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CRC LEME is an unincorporated joint venture between CSIRO-Exploration & Mining, and Land & Water, The Australian National University, Curtin University of Technology, University of Adelaide, Geoscience Australia, Primary Industries and Resources SA, NSW Department of Primary Industries and Minerals Council of Australia.

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Reference: Corriveau J. 2007. Estimation of the isotopic composition of evaporated water at Loveday Disposal Basin using a constant-volume evaporation pan experiment. *CRC LEME Open File Report 230.* 21pp.

Keywords:
1. Loveday Disposal Basin 2. Isotopic composition 3. Evaporation pan experiment. 4. Murray Darling River

ISSN 1329 4768
ISBN 1 921039 78 7

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Publisher:
CRC LEME, c/o CSIRO Exploration and Mining
PO Box 1130, Bentley, Western Australia 6102

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Photograph from Julie Corriveau. North basin of Loveday Disposal Basin, February 2007

Acknowledgements
I gratefully thank CSIRO Land and Water for welcoming me as visiting scientist. I would like to thank John Dighton for his assistance in the elaboration and adaptation of the constant-volume evaporation pan, Andrew Herczeg and Fred Leaney for their valuable advices and suggestions in all stage of this experiment, and Megan Lefournour for her efficient work in the isotopic analyses of water samples. I am grateful to Andrew Biele and his team from PIRSA (Department of Primary Industries and Resources, South Australia) for allowing us to install the evaporation pan experiment at Loxton Research Centre and also for their assistance with sample collection.

A particular thanks to Sebastien Lamontagne, CRC LEME/CSIRO Land & Water, who proposed this project and provided assistance throughout the experiment. I would also like to thank INRS-ETE for granting me a scholarship for my stay in Australia in order to work on a different water issue, and the encouragement of Daniel Cluis, my supervisor at INRS-ETE.

Executive Summary

A constant-volume evaporation pan experiment was conducted to estimate the isotopic composition of evaporated water (δ_E) at Loveday Disposal Basin. This approach can be used to estimate *m* and *K*, the two exchange parameters required to estimate the specific δ_E for a given water body (Allison and Leaney 1982). A pan set-up was installed at the Loxton Research Centre, approximately 40 km from Loveday Disposal Basin, and was operated from January 23 to February 24, 2007. The pan was set next to an Australian Bureau of Meteorology station, where ancillary meteorological data (temperature, potential evapotranspiration, relative humidity, etc) was collected. Due to logistical constraints, only the δ^{18}O is analysed in this report.

The δ^{18}O of the pan took approximately two weeks to reach a pseudo-steady state value of 8.3‰ (the *K* parameter), between February 8 and 19. The pseudo-steady state was broken on February 20 following a small rain event and another steady state had not been reached by the time the experiment was concluded. Using *m* values calculated from relative humidity measurements at Loxton, monthly δ_E for Loveday were estimated for the summer months in 2005-06 and 2006-07. The estimated *K* value for ^{18}O was within the range of annual δ^{18}O values of Loveday water and similar to summer months values.

There are a few caveats to the estimates of δ_E obtained with the pan experiment. It was noted that daily water temperature variations were greater in the pan than in Loveday, and that on average the pan was slightly cooler. These differences could have induced a bias in the estimation of *m*. However, the mean *m* calculated from either free atmospheric *h* or normalized *h* showed no significant difference, so either method can be used at this location. Due to the short duration of the pan experiment, the *K* and *m* values are probably only applicable to summer months.

A number of improvements to the design of the experiment are proposed to enhance the capability to measure δ_E accurately in Loveday and similar water bodies It is recommended that measures be taken to limit the variability in water temperature between the pan and the targeted water body. The experiment should be repeated on a seasonal basis to provide seasonal estimates of δ_E. Relative humidity should also be measured at the water body itself in case the atmospheric environment is slightly different on floodplains than the nearby upland areas, where meteorological stations tend to be located.

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1. Introduction

In the lower Murray-Darling River region, a number of floodplain wetlands have been used as disposal basins during the 20th century to store and evaporate excess saline drainage water. These wetlands are generally isolated or have little connection to the river, except during overbank flow events. Lately, the improvement in irrigation efficiency, the decrease of flooding events and a drought in the Murray-Darling Basin have partially dried many of these floodplain disposal basins. This has resulted in hypersaline conditions and the production of foul odours from exposed sulfide-rich sediments (Lamontagne et al. 2004; Hicks and Lamontagne 2006). Recent management policies adopted by state and basin agencies aim to remove all disposal basins from Murray-Darling River floodplains and to return these wetlands to a more natural state (Lamontagne and Hicks 2006). Loveday Disposal Basin has been targeted by the Murray-Darling Basin Commission and the South Australia Department of Water, Land and Biodiversity Conservation (DWLBC) as the test case for the rehabilitation of disposal basins located in floodplains (Lamontagne and Hicks 2006). However, in order to be able to ensure adequate management practices and minimised environmental risks in the future rehabilitation of Loveday Disposal Basin, an improved knowledge of the water balance is essential.

Stable isotopes of water ($\delta^{18}O$ and $\delta^{2}H$) can be used to estimate the water balance of wetlands. The stable isotopes mass balance method is described as a combination of the hydrologic budget and the isotopic mass balance expressions for a water body assumed to be in hydrologic and isotopic steady state (Krabbenhoft et al. 1990). Terminal lakes in arid and semi-arid regions, such as Loveday Disposal Basin, can reach an equilibrium isotopic enrichment balanced by inflow, infiltration, evaporation and isotopic exchange with the atmosphere (Ingraham and Criss 1993). A key for the successful application of the isotopic technique is that the fractionation occurring during evaporation (δ_E) must be characterized. Therefore, an adequate estimation of δ_E is essential in order to evaluate the role of evaporation in the hydrologic balance of Loveday with stable isotopes. As discussed by Allison and Leaney (1982), constant-volume evaporation pans can be used with some confidence to estimate δ_E for water-balance studies. Unlike conventional evaporation pans, constant-volume evaporation pans overcome variations due to changing meteorological conditions, which delay the approach to isotopic equilibrium (Allison and Leaney 1982). In addition, the isotopic composition of water in conventional evaporation pan fluctuates greatly when the pan is almost empty, resulting in potential errors in the estimates of δ_E. The isotopic composition of atmospheric water vapour (δ_A) and relative humidity (h) are the principal parameters determining the isotopic composition of a water body through evaporation.

