MDBRC Submission – Rob Foster

There is little doubt **much is wrong in recent administration of water extractions in the Murray Darling basin – especially in relation to the Barwon Darling**. Exposure of these flaws (including the ABC '4 Corners' program), and the impacts on consideration of the proposal to reduce the water recovery target for the northern basin, played a role in establishment of this Royal Commission. I hope it can contribute to a major improvement in water administration (especially in the northern basin) as quickly as practicable.

I will limit my submission to areas where I can contribute some objective research over many years, some of which I believe to be original – and in an area where I (a retired statistician of some repute) have expertise. Having been raised near the junction of the Murray and Darling, and a lifelong interest in the rivers welfare, my interest is in the health of the river system, the communities within it, and the nation as a whole, as it confronts the realities of climate change.

I began my own detailed research in 2010, associated with the 'Guide to the proposed basin plan' – but became very focused on the lower Darling (including Menindee) in 2015. This was when the river` ran dry for the third time in a dozen years – and Menindee had its 'worst ever' extended period of low or no inflow. This prompted me to undertake a detailed analysis of annual (and then monthly) 'rainfall' and 'flows to Menindee' for as far back as data were available (ie to the late 19th century). Apart from demonstrating the huge variability of rainfall and river flows in the Darling system, my research also showed,

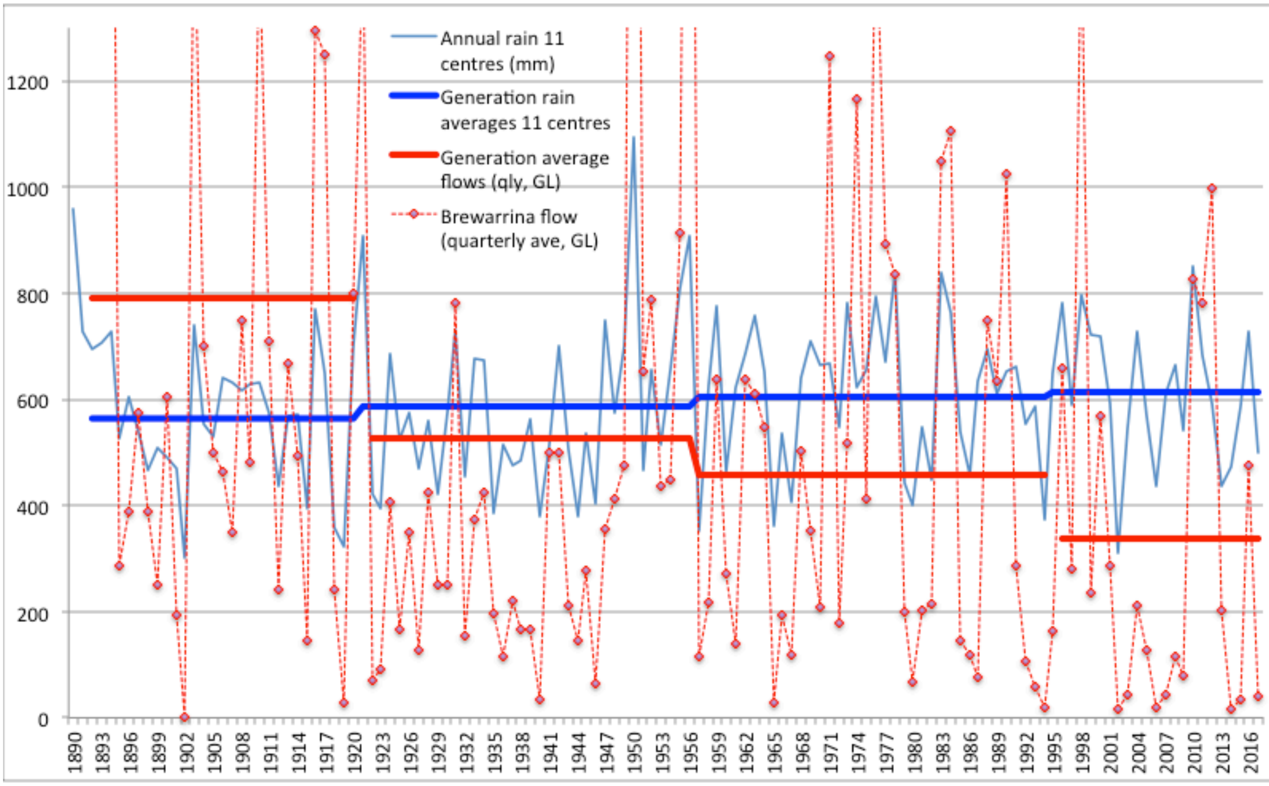
- it only took a comparatively **small number of representative rainfall centres to obtain strong correlations of rainfall in the Darling catchments and flows to the lower Darling** – on both a annual and monthly basis. It was also better to eliminate any 'seasonal' influences by putting monthly data onto a 12 month moving total basis.
- **a major shift in the relationship between rainfall and river flows over the last century**. It now takes periods of 'above average' rainfall to produce significant flows to the lower Darling – whereas once significant volumes flowed to the lower Darling thru lengthy periods of below average rainfall (eg the mid 1920s to mid 1940s).

