Water Resources Investigations of Menindee Lakes, NSW

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Summary

The Menindee Lakes System is located on the Darling River and is used to supply irrigation and other water supply requirements along the Lower Darling and Lower Murray Rivers. The Lakes system comprises four interconnected lakes, some constructed as off river storages in old dry lake beds. The Lakes are relatively shallow compared with their surface area and a major water loss occurs through evaporation (1.6m p.a.). Excessive evaporation from the Lakes may lead to significant salinity increases which can have detrimental effects on downstream water users.

A range of options including some major structural works are being investigated to improve the operation of the Lakes system. As part of these investigations, a revised computer model of the Lakes and the Lower Darling has been utilised.

The paper provides an example of the broad range of technical, environmental, social and political issues which must be addressed in dealing with many of today's water resource management issues. There are a number of complex and diverse aspects to the project given its arid location, the hydraulic characteristics of the Lakes system, and its unique riverine environment and political setting.

1. EXISTING SYSTEM

1.1 System Description

The Menindee Lakes system comprises four major lakes: Wetherell, Pamamaroo, Menindee and Cawndilla. The Lakes are located on the reaches of the Lower Darling River in western NSW (see **Figure 1**). The catchment area of the Darling River at the Lakes is 575,000 square kilometres which is about 88% of the total catchment area of the Darling River at its junction with the Murray River. Prior to the construction of the regulating structures on the Lakes from 1949-1962, the Lakes were filled only during flood conditions and were connected to the Darling River by a series of creek systems which allowed for filling and draining of each lake to the Darling River. An exception to this was Lake Cawndilla which was (and still is) connected to the Darling via Lake Menindee (see **Figure 2**).

Construction of regulating structures began in 1949 and after some delays was substantially completed in 1962. Following the failure of the Cawndilla embankment in 1962, works were finally completed in 1968.