1.1. Theory

When the temperature of the pan water is within a few degrees of that of the water body (wb), Allison and Leaney (1982) have determined the relationship between the isotopic composition of the evaporated water of the water body and the exchange parameters estimated by a constant-volume pan:

$$\delta_{E(\mathrm{wb})} = (m+1)(\delta_{\mathrm{wb}} - K) + \delta_I \qquad (1)$$

where δ_{wb} and δ_I are the isotopic composition of residual water of the water body and of the pan water inflow , respectively. The exchange parameters K and m are:

$$m = (h-\varepsilon)/(1-h+\Delta\varepsilon) \qquad (2)$$

and

$$K = \delta_I /(m+1) + m(h\delta_A + \varepsilon)/[(m+1)(h-\varepsilon)] \qquad (3)$$

where *h* is the relative humidity, ε is the total enrichment factor from an equilibrium term (ε^*) and a kinetic term ($\Delta\varepsilon$) such that $\varepsilon = \varepsilon^* + \Delta\varepsilon$, and δ_A is the isotopic composition of atmospheric water vapour. The ε^* and $\Delta\varepsilon$ terms can be estimated from the literature. For example, for a daily average temperature of pan water of 22.27 ^{o}C, ε^* is 0.010 for ^{18}O and 0.078 for deuterium (Horita and Wesolowski 1994). Gat (1970) suggested that $\Delta\varepsilon^{18}$O = 0.016 (1-*h*) and Merlivat (1970) that $\Delta\varepsilon^{18}\mathrm{O} \sim \Delta\varepsilon^{2}\mathrm{H}$.

Several methods are available to estimate δ_A. One approach is to collect atmospheric water vapour with a freeze trap system, without inducing artificial isotopic fractionation. Alternatively, Allison and Leaney (1982) have demonstrated that it is possible to obtain accurate estimation of the exchange parameters *m* and *K* over an extended period of time using relative humidity and isotopic composition of pan water, provided pan water temperature is recorded continuously. They evaluated that when evaporation proceeds for a sufficient length of time, a steady state isotopic composition with $\delta = K$ should be reached. However, under field conditions, the isotopic composition of the pan water will reach a pseudo-steady state only after a period of equilibration because of daily fluctuations in meteorological conditions (Allison and Leaney 1982; Fig. 1). However, a *K* value can be estimate by taking the average of δ values once the pseudo-steady state has been reached.

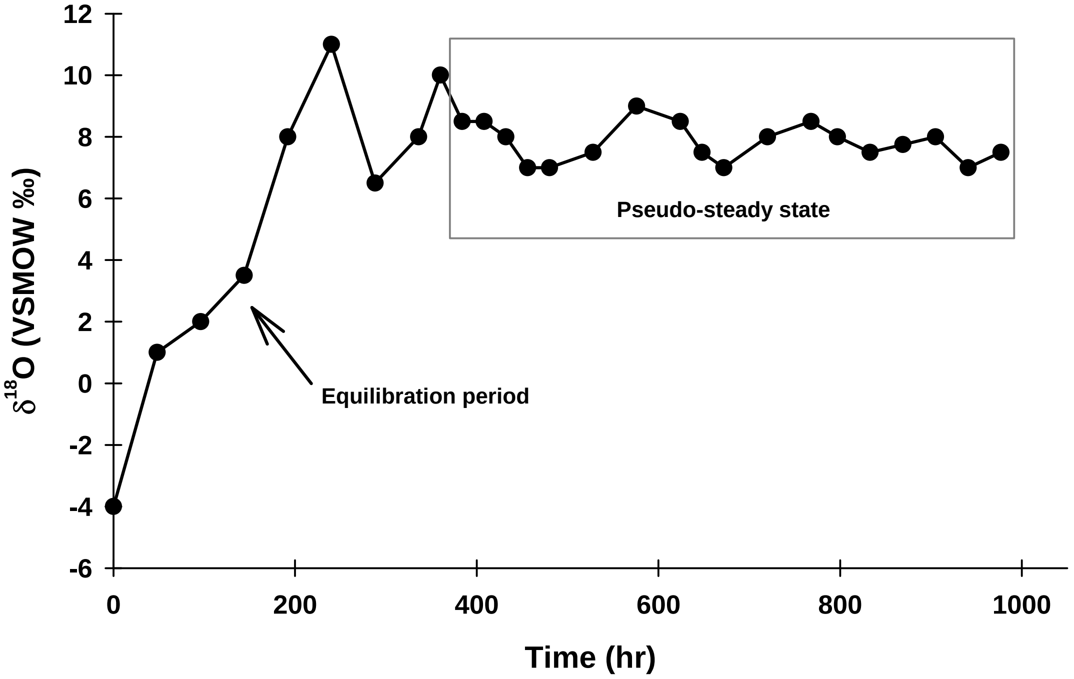

Figure 1: Representation of the approach of the pseudo-steady state in an evaporation pan experiment.

This study has investigated evaporation process at Loveday Disposal Basin with the stable isotopes of water. The main objective consisted in the characterization of the isotopic composition of evaporated water from Loveday Disposal Basin ($\delta_{\mathrm{E\ (Loveday)}}$) with a constant-volume evaporation pan experiment. As not all the deuterium data was available at the time of writing, only the results for ^{18}O will be presented in detail here.

