Australian Government

Government of South Australia

MURRAY**FUTURES**

Lower Lakes & Coorong Recovery

Environmental Water Requirements for the Coorong, Lower Lakes and Murray Mouth

Author's Response to the Peer review

June 2011

WATER FOR GOOD

For further **information please contact:**

Email: cllmm@deh.sa.gov.au

Phone: 0800 226 709 (free call during normal business hours)

Post: Coorong, Lower Lakes and Murray Mouth Program
Department of Environment and Natural Resources
Reply paid 1047
ADELAIDE SA 5001

Website: www.environment.sa.gov.au

Printed on recycled paper
June 2010

Citation

This report should be cited as:

DENR (2011). Environmental Water Requirements for the Coorong, Lower Lakes and Murray Mouth - Author's Response to the Peer review.

Requirements for the Coorong, Lower Lakes and Murray Mouth Author's Response to the Peer review

Department of Environment and Natural Resources
Flinders University
Deakin University
Department for Water

June 2010

Acknowledgements

The development of this environmental water requirement for the CLLMM region has largely been a task of synthesis, and we would like to acknowledge the contribution and sincerely thank the following researchers, managers and institutions:

- those researchers who have contributed as authors to the individual reports that form the body of work that was used to develop this EWR and has been summarised within this report, particularly Ian Webster from the CSIRO for his ongoing willingness to provide access to his hydrodynamic model for the Coorong, and the numerous experts who reviewed the sections on the various sets of indicators (and have been cited explicitly in Lester et al., 2011a);
- the researchers and managers who have contributed their expertise, understanding and data from the region to this process, particularly researchers associated with the CLLAMMecology Research Cluster and/or the monitoring undertaken by the SA Murray-Darling Basin Natural Resource Management Board as a part of The Living Murray initiative;
- those researchers and managers who have contributed their time and expertise to comment on various aspects of this body of work, especially the government reference group who provided guidance throughout the process and those from the Department of Environment and Natural Resources and the Department for Water who provided helpful review comments on earlier drafts of this report; and
- The independent peer reviewers of the reports Professor Ed Maltby and Dr Dugald Black whose input greatly improved the reports as outlined in this report

Finally, a special thank you to Rebecca Langley, Courtney Cummings and Ben Hamilton who provided excellent research assistance throughout this process and contributed to many aspects of the work, particularly the ecological modelling for the Coorong and the development of the indicator sets.

This report was prepared for the South Australian Government by Flinders University, Deakin University, the Department for Water and the Department of Environment and Natural Resources. It supports Securing the Future: A long-term plan for the Coorong, Lower Lakes and Murray Mouth (DEH 2010). The long-term plan is part of the South Australian Government's Murray Futures project, funded by the Australian Government's Water for the Future initiative and the South Australian Government.

Table of Contents

Introduction

The Coorong and Lakes Alexandrina and Albert wetland is one of Australia's most important wetland areas. Designated as a Wetland of International Importance under the Ramsar Convention in 1985, the 142 500 ha site is a complex array of many bioregions and environments including permanent and seasonal freshwater lakes and marshes, streams, estuarine waters, coastal lagoons, intertidal mudflats and forested wetlands.

These wetlands provide habitat for more than 1000 species including many listed under the EPBC Act. In addition to the conservation and environmental significance, the culture and wellbeing of the region's Traditional Owners, the Ngarrindjeri, are directly linked to the health of the Lakes and Coorong. Central to the region's economy is a mix of primary industries, as well as boat building, tourism, and a vibrant commercial and recreational fishing industry.

The Australian and State Governments have allocated more than $186 million in funding to support projects and actions for the region as part of the long-term plan for the CLLMM region which was prepared to ensure the region and its people have a healthy, viable and sustainable future in the context of variable climatic conditions and water resources. A key element of the overall strategy is the determination of the site's Environmental Water Requirements.

For the long-term plan to be effective, securing sufficient environmental flows for the site is a key action. The Department of Environment and Natural Resources commissioned the project team to ascertain the environmental water requirements for the site as a key element of that action.

Following the completion of the initial investigations, the work was provided through the Goyder Institute for an independent and international review of the science underpinning the environmental water requirements of the Coorong, Lower Lakes, and Murray Mouth, as reported in:

- Heneker TM (draft, 2010) Development of flow regimes to manage water quality in the Lower Lakes, South Australia. Department for Water, Government of South Australia. Version received 8 October 2010.
- Lester RE, Fairweather PG and Higham JS (draft, 2010) Determining the Environmental Water Requirements for the Coorong, Lower Lakes and Murray Mouth region: Methods and Findings to date. A report prepared for the South Australian Department of Environment and Natural Resources. Flinders University, Adelaide, Australia. Version received 8 October 2010.

These reports were independently reviewed by Professor Ed Maltby of Liverpool University and Dr Dugald Black of CSIRO Land and Water respectively as part of a larger scientific review by the Goyder Institute of the Murray-Darling Basin Authority's Guide to the Proposed Basin Plan. The report can be found on the Goyder institute website www.goyderinstitute.org.

