 20: *Modules were lifted from the water surface during a storm, increasing the potential evaporation from the covered storage during this period.*

The economics of deploying an evaporation control product will vary and the decision to install a system will depend on the value of water and the potential gross margin of the activity in which the water is to be used. High capital cost systems are best suited to storages with water in them 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:

- installation and maintenance costs and replacement period, which are very dependent on site situation and installation issues;
- annual and seasonal evaporation losses from storage at the location;
- efficiency of the product in mitigating evaporation; and
- storage operating conditions.

Others ways of reducing evaporation and seepage such as redesigning the storage, operating the storage to minimise the volume of water storage, and lining and/or compacting the storage, may prove to be more economical and save more water than installing a cover. All options should be considered when looking to optimise the operation of a water storage.

7. Conclusions

Deployment of floating modules to cover the surface of a water storage on Northparkes Mine resulted in a 85 % reduction in evaporation losses. This is equivalent to a depth of water of 3.6 mm/day. For areas with higher potential evaporation, this water saving could be much higher. The evaporation reduction achieved using Rio Tinto's floating modules is higher than achieved with other products tested by NCEA.

The water saved by reducing evaporation can be used to increase the security of water supply for the site, and may result in a site not having to buy more water or to limit or stop production because of water shortages.

Floating modules can be very expensive to install, and other techniques could be employed prior to their installation to reduce the cost. These include:

a. **Decreasing the surface area of the storage** by making the storage deeper if needed or using a cellular storage design. Decreasing the surface area will automatically reduce evaporation losses. Seepage losses may, however, increase, though this would need to be measured.
b. **Operating the storage more efficiently.** Ensure that the storage only stores water as needed. Limit removal of water from sources that do not evaporate (such as ground water supplies) and limit the time that the water sits in a storage and hence the time that evaporation can occur.

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