Options for Reducing the Risk of Closure of the River Murray Mouth

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MDBC Technical Report 2002/2

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SUMMARY

Over the last thirty years, the frequency and severity of the siltation of the Mouth of the River Murray has increased. In 1981 the Mouth closed completely for several months. The main reason for the increased siltation of the Mouth is the reduction in outflow from the River Murray System. As a consequence of development upstream, average outflows are now only 39% of the natural outflows. David Walker (2002) developed a model which relates the degree of opening of the River Murray Mouth with the monthly flow over the Barrages. This report describes the incorporation of the Walker model into the Murray-Darling Basin Commission's (MDBC) River Murray model and the use of the two models to assess the impacts on Mouth closure of changes to the River Murray flow regime.

Five possible options for modifying the flow regime to reduce the risk of Mouth closure have been examined.

The results show that options that aim to provide Barrage flows of 2000 ML/d for extended periods could be very successful at reducing the risk of Mouth closure. However, these options will increase the overall degree of regulation of the Murray System which may have adverse environmental impacts elsewhere. They will also affect the reliability of River Murray water supplies and may have adverse local impacts around the Lower Lakes.

1 INTRODUCTION

The mouth of the River Murray is located near Goolwa in South Australia (Figure 1).

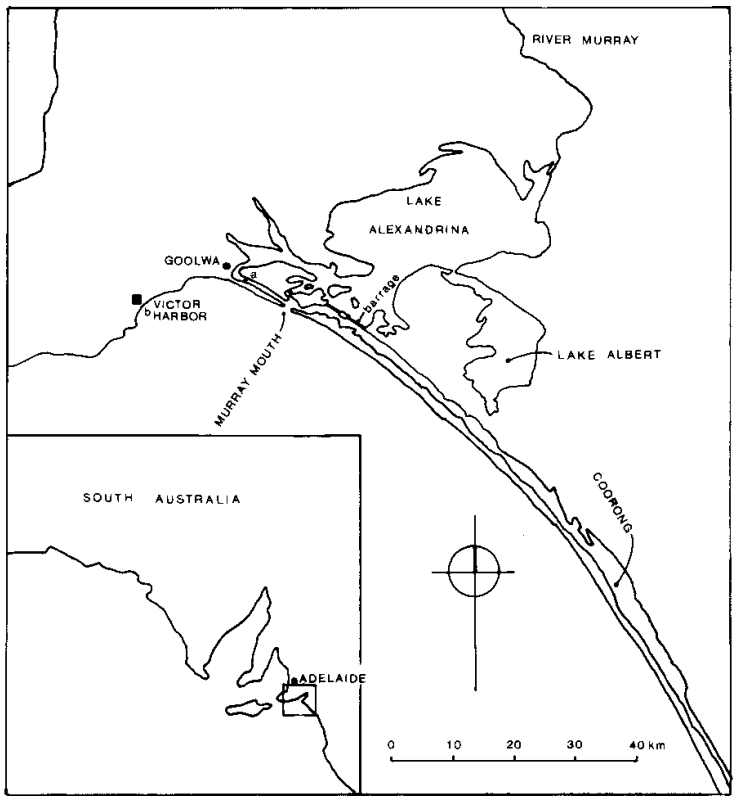

Figure 1. Location of the Murray Mouth

Inside the mouth, a line of barrages maintains a water level of approximately 0.75m AHD in Lakes Alexandrina and Albert and in the Lower River Murray for irrigation and recreation. The barrages also separate the fresh water in the lakes from the sea. At times of low river flow, significant volumes of sand build up inside the mouth which restricts the tidal movement through the mouth. Because of development upstream, periods of low flow are now much more frequent and average outflows over the barrages are now only 39% of the natural outflows prior to development. In April 1981 the mouth completely silted up only opening later in 1981 with the advent of flood flows. In the ensuing years the mouth has been severely silted on several occasions but

has not closed. Because of the possible adverse environmental impacts of mouth closure on the Ramsar-listed Coorong area which lies between the barrages and the mouth, the prevention of the closure of the Mouth is seen as an important goal for the management of the Murray-Darling Basin.