2. Methods

2.1. Site Description

The Loveday Disposal Basin is situated near the township of Cobdogla (Fig. 2), in an area considered as one of the oldest irrigation districts in South Australia. This region has a semi-arid climate characterized by an extremely low mean annual runoff, induced by a higher potential evapotranspiration (~2000 mm y^{-1}) when compared to precipitation (~300 mm y^{-1}). Loveday Disposal Basin is divided into a North and a South basin by a causeway connected by culverts, and covers an area of 330 ha. The North Basin is connected to the Murray River through an inlet at its northern end, while the South Basin's main connection is by flow through from Mussel Lagoon (Lamontagne et al. 2006).

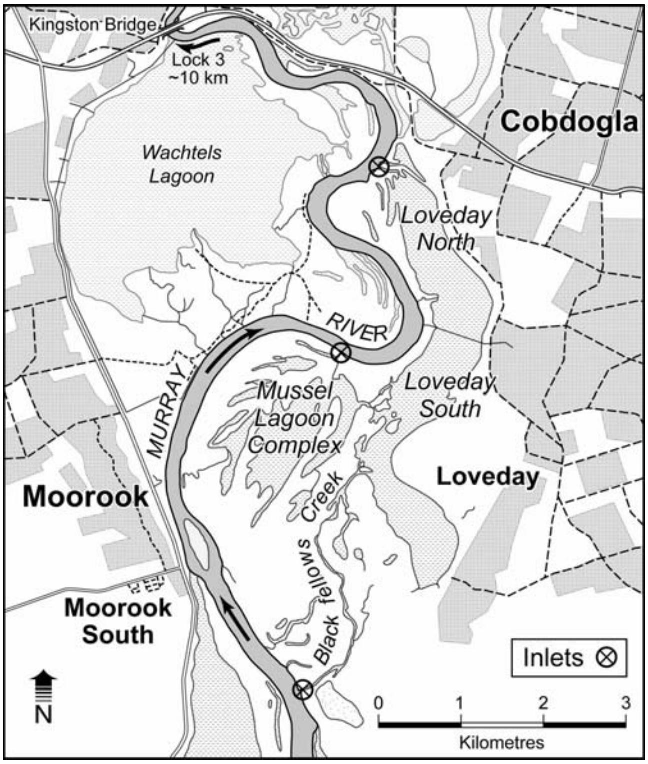

Figure 2: Loveday Disposal Basin and the location of river inlet to the systems (from Lamontagne et al. 2005).

Prior to European settlement, the native vegetation across the basin was a lignum swampland, surrounded by river red gum and black box communities (GHD 2004*a*). Nowadays, the vegetation in and around the basin is mostly halophytes, with extensive areas of bare soils (Lamontagne et al. 2006).

2.1.1. Hydrology

Before Murray River regulation, Loveday was an ephemeral wetland that would be filled in late spring and dried during the summer months (Lamontagne et al. 2005). Subsequent to flow regulation, the hydrology of the swamp was seriously modified. Regulated flow conditions induced a decrease of the frequency and magnitude of flooding events (Jolly 1996). In addition, river levels are now raised by weirs along river, which would have resulted in Loveday being permanently inundated if control structures had not been installed at its various inlets (Lamontagne et al. 2005). This raised river level also results in elevated water tables across the floodplains. Figure 3 demonstrates that Loveday is now a terminal basin because it has the lowest water level in the landscape (Lamontagne et al. 2005). The basin lies between the highland irrigation areas to the east and the river and wetlands to the west (GHD 2004*b*).

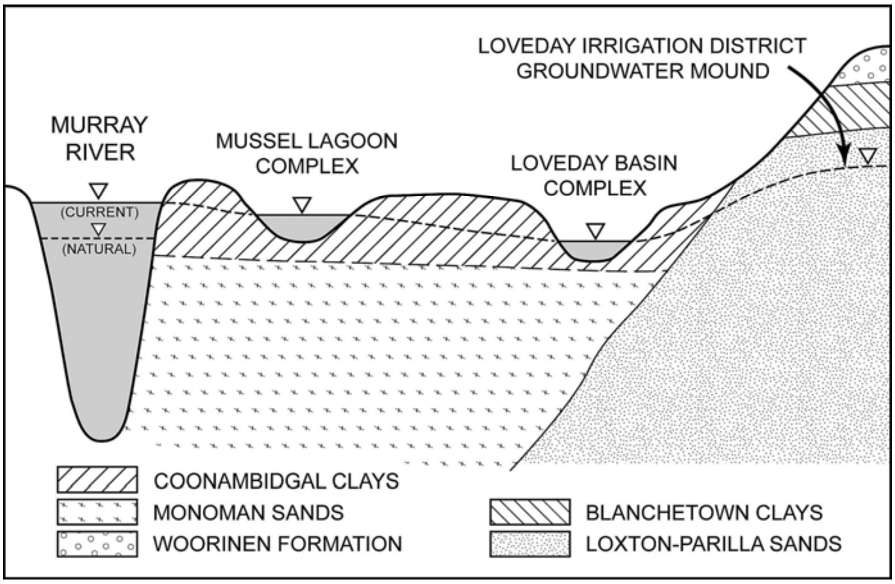

Figure 3: Conceptual representation of the Loveday Disposal Basin hydrological system (from Lamontagne et al. 2005).

Irrigation water from the highland agricultural areas is either captured by shallow drains or enters the water table aquifer system (GHD 2004*b*). Part of the water captured by surface drains is discharged to Loveday, whereas the irrigation water reaching the aquifer system forms a groundwater mound which is discharging towards the Loveday Disposal Basin. In addition, the basin also receives groundwater sourced from the river.

Lamontagne et al. (2005) have estimated a preliminary water, salt and sulphur balance for Loveday, from 1970 to 2000 (Table 1).

Table 1: Preliminary water and salt balances for Loveday Disposal Basin for 1970-2000 (from Lamontagne et al. 2005).