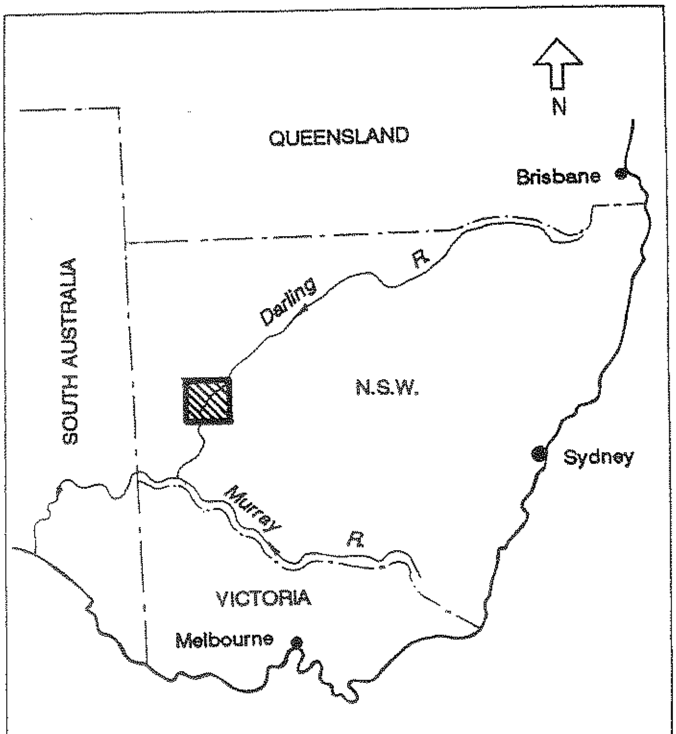

FIGURE 1: LOCALITY PLAN

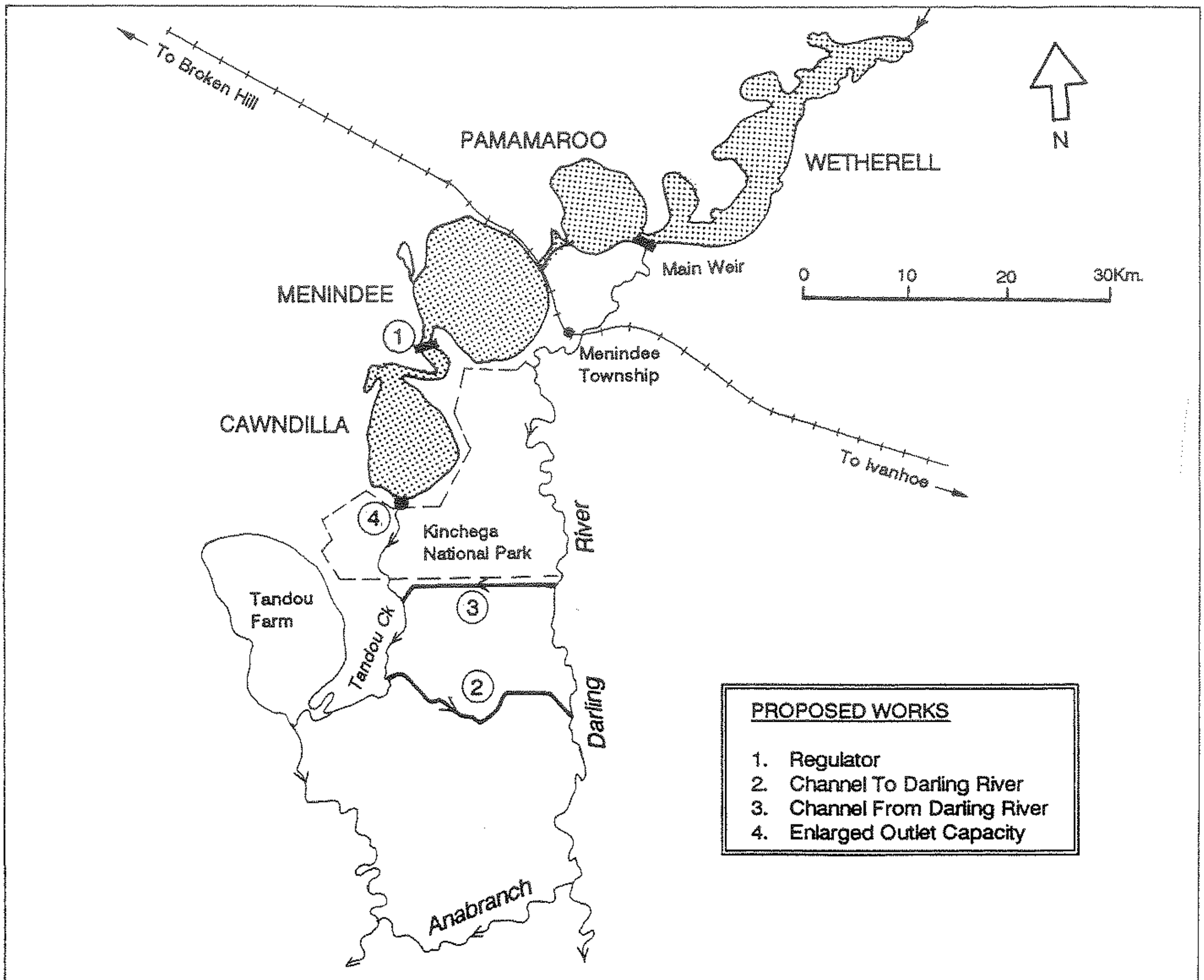

FIGURE 2: MENINDEE LAKES SYSTEM INCLUDING PROPOSED WORKS

The most upstream storage is Lake Wetherell and this was formed behind a block bank and weir across the Darling River. Water impounded in Lake Wetherell behind the Main Weir can flow past regulators under gravity to Lake Pamamaroo and then to Lakes Menindee and Cawndilla. Outlet regulators on Lakes Pamamaroo and Menindee allow stored water to be discharged to the Darling River. Lake Wetherell water can also be discharged to the Darling via the Main Weir. The Main Weir has a discharge capacity of approximately 100,000Ml/d and is used to pass flood flows down the Darling, bypassing the lower lakes.

1.2 Geomorphology

The Lakes are similar to many other "off river" lakes found along the Darling River and the Darling Anabranch. These lakes all have common features such as rounded (slightly elliptical) shapes, shallow "saucer" shaped bed profiles, crescent shaped dunes (lunettes) on the eastern perimeter and a steep western bank (Reference 1).

These features have been formed by geomorphic processes common to all the lakes, i.e.:

- initially water bodies formed in low lying places along the river (e.g. billabongs) or at the termination of creeks on arid plains;
- wave action generated by the prevailing westerly winds then transported sediments from west to east across these initial basins;
- the sediments were then transported to the eastern beach and blown by wind to form lunettes.

The Lakes are at least 25,000 years old. Many Aboriginal materials and remains can be found in narrow layers at the foot of the lunettes, particularly around Menindee and Cawndilla. During the last 200 years, and most noticeably since 1960 when water was impounded at high lake levels, a foredune has formed along the shore line. Erosion associated with the foredune formation has exposed some aboriginal remains.