2 DETERMINATION OF FLOW OVER THE BARRAGES

The closest site to the Mouth at which flow in the River Murray is measured is at Lock 1 which is 274 km upstream. Downstream of Lock 1, Lakes Alexandrina and Albert, with a surface area of over 80,000 ha, evaporate an average of 745 GL/year.

Flows over the barrages have been estimated by water balance using the MDBC's Murkey model (Close and Bradshaw 1983). The Murkey Model operates on a monthly time step and models the River Murray from the South Australian Border to the sea. Observed flows to South Australia, historical diversions and rainfall were input to the model and the water balance processes of travel time and loss were determined by calibration. The model was calibrated to the observed flows at Lock 1 and to the observed water levels in Lake Alexandrina. The two parameters determined by calibration were the reach storage to flow relationship, which adjusts the travel time of floods, and the pan factor used to convert pan evaporation to evaporation in the river and lakes, which adjusts losses.

The measurement of water level in Lake Alexandrina is complicated by the effect of wind which causes large variations in water level. To minimise these effects, the water level of the Lake at Goolwa Barrage, Tauwitcherie Barrage and Milang are averaged. The end of month value of this averaged level is determined by averaging the levels on the five days around the end of the month.

Months when all the gates in the barrages were closed have been determined by examination of barrage records since 1962. Figure 2 shows the fraction of

each month that the barrages have been closed since 1962. Over this period the barrages were completely closed 49% of the time. During calibration of the model, lake outflows were set to zero when the Barrages were closed. During months when the barrages are open, water levels in Lake Alexandrina were set to the historically observed levels.

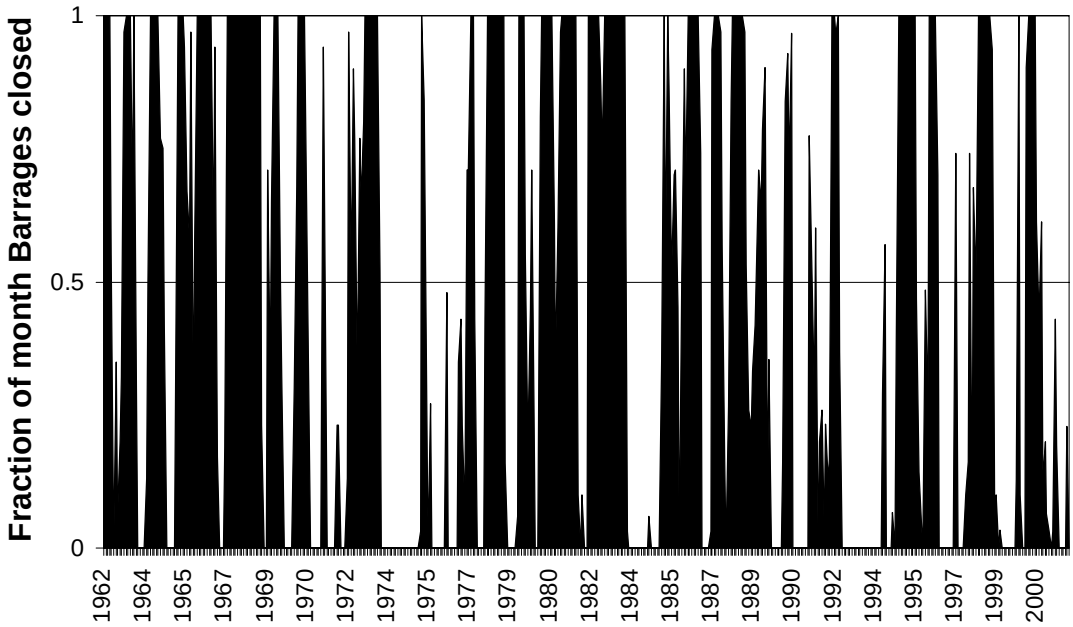

Figure 2. History of Barrage Closure

The Murkey Model was recalibrated as part of this study for the first time since 1983. It was found that a pan factor of 0.81, when applied to the average monthly evaporation at Wellington, Pelican Point and Milang and used in conjunction with the observed rainfall at Tailem Bend gave the best calibration for Lake Alexandrina levels. Figure 3 shows the accuracy of the calibration for lake levels.