	Water balance (ML year^{-1})	Salt load (ton year^{-1})
Input		
Irrigation disposal	2869	7327
Groundwater mound	316	7900
Rainfall	1718	17
Upstream wetlands	586	205
Surface runoff	363	73
Seepage from river	167	62
Surface inputs from river	177	58
Outputs		
Evaporation	-6175	0
Surface flow to river	-22	-550

There were two main inputs of water in the basin between 1970 and 2000, irrigation drainage disposal and rainfall, whereas the main output of water was by evapotranspiration. Groundwater discharge was a small water input to Loveday, but contributed a similar load of salt as irrigation drainage disposal. As reported by Lamontagne et al. (2005), irrigation disposal has now been significantly reduced since 2000, but the salt load has only been reduced by 43%. In recent years, occasional releases of water from the Murray River and the Mussel Lagoon have been made into the North and the South basins, respectively, to partially cover the sediments in order to control noxious smell generation (Lamontagne and Hicks 2006).

2.2. Experimental Design

A constant-volume evaporation pan was used in order to estimate the isotopic composition of evaporated water (δ_E) from Loveday Disposal Basin. The evaporation pan was operated between January 23 to February 24, 2007, at The Loxton Research Centre, 40 km of Loveday Disposal Basin. This was close to a meteorological station of the Australian Bureau of Meteorology at the same site. Ideally, the evaporation pan should have been installed within Loveday to ensure similar conditions. However, the Loxton Research Centre was a safer area for the smooth running of the experiment because Loveday Disposal Basin is situated in a public area. The evaporation pan used was a standard Class-A evaporation pan in stainless steel. The pan was connected to a water reservoir of approximately 0.400 m^3 (Fig. 4). Murray River water was used to fill the reservoir and the pan. Loss of water from the pan by evaporation operated an automated water dispenser that maintained the pan water at constant level. Water level in the evaporation pan was maintained at 50 mm so that the pan water could reach an isotopic pseudo-steady state within a few weeks (Allison and Leaney 1982).

Figure 4: The evaporation pan set-up at the Loxton Research Centre (picture by Julie Corriveau).

Evaporative loss was measured every 15 minutes with two pressure sensors (Mini-Diver, Van Essen Instruments, The Netherlands) installed in the reservoir. The sensors were installed at the bottom and above the reservoir water column in order to measure the absolute pressure and the atmospheric pressure, respectively. Water level in the reservoir is calculated by the difference between absolute pressure and the atmospheric pressure. An initial water sample was collected after the installation of the pan in order to have the initial isotopic composition of the water used in the experiment. For the following days, a water sample was taken every morning in the middle of the pan. All water samples were collected with a gas tight bottle (McCartney bottle) and stored inverted at room temperature until analysis. A rain water collector was installed four meters from the pan to measure the isotopic composition of rainfall. A thin oil film was added to the collecting vessel of the rainwater collector to prevent evaporative losses. Samples were analysed for the stable isotopes of water (δ^2H and δ^{18}O) at the Adelaide Environmental Isotope Laboratory. Water temperature in the pan and in Loveday Disposal Basin were measured every 15 minutes with sensors (Mini-Diver, Van Essen Instruments, The Netherlands) for the duration of the experiment. The meteorological station at the Loxton Research Centre provided information about the air temperature, relative humidity and evaporation (Australian Government Bureau of Meteorology; http://www.bom.gov.au). Relative humidity was measured twice a day, at 9 am and 3pm, and evaporation daily at 9 am. In addition, monthly water samples from the North and South Basins, the Murray River, the Mussel Lagoon Complex and from a surface drain have been collected and analysed for the stable isotopes of water as a part of a water quality monitoring program at Loveday Disposal Basin (Lamontagne and Hicks 2006). Local meteoric water lines (LMWL) of Adelaide ($\delta^2H = 8.26 \times \delta^{18}O + 12.63$; $r^2 = 0.9686$) and Melbourne ($\delta^2H = 7.90 \times \delta^{18}O + 11.51$; $r^2 = 0.9878$) were calculated from data of rainfall isotopic composition available on line from the Global Network for Isotopes in Precipitation (http://isohis.iaea.org/). These two stations were the closest from the experimental site.

3. Results

The comparison of water temperature readings from the pan and Loveday has indicated that daily fluctuations in the pan are greater than those in Loveday Basin (Fig. 5; Appendix A). However, the mean daily pan water temperature was generally within 5 ^{o}C of the mean daily Loveday Basin temperature.