This report is a compilation of the author's response to these peer reviews and details the changes that resulted and how the comments have been addressed in the revised reports.

- Heneker TM, (2010). Development of Flow Regimes to Manage Water Quality in the Lower Lakes, South Australia, DFW Technical Report 2010/05, Government of South Australia, through Department for Water, Adelaide
- Lester, RE, Fairweather, PG and Higham, JS (eds) (2011) Determining the Environmental Water Requirements for the Coorong, Lower Lakes and Murray Mouth Region. Methods and Findings to date. A report prepared for the South Australian Department of Environment and Natural Resources, Adelaide.

The response by the authors is divided into two parts:

- Part 1: Author's response to the peer review by Dr Dugald Black of the draft report: Development of Flow Regimes to Manage Water Quality in the Lower Lakes, South Australia
- Part 2: Author's response to peer review by Professor Ed Maltby of the draft report: Determining the Environmental Water Requirements for the Coorong, Lower Lakes and Murray Mouth Region: Methods and Findings to Date

The concerns of or suggestions made by the relevant reviewers are reproduced in full in italicised text while the author's response and any actions are listed below this in plain text. The reviews refer to chapters, tables and sections in the draft reports provided for review and as such, in some instances are no longer current.

Part 1: Author's response to the peer review by Dr Dugald Black of the draft report: Development of Flow Regimes to Manage Water Quality in the Lower Lakes, South Australia

Dr Theresa Heneker, Department for Water

The comments and suggested changes to the draft report have been reproduced from Dr Black's review (Maltby and Black, 2011)

Review Criteria used & response

The criteria used in the review were provided by the Department for Water (DFW), relevant to the scope of work to be reviewed as follows:

- *Is the modelling described credible?*
- *Is the foundation of the modelling documented or referenced in sufficient detail?*
- *Is there sufficient reporting against data?*
- *Are the assumptions described in sufficient detail?*
- *Is the scale (temporal and spatial) of analysis considered appropriate?*
- *Are the scenarios (i.e. climate, flow allocations) considered in the analysis appropriate and consistent with the described objectives in the report?*
- *Has the best available data and knowledge been used?*
- *Is the description of the results sufficient and credible?*

Author's response
Only the function of the model, the assumptions used and the results presented were assessed, not the actual models themselves. This was because the models are well established and utilised across the Murray-Darling Basin.

Is the modelling described credible?

Based on the information in the report, overall the modelling is credible.

Author's response
No action required.

Is the foundation of the modelling documented or referenced in sufficient detail?

The foundation of the modelling discussed in Sections 3.1, 3.2 and 3.3 is documented or referenced in sufficient detail.

Author's response
No action required.

Is there sufficient reporting against data?

The evaluation of model performance by comparing model results with observed data is generally sufficient. Reporting on testing of modified flow patterns is also sufficient. However, as discussed further below, the potential sensitivity of the overall

results obtained to the use of the adopted flow-salinity regression relationship, and also to the sequencing of the historical data, may warrant further consideration.

Author's response
Consideration was given to the sequence of the historical data that was used to determine the flow-salinity regression relationship. The discussion of this process has been expanded in the text and is discussed further below.

Are the assumptions described in sufficient detail?

In general, the assumptions and methodology are described sufficiently. However, there are some specific instances where clarification or additional information would be beneficial. For example:

Bottom of page 10: "As flows are set at Lock 1, the desired inflows to Lake Alexandrina are increased by the average daily loss for each month, as will be applied in the model." Should this refer to a decrease in flows between Lock 1 and the lake rather than an increase?

Author's response
Paragraph reworded to clarify assumption. To ensure that the desired inflow to Lake Alexandrina is preserved, the flow at Lock 1 in a given month must set to the required inflow to Lake Alexandrina plus the net loss between Lock 1 and Wellington.

Top of page 12: "For the main river channel between Lock 1 and Wellington, which includes the major pumping stations, no water supply, irrigation or other stock and domestic diversions were applied." Would ignoring these not introduce an error into the modelled volumes of inflows to Lake Alexandrina?

Author's response
Paragraph reworded to clarify assumption. As the flow in each month at Lock 1 was calculated to preserve the required inflow to Lake Alexandrina (given the net loss between Lock 1 and Wellington), assumptions for these diversions were not required. If these diversions had been included, the flow at Lock 1 would have been adjusted to again ensure the preservation of the required inflow to Lake Alexandrina.

Top of page 12: "While these extractions affect the total salt load reaching the lower lakes, the salinity of lake inflows is reset at Wellington using the relationship defined in Section 3.4.4." This comment implies the relationship was used in all salinity modelling, including the work reported in Sections 4.1 and 4.2, and the actual situation could beneficially be clarified.

Author's response
Section 2.2 on model setup was expanded to clarify where both the modified historical (including the flow-salinity relationship) and the standard historical models were used.

Figures 11 and 12: it is not obvious whether these refer to only groundwater salt loads or to total salt loads (from the magnitude of the numbers, it appears they refer to groundwater salt loads).

Author's response

These refer to the groundwater and EMLR salt loads into Lake Alexandrina. The salt load entering Lake Alexandrina from the River Murray is determined in the flow-salinity relationship. The graphs have been reworded to reflect this.

