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Science Review of the Estimation of an Environmentally Sustainable Level of Take for the Murray-Darling Basin

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Description: Vegetation 296 km from the Murray Mouth, above Lock 1 near Murbpook Lagoon, SA. September 2007
Photographer: Greg Rinder

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ACKNOWLEDGMENTS

CSIRO was commissioned by the Murray-Darling Basin Authority (MDBA) to undertake this science review. CSIRO brought together a review team representing leading relevant expertise from across the national innovation system. CSIRO thanks the panel members and their respective institutions for contributing at short notice to this important work.

The review team relied on the MDBA for access to documents, provision of briefings and for organising various meetings and interviews. Jody Swirepik, MDBA Executive Director, Natural Resource Management, provided oversight to the review process and acted as liaison with the MDBA Chief Executive, the Chair of the MDBA Board and other Board members. Several officers from MDBA provided helpful briefings and supporting information. The panel thanks all the MDBA officers who supported the review process.

The review was funded by MDBA on a cost-recovery basis.

DISCLOSURES

The authors have strived to provide a fully independent review guided by strong professional and ethical standards. The authors all have long experience in water-related science in the Murray-Darling Basin. This being the case, it is inevitable that they have associations with the MDBA and past associations with the former Murray-Darling Basin Commission. Below, for each of the review panel members, are details of their institutional affiliations and their current and recent relevant relationships with MDBA and other organisations involved in research relevant to the Murray-Darling Basin Plan.

Dr Bill Young (Review Chair) is Director for the CSIRO Water for a Healthy Country National Research Flagship. CSIRO has received funding from MDBA for several projects related to the development of the Basin Plan. CSIRO made a submission on the *Guide to the Proposed Basin Plan*. Dr Young is a member of the Board of the Goyder Institute for Water Research in South Australia; the Goyder Institute has published reports describing assessments of the adequacy of the scenarios described in the *Guide to the Proposed Basin Plan* for meeting the environmental objectives of the South Australian Government. Dr Young was seconded from CSIRO to MDBA from March 2009 until May 2010 as Director, Basin Plan Modelling; in this role he lead the early development of the river modelling work for the Basin Plan, some of which (albeit much progressed) is considered by this review. He led the preparation of some of technical reports documenting the hydrologic modelling work. Dr Young was also the Project Leader for the CSIRO Murray-Darling Basin Sustainable Yields Project from late 2006 to mid-2008; this project provided important underpinning hydrologic assessments (especially on the likely impacts of future climate change) and developed the integrated hydrologic modelling system used to guide development of the Basin Plan. Dr Young was a member of the MDB Living Murray Scientific Reference Panel (2001–03 and 2006–07).

Dr Nick Bond is a Senior Research Fellow at Griffith University. Prior to this Dr Bond was a Senior Research Fellow at Monash University and a program leader in the eWater CRC. Dr Bond was involved in an earlier review of the proposed methodology for “determining the environmentally sustainable level of take” as part of the Basin Plan development process. This earlier review is published on the MDBA website. Dr Bond was also involved in a peer review of the Native Fish Strategy for the MBDA in 2009. In 2010 Dr Bond collaborated on a project examining the impacts of climate change on aquatic ecosystems in the MDBA led by Griffith University and a project on ecosystem responses to water regimes in Hattah Lakes being undertaken for the MDBA by the eWater CRC.

Dr Justin Brookes is Director of the Water Research Centre at the University of Adelaide. Dr Brookes has received funding from the MDBA for intervention monitoring and reviewed reports for condition monitoring for the MDBA (administered through South Australian government agencies). He led the CLLAMMEcology Cluster (funded by CSIRO) that provided scientific knowledge to inform environmental planning and management for the Coorong. He has had no prior involvement in the development of the Basin Plan.

Dr Ben Gawne is Director of the Murray-Darling Freshwater Research Centre – an incorporated joint venture between CSIRO, La Trobe University and MDBA. In addition to providing core funding, MDBA has contracted MDRFC to undertake numerous projects in recent years, some related to the development of the Basin Plan. In particular Dr Gawne led a review of river condition for the MDBA that was published in 2011.

Prof Gary Jones is Chief Executive of eWater Cooperative Research Centre and a professor at the University of Canberra. MDBA is a partner in eWater CRC and provides funding to support its research, model development and adoption activities. eWater CRC has used Living Murray Icon Sites (primarily Hattah Lakes) for trialling its ecological modelling tools. Professor Jones led the MDB Living Murray Scientific Panel (2001–04) and was a member of the earlier 1999-2000 expert panel investigation of the River Murray (Thoms et al, 2000). Prior to this review has had no involvement in the development of the Basin Plan.