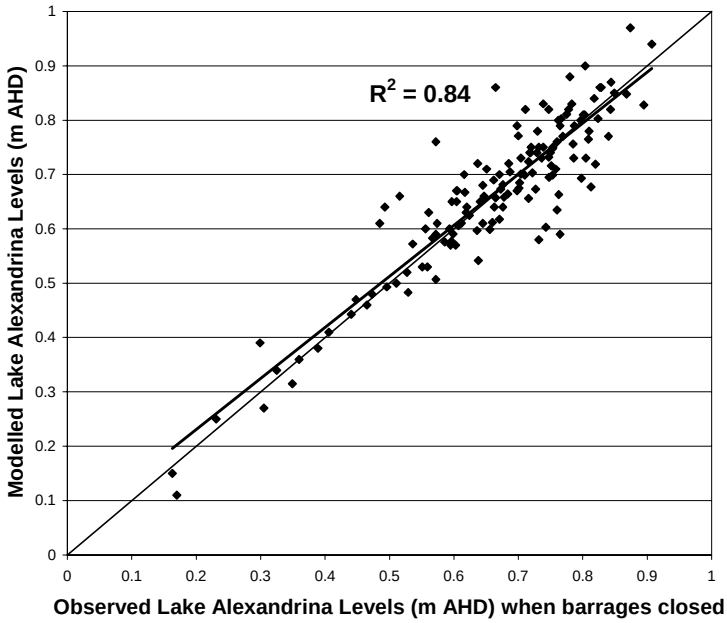

Figure 3. Accuracy of Murkey Model calibration for Lake levels

Figure 4 shows the historical monthly flow over the barrages since 1963 as calculated by the newly calibrated model when the lake levels in the model were set to the observed lake levels.

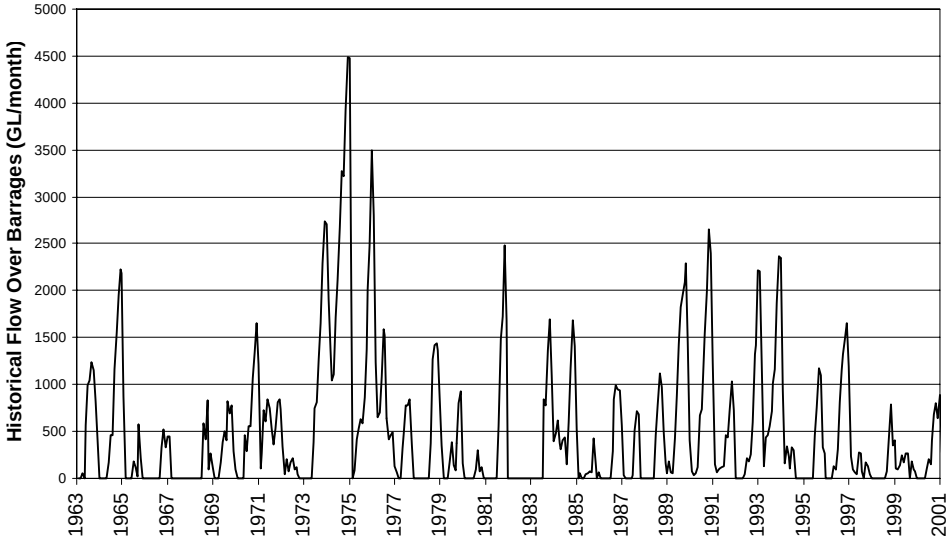

Figure 4. Calculated Historical Monthly Flows over Barrages

3 WALKER MODEL OF MOUTH OPENING

Walker and Jessup (1992) proposed quantifying the opening of the River Murray Mouth by comparing the tidal data downstream of the Goolwa and Tauwitcherie Barrages with the tidal data in the sea outside the Mouth at Victor Harbor. They derived an indicator called the relative tidal energy (R) which was defined as:

$$R = E_{inside}/E_{outside} \quad (1)$$

Where E = tidal energy in 12 hour components at location inside and outside the Mouth.