1.3 Storage Volumes and Areas

The Lakes have a combined nominal full supply capacity of 1680Gl and a surface area of some 46km². Individual lake capacities and levels are summarised in **Table 1.**

Table 1 - Lake Capacities and Levels

Lake	Bed Level (m AHD)	Full Supply Level (m AHD)	Full Supply Capacity (Gl)	Surcharge Level (m AHD)	Surcharge Capacity (Gl)
Wetherell	49.6	61.67	267	62.28	343
Pamamaroo	55.3	60.45	270	61.93	377
Menindee	55.3	59.84	595	61.36	858
Cawndilla	53.0	59.84	547	61.36	706
TOTAL			1678		2285

The maximum volume permitted in the Lakes after construction in the early 1960's was 2285Gl. This was subsequently reduced to 1680Gl following the failure of the Cawndilla outlet levee in 1962. These two volumes are referred to as the "surcharge" volume and "full supply" volumes respectively. In recent years the storage has again been operated to the surcharge volume of 2285Gl.

The surcharge and full supply volumes quoted above were determined following a resurvey of the Lakes in the mid 1980's. This resulted in the adoption of volumes which were about 7% lower than those estimated at the time of construction.

1.4 Evaporation

The Menindee Lakes are located in a hot semi-arid environment and are generally very shallow with maximum water depths when full of 4 to 5m in the upper two off-river lakes and 7m in Lake Cawndilla. As a result, the loss of water by evaporation is a significant constraint on the operation of the Lakes. Rainfall exceeds evaporation in only about one month in 30 in the area. The average net evaporation (after allowing for rainfall) is 1.6m per annum.

Long term studies of the Lakes system have identified that the average evaporation from the system is 440Gl/year. Given that the normal full supply capacity is 1680Gl and that the Lakes are frequently at reduced volumes, the relative size of evaporation loss is major.

Various studies of Menindee Lakes and other lakes at nearby Broken Hill were carried out as early as the 1950's to investigate means of reducing lake evaporation through such devices as the application of cetyl alcohol films or polystyrene beads to the water surface. None of these investigations managed to identify practical and environmentally acceptable means of reducing evaporation and the current water management procedures for the Lakes system generally rely on minimising the total surface area of Lakes by optimum distribution of water to minimise evaporation.

New options to improve the water management of the Lakes through reducing surface areas are currently under investigation and these are described in **Section 2** of the paper.

1.5 Water Supply

Regulated water supplies are released from the Lakes for irrigation, stock and domestic, town water and environmental purposes. The location of these uses include:

- Lower Darling between Menindee and Wentworth;
- Lower Murray downstream of Wentworth including "entitlement flows" provided to South Australia under the Murray Darling Basin Agreement;
- Broken Hill township (via pumping);
- Tandou Farm and the Darling Anabranch (supplied from the Cawndilla outlet regulator).

The major potential demand is the South Australian entitlement flow which is 1850Gl/year. The portion of this demand, not available from uncontrolled flows in the Murray River, is normally supplied from Menindee Lakes subject to availability of the water in the Lakes and adequate outlet capacity from the Lakes to deliver it. On average 720Gl/year is supplied from the Lakes to South Australia. The extent of other uses varies significantly from year to year with the following being typical:

- Tandou farm 60Gl/yr;
- Anabranch replenishment 50Gl/yr;
- Lower Darling irrigators 20Gl/yr;
- Broken Hill town supply 5Gl/yr.

Water spilt from the Lakes or supplied for non-consumptive uses for environmental and water quality improvement purposes total approximately 800Gl/yr.

1.6 Water Quality

Until recently the major water concern in the Lakes was salinity. Due to the high evaporation rates, significant increases in salinity occur in the Lakes as water levels are reduced by evaporation, and on occasions, this water may be unsuitable for various irrigation uses.

However in recent years significant concerns over cyanobacteria (blue-green algae) blooms have arisen. In November 1991, the most extensive algae bloom ever recorded developed in the Darling River upstream of the Lakes. Blooms also occurred in Lake Menindee and the Lower Darling. Blooms in and adjacent to the Lakes have been a regular occurrence since.

1.7 Interstate Water Sharing

Under the terms of the Murray Darling Basin Agreement the Lakes are operated by the Murray Darling Basin Commission (MDBC) and water stored in the Lakes is shared between New South Wales, Victoria and South Australia. Generally the inflows to the Lakes and storage capacities are shared equally by New South Wales and Victoria and various water accounting rules have been developed to determine the shares of water in storage or in transit at any time.

An exception to the above sharing policy occurs during drought periods when the total storage drops below 480GL. Under these conditions the Lakes come under New South Wales control and the water in the Lakes is generally used for New South Wales supplies in the Lower Darling, Broken Hill, Anabranch and other local uses. The Lakes remain under New South Wales control until the volume rises above 640Gl at which time the difference in water shares between New South Wales and Victoria upon crossing 480GL is re-established and operational control reverts to the MDBC.