EXECUTIVE SUMMARY

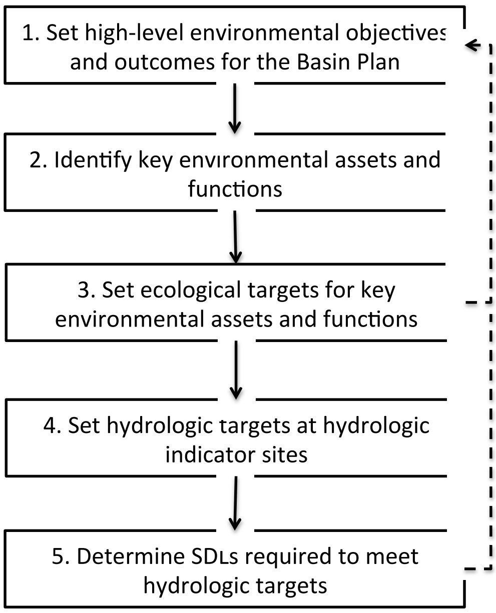
Under the *Water Act (2007)* the Murray-Darling Basin Authority (MDBA) is required to prepare a Basin Plan on the basis of best available scientific knowledge and socio economic analysis. The Plan is required to establish environmentally sustainable limits on water diversions.

In June 2011 MBDA invited CSIRO to lead a review of parts of the information base and analyses used by MDBA to determine an environmentally sustainable level of take (ESLT) for surface water and thus establish proposed sustainable diversion limits (SDLs). The review was limited to a consideration of the environmental and hydrologic science, modelling and analyses used by MDBA. CSIRO assembled a team of leading Australian water scientists from several institutions to undertake the review.

This review builds on previous reviews of individual components of the technical methods undertaken prior to the release of the Guide to the Proposed Basin Plan. The review considers recent refinements to the methods and their combined application in guiding the preparation of the proposed Basin Plan. The review was conducted from July 2011 to October 2011 in response to documents and information provided progressively by MDBA.

The review was based on a consideration of (i) published reports from MDBA and consultants to the MDBA, (ii) unpublished and incomplete MDBA reports, (iii) iterations of unpublished tabular and graphical summaries of modelling results and (iv) interactive discussions with MDBA staff regarding methods and assumptions. A listing of the reports considered – both published and unpublished – is provided in an appendix to this report.

The terms of reference for the review required the articulation of a conceptual framework that captures the mains steps in the process of SDL determination. A comprehensive framework was developed and is included in this report, but the simplified version below encapsulates the overall process. This sequence of steps is used to structure aspects of this review. Recommendations are made for how MDBA can strengthen the elements of work within the last four steps of this framework.



Important caveats on the comprehensiveness of this review against the terms of reference are (i) that at the time of the review the documentation to describe the large body of technical work was incomplete, and (ii) a comprehensive synthesis of the modelling results against targets and objectives was not available for consideration by the panel.

The original terms of reference for the review were focussed on nine specific questions that frame an assessment of the ESLT method and its implementation. The initial assessment against these questions was presented to MDBA in an Interim Report in September 2011. In response to this report MDBA broadened the terms of reference to include three more general questions seeking an assessment of the sufficiency of the work undertaken.

Summary assessments against the three “questions of sufficiency” are presented below, followed by summary assessments against the nine more specific questions from the original terms of reference. Finally, recommendations for short-term work that is considered critical to support effective consultation around the proposed Basin Plan are summarised. Recommendations for medium and longer-term work are made in the body of the report.

Questions of Sufficiency

Overall, is the body of science sufficient to make an informed decision on an environmentally sustainable level of take for the Basin?

Given the knowledge derived from over thirty years of Australian water research, and in the context of an adaptive management framework being adopted for the implementation of the Basin Plan, there is sufficient scientific knowledge to make an informed decision on an ecologically sustainable level of take.

Are the methods adopted fit for purpose?

In the context of an adaptive process for managing the level of take in the Basin the methods adopted are considered fit for purpose. In line with this adaptive approach recommendations are given in the report on how to improve the methods over the short, medium and long term.

Does the body of work undertaken represent a sufficient basis to begin an adaptive management process around the level of take in the Basin?

The body of work that has been undertaken is substantial and is considered to represent a sufficient basis to begin an adaptive management process around the level of take. At the time of the review the technical documentation of this body of work was incomplete.

Original Specific Questions

The review findings against the nine questions in the original terms of reference are summarised below. These questions focus on the scientific robustness of the hydrologic and environmental aspects of the ESLT method and its implementation to determine surface water SDLs.