They modelled the variation of R in terms of the monthly river flow. Walker revised this relationship in 2002. The Walker (2002) relationship for relative tidal energy between Victor Harbor and Goolwa Barrages was developed using Time Series Analysis from data for 1976 to 2000. The relationship is:

$$R_t = 0.80\ R_{t-1} + 0.0002\ F_{t-2} \quad (2)$$

Where R_t = relative tidal energy in month t;

R_{t-1}= relative tidal energy in month t-1;

F_{t-2} = flow two months previously.

The Walker (2002) formula was incorporated into the MDBC Murkey Model to produce a modelled Mouth opening index (MOI) where $MOI = R_t$

This modelled index was used to assess a number of options for modifying the flow regime to reduce the risk of closure of the River Murray Mouth.

Because the Walker Mouth opening model only explains about half (R^2 = 0.46) of the variation in relative tidal energy and because the Mouth has closed only once despite historical periods of low flow, there is no guarantee that the Mouth will close when the MOI is at low levels. It is therefore proposed that the MOI be described as an indicator of the **risk** of Mouth closure. It is proposed that a suitable statistic would be the percentage of years that the minimum MOI for that year was less than 0.05. For this purpose, it is proposed that years ending in September should be used since periods of low flow will typically end before that month. This indicator could then be described as the '**Percentage of years with a risk of Mouth closure'**.

3 COMPARISON OF NATURAL AND CURRENT CONDITIONS

The MDBC's Models have been used to model the natural and current development conditions in the Murray-Darling Basin. The modelled Mouth Opening Index (MOI) corresponding to these conditions is shown in Figure 5 and the frequency distribution of the minimum MOI in each year is shown in Figure 6. These figures indicate that there was negligible risk of Mouth closure under natural conditions and that 31% of years are at risk of Mouth closure under current conditions.

