A seepage meter in place: the evaporation bays' clear waters made monitoring easy.

Researchers check the cables leading from remote sensors to the mobile laboratory.

Tube-wells pump 15 000 megalitres of saline groundwater into the Wakool/Tullakool Scheme every year.

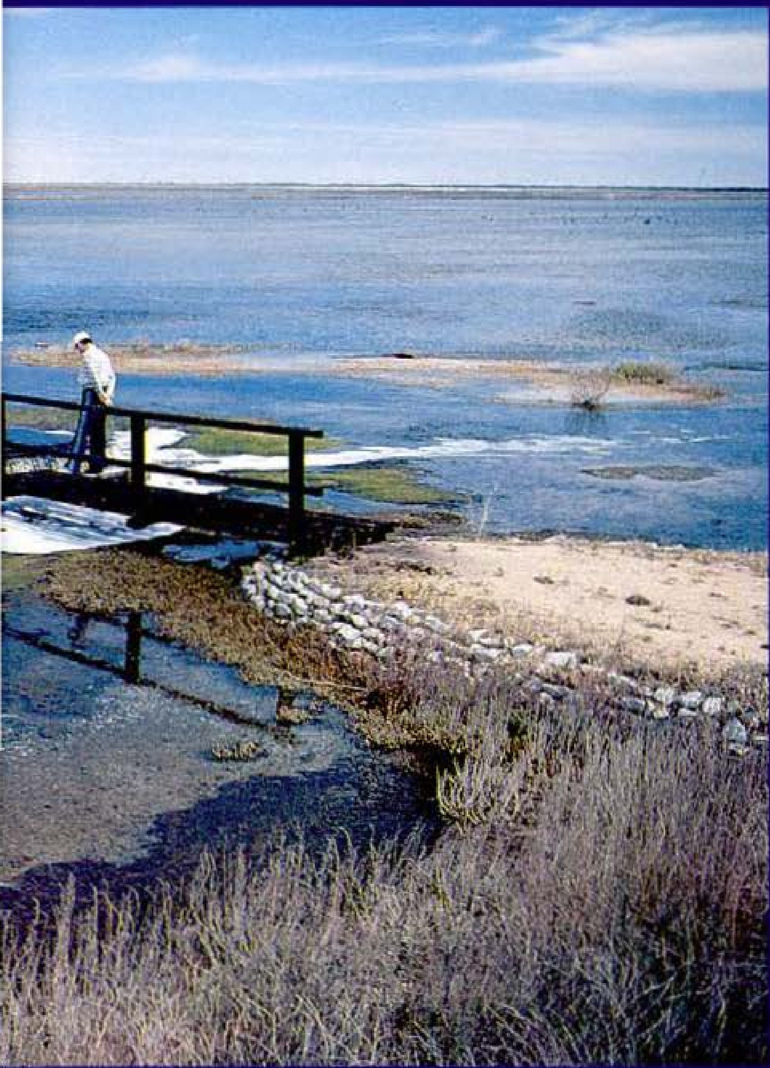
A direct approach to salinity control

In 146 BC, the Roman army deliberately destroyed the fields of rebellious Carthage by sowing them with salt. Two thousand years later, land use in 20th century Australia is — unintentionally — having the same effect on the fields of the Murray–Darling Basin.

Much of the region's native vegetation, which uses 99·6% of rainfall before it can seep down to recharge aquifers deep below the surface, has been removed, and tree loss in combination with irrigation — by raising the groundwater and the salt stored in those aquifers to the surface — has made an increasing amount of the Basin's fertile soil unfit not only for grazing but for crops and other plants.

The problem isn't new (various aspects of salinisation have been discussed in *Ecos* 53, 54, 58, and 64), but it continues to grow... and the prognosis is grim. With about 500 000 tonnes of salt finding its way to the surface every year, the Basin's environment is under direct threat. In some areas farmers have already been forced to leave their properties as the land has degenerated into what is little short of a man-made desert, so we must try to repair or reduce the damage salinisation has already caused, and to prevent further damage.

Repair is a long-term solution that involves the gradual modification of badly salt-affected areas — through changes to agricultural practices and the planting of salt-tolerant, salt-trapping species that contribute to the lowering of the water table.



Wakool/Tullakool is far from the ideal environment for research: water temperatures can rise to 45°C.

Installing seepage meters in 45-degree water and stinging salt made this aspect of research far from enjoyable.

As these plants lower water tables and 'lock up' salt below the surface, they will eventually create micro-environments that allow less salt-tolerant species to survive.