2. PROPOSALS UNDER INVESTIGATION

2.1 Options For Water Management Improvement

A range of options to improve the operation of the Lakes system are currently under investigation. These options include:

- hydraulic separation of Lakes Menindee and Cawndilla. This option would allow the two Lakes to be maintained at different levels which may, under most situations, result in a reduction in surface area. Evaporation losses and salinity concentrations would be reduced as a consequence;

- accelerated low-level drawdown of Lakes Menindee and Cawndilla. When Lakes Menindee and Cawndilla are drawn down to low levels, reduced outlet capacities from these Lakes make the rapid emptying of the Lakes impossible and as a result evaporation losses are excessive. To overcome these problems, the installation of pumps and cuttings within the Lake beds under these conditions may allow the Lakes to be evacuated at a faster rate. In addition, the water previously lost in dead storage may also be accessed;

- installation of block banks on the Lake Wetherell floodplain. When Lake Wetherell is above 50% capacity, significant areas of river flats are inundated to a shallow depth and relative high evaporation losses result. A number of smaller lakes such as Lakes Bijijie, Balaka and Malta are also inundated. However as the level of Lake Wetherell drops, water can be trapped within these smaller Lakes due to the high sill of their outlet channels. A proposal to temporarily block off these smaller storages during low to moderate level filling of Lake Wetherell may reduce the losses in these Lakes. Under high level filling of Lake Wetherell these block banks would be removed;

- altering the storage distribution within the Lakes. In spite of the fact that all filling and emptying of the Lakes system occurs under gravity, there are various alternative operating procedures which could allow the Lakes to be maintained at different levels. Each procedure may result in a different total storage distribution and total surface area, with a direct impact on evaporation. Whilst this may at first glance seem a trivial exercise to determine the optimum storage distribution for a given total volume in the Lakes, the procedure is complicated by the gravity conveyance system between the Lakes, lack of knowledge about future inflows and demands, and other operational constraints;

- increased releases from the Lakes to the Darling River to control algae and maintain fish habitat. At present, releases are made from the Lakes to maintain Darling River flows of 200Ml/d (winter) and 350Ml/d (summer). Strategies are currently being investigated to disperse any blue-green algae blooms which may develop in the River by releasing "pulses" of water from the Lakes at higher discharges around 2000Ml/d (winter) and 5000Ml/d (summer). The magnitude, duration and effectiveness of these flushing flows is dependent on the location of the bloom in the River.

Within the constraints of this paper, it has only been possible to provide details below of the first of the above options, i.e. the hydraulic separation of Lakes Menindee and Cawndilla.

2.2 Water Resource Modelling

The Menindee Lakes system forms part of the resources of the Murray Darling Basin and therefore the possible impacts on the whole basin must be considered as part of any proposal to alter the operation of the Lakes.

Impacts on salinity, flood control, irrigation and other water supplies in the system have been assessed using the MDBC's Murray monthly simulation model (MSM) and associated suite of salinity assessment routines (**Reference 3**). This model assesses the monthly storage volumes, river flows, irrigation diversions, etc, over all principal reaches in the basin from Hume and Dartmouth Storages on the Murray to South Australia, and from Menindee Lakes downstream on the Darling.

The model simulates behaviour over a period of approximately 100 years and predicts how the system would behave if the last 100 years of climatic conditions were to repeat themselves in the future under existing development conditions (or any other specified conditions). Examination of the results allows the risks of various outcomes to be assessed. MSM (in various forms) has been the principal planning tool used to assess major water management options in the Murray/Darling system for the last 25 years.

As part of the current investigation of Menindee Lakes, MSM has been modified to provide greater detail of the impacts of the alternative management proposals. These changes have included:

- shorter time step modelling to allow inclusion of channel capacity restraints between Lakes;
- simulation of salinity levels in each Lake at each time step;
- inclusion of the proposed regulator and additional channels associated with the hydraulic separation of Lakes Menindee and Cawndilla, as discussed in **Section 2.3** below;
- different operating procedures to achieve specified storage distribution "targets" within the Lakes.

2.3 Hydraulic Separation of Lakes Menindee and Cawndilla

2.3.1 The Proposal

The construction of a regulator between Lakes Menindee and Cawndilla would allow the two Lakes to be operated at different levels. Under current arrangements the two Lakes are normally at the same level, except at very low levels when Cawndilla becomes isolated from Menindee.