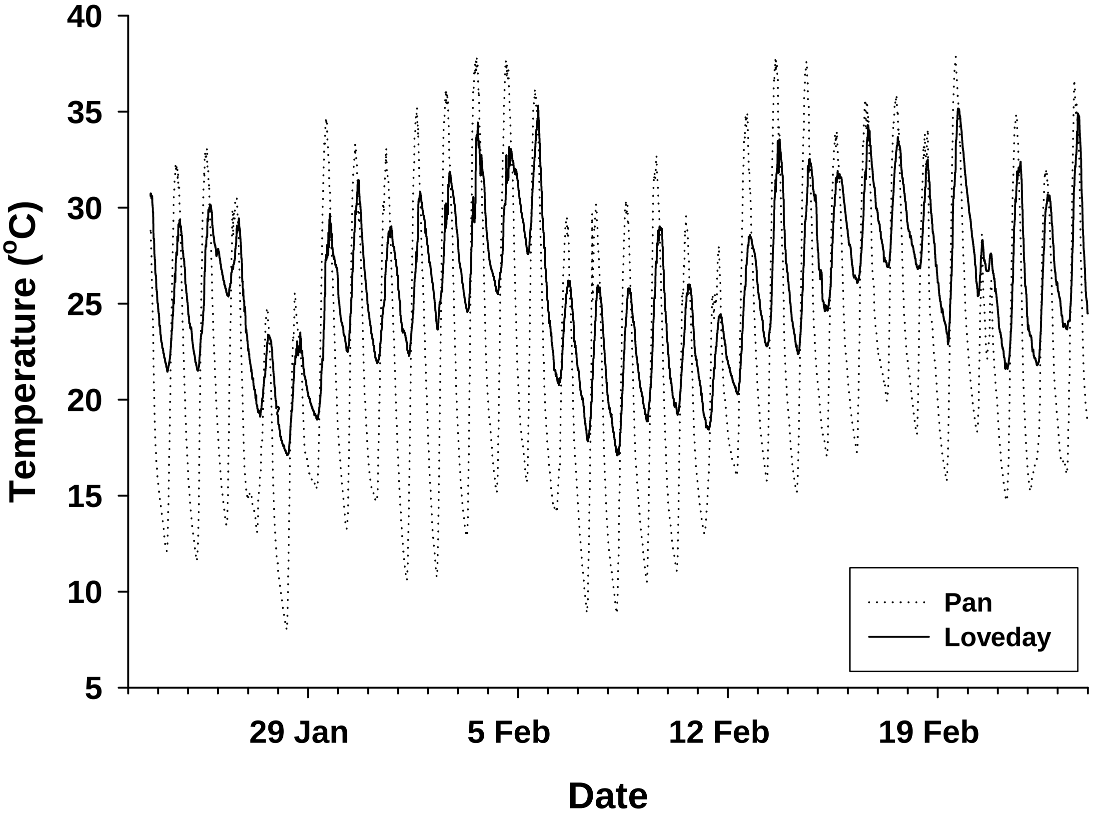

Figure 5: The comparison of water temperature from the evaporation pan and Loveday Disposal Basin during the experiment.

In this study, since relative humidity was limited at two readings per day, mean daily relative humidity and mean daily relative humidity normalized to Loveday temperature were calculated in order to compare their respective daily fluctuations (Fig. 6).

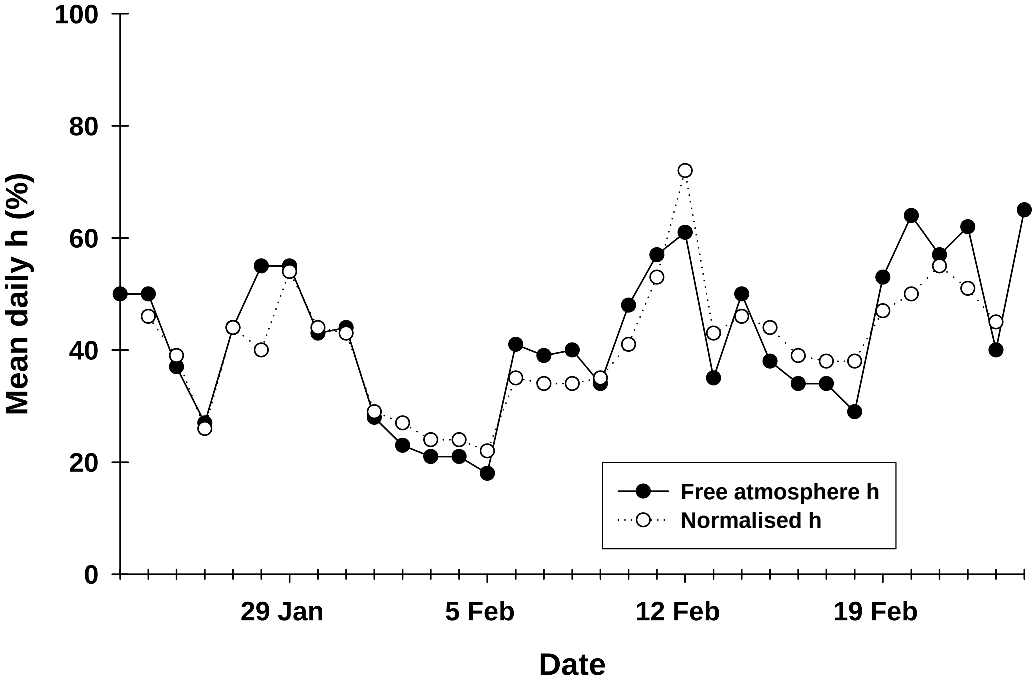

Figure 6: Comparison of mean daily relative humidity and mean daily relative humidity normalized to Loveday water temperature during the experiment.

The comparison of the two relative humidity types demonstrated a similar general trend during the experimental period. Mean estimates of *m* were calculated using relative humidity and normalized relative humidity (Table 2). The mean *m* values for ^{18}O and ^{2}H calculated from normalized *h* are slightly lower than those with free atmosphere *h*. However, a paired-sample *t*-test revealed no statistical difference between the mean *m* values of the two relative humidity types, for both isotopes.

Table 2: Comparison of mean values of *m* calculated from relative humidity and normalized relative humidity during the experimental period.

	Mean *m*			
	Calculated from air *h*		Calculated from normalized *h*	
	mean	s.d.	mean	s.d.
^{18}O	0.777	0.432	0.712	0.406
^{2}H	0.655	0.403	0.594	0.378

Most of the pan water samples collected were analysed for their composition in δ^{18}O and δ^{2}H. The initial isotopic composition of the pan water was –1.53‰ and –11.2‰, for δ^{18}O and δ^{2}H, respectively. There was an enrichment phase in the first two weeks of the experiment (Figure 7) until an isotopic pseudo-steady state was reached. Once the pseudo-steady state was reached, there were still considerable fluctuations in δ values. These would have resulted from small variability in daily meteorological conditions and δ_A. However, the major shift in δ^{18}O and δ^{2}H on February 20 and 22 was probably due to rainfall input into the pan and considerable changes in meteorological conditions during that period (Appendix B). The decrease in δ^{18}O and δ^{2}H on February 20 and 22 was consistent with the depleted isotopic value of water obtained in the rain water collector (δ^{18}O = 1.18‰ and δ^{2}H = 3.3‰).