Following the '4 Corners program' in 2017, and its focus on over-extraction around and upstream of Brewarrina, I modified my research to focus on Brewarrina as well. Lags between rainfall and river flow are shorter at Brewarrina, which means a higher proportion of rainfall reflects in river flow at Brewarrina in the same 12 monthly period than for Wilcannia/Menindee. Although it meant dropping some rainfall centres which did not affect Brewarrina, it had the advantage of having a longer run of river flow data than Menindee (o Wilcannia – the usual proxy for 'inflow to Menindee')[i]. It also meant a fourth 'broad generational' period over which average rainfall was about equal to its long term average[ii]. Comparing average river flows across successive generations – shows that the **long term decline in flows to the lower Darling** (whether measured Brewarrina, or Wilcannia/Menideee)[iii] **can't be blamed on lower rainfall**. Increased water use upstream is the most obvious reason.

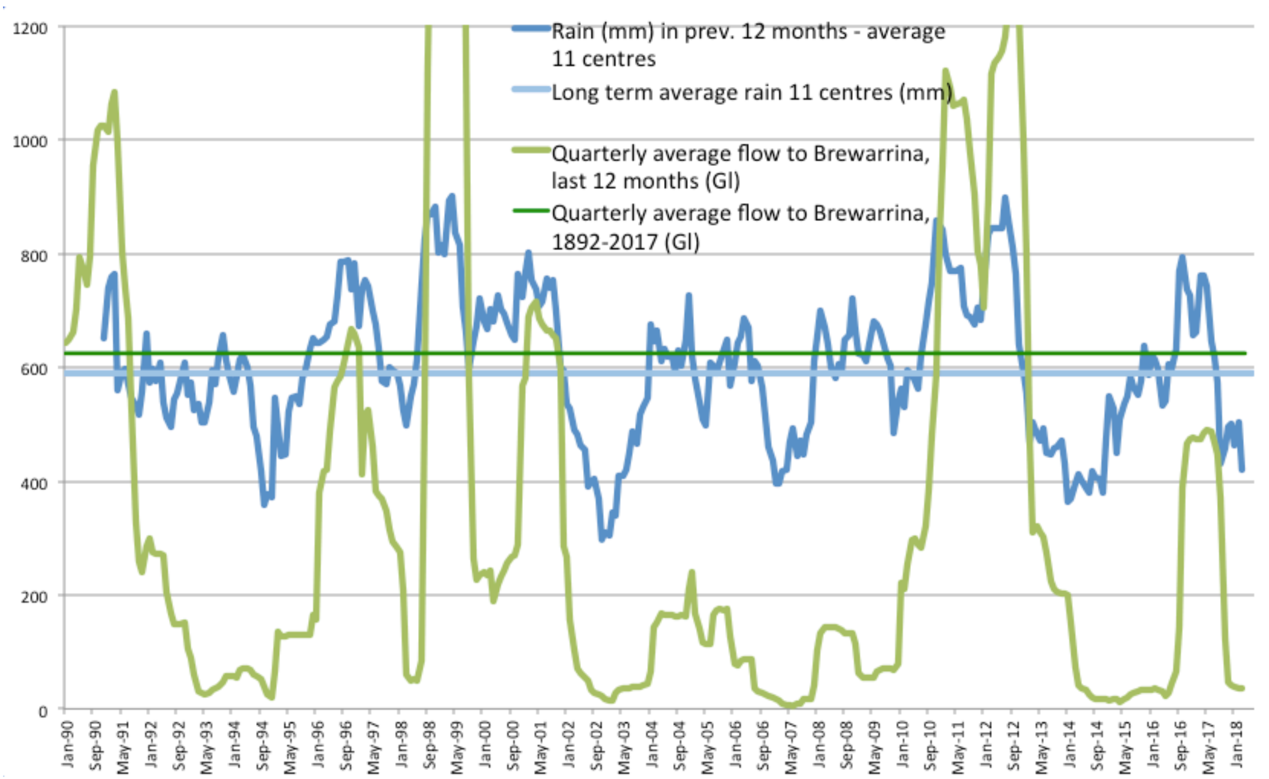
Assessing the impact of 'climate change' on flows to the lower Darling is more difficult – partly because temperature observations before 1911 are not as rigorously standardized – and are available for less centres (and do not coincide with the centres that are included in my rainfall sample). Furthermore, evaporation data (a key variable thru which highe temperatures thru climate change would effect end of system river flows) is only readily available for a much small number of places – and for only quite recent periods.