Middle of page 13: "An analysis of the salinity of inflows to Lake Alexandrina from the current conditions model run was undertaken to develop [an] inflow-salinity relationship that could be applied to all inflows at Wellington, thereby preserving the characteristics of salt inflows and removing the influence of any extractions between Lock 1 and Wellington." While the mean may have been preserved, the standard deviation and other characteristics almost certainly will not have been, which may have implications for dependent results and conclusions.

Author's response
The mean of the data within each of the three flow bands for which regression lines were determined is well preserved. It is agreed that the standard deviation is lower for the regression model than for observed data, as is likely for any regression model of this type. However, given the further discussion below, it is not considered to have a significant impact on the results and conclusions. In any case, lake inflows may need to be adjusted based on actual losses and diversions (as stated in the report conclusions) as well inflow salinity that is much higher or lower than that assumed (added to report conclusions).

The variability in the actual flow salinity relationship (Figure 13) is a reflection of where in the Murray-Darling system the water is coming from. For example, during extended low flow periods, inflows are likely to be predominantly very low salinity water originating from Hume and/or Dartmouth Dams whereas during short low flow periods inflows could come from a range of sources with higher salinities, including the Darling River, depending on time of year and other factors. Thus, the use of this regression relationship with extended low flow periods might lead to adverse salinity impacts in the lakes being overstated. Likewise, the benefits of high flows may be understated. However, supporting information did not seem to be available to assess this, such as comparing statistics from applying the regression relationship to an independent period where data is available with the statistics of the available data.

Author's response
This issue was considered and the discussion of the approach has been significantly expanded in the report. Sequences of salinity data from both low and high flow periods across the full dataset were evaluated to determine if the overall variation in inflow salinity was due to separate events, that is, if some events have consistently higher inflow salinities while others have consistently lower salinity. If this was the case, the relationship could be developed to avoid any bias such as an overstatement of adverse salinity impacts during extended low flow periods or an understatement of the benefits of higher flows.

This analysis found that there was no observable pattern between individual high and low flow periods and the associated inflow salinity data for those periods (i.e. individual low flow periods resulted in both high and low inflow salinity entering Lake Alexandrina). Therefore, it was determined that a regression relationship would provide a suitable representation of data. For inflows up to 100,000 ML/day, the salinity data from individual events were scattered around the regression relationship used.

Further, transforming the data may give a different result, perhaps one that is more robust. Use of multiple variables, such as including lagged inflows or lake levels (as a means of capturing recent flow regime history), may also lead to more robust results.

Author's response
Transforming the data did not reduce the scatter significantly to provide the ability to fit a different relationship. Given the analysis above the use of lagged inflows to capture recent flow regime history was not considered necessary. It is not possible to use lake levels as lake salinity is dependent on barrage outflows rather than lake levels i.e. lake salinity can increase significantly over a number of years despite lake level remaining relatively constant if inflows only meet the net loss and do not provide enough barrage discharge to export salt.

Top of page 17 should clearly state whether it is the "Averaged distribution of Lake Alexandrina inflows" or the "Alternative distribution for Lake Alexandrina inflows" which has been adopted, and terminology could beneficially be standardised between the text, Figure 19 and Figures 20-22 to minimise confusion.

Author's response
The "Averaged distribution of Lake Alexandrina inflows" was used and has been clarified in the text.

Sections 4.1 and 4.2: notwithstanding the comments in Section 3.4.4 about resetting the salinity of lake inflows, it appears the analyses in these sections use salinity values taken from standard BigMod results; this could beneficially be clarified.

Author's response
Section 2.2 on model setup was expanded to clarify where both the modified historical (including the flow-salinity relationship) and the standard historical models were used.

Section 4.2: in common with other storages, the salinity "memory" in Lake Alexandrina should be a function of throughflow as a proportion of the storage capacity of the lake (or, in other words, the residence time of the water). If the throughflow rate is large relative to the storage capacity of the lake then the "memory" will be short; if the throughflow rate is small relative to the storage capacity of the lake then the "memory" will be long. The persistence of short and long memory phases will depend on the sequencing of the inflows. In this investigation, the results could be sensitive to the sequencing of the historical data. While the concept of using a multi-year period for management is a good one, it is not immediately obvious why an upper limit of 3 years was chosen, as distinct from, say, 2 years or 4 years (apart from the requirements in the objectives, but where did these come from?).

Author's response
It is agreed that the persistence of short and long memory phases will depend on the sequencing of the inflows and Section 4.2 was undertaken to gain an understanding of this. Once development of the required flow regimes for salinity management commenced, artificial flow sequences with extremes in various sequential combinations were explored to ensure that the salinity requirements could be met irrespective of the annual sequence of flows and the starting salinity conditions. The aim was to find the critical minimum flows that are needed in a given year, linking them with what had occurred in the previous year (high and low inflow). The historical sequence was then used to validate the rules developed.

The results were not considered to be sensitive to the sequence of the historical data used to determine the inflow-salinity relationship as discussed above.