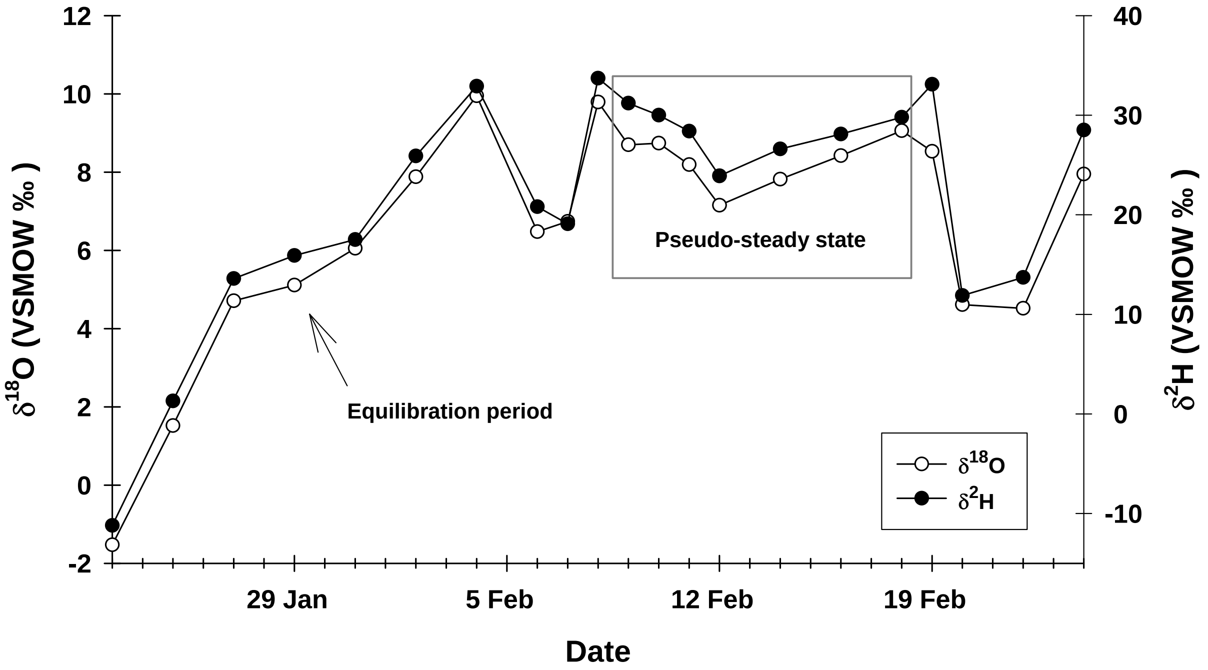

Figure 7: Change in the isotopic composition of the pan water during the experimental period.

The *K* value was determined by taking the mean of all δ after pseudo-steady state had been attained, with samples from February 9 to February 18. The estimated *K* for ^{18}O and δ^2H are 8.34‰ and 28.29‰, respectively.

Using Eq. 1 and the estimated exchange parameters *m* and *K*, the δ_E for Loveday Basin for ^{18}O and ^2H were calculated for summer months 2005-06 and 2006-07(Table 3).

Table 3: Estimated δ_E values of Loveday Disposal Basin for ^{18}O during summer months 2005-06 and 2006-07.

	δ_E (Loveday)						
Sampling Station	Summer 2005-2006				Summer 2006-2007		
	Dec.	Jan.	Feb.	Mar.	Dec.	Jan.	Mar.
	For $\delta^{18}O$ (‰)						
Loveday North-N	–5.91	–8.54	–1.35	–2.00	–3.05	–1.28	6.68
Loveday North-S	0.05	4.33	1.23	2.57	–2.62	--	--
Loveday South	–1.98	–19.04	–21.68	–14.00	9.28	–6.26	--
	For δ^2H (‰)						
Loveday North-N	–15.33	–27.60	1.57	2.84	–3.29	7.63	41.10
Loveday North-S	0.45	21.33	14.80	14.00	–1.62	--	--
Loveday South	3.48	–68.57	–83.71	–51.19	48.75	–15.81	--

-- Missing data

4. Discussion

The observed changes in isotopic signature in the evaporation pan were consistent with the behaviour expected from a continuous-feed pan set-up, with an equilibration period followed by a pseudo-steady state. The pan instrumentation was adequate and no major logistical problems were encountered during the two-month deployment period. There was a tendency for the pan to accumulate dirt over time, which may change its properties by darkening the bottom. However, it was possible to partially clean the pan without draining it or adding water by scrubbing and filtering the resuspended dirt through a cloth.

While the experimental set-up worked properly, the design of the pan experiment did not allow to accurately replicate some of the physical properties of Loveday Disposal Basin, such as the diurnal variability in water temperature. It is preferable that pan experiments maintain a similar temperature regime as the actual water body being investigated in order to replicate the physical conditions controlling isotopic exchange processes (Allison and Leaney 1981). In our case, the lower average in water temperature in the pan relative to the water body would tend to overestimate the normalized relative humidity at the water surface and, consequently, also the parameter m. In turn, this could either under- or overestimate δ_E depending on the isotopic composition of the water body. Additional artifacts may also be generated by the larger diurnal variations in temperature in the pan relative to Loveday.

Only a few studies have reported estimates of the exchange parameters m and K, and of the isotopic composition of evaporated water, δ_E. I have found only one study that was using a constant-volume evaporation pan experiment to estimate the exchange parameters m and K. Allison and Leaney (1982) estimated m values for ^{18}O and ^{2}H that varied from 2.40 to 3.00 and 2.15 to 2.70, respectively, and K values from 5.43 to 5.52‰ and 16.0 to 16.2‰ for the same isotopes, respectively. However, their experimental was set-up in a controlled environment where the normalized relative humidity ranged between 45 and 95%. The environmental conditions prevailing in their study were different from the ones at Loveday Disposal Basin, which could explain the differences in the m and K estimates between the two studies. Other studies have used regular evaporation pan experiment and different mathematical approaches to estimate m, K and/or δ_E, but none of them in semi-arid climates. Consequently, the estimated m and K values from these studies tend to have a different range than the ones found here. In Ontario, Allison et al. (1979) have calculated m values from normalized relative humidity for ^{18}O and ^{2}H that ranged from 0.98 to 1.36 and from 0.83 to 1.17, respectively. K values were determined only for ^{2}H and varied from –5.32 to –0.85‰. Their estimated δ_E for ^{18}O and ^{2}H ranged from –45 to –15‰ and –300 to –100‰, respectively. These values are representative for summer in Ontario, a sub-humid climate. In a lake study situated in northern Wisconsin, Krabbenhoft et al. (1990) have calculated average monthly δ_E during summer for ^{18}O. Values varied from –25.24 to –13.90‰ and are only valid for a climate where the monthly average of normalized relative humidity during summer ranges between 75 and 86%.