The results of my work on rainfall and river flows are summarized in the following graphs 1&2 and a table. Some temperature data is covered in graphs 3 & 4.

Graph 1 Rainfall and river flows 1890-1917



Graph 2 Rainfall and river flows, monthly plots, 1990-2018



Graph 1 shows annual calendar year rainfall and river flows together with their respective 'generation averages'. To get 'gigalitres of flow' onto a comparable scale with 'millimeters of rain', river flows were divided by 4, ie 'average quarterly flows'. The huge variability of annual rain and river flows stand out – as does the major decline in 'generation average' river flows, despite little change in 'generation average' rainfall (or temperatures – as shown in the table).

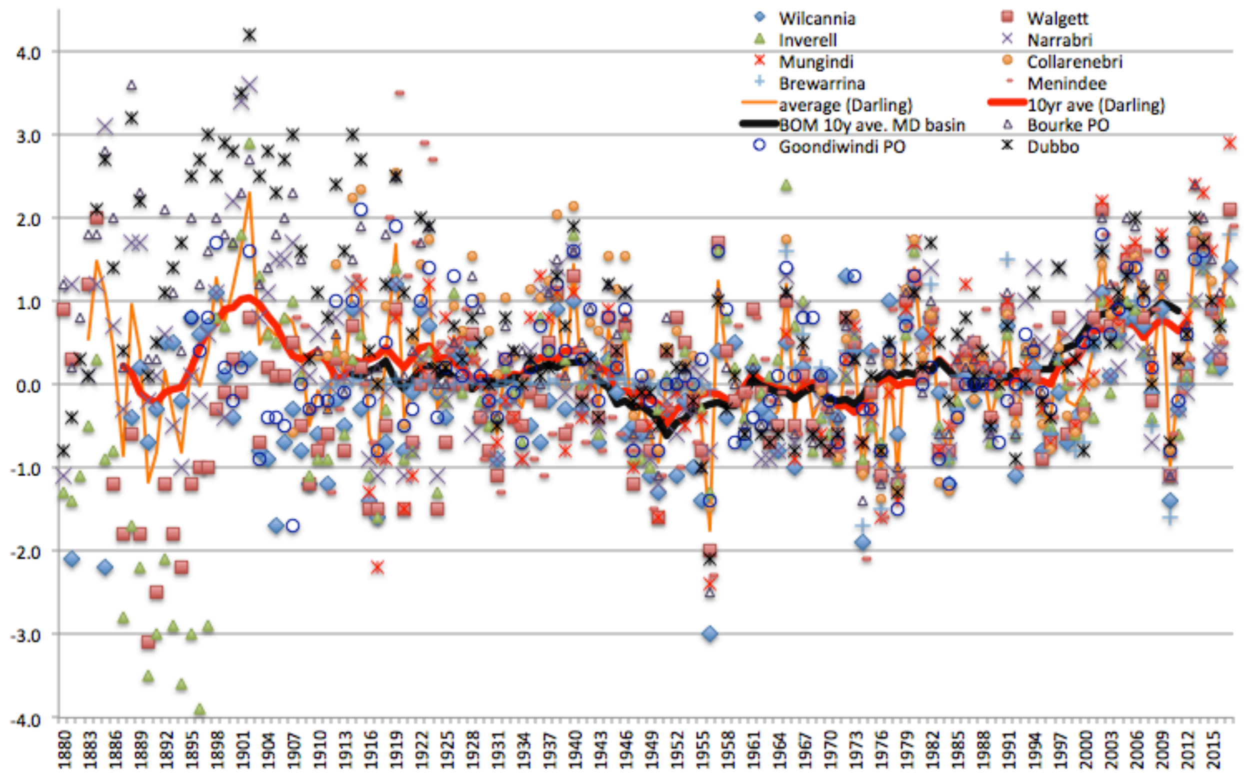
Graph 2 shows '12 month ended' rainfall and river flow rates from 1990 to end March 2018. It shows how significant flows past Brewarrina now require 'above average' rainfall – or well above average over short periods. This was the case with 2016 rainfall, with record levels in some areas of western NSW (Maquarie/Castlereagh/Bogan catchments). It also shows that low rainfall since late 2016 has, yet again, put the lower Darling under pressure.