Reduction, too, is a long-term management strategy. While trees can be planted in some areas to lower water tables, revegetation is obviously inappropriate in areas that are so badly affected almost nothing will grow. There, as much as possible of the salt must be relocated before repair strategies can begin to work. Many different methods have been employed to prevent the rise of saline water tables. The simplest was to pump saline water into the Murray River itself; an 'out of sight, out of mind' approach that is no longer environmentally or politically possible.

Salt in safe storage

The most efficient solution in environmental, social, and economic terms so far has been to pump saline groundwater into disposal basins, where evaporation removes as much as possible of the water — which then re-enters the hydrological cycle — and leaves a concentrated solution that can be stored indefinitely, crystallised and purified for commercial use, or returned to deep aquifers.

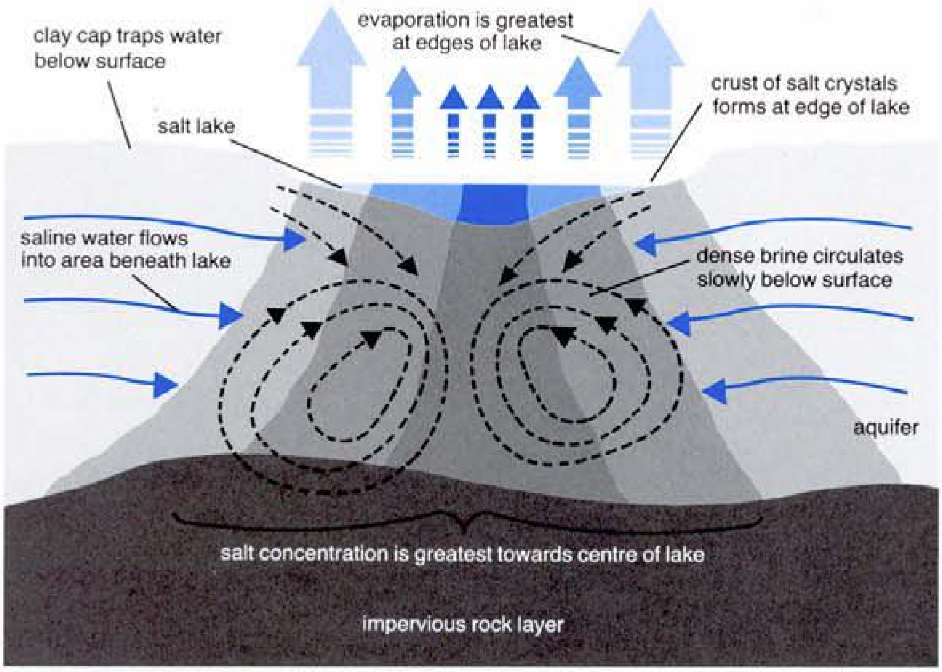
Efficient design of disposal basins — there are 90 in the Murray Basin — is central to the removal of saline groundwater: after all, there is little point in using a sieve to carry water. Yet many basins have been sited purely on the grounds of convenience, on low-lying or unused land. At one extreme, Lake Noora, a salina or natural 'dry' salt lake about 200 km east of Adelaide that is used for saline groundwater disposal, loses through seepage almost 95% of the saline water that flows into it.

Lake Noora was chosen, in fact, for just that reason — to dispose of saline water by deep seepage rather than by evaporation. Most disposal basins leak, but leakiness itself is not the problem: more important are the type of seepage, its effects, and over what time those effects will be felt.

Lateral seepage of concentrated brine at shallow depths has an immediate local impact on the environment, exacerbating the very problems groundwater disposal is intended to address. Aquifer seepage (which, as its name suggests, tends to be vertically downward from the basin) has less immediate effects: for example, it has been estimated that it will take 23 000 years for salt to reach the Murray River from the Woolpunda Groundwater Interception Scheme, downstream from Lake Noora.

However, today's farmers are naturally concerned that uncontrolled return of con-

How a salt lake traps saline groundwater



Mathematical modelling suggests that, as saline water evaporates, the brine moves toward the centre of the lake and sinks as it becomes denser. It then circulates slowly beneath the lake and remains trapped.

centrated brine into the water table could destroy the land on which their livelihoods depend. Choosing the best locations and soils for saline groundwater disposal basins is vital, so the New South Wales Department of Water Resources approached CSIRO's Centre for Environmental Mechanics (CEM), in Canberra, to assess the performance of existing basins. CEM recognised that this work could help develop techniques that will not only allow the best use to be made of existing facilities but will also improve the design of future disposal basins.