Overall, it was difficult to evaluate the accuracy of my estimates relative to similar studies. However, I used daily average relative humidity normalized to the water body temperature to calculate m, as recommended by Alison et al. (1979). The K estimates were in the range of $\delta_{Loveday}$ for summer, suggesting that the estimates are plausible (Allison et al. 1979; Allison and Leaney 1982). I propose that the δ_E values obtained in this study are accurate enough to evaluate the water balance for Loveday Disposal Basin during summer using the stable isotopes of water. However, a range of δ_E values should be used to account for the possible error in the δ_E measurements.

5. Recommendation

A number of improvements to the design of the experimental set-up can be proposed to improve the accuracy of δ_E estimates for Loveday and similar water bodies It is recommended that measures be taken to limit the variability in water temperature between the pan and the targeted water body. One option would be to house the pan in a shelter, which would lower heating by solar insolation during the day and may diminish cooling at night. In addition, the shelter would prevent rainfall from changing the water level and isotopic signature in the pan. Alternatively, the pan could be set in a larger pool to increase thermal inertia. If the pan can be located close to the water body, the water in the pool could be circulated from the water body using a pumping system to further help maintain a similar temperature regime.

The experiment should be repeated on a seasonal basis to provide seasonal estimates of $\delta_{E.}$ Relative humidity should also be measured at the water body itself in case the atmospheric environment is slightly different on floodplains than the nearby upland areas, where meteorological stations tend to be located.

Appendix A. Water temperatures of Loveday Disposal Basin and evaporation pan

Table 4: Fluctuations of mean daily water temperature of the evaporation pan and Loveday Disposal Basin during the experimental period.

Date	Pan water temperature (^{o}C)		Loveday water temperature (^{o}C)	
	mean	s.d.	mean	s.d.
Jan 23	--	--	--	--
Jan 24	21.22	7.17	24.98	2.55
Jan 25	21.68	7.60	25.55	2.99
Jan 26	20.79	6.11	26.59	1.46
Jan 27	17.10	4.02	21.10	1.32
Jan 28	16.66	6.07	19.94	2.12
Jan 29	23.23	6.98	23.46	3.90
Jan 30	22.25	6.80	26.26	2.76
Jan 31	22.40	6.45	25.25	2.44
Feb 1	22.00	8.39	26.10	2.85
Feb 2	22.98	8.75	27.75	2.53
Feb 3	24.70	9.02	28.82	3.04
Feb 4	25.92	7.96	29.11	2.73
Feb 5	24.30	7.05	30.06	2.44
Feb 6	19.97	5.38	23.29	1.72
Feb 7	18.38	7.25	21.64	2.57
Feb 8	18.71	7.47	21.25	3.00
Feb 9	20.37	7.63	23.38	3.54
Feb 10	19.19	6.22	22.31	2.21
Feb 11	19.78	5.01	21.31	2.04
Feb 12	24.14	6.67	24.21	3.15
Feb 13	25.18	7.59	27.27	3.62
Feb 14	24.58	7.66	27.13	3.55
Feb 15	24.78	5.88	28.23	2.62
Feb 16	25.60	6.30	29.43	2.62
Feb 17	26.55	5.60	29.89	2.17
Feb 18	24.47	5.13	28.71	1.71
Feb 19	25.71	7.69	28.76	4.32
Feb 20	22.25	2.57	27.23	1.30
Feb 21	22.75	7.05	26.07	3.72
Feb 22	22.37	6.01	25.79	3.17
Feb 23	23.80	7.12	27.53	3.76
Feb 24	--	--	--	--