The following table shows 'generation averages' for rainfall upstream of Brewarrina and deviations in average maximum temperatures from 1961-90 averages. It also shows the 'generation averages' of flows for Brewarrina and further downstream. It includes Bourke (by when all major tributary flows have reached the Darling) and the 'end of system' flow – ie Bertundy, where average flows have declined by much more than places further upstream. Although there are the only 2 'generation averages' available for Bertundy, they are the 2 most relevant, because they cover the periods after Menindee was converted to a discretionary storage system – and some of the decline in Bertundy flows reflect water being held at Menindee (much of it to supply Broken Hill).

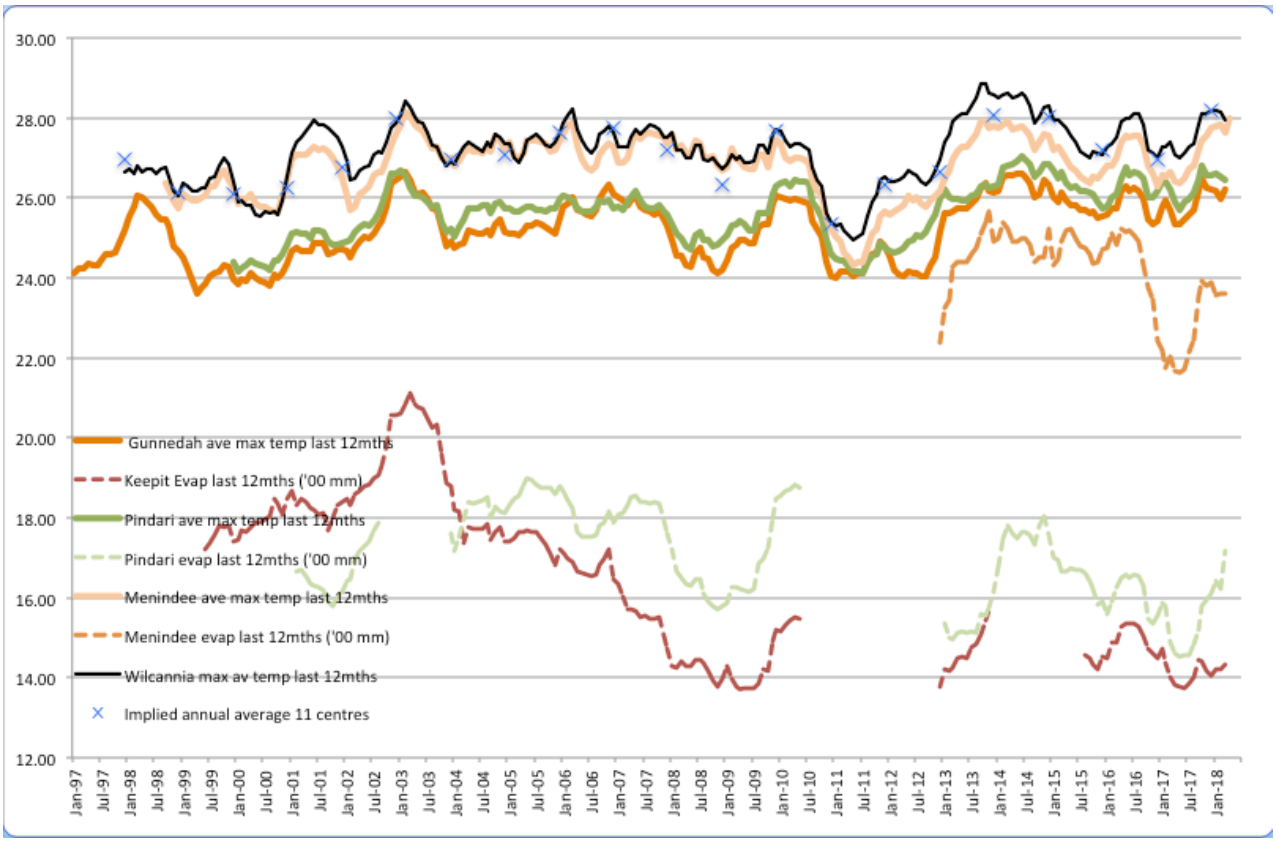
Generational period	1892-1920	1921-56	1957-94	1995-2017
Average annual rainfall (mm,11 centres)	564	587	606	613
Average annual Brewarrina flow (GL)	3161	2105	1834	1348
Average annual Bourke flow (GL)	n.a	n.a	3143	2245
Average annual Wilcannia flow (GL)	n.a	3214	2356	1490
Average annual Bertundy flow (GL)	n.a	n.a	1421	812
Deviation from 1961-90 average maximum temperatures (deg C				
Average of 11 Darling centres	0.43	0.07	0.41	0.60
Murray Darling basin (BOM)	n.a.	-0.07	0.04	0.79

Graph 3 shows available average temperature data from 1880. The thick black line shows Bureau of Meteorology (BOM) data, for the whole Murray Darling basin, for deviations in maximum temperatures from the 1961-90 average. It is shown as a centred 10 year moving average. The thick red line shows a centred 10 year moving average for the best sample of Darling catchment centres I could find that was consistent as possible with the rainfall data sample – and calculated on as close as I could get to BOM methodology. The thin red line shows the annual observations for the Darling underlying the 10 year averages. The scattered dots show annual observations for individual centres in the Darling basin. Close examination of the graphs shows there is an inverse correlation between temperature deviations and rainfall. The most obvious example is much lower than average temperatures in 1956, the year of record high rainfall and river flows. There are many other examples of lower temperatures in wet years, 2010 the mid 1970s etc. Hot & dry years include 2017, 2013, 2006, 2002 and the infamous 'Federation drought' – and 1918-19 drought. Indeed, much of what appear like a more widely dispersed scatter of temperature in the decades before 1911, actually coincide with wide swings in rainfall. The graph and 'generation averages' shown in the table suggest that impacts from rising temperatures associated with 'climate change' may not have been particularly important – so far.