An upper limit of three years was chosen after examination of a range of sequence lengths (up to 10 years). The objectives have been reworded to reflect the actual situation, which was to consider multi-year flow sequences, rather than defining the objective by partially including the resulting sequence lengths determined as critical.

At the end of Section 4.2 it is stated that "it is not appropriate to manage salinity based on a long-term average outflow" and then this is immediately followed by Section 4.3 which is headed "Average annual inflow and barrage outflow requirements". The rationale for including the step described in Section 4.3, in the face of the comment stating the approach is inappropriate, could beneficially be made clearer.

Author's response
While not appropriate for managing salinity, an estimate of the average annual inflow and outflow requirements does provide a guide to the magnitude of throughflow needed to manage salinity. This has been clarified in the text.

In Section 4.3 it is not certain but it appears, from looking at Figures 36-41 and comments in Section 4.4, that in each case investigated a fixed inflow pattern was applied to each year of modelling using one or other of the average patterns adopted on page 17, scaled so that the annual total equalled the required average each year. Historical dates should not be assigned to these results as doing this is misleading. Also, the salinity results would be an artefact of the flow pattern (especially the maximum and minimum) and with a different pattern a different conclusion might be reached. In addition, as Figures 36-41 show time series results and there is presumably some importance attached to these, the rationale for the starting conditions adopted and the influence these might have on the modelled time to equilibrium is not clear. The situation with these points could beneficially be clarified.

Author's response
The fixed inflow pattern and volume was applied to each year to determine the average inflow and outflow required but also to observe how quickly equilibrium was achieved. The results shown are from low salinity starting conditions as these provide some insight into the length of time that the salinity benefit from such high flow events is sustained. Historical dates have been removed from the results. Salinity results were not shown to be significantly dependent on the intra-annual flow pattern, as discussed in Section 3.4.6 of the reviewed report. As such, the maximum and minimum salinities were not an artefact of the intra-annual flow pattern. They are related to the annual flow pattern but this was the purpose of the analysis. A discussion of the starting conditions and the sensitivity to the results has been included in the report.

In Figures 43 and 44, as the time series used are artificial constructs, historical dates should not be assigned to these results as doing this is misleading.

Author's response
Historical dates have been removed from the results.

The work reported in Section 4.5 is a valuable contribution to achieving the objective of delivering flow sequences in a form suitable for an operational model. It should be noted though, that the results could be sensitive to the choice of flow-salinity relationship and the sequencing of the historical data. Also, as there is always the likelihood that the additional water will not be available when it is wanted (discussed in Section 5), comments such as at the bottom of page 62 in relation to Figure 83 that it "shows ... the threshold rules applied in this instance have been successful in managing salinities within the 1200 to 1400 EC range" need qualifying so as not to unreasonably raise expectations.

Author's response
Discussion of flow-salinity relationship has been undertaken as above. The application of the proposed threshold rules shows that salinity can be managed to the corresponding salinity level. Potential water availability doesn't affect the success or otherwise of the proposed rules. The potential availability of water is a separate issue and discussed in the Section 5 and the conclusions.

In Section 4.6.1 it could usefully be clarified whether the salinity data used in obtaining all results reported in this section comes exclusively from the regression relationship or otherwise.

Author's response
This has been clarified in the section on model setup.

Also in Section 4.6.1 the rationale for forcing lake inflows to never fall below 350 GL/y in the Cmid and Cdry scenarios is not obvious. As this is an artificial construct, it could beneficially be made clear that in reality annual inflows could well fall below this value and this eventuality should be managed for. It is uncertain what implications, if any, this might have for the discussion in Section 5 and the conclusions in Section 6.

Author's response
To ensure that the salinity at the major pumping stations downstream of Lock 1 remain below 1400 EC, 896 GL is required to be delivered to South Australia. This 896 GL consists of the minimum entitlement of 696 GL under the MDB Agreement and 201 GL of critical human water needs, which the South Australian Government has committed to providing. This results in 350 GL of inflow to Lake Alexandrina under is the worst case inflow level used in all South Australian drought contingency planning. Hence, it is very unlikely that annual inflow to Lake Alexandrina will fall below 350 GL and for this reason the minimum inflow to Lake Alexandrina was assumed to be 350 GL for all modelling.

Is the scale (temporal and spatial) of the analysis considered appropriate?

The temporal and spatial scales of analysis are considered appropriate.

Author's response
No action required.

Are the scenarios (i.e. climate, flow allocations) considered in the analysis appropriate and consistent with the described objectives in the report?

The climate and water sharing scenarios considered in the analysis are seen to be appropriate for the objectives of the investigation.

Author's response
No action required.

Has the best available data and knowledge been used?

The modelling approach and the data and knowledge underpinning the model are either the same as, or consistent with, that used to underpin implementation of the Basin Salinity Management Strategy and the salinity registers in the Murray River. As such they would represent the best available at the time the work was done (noting that MDBA are continually updating their modelling). The approach adopted for representing climate change scenarios is also the best currently available that is suited to the purposes of this investigation.

Author's response
No action required.

Is the description of the results sufficient and credible?