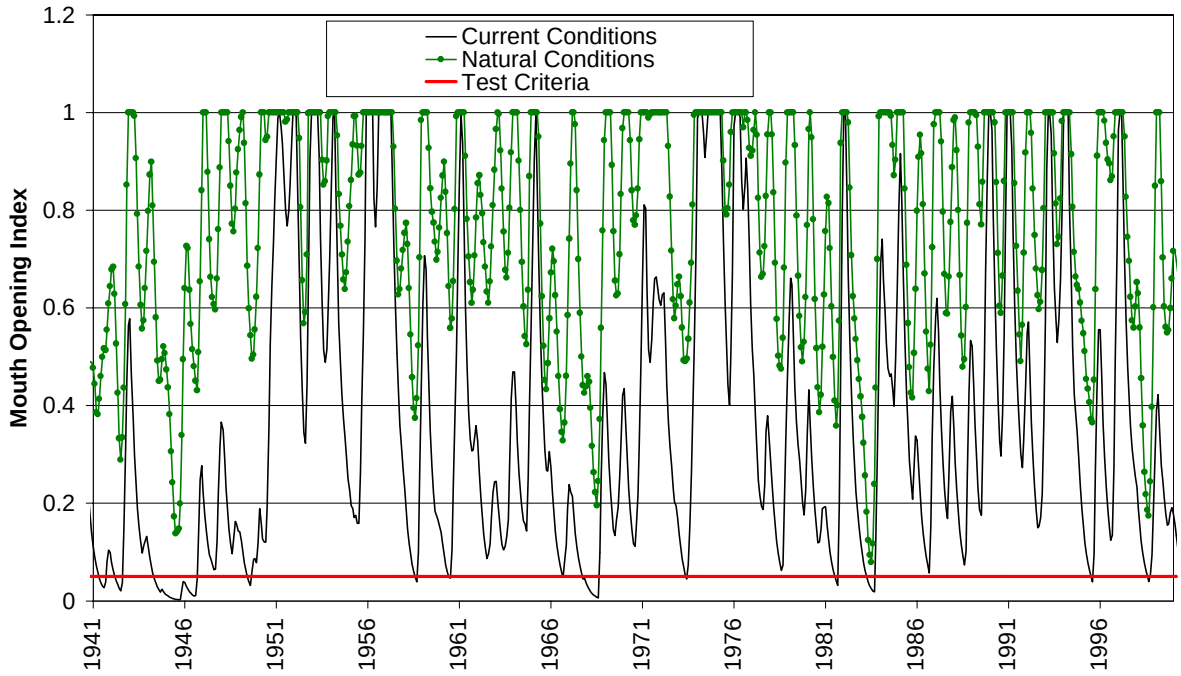

Figure 5. Current and Natural Conditions Mouth Opening

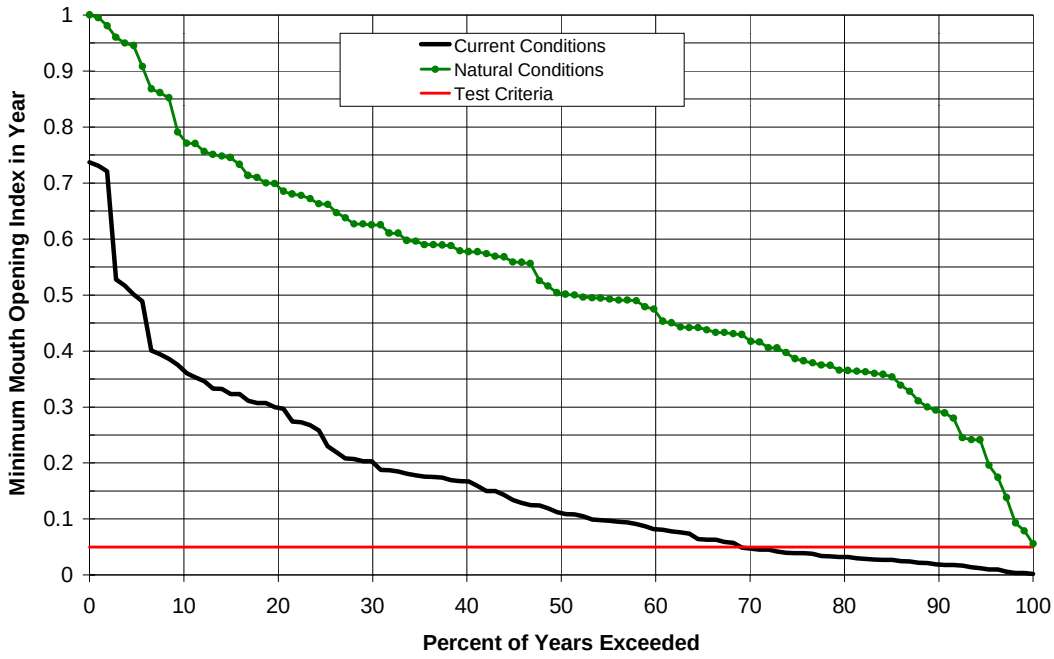

Figure 6. Frequency Distribution of Natural and Current MOI (Annual minimums for year ending in September)

4 FLOW OPTIONS FOR REDUCING THE RISK OF MOUTH CLOSURE

Because the reduction in River Murray flow is the key reason for the increased risk of closure of the Mouth, five options for changing the flow regime to reduce the risk of Mouth closure have been examined:

- Operating the Lower Lakes between 0.9 and 0.6 m AHD to supply 2,000 ML/d over the barrages for as long as possible;

- Increasing South Australia's entitlement flow by 2,000 ML/d in each month (eg from 7,000 ML/d to 9,000ML/d in January) (Note that this option will not increase the flow over the barrages by 2,000 ML/d in every month);

- The combination of a 2,000 ML/d increase in South Australia's entitlement with the operation of the Lower Lakes between 0.9 and 0.6 m AHD to supply 2,000 ML/d over barrages for as long as possible;

- Increasing South Australia's entitlement in September to 20,000 ML/d (The current entitlement flow in September is 4,500 ML/d);

- Reducing the diversion Cap across the Basin by 20%.