Under favourable storage volume conditions, the proposal would allow the majority of the water which is currently stored in both Lakes to be stored solely in Lake Menindee. This would reduce surface areas and evaporation, and as a consequence, also reduce Lake salinities in most situations. **Figure** 3 shows the surface areas and typical annual evaporations which occur for existing conditions and with the proposed regulator (assuming that all water previously stored in both Lakes is stored in Menindee first until it is full and then is stored in Cawndilla).

As can be seen from **Figure** 3, most benefits occur when the combined Menindee-Cawndilla storage volume is in the range 300 to 800Gl. Small disbenefits may occur below combined volumes of 200Gl, and little if any benefits occur when the combined storage exceeds 900Gl.

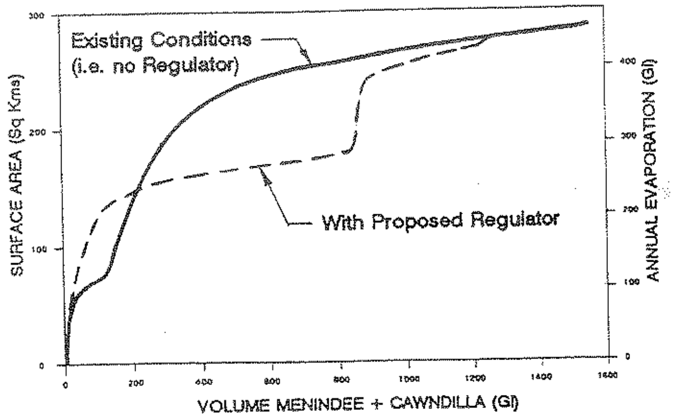

FIGURE 3: EVAPORATION BENEFITS

In addition to providing a regulator to separate the two Lakes, other channels and structures (see **Figure 2**) are proposed to be constructed including:

- a channel from the Darling River to Tandou Creek. This channel would be fed by pumping from the Darling River and allow Tandou farm and the Anabranch to be supplied from the Darling during periods when Lake Cawndilla is empty;
- a gravity channel from Tandou Creek to the Darling River. This channel would permit Lake Cawndilla to be used to supply Lower Darling and other downstream demands. Thus the Lake could be emptied whilst maintaining high levels in Lake Menindee.
- increased outlet capacity from Lake Cawndilla. This will allow Lake Cawndilla to be emptied more quickly than is currently possible.

2.3.2 The Water Quantity and Quality Benefits

The assessment of the benefits of the proposal have been carried out to a preliminary level and therefore only indicative results are available to date.

The results indicate that a 15 to 20Gl/yr saving in evaporation will occur when averaged over the long term. Considerable variability will occur over the short term. If local irrigation entitlements were to increase by 20Gl/yr, this increase would not adversely impact any other water supplies in the system.

Significant salinity reductions of up to 5 EC in the River Murray at Morgan, South Australia, would also occur with the magnitude of the benefit decreasing if additional irrigation entitlements were granted. These benefits would be valuable given that irrigation water in the area is typically valued at $100,000 to $200,000 per Gl, and one EC unit benefit at Morgan may be worth $100,000 per annum.

It is likely that the proposal will have positive benefit/cost ratios, after all capital and recurrent operating costs have been considered.

2.3.3 Environmental Issues

The proposal raises a number of environmental issues and it is likely that an extensive environmental impact statement (EIS) will be prepared for the project over the next nine months.

Lake Cawndilla and the proposed regulator site lies within Kinchega National Park and this heightens the environmental concerns over the project. There is the possibility that significant environmental benefits may also occur as the more frequent drying out of Lake Cawndilla may return the Lake bed and the surrounding environment to a more "natural" i.e. pre-regulation condition.

The environmental issues which have been raised to date and which will be addressed in the EIS include:

- changes to fish habitat and fish access between the Lakes;
- changes to the lake bed ecology of Lake Cawndilla;
- impact on foreshore erosion and archaeological issues in Lakes Menindee and Cawndilla;
- impact on regional groundwater;
- impact on water quality and quantity supplies to other irrigators in the Murray-Darling system;
- impact on flora and fauna including water birds in Lake Cawndilla;
- impact on recreational activities in Lakes Menindee and Cawndilla.

3. CONCLUDING COMMENTS

This paper has been prepared as an example of resource management applications of the science of hydrology and water resources in the 1990's. In the past, water resource management was often preoccupied with quantity issues at the exclusion of other issues. Practitioners working in the field must now be multidisciplinary and be prepared to consider a range of diverse and sometimes competing issues.

This investigation of Menindee Lakes demonstrates the broad range of environmental, social, political and technical issues which must be addressed when dealing with today's resource management issues — particularly those relating to the Murray-Darling Basin.

4. REFERENCES

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