Subject to the points raised above, the description of the results is sufficient and credible. In particular, the discussion in Section 5 and the conclusions in Section 6 appear sensible based on the information in the report.

Author's response
No action required.

Part 2: Author's response to peer review by Professor Ed Maltby of the draft report: Determining the Environmental Water Requirements for the Coorong, Lower Lakes and Murray Mouth Region: Methods and Findings to Date

Dr Rebecca Lester (Deakin University)
Professor Peter Fairweather (Flinders University)
Jason Higham (DENR)

The comments and suggested changes to the draft report have been reproduced from Professor Maltby's review (Maltby and Black, 2011).

Review Criteria used & response

The criteria used in the review as follows:

1. *Is the report presented in a form such that it fulfils its objectives?*
2. *Is the best available evidence used for deriving indicators and thresholds?*
3. *Are the modelling methodologies described (i.e. hydrodynamic modelling and ecosystem state modelling) appropriate and rigorously executed?*
4. *Are the recommendations and conclusions sound given the evidence-base?*

A full set of assessment criteria can be found in Maltby and Black (2011).

Author's response
No action required.

Overview of the report

By any standards the body of the work represented by the report is exceptional and covers a wide range of studies / reviews at least comparable in quality and comprehensiveness to high profile assessments carried out elsewhere in the world (e.g. Everglades). The project team are to be congratulated on carrying out, reporting and integrating such a complex and wide-ranging set of investigations which is most certainly at the cutting edge of our present understanding. The authors are careful to document where possible the levels of uncertainty with their findings, assumptions in methodology and limitations associated with techniques especially in modelling as well as of data.

The methods and findings presented draw on or are paralleled by other studies found in a wide range of other reports which in their own right are detailed and comprehensive, as well as other sources in the literature. A synthesis of the findings is presented in a separate report. This organisation makes it more difficult to access the outcomes of the research than would be possible in a more integrated document, which could include for example:

- *Executive summary*
- *Summary of key findings*
- *Main text (as is) with clear highlighted pathways in RH margin to other reports*
- *Use of boxes to indicate key finding(s), distilling the complexity and emphasising 'so what?'*

Author's response

The exact format of the report will depend on how the report is to be used and who will use it. It is advised to decide on the precise target audience(s) before finalising the shape of the document.

Prof. Maltby suggested altering the layout of:

- Executive summary
- Summary of key findings
- Main text (as is) with clear highlighted pathways in right-hand margin to other reports
- Use of boxes to indicate key finding(s)

The layout of the report has been edited as suggested with the exception of the highlighted pathways in the right-hand margin. Instead, most of the information previously contained in other reports (with the exception of Heneker 2010) have now been included in Lester *et al.* (2011) for ease of access, and the number of cross-references within and between documents has been increased.

Decide on an exact format for the final report, dependent on the target audience.

Author's response
We have decided to leave the layout of the report to the technical staff at DENR who will be producing the report for release. We have added an executive summary and summary of key findings though.

Presentation

Report organisation

The report summarises the methodologies used to provide guidance on the environmental water requirements for the CLLMM region. A clear short executive summary using boxes to highlight the objectives (and methods) and bullet points to emphasise the key findings (conclusions) would have an immediate impact to the readership and help in navigation through the report.

Author's response
A short executive summary has been included to emphasise key findings, as well as a specific list of key findings. The use of marginal boxes has been left to the DENR production team.

Clear pointers to other documents in the margin rather than the body of the text would help in making the important links to evidence / sources.

Author's response
We have tried several ways to insert pointers of this type in the document and found it difficult to do so without duplication given that other reports are cited. We have decided to leave this idea to the technical staff at DENR who will do the layout for the release of the report.

Objectives

A bold set of stated objectives would help set the tone for the report.

Author's response
A statement of the report's objective is included, as well as a key summary point in the Introduction.

A reminder of the impressive set of qualifying criteria under Ramsar would also be useful.

Author's response
A statement to that effect has been added.

It might be helpful to review the cautionary remarks regarding the constraints to the report (page 8).

Author's response
The cautionary remarks have been reviewed and additional comment made regarding the limitations of the modelling tools used.

It is counter-intuitive to dismiss the need for recovery from the present degraded condition especially in the light of the 2005 revision of the definition of 'desired ecological character' under the Ramsar Convention to '..... at a given point'. Phillips and Muller (2006) discuss the views on the 'desired' condition including the position of the local indigenous people and long-term stakeholders which advocate an improvement of the 1985 situation existing at the time of Ramsar listing. This would be both logical and credible in ecological terms (assuming capability within the current/anticipated future hydrological envelope).

Author's response
This comment has been addressed. While we certainly believe that securing an environmental water requirement for the region is one action to assist in the recovery of ecological character in the region, it may not be the only action necessary. Targeted management interventions may be needed to recover one or more aspects of ecological character from the current severely-degraded condition, and it is beyond the scope of this report to explore any such additional management actions in detail. They will be dealt with separately by DENR.

It would be useful if the authors could indicate more positively how their work to date and /or future modifications could be used to define a different (improved) 'desired' ecological character.

Author's response
Changed as requested.