CEM researchers Dr Ian White and Dr Tom Denmead were contracted to investigate the relative contributions of evaporation and seepage to the disposal of saline groundwater at the Wakool/Tullakool Subsurface Drainage Scheme, 60 km from Deniliquin in south-western New South Wales.

The region, devoted to dairying, cereal crops, sheep pasturage, and rice-growing, has experienced rapid salinisation, with water tables rising to within 1·5 metres of the ground surface and consequent scalding of soils and production losses of 50% or more in rice-growing areas. The Wakool/Tullakool Scheme was established in 1978 to lower saline groundwater tables over 28 000 hectares and to prevent the rise of groundwater tables across a further 19 000 ha, thus maintaining safe groundwater depths for a total of 47 000 ha.

Its 48 pumps extract saline groundwater from 107 tube-wells and deposit it in two evaporation basins. Both basins contain a number of concentration and crystallisation bays, each about a metre deep. Stage One, which has been operating since 1982, covers 700 ha and has 40 bays; Stage Two, completed in 1987, has 30 bays over 1300 ha.

The researchers looked at seepage in three concentration bays, using a combination of whole-basin and 'point' measurements (see the box below), and found that seepage accounts for no more than 3% of water loss from the basins.

Pass the salt, please — underground

Once the amount of seepage had been measured, the next task was to find what was happening to it. Groundwater beneath the Wakool/Tullakool Scheme flows generally from the south-east, so Dr Lyn Plumb of CSIRO's Division of Water Resources (DWR) took water samples from a number of tube-wells to the north-west to determine whether brine seeping from the basins was increasing the salinity of nearby land.

Water from any one place has distinctive isotopic 'fingerprints' that reflect the relative amounts of hydrogen (H^1), deuterium (H^2), and oxygen (O^{16}, O^{18}) isotopes. By identifying Wakool/Tullakool water and

Ups and downs: measuring seepage and evaporation

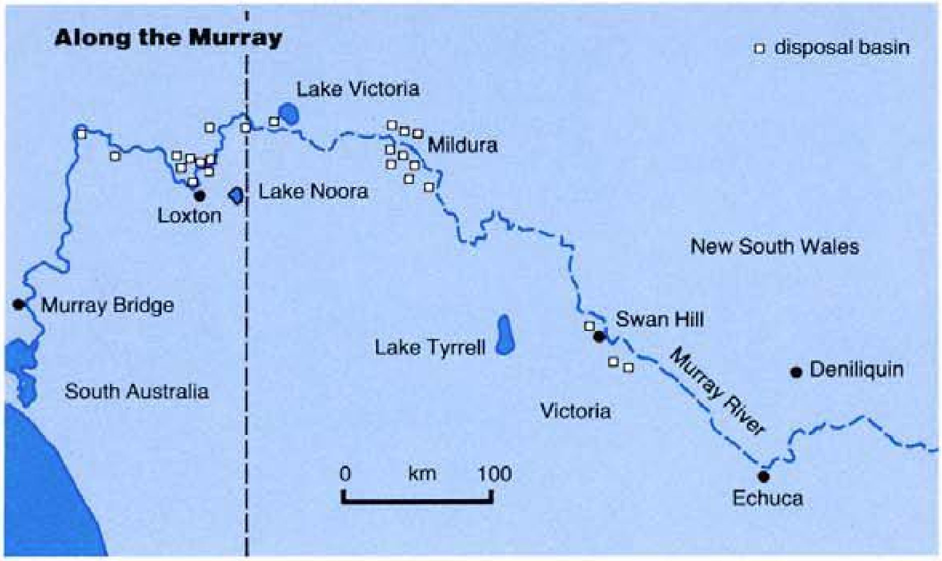
To measure seepage through the floor of the Wakool/Tullakool Basin, the researchers installed domed steel tanks about the same diameter as a 100-litre drum (albeit without a base) on the clayey bottom of the concentration bays. They allowed any air trapped in the drums and gases produced from the bottom of the bays to escape through an air-bleed valve and attached a floating capillary scale to the top of the drums, then withdrew water from the drums until the capillary tube was full: movement of the air–water meniscus in the capillary tube thus gave them a measure of the rate at which water seeped down through the ground below the drums.

These readings provided local seepage measurements. The researchers also wanted estimates of seepage over the entire basin, and derived this information from the 'water balance' — changes in water stored in the basin through inflow or outflow, rainfall, evaporation, and seepage. No rain fell during the measurement period, and no water flowed into or out of the basin, so the seepage rate equalled the difference between changes in the water stored in the basin and the measured evaporation rate.