The performance of these options is summarised in Table 1 and their impact on the frequency of years at risk of Mouth closure is presented in Figure 7.

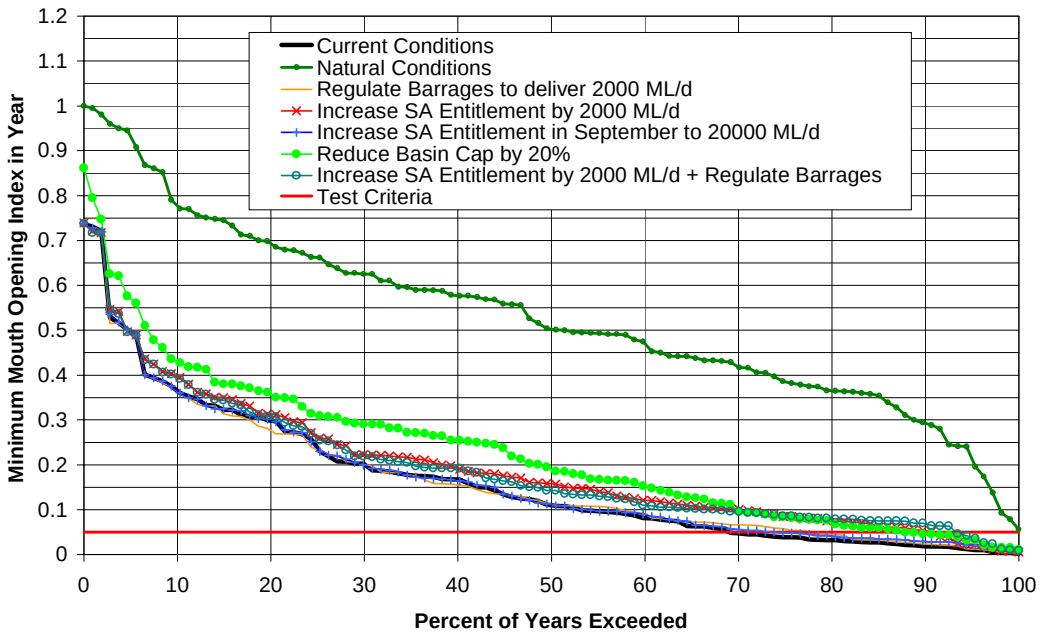

Figure 7. Performance of Options in Reducing Risk of Mouth Closure

Table 1. Performance of Options for Reducing the Risk of Mouth Closure

	Current Conditions Benchmark	Regulate Barrages to deliver 2,000 ML/d as long as possible	Increase SA Entitlement by 2,000 ML/d in each month	SA Entitlement up by 2,000 ML/d plus Regulate Barrages	Increase SA Entitlement to 20,000 ML/d in September	Reduce Basin Diversion Cap by 20 Percent
Run No.	5903	5908	5909	5914	5912	5913
	Absolute	Difference from Current Conditions				
% of years at risk of Mouth closure	31.5	-8.4	-22.2	-24.1	-4.6	-19.5
% of months Barrage ≥ 2000 ML/d	57.0	+17.8	+17.0	+37.9	+0.4	+12.9
Barrage flow (GL/year)	5,079	-10 -0.2%	+161 +3.2%	+147 +2.9%	+89 +1.8%	+1441 +28.4%
Irrigation Diversion (GL/year)	11,130	0 0.0%	-152 -1.4%	-152 -1.4%	-83 -0.7%	-2226 -20.0%
% of years with flow to SA > 80,000 ML/d (re: Chowilla flooding)	12	0	-1	-1	-1	+5
% of months that Lake Level is at 0.9 m AHD (flooding of shore)	1	+47	0	+58	0	0
% of months that Lake Level is less than 0.6 m AHD (impacts on navigation)	12.6	+3.6	-10.2	-9.3	+0.7	-9.9
Minimum Lake Level m AHD [absolute levels m AHD] (impacts on navigation)	0.25	-0.12 [0.13]	-0.15 [0.10]	-0.23 [0.02]	-0.14 [0.11]	+0.21 [0.46]