Supporting evidence
There is a wealth of evidence to support the report but it is highly dispersed among numerous reports. It is not possible to integrate it all within the body of this report but essential to make the links easier to identify and follow if required. This could be more easily done by reference in boxes in the right-hand margin.

Author's response
See comment above regarding marginal text boxes.

It would be useful to comment more specifically on the level of uncertainty associated with data. This is particularly important where data are original empirical time or spatially limited or where inputs to a model may be outputs from another.

Author's response
Changed as requested.

There is clear recognition of the need for further research especially in relation to the effects of climate change, interactions between inflows from the Murray with other sources and the effects of other management actions in relation to water diversion, the refinement of indicator sets and the setting of limits of acceptable change to enable assessment of success in meeting objectives.

Author's response
The draft report includes additional investigations to examine the implications of delivering less water to the site and an exploration of the interaction between barrage flows and the Upper South-East Drainage scheme (USED). Further work is envisaged utilising the indicator sets to set appropriate limits of acceptable change that enable assessment of success in meeting objectives

Reference to other contributions in the field
Generally excellent reference is made throughout the supporting documentation to the directly relevant literature supporting the reviews and technical aspects of modelling. There is a gap in the referencing of other approach from the literature such as the Building Block Methodology developed in South Africa but also trialled in Australia (e.g. Arthington & Long, 1997; Arthington, 1998). A useful summary of different approaches, techniques and case study examples is given by Acreman & King in Dyson et al (2003). It would certainly strengthen the choice of approach adopted in the present work to develop a succinct synthesis table from international experiences which summarised the advantages and limitations of different approaches in relation to different management / flow objectives to reinforce the logic of the framework adopted here. There is also considerable research expertise / experience in Australia on determination of environmental flows which could help set the context for the approach developed here, necessary because of the special conditions of CUMM.

Author's response
A table summarising some other approaches has been added to the report. Text has also been added illustrating the various strengths and limitations of these approaches as suggested.

Methodology
What is outlined on page 9 as a proposed methodology reads more like aims and the link to achieving the overall outcome of a 'healthy, resilient wetland of international importance' not sufficiently explicit. A wide range of individual techniques comprises the methodological framework for the study. The rationale behind the choice of method, analysis or interpretation is given comprehensively throughout the report and accompanying documentation. There may be other feasible approaches (which could be related to the review indicated in the previous section) but there is no reason to doubt the methodology actually used.

Author's response

The summary of the methodology has been edited to read much less like aims. The summary figure illustrating the links among the various methodological steps has been updated to specifically include the overall outcome. We have also edited the text to highlight this link more obviously.

Indicator sets and tolerances

One of the features of the present study which takes it beyond most previous examples is that it is attempting to define flows for a complex mix of species, processes and conditions rather than, for example, a single species – often this might be a fish or a bird population. It breaks down the broad objective of a 'healthy, resilient wetland' into practical objective elements.

The criteria for inclusion of species (keystone, canary, threatened) are sound and the choice of characteristics (water quality, flow regime, connectivity, water level) permitted the identification of thresholds that could be related directly to the hydrological regime.

A figure would be beneficial in summarising more clearly the 5 process steps described from sections 3.2 to 3.7 There is a clear statement of species objectives, a substantiated rationale and indication of anticipated outcomes whilst all not necessarily always attainable are all nevertheless supported by reference to the literature.

Author's response

A figure has been added, as suggested, to clearly summarise the five process steps described. The headings for the sections following this figure have also been colour-coded to further clarify this.

Indicator sets

An impressive number of indicators have been assembled under different groups: vegetation, fish, macroinvertebrates as well as ecological processes. This is arguably the most comprehensive attempt to link hydrology to the 'whole' system as opposed to a specific component or limited combination of elements. Such a comprehensive list, however, undoubtedly masks considerable variation in the availability, quality and spatial extent of information. This could be covered by either a general qualifying comment or some indication of the variation that could exist in the interpretation of ticks or other symbols in the summary outcomes table.

Author's response

A general qualifying comment has been added to indicate the variability of the availability, quality and spatial extent of information used.

The objectives, outcomes selected and indicators all appear reasonable. Most debate is likely to surround the strength of the evidence base from the individual ecological processes selected and commentary on this aspect could be usefully strengthened especially in relation to the specification of thresholds. It is perhaps surprising but certainly noteworthy for future considerations and infrastructure that the authors found vegetation indicators not to useful primary indicators. In the case of fish there are significant gaps in knowledge.

Author's response

It has now been clarified that we did not really use these for the thresholds because there was not currently enough data, but that we think it has potential for future management. Vegetation indicators have been reviewed in conjunction with a recognised expert in the field to better articulate the linkages between vegetation indicators and outcomes and therefore their utility as primary indicators. All other indicators were also reviewed and additional information included. Knowledge gaps were explicitly identified and included in the tables.