The scientists made use of three micrometeorological methods to estimate evaporation. The first involved an eddy correlation technique, in which a fast-response hygrometer and a CEM-designed sonic anemometer were employed to measure the 'instantaneous water vapour flux'. Readings taken 20 times per second over 15-minute periods were transmitted by digital cable to a computer in the research team's mobile laboratory.

A second, aerodynamic technique calculated the evaporation rate at 15-minute intervals, based on changes in humidity with height above the water surface.

The equipment used in both approaches is very sensitive, and cannot be left to run unattended for long periods. So for longer-term measurements the team used a third method: the evaporation rate was calculated from a wind-dependent 'bulk transfer coefficient' and the difference in vapour concentration between the surface and the air at a nominated height. The first two sensitive methods were used for 'calibration' of the third, and determined the precise wind-speed-dependence of the bulk transfer coefficient.



Major saline groundwater disposal basins along the Murray River.

following its movement, Dr Plumb found that lateral seepage at shallow depths was, for all intents and purposes, non-existent: not only were the basins virtually watertight, but what little brine did escape through seepage was moving downward and posing no threat to local landholders.

Designing for maximum evaporation seems simple enough: all you need is a shallow pond and sunlight. But measuring evaporation is very important for the improvement of basin design. Accordingly, the CEM researchers used three different micro-meteorological methods to measure it (see the box).

Their measurements showed that up to 30% of total evaporation from the basins occurs at night. During the day, clear water permits substantial heating of the evaporation-bay floors and the heat thus stored is released after sunset.

The results of the project do more than reveal the Scheme's efficient design and provide information of benefit for future disposal basins. They also provide valuable data on measurement techniques, enabling scientists in other locations to compare readings and equipment and, most importantly, to enhance our understanding of how saline water evaporation and storage work.

Using natural disposal systems

This information in turn has direct value in an exciting and ambitious project, developed by CEM and DWR in collaboration with the Bureau of Mineral Resources, to investigate the effective use of salinas as sites for the disposal of saline groundwater and the enhancement of evaporation.

Lake Noora may appear to have a disappointing record as a natural groundwater 'trap', since it leaks so much. However, the direction of leakage is more important than the amount; so if saline water seeps downward rather than outward, salinas could help solve the problems of salt disposal and storage. Salinas also have the appeal of making highly efficient use of natural systems: Victorian researchers have calculated that just one salina, Lake Tyrrell, west of Swan Hill, has a potential evaporative capacity close to the total combined capacity of all existing evaporation basins in the Murray Basin. Furthermore, according to Dr Chris Barnes of DWR, salinas may be able to store brine for tens of thousands of years, with a suitable management strategy.

The concept has great appeal: it involves only a fraction of the cost of designing, constructing, and operating artificial saline groundwater disposal basins; it does not alienate arable land; it makes use of low-lying land, making transport of concentrated brine to the disposal site by pipeline easier and cheaper; and it offers the possibility of improving natural evaporation rates through management of the surface properties of salinas. Knowledge gained from studies of the Wakool/Tullakool Scheme, in combination with research into the natural hydrological and geochemical properties of salinas, has enabled CEM and DWR scientists to develop numerical models of seepage flows beneath salinas and artificial groundwater disposal basins.

How a salt lake 'works'

Preliminary numerical modelling by Dr Robin Wooding at CEM has suggested that brine circulates slowly beneath salinas. As evaporation increases the relative density of the brine in the centre of the lake, fresher water flows in from outside, trapping the brine and preventing its escape into the surrounding water table (see the diagram on the previous page).

The system is remarkably stable, with little risk of reversing that inward flow unless the salina is unbalanced by too much water that is too 'unsalty', as appears to have happened at Lake Noora. Naturally occurring floods do not disturb a salina's salt-trapping system, since they are short-lived and affect the surface of the salina rather than the water stored beneath it.

Dr Barnes's research indicates that pumping saline groundwater at the correct concentration, at a carefully calculated rate and to the centre of a salina's surface, would promote the production of small-scale 'fingers' of salt. These draw the brine into the closed circulation system so evaporation (and thus concentration of the brine) could be enhanced and the growth of a salt crust (which reduces evaporation) retarded or prevented.

Understanding the processes of seepage and evaporation in salinas involves complex mathematics, precise laboratory modelling, and arduous field work. The scientific, technical, and environmental challenges are enormous... but so is the threat salinisation poses to the Murray Basin.

Carson Creagh

More about the topic

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'Wakool–Tullakool Survey of Isotopic Distribution in Groundwaters.' L.A. Plumb. (CSIRO: Canberra 1990.)

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