Impact on Mouth Opening

The results of the modelling indicate that maintaining low flows over the Barrages is sufficient to prevent the complete silting of the Mouth. By substitution in the Walker formula, it can be shown that a flow of 50 GL/month (~ 1650 ML/d) is sufficient to prevent the index from falling below 0.05. This is reflected in the substantial reduction in the risk of Mouth closure for the options which target these low flows both by increasing the entitlement flows to South Australia by 2000 ML/d and by drawing down the level in the Lower Lakes to extend the period with a flow of 2000 ML/d. With both of these options in combination, the percentage of years at risk of Mouth closure can be reduced from 31.5% of years to 7.4% of years.

By comparison, the option of boosting flow to 20,000 ML/d in September is less effective, reducing the years with a risk of Mouth closure from 31.5% to 26.9%.

A reduction in the Basin Cap by 20 % reduces the risk of Mouth closure from 31.5% of years to 12% of years.

Other Impacts of Options

The frequency distributions of Lower Lake levels for the various options are shown in Figure 8.

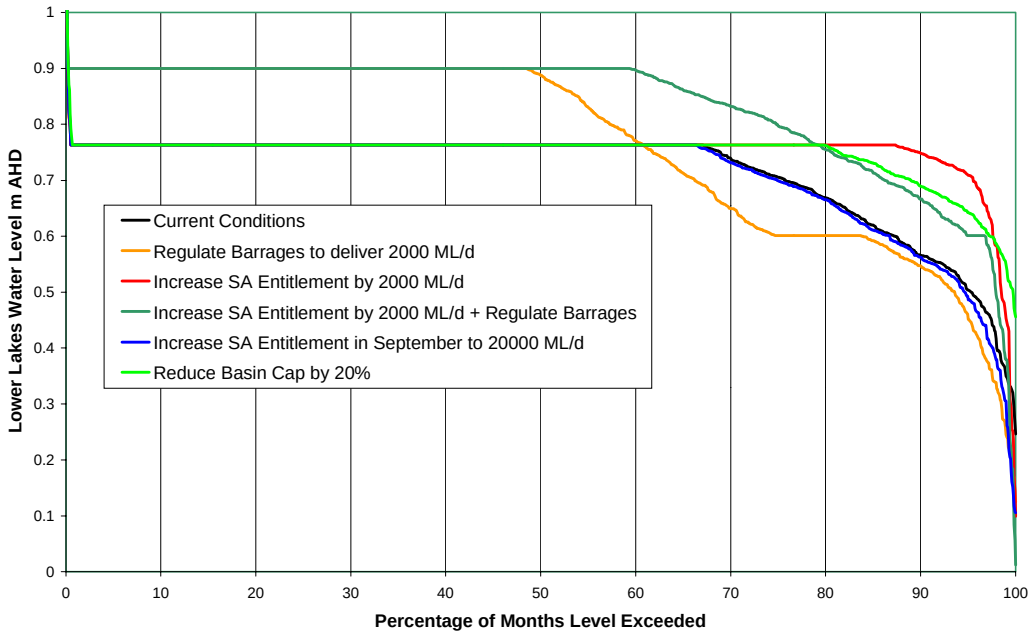

Figure 8. Frequency distribution of Lower Lake levels for each option

The use of the Barrages for regulating outflows has some adverse local impacts. As modelled, the lakes will be held at 0.9 m AHD in readiness to being called on for between 50 and 60% of the time. Erosion and evaporation will both be higher at this level. Barrage regulation also tends to increase the frequency of lake drawdown below 0.6 m AHD. This could affect boating around the lake. It also increases the peak drawdown of the lakes in the extreme droughts.