-- Data not available over 24 hours period

Appendix B. Evaporation and Rainfall at Loxton meteorological station

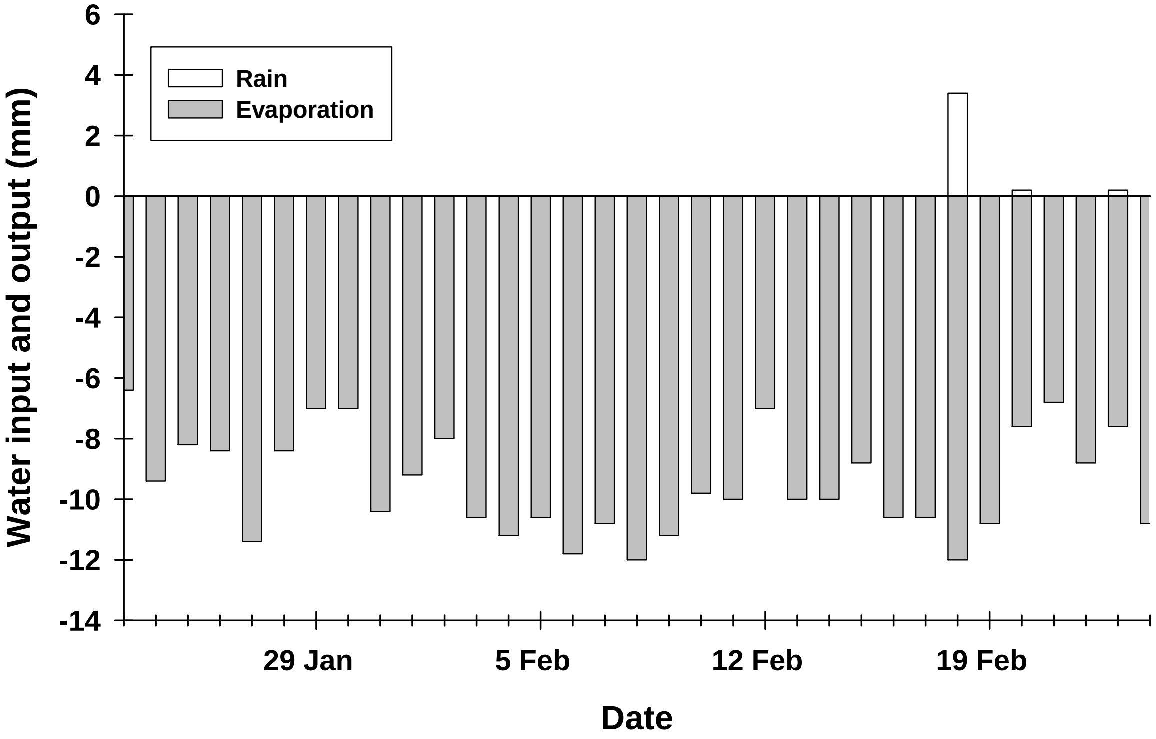

Figure 8: Evaporation and rainfall data from Loxton meteorological station during the experiment.

Appendix C. Isotopic composition of water at Loveday Disposal Basin

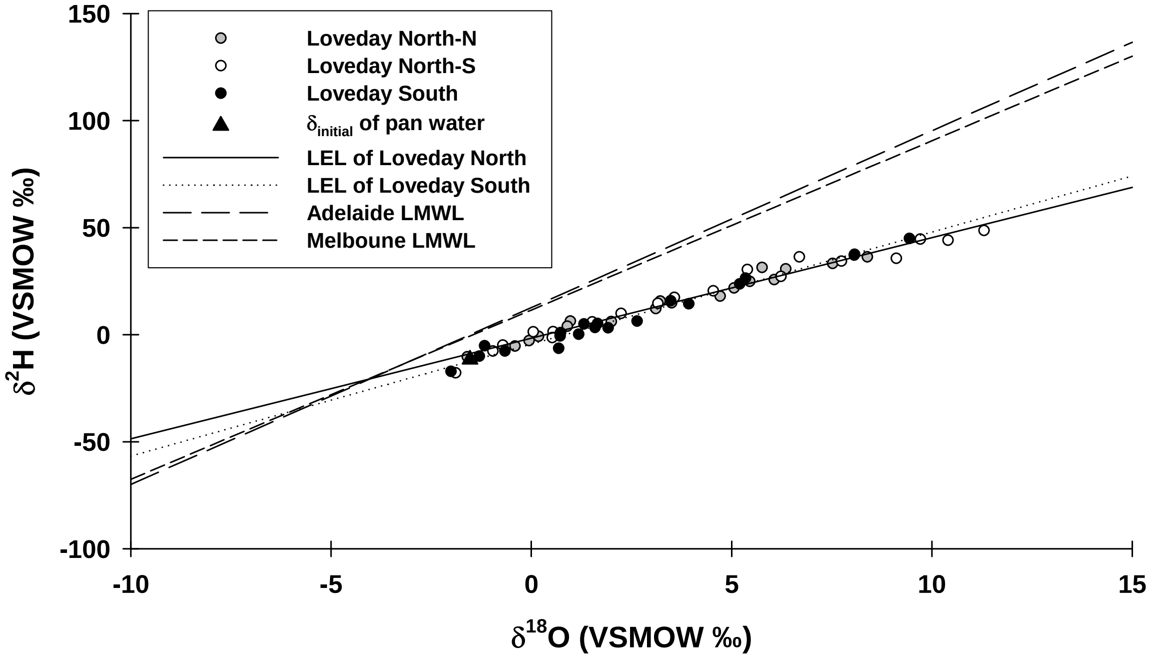

Figure 9: Local meteoric water lines (LMWL) and local evaporation lines (LEL) for Loveday Disposal Basin.

Appendix D. Summer isotopic composition of water at Loveday Disposal Basin

Table 6: Monthly values for isotopic composition of water in Loveday Disposal Basin during summer 2006.

Sampling Station	Dec 05	Jan 06	Feb 06	Mar 06
		For $\delta^{18}O$ (‰)		
Murray River	-3.43	-2.17	-1.24	-0.59
Loveday North-N	6.06	4.71	8.39	8.06
Loveday North-S	9.11	11.3	9.71	10.4
Loveday South	8.07	-0.66	-2.01	1.92
Mussel Lagoon	-2.98	-2.14	-0.92	-0.43
Drain	-1.04	-1.59	-1.61	-1.52
		For $\delta^{2}H$ (‰)		
Murray River	-16.7	-13.2	-9	-6.7
Loveday North-N	25.7	18	36.3	37.1
Loveday North-S	35.6	48.7	44.6	44.1
Loveday South	37.5	-7.7	-17.2	3.2
Mussel Lagoon	-15.9	-13.1	-6.2	-3.4
Drain	-7.3	-10.6	-10	-10.9

Appendix E. Summary of the isotopic data collected during the pan evaporation experiment

Sample Date	$\delta^{18}O$ (‰ VSMOW)	$\delta^{2}H$ (‰ VSMOW)
23 Jan 2007	–1.53	–11.2
25 Jan 2007	1.52	1.30
27 Jan 2007	4.71	13.6
29 Jan 2007	5.11	15.9
31 Jan 2007	6.05	17.5
2 Feb 2007	7.88	25.9
4 Feb 2007	9.95	32.9
6 Feb 2007	6.48	20.8
7 Feb 2007	6.74	19.1
8 Feb 2007	9.79	33.7
9 Feb 2007	8.70	31.2
10 Feb 2007	8.74	30.0
11 Feb 2007	8.19	28.4
12 Feb 2007	7.15	23.9
14 Feb 2007	7.82	26.6
16 Feb 2007	8.42	28.1
18 Feb 2007	9.06	29.8
19 Feb 2007	8.53	33.1
20 Feb 2007	4.61	11.9
22 Feb 2007	4.52	13.7
24 Feb 2007	7.95	28.5
Reservoir	–1.91	–13.4
Rainfall	1.18	3.3

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