Critical thresholds

There is clear acknowledgement of the limited and variable information on thresholds and especially in relation to the potential (but generally unknown) effects of interaction of stresses causing significant variation in threshold levels. The tabular representation of tolerances associated with the indicators in table 5.5 – 5.7 are appropriate but it should be better explained how these work as 'trade-off' tables. It is impossible to judge whether the indicators and their tolerances have drawn on the best available data and knowledge without interrogating all original sources. However, judging from the general quality of citation, interpretive and precautionary guidance given, there is no reason to doubt the integrity of the information used. This is explained generally in section 5.6 – 5.8 and the key limitations particularly well emphasised in 5.8.3

Tabulation of the specific relationships between macro-invertebrate indicator species and outcomes is also supported by a note of knowledge gaps. Categorisation across freshwater, estuarine / marine and hyper-saline habitats underlines the potential universality of using macro-invertebrates but the authors caution against their unqualified and non-discriminatory use because of limitations of the knowledge base.

Author's response

An example of how to read the trade-off tables has been added to the appendix of the report to demonstrate how the tolerances associated with the indicators have been shown.

The inclusion of ecological processes for consideration as indicators is ground-breaking. Their capacity to integrate responses across multiple species, relative ease of measurement and direct indication of change / impact are powerful arguments. Unfortunately there is still a lack of data-base and limited understanding of the links between process and outcome which restricts more general application. The limitation could be usefully addressed in further qualification of the 'ticked' boxes in table 7.23 (though the more detailed text following, broadly covers this). Inclusion of colonisation by invasive species is significant and underlines the potential for major (and often unforeseen) switches in ecological character.

Author's response

Qualification of the lack of an available database and limited understanding of the links between process and outcome has been detailed within the introduction sections for each of the individual processes.

Hydrodynamic model

The fundamental features of the modelling is summarised and reference made to the greater detail shown elsewhere. Its spatial structure is given, connectedness and drivers explained. Explanation is given of model calibration against the continuously-

changing elevation of the bed of the Murray Mouth channel and other fixed parameters. The experience of calibration and model testing is used to indicate the high credibility of the model in simulating the response of the system in both salinity and water level. The authors are careful, however, to indicate potential sources of error and uncertainty. It would be useful to indicate the overall assumptions and limitations of the model more precisely and specifically e.g. in a box.

Author's response
Box 10.1 has been added to clearly summaries the structure, assumptions and limitations of the model.

The spatial scale of analysis is clear but the temporal scale needs to be made more specific.

Author's response
A comment verifying the temporal scale of analysis for the hydrodynamic model has been included.

Application
The conceptual basis of the model takes account of the special configuration of the Coorong (e.g. as an 'inverse' estuary) and including, also, water control structures. The 19 scenarios selected covered a range of flow and climate conditions which would seem reasonable in the context of the report's objectives. The scenarios are dependent on the output from climate change projections made from other sources. There is a risk that the resulting forecasts may prove wide of the mark. It is not possible for the reviewer to comment on the likelihood or not of this but it would be useful to include a brief commentary on the possible implications of the hydrodynamic model prediction if the possible climates selected should prove inappropriate or inaccurately determined.

Author's response
A paragraph as been added regarding the potential implications of the climate scenarios being inaccurate on the predicted effects on the hydrodynamics of the Coorong.

The authors could strengthen their position by indicating more precisely the rationale for the particular range of scenarios and the data / climate model outputs from other sources that determined their choice.

Author's response
An explanation for the range of scenarios included has been added.

Readers external to Australia would benefit from explanation of the 114 year run period.

Author's response
A fuller explanation for the 114-year run period has been added.

The actual scenario descriptions and underlying assumptions are clear. The results are described with the help of diagrams. Interpretation deals with numerous interactions and comparisons between scenarios. It would enhance the impact of the report if the most salient points emerging from the results could be highlighted as a set of bold statements. This would also be useful for the analyses relating to the

effects of adjusting timing of flow delivery and climate change; effect of constant environmental flow delivery; effects of rules-based environmental flow delivery (and under climate change).

Author's response
A summary of the key findings has been added to each chapter. The summary for this chapter highlights the points suggested by Professor Maltby.

There is a technically sound discussion of the outcomes but an orientated summary of the question 'so what?' could help in the evaluation of the strength of the science/evidence-base.

Author's response
The final point in the summary of key findings addresses the 'so what' question for this modelling work.

Ecosystem state model
Determination of the most probable mix of ecosystem states that will be supported by a particular flow regime is arguably the most important and technically challenging part of the work. This stems at least in part because of the non-linear relationships in the ecosystem but also because of imperfect or unavailable knowledge. Because of this the decision to develop a statistical model is entirely reasonable. Limited detail of the actual model is give but reference is provided to its source. It would strengthen the credibility of this section if a box was inserted which distilled the model's foundation, assumptions and limitations.

Author's response
This has been added in, as Box 11.2.

The authors explain the particular issue of the model's inability to correctly predict recovery of the ecosystem, constrained by its development using 1999 – 2007 data (when the system was deteriorating). A more positive message could be given that indicated how the model could be used with the benefit of new data in response to the flow changes resulting from the break of the recent drought period and / or the effects of a new environmental flow regime.

Author's response
This has been changed as suggested.

In the descriptions of the results it would be useful to identify summary key points (for example in the right hand margin). These would be picked up in the following discussions.