The provision of extra entitlement flow results in extra draw on Murray-Darling Basin Commission Storages. This results in reduced security to water users in the Murray and more severe periods of water supply restriction. South Australia's entitlement flow is also restricted more heavily in the severe droughts and this results in lower lake levels in the extreme droughts. South Australia's entitlement flow is only a minimum monthly flow. In about 50% of months South Australia receives surplus flow above its entitlement. Changing South Australia's entitlement will not increase flows in these months. Because September often has periods of unregulated tributary inflow, there will be many Septembers when little if any extra release is required to achieve the 20,000 ML/d minimum flow. This is one of the reasons why the large September option has only half the impact on irrigators as a 2,000 ML/d increase in all months. Increasing the entitlement flow increases the draw on storages, reduces spills and hence results in a more regulated river. This is

reflected in the reduced percentage of years with a flow of 80,000 ML/d at Chowilla. There will therefore be some adverse environmental impacts in other parts of the Basin if extra entitlement flow is provided to benefit the Murray Mouth.

The 20% Cap reduction option benefits the Mouth and also provides environmental benefits elsewhere in the Basin. However it has a substantial impact on water users and the economy through the use of 20 % less water.

5 CONCLUSIONS

The MDBC has incorporated the Walker (2002) Mouth opening model in its Murkey Model of the River Murray. This has enabled flow management options for the River to be assessed for their impact on Murray Mouth closure. Modelling natural and current conditions using this model indicates that there was negligible risk of closure under natural conditions but that under current conditions there is a risk of closure in 31.5% of years.

Five options for reducing the risk of closure have been tested:

- Operating the Lower Lakes between 0.9 and 0.6 m AHD to supply 2,000 ML/d over the barrages for as long as possible;
- Increasing South Australia's entitlement flow by 2,000 ML/d in each month (eg from 7,000 ML/d to 9,000ML/d in January) (Note that this option will not increase the flow over the barrages by 2,000 ML/d in every month);
- The combination of a 2,000 ML/d increase in South Australia's entitlement with the operation of the Lower Lakes between 0.9 and 0.6 m AHD to supply 2,000 ML/d over barrages for as long as possible;
- Increasing South Australia's entitlement in September to 20,000 ML/d (The current entitlement flow in September is 4,500 ML/d);
- Reducing the diversion Cap across the Basin by 20%.

Substantial reductions in the risk of Mouth closure can be achieved by maintaining flow through the Mouth more often. A combination of an increase in South Australia's entitlement flow by 2,000 ML/d and the use of the Barrages to maintain a steady release reduces the percentage of years at risk of Mouth closure from 31.5% to 7.4%. However increasing South Australia's entitlement increases the degree of regulation across the rest of the River Murray with consequential adverse environmental impacts and this option also adversely affects the water supply security to water users. Using the Barrages to regulate outflows may also have adverse local impacts.

Providing a larger flow once a year appears to be a less effective strategy for keeping the Mouth open while a 20 percent reduction in the diversions from the Murray-Darling Basin is effective but involves considerable sacrifice by existing water users.

6 REFERENCES

1. Close A.F. and Bradshaw P.L. (1983), *River Murray water Resources Planning Study – Phase 1. The Murkey Computer Model*, Engineering and Water Supply Department Library Reference 83/46, September 1983.

2. Walker, D.J. and Jessup, A. (1992) *Analysis of the Dynamic Aspects of the River Murray Mouth, South Australia*. Journal of Coastal Research, 8(1), 71-76.

3. Walker, D.J. (2002) *The Behaviour and Future of the River Murray Mouth,* Centre for Applied Modelling in Water Engineering, Adelaide University, February 2002.