Graph 3, Annual Deviations in Maximum Average Temperature from 1961-90 average



Graph 4, Average Maximum Temperature & Evaporation – 1997-2018

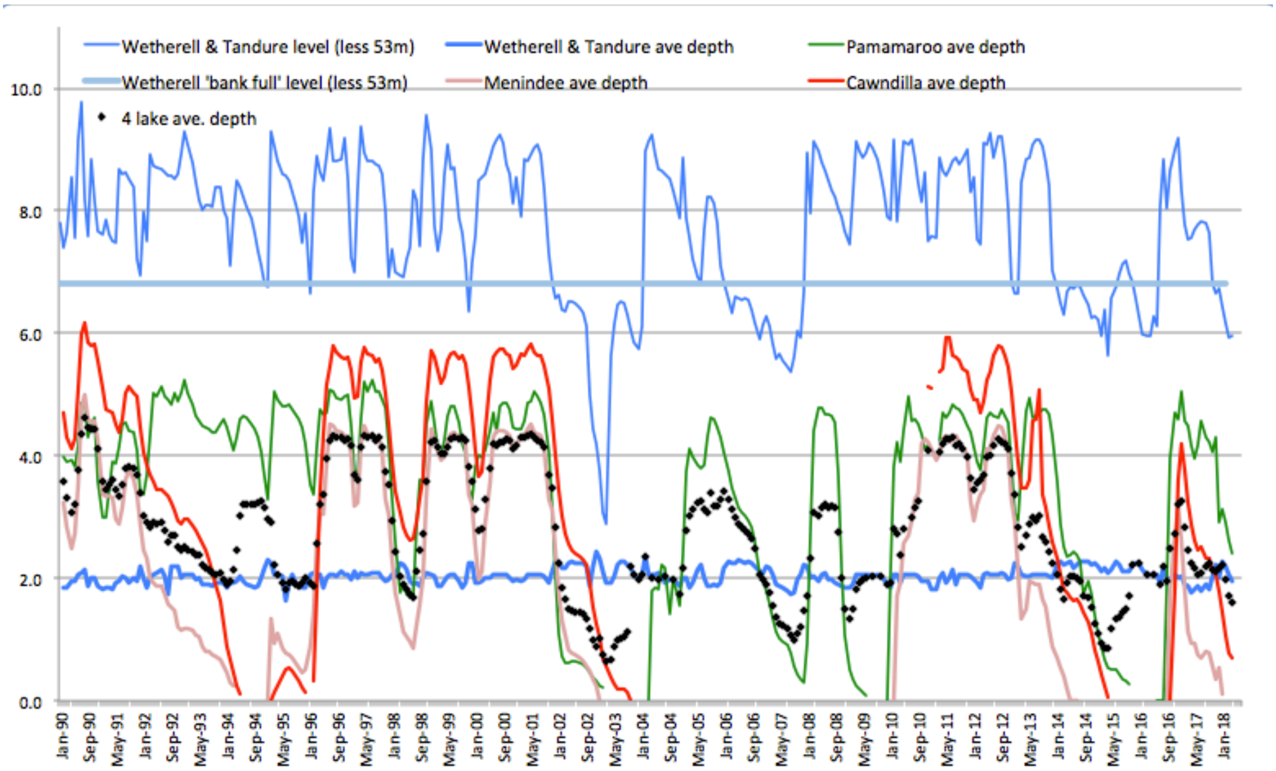


While the absence of readily accessible long term series of empirical data on evaporation in the lower Darling is a drawback, there is little doubt that a rise of couple of degrees in average temperature has a significant impact on 'transmission losses' for a river as long and slow flowing as the Darling. Some of the relevant readily available data is shown in graph 4 – which is plotted monthly on a '12 months ended basis'. While most data has been plotted to March 2018, average maximum temperatures for Menindee have been plotted to include April 2018, when new records were set for maximum April temperatures over large areas of Australia – including the Darling basin.

Despite the absence of data for several periods, the graph shows how fluctuations in temperature are generally associated with larger fluctuations in evaporation. The difficulty is how to separate cyclical swings in higher average temperatures (and evaporation - and usually lower rainfall) from more permanent increases. Although, the 'generation averages' for temperature deviation suggest a comparatively small rise in temperatures in the Darling basin over the last century, the evidence is mounting that the higher average temperatures in the last couple of decades is part of a permanent upward shift.