Author's response
A summary section has been added, describing the major findings. See above regarding right-hand marginal formatting.

For example confirmation of the links between hydrodynamics and ecology is certainly re-assuring (and fundamental to the rationale of the whole overarching objective) but to what extent could this be the result of interaction with the data sets rather than of independently determined variables?

Author's response

This comment has been addressed. It is unlikely that the interaction of data sets would produce this result, as the potential pool of predictive variables included many factors other than just the hydrodynamics of the region (e.g. water quality and meteorology).

The description of actual states is found in a separate report. Whilst this is referenced it would be helpful to have a box here which summarised the individual categories indicating in particular the basis on which they were considered unhealthy or healthy.

Author's response
Box 11.1 describing the individual states, indicating the basis on which they were considered healthy or unhealthy has been added as suggested.

Conclusions / Recommendations

The conclusions relate specifically to the Coorong, but acknowledging the links to conditions in the Lakes. Rather than a simple reference to the reports of Muller and Heneker it would help for completeness to distil key relevant points from those reports in a marginal box for example.

Author's response
Key findings from Heneker (2010) have been included in the executive summary and expanded upon in the synthesis report. A final version of Heneker (2010) will be released concurrently with this work. All work by Muller has been incorporated into the document.

Objectives are identified which are not explicitly identified at the outset or the report viz:

1. *avoiding ecological degradation in the Coorong and ensuring sufficient flow to maintain an open Murray Mouth without the need for dredging (in 95% of years);*
2. *achieving high-flow conditions critical for the long-term health of an estuarine system.*

These are surely better expressed as 'target conditions'.

Author's response
These targets have been included at the commencement of the discussion of the ecosystem states model. They have been changed to be termed target conditions.

In any case they should refer back to the context of 'desired' ecological character and assess specifically in relation to the important debate as to whether this should be the 1985 or some other condition.

Author's response
The targets have been set in the context of the desired ecological character and the advisability of using 1985 as a benchmark.

Two methods were used to determine the minimum flow requirements of the Coorong – one which linked the proportion of the degraded ecosystem states to different flow volumes (based on the alternative ecosystem states model) and a

second based on models of future degraded ecosystem states (based on the original ecosystem states model).

In the first case the authors caution that their analysis will likely underestimate the proportion of degraded ecosystem and that there is further work required to correct for this in the determination of the recorded minimum flows. Their estimates are based on the likely percentage of the Coorong falling into degraded ecosystem states. This provides a useful basis for decision-making based on the level/degree of desired outcome.

The summary flow requirements are clearly stated (and substantiated from the previous evidence/linked reports cited) for an historical flow-delivery and a modified flow-delivery pattern both under any climate. The recommendations specify temporal as well volume considerations. The report emphasises further the important effects that can result from the actual timing and distribution of flow delivery. The summary findings for minimum flow requirement and linkage to the minimum requirements to maintain a maximum salinity in Lake Alexandria appear reasonable and evidence-based.

Slightly different requirements result from the second approach assuming that flow delivery can be optimised and based on a model threshold for average south lagoon salinity. The resulting overall recommendations are strengthened by the dual approach and the cautionary remarks qualifying their use.

Author's response
No action required.

The authors urge the need for further analysis to improve the reliability of flow requirements. This will always be true but in this case is particularly relevant. The region has just experienced a major break in drought conditions and the likelihood is that the previously degraded ecosystems of the CLLMM may now experience a new trajectory of ecological recovery. This emphasises the need for new monitoring and assessment data to feed into the modelling work to continue the refinement of the estimated environmental flow requirements.

Author's response
A monitoring framework for the site is being developed partly based on the indicator and threshold information identified in this report, together with additional knowledge gained regarding soil and water in the region for submission to the Australian Government for funding under the Murray Futures program. Funding has also been requested regarding the further development of an improved ecosystem response forecasting tool to assist in the refinement of environment flow requirements and management of the site.

Additional changes made by the authors

Additional EWR-related work previously done has been incorporated into the combined report, including the vegetation and fish indicators and the lake levels, to make this single document more accessible.

Summaries have been created to emphasise the key messages after each chapter.

To further integrate the two reports, cross-referencing has been augmented in lieu of right-hand margins. See above regarding right-hand marginal formatting.

Discussion

The final reports benefited substantially from the peer review process allowing the authors to clarify previously-implicit explanations, include additional information and improve the presentation, accessibility and intelligibility of the reports and their findings as outlined in the authors' responses.

References

Heneker TM, (2010). Development of Flow Regimes to Manage Water Quality in the Lower Lakes, South Australia, DFW Technical Report 2010/05, Government of South Australia, through Department for Water, Adelaide

Lester, RE, Fairweather, PG and Higham, JS (eds) (2011) Determining the Environmental Water Requirements for the Coorong, Lower Lakes and Murray Mouth Region. Methods and Findings to date. A report prepared for the South Australian Department of Environment and Natural Resources, Adelaide.

Maltby E and Black D (2011) Synthesis review of the science underpinning the environmental water requirements of the Coorong, Lower Lakes, and Murray Mouth. Goyder Institute for Water Research, Adelaide.

Government of
South Australia