Evaporation, Menindee - and flows to the lower Darling and South Australia

Graph 5 Menindee lakes depths



Menindee lakes are an extremely inefficient water storage. Extraordinarily, as demonstrate by graph 5, the average depth of the 'first filled last emptied' part of the system (lakes Wetherell and Tandure) have an average depth of about 2 meters – almost irrespective of the height at the main weir. The top blue line shows the level at the main weir expressed as the height above the 'no flow' level below the weir (about 53mAHD). The lower blue line shows the combined average depth of Wetherell and Tandure. The green line shows the depth of the 'next filled' Pamamaroo, the pink shows Menindee with Cawndilla in red. The black dots show the combined average depth of all the lakes shown[iv]. Given that average rainfall over the 25-30 year period to 2017 was close to its long term average (graphs 1&2), the above average depths should be treated as representative of what is likely in the systems current configuration. In an area where average annual evaporation is well over 2 meters, and major inflows now occurring less frequently, such shallow depths mean water shortages will occur frequently – as has been the case in the last 20 years. In the 12 months to March 2018, inflows were only around 100Gl, and the volume in Menindee fell about 640Gl (from 900GL to 260Gl) with almost as much lost to evaporation as was sent downstream – either past weir 32 or thru the Cawndilla outlet. As salt and most other impurities don't evaporate, the quality of the water remaining deteriorates faster the lower the average depth.

Clearly there is a **compelling case for a major effort to reduce evaporation loss from the Menidee system by as much as possible** – having due regard for environmental and heritage constraints. This would involve more regulators (eg between Menindee and Cawndilla), drainage channels in lake beds to limit water being trapped from exits, and embankments to limit the spreading of water to shallow areas – especially the flood plain within Wetherell.[v].

Quantifying how much could be saved by reducing evaporation loss depends on the measures implemented – and the assumptions used in calculating the savings. However savings of the order of 100Gl a year are certainly possible – much of which would be reflected in higher flows to the lower Darling (and South Aust). Reducing water losses close to the lower Darling (and S.A.) provides a much greater benefit to those places than saving the same volume of water a lot further upstream – especially in a river with 'transmission losses' as high as the Darling.

Thus, while it is important that better management of upstream extractions should increase the amount of water reaching Menindee, much greater control of evaporation losses at Menindee could deliver greater quantities of water to the lower Darling – and on to South Australia.

Finally, the subject of evaporation loss (and the environment), should bring Lakes Alexandrinia and Albert (and the existing barrages) into the conversation – much more fresh water evaporates from these than Menindee. The lower lakes 'natural state' is river estuary – whose salt content varies according to the volume of fresh water entering them from upstream. In recent times, there have been considerable moves to for water users to take water upstream of Wellington rather than the lakes. Given that 'climate change' and growing population will make fresh water scarcer and more valuable, it is time to advance serious discussion on replacing the existing barrages with salt barriers at Wellington (or further upstream).

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April 2018

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[i] The Menindee study covered 14 centres, aiming for a wide geographical spread and one in the upper catchment and one on the plains for each major tributary – with as long run of consistent data as possible. 4 of the 14 could not affect Brewarrina flows and were thus deleted. Adding in Walgett increased the number back to 11. The other 10 were Glen Innes, Wallangra/Pindari, Moree, Mungindi Collarenebri, Brewarrina, Manilla/Split rock, Wee waa, Mudgee, Gilgandra.

[ii] As the objective is to compare river flows produced by a given amount of rainfall, 'generations' have been chosen over periods which aggregate rainfall has been around long term averages. Thus 'generations' have different lengths – determined by the 'best fit' with long term average rainfall.

[iii] The Wilcannia/Menindee and Brewarrina studies showed broadly similar correlations between rainfall and river flows – but there were differences. Significant differences in rainfall in the Culgoa catchment meant that some peaks in inflows to Menindee were different (eg higher 1991, lower in 1999) to those suggested by the flow past Brewarrina.

[iv] Average monthly depth was calculated from monthly changes in level and volume for each lake, to get an implied average surface area. Average volume divided by surface area gave average depth.

[v] Early in 2017, the NSW govt. announced plans that included, a regulator between Menindee & Cawndilla to allow the lakes to be operated at different levels (and facilitate reduced use of Cawndilla) and a drainage channel within Menindee, connected to a much larger outlet regulator at Menindee. These collective measures would have saved a lot of evaporation of the 2016 inflows – but would not have helped at all in the 7 years to early 2010. The disappointing features of the NSW announcement were absence of drainage channels in the upper lakes or measures to control the spread of water onto the flood plain within Wetherell. Further, the yardstick used to show the impact of the proposed measures seemed fundamentally flawed – it used 1895-2009 averages as the base case – when post 1990 averages are a more relevant yardstick – as I demonstrated above.