We stress however, that determination of the magnitude of the ESLT and thus SDLs involves consideration not only of environmental objectives but also of social and economic objectives for the Basin Plan. Determining this balance across objectives requires policy judgments made in the context of the requirements of the *Water Act* and reflecting multiple trade-off decisions. Consideration of the social and economic dimensions of ESLT determination is outside the terms of reference of the review.

Foundation Information

Has the best available scientific information been accessed?

MDBA has accessed much of the existing relevant formal scientific information. MDBA could have accessed additional scientific information that would have strengthened the scientific basis of the proposed Basin Plan. There is no evidence however, that this would have materially changed the magnitude of the proposed ESLT and SDLs.

Because of limited formal scientific knowledge to guide environmental water planning, expert opinion remains an important component of best available scientific information. MDBA has made limited use of expert scientific opinion in developing the proposed Basin Plan.

Have the best available hydrologic and environmental models been used?

The best available hydrologic models for the Murray-Darling Basin have been used enabling integrated Basin-wide modelling of water sharing scenarios. For the Coorong, the best available hydrodynamic model has been used together with a simple ecosystem state model.

MDBA has made limited use of available floodplain inundation models, and other than for the Coorong, has not used available ecological response models. As a part of an adaptive approach, broader application of, and improvements to, such models would both reduce ESLT uncertainty and provide a more comprehensive description of the expected ecological outcomes from the Basin Plan.

Interpretations and Assumptions

Has the use of scientific information been consistent and defensible?

The use that MDBA has made of individual items of scientific information is defensible. The use that MDBA has made of the collected body of scientific information is not fully consistent because of the absence of a clear over-arching conceptual ecological model linking site-based KEA and KEF assessments to regional and Basin-scale ecological condition and flow regime change.

To-date the work lacks a biophysical classification able to demonstrate that the iKEA and KEF indicator sites adequately represent the full range of ecosystem types across the Basin. While this is unlikely to materially affect the Basin-scale SDL, it may introduce significant uncertainty for individual water resource plan areas if indicator sites within a water resource plan area are not adequately representative of the range of ecosystem types in that area.

MDBA has modelled the likely impacts of climate change to 2030 on water availability and this modelling is robust. MDBA has not used this information in the determination of SDLs for the proposed Basin Plan but rather has determined SDLs using only the historical climate and inflow sequences. The panel understands that this reflects a policy decision by MDBA to initially accept the climate change risk sharing amongst users that is represented in current water sharing plans. Under most current water sharing plans planned environmental water is the least secure water share under a drying climate.

Is the approach to determining key environmental assets (KEA) and key ecosystem functions (KEF) scientifically defensible and are the resulting targets clear and appropriate in the context of a managed water resource system?

The method for determining KEA is scientifically defensible and appropriate given currently available environmental data sets. The ecological and hydrologic targets for KEA are all clear. Not all the targets being used at the time of the review are appropriate in the context of a managed water resource system.

The method for determining KEF is not fully defensible because the KEF classification is scientifically weak, the links between KEF and hydrologic variability are poorly described and there is a lack of scientific evidence to justify the hydrologic targets adopted.

Is the concept of indicator sites sound?

The use of indicator sites to assess overall environmental water requirements is an appropriately pragmatic approach, as is using sites with high water requirements rather than using random (or stratified-random) approach to site selection. It has not been demonstrated that the indicator KEA are ecologically representative of the range of water-dependent ecosystems across the Basin.

MDBA has assumed that the water requirements of iKEA encompass the water requirements of the full set of KEA; this assumption is untested. This assumption is unlikely to be an important source of uncertainty at the Basin scale but may be an important source of uncertainty for individual water resource plan areas.

Are the expressions of environmental water requirements to meet specified objectives and targets scientifically sound?

The expressions of environmental water requirements are scientifically sound. The expressions of water requirements are primarily – although not solely – based on the robust information available on the water requirements of floodplain vegetation. Incorporating into the analysis information available on the water requirements of other species associated with iKEA would increase the confidence in the specification of iKEA water requirements.

Modelling, Analysis and Results Interpretation

Are the hydrologic and environmental modelling and associated analyses transparent, appropriate and defensible?

The hydrological and environmental modelling and analyses undertaken to guide ESLT and SDL determination were not fully documented by the conclusion of this review (October 2011) making it difficult to assess the appropriateness and defensibility of this work.

The draft documentation and verbal descriptions provided suggest that the hydrologic and environmental modelling and analyses are appropriate. Undocumented assumptions and modelling choices are a source of uncertainty in SDL determination. The modelling of environmental flow regimes for the unregulated rivers of the Basin appears to have been problematic with lower confidence in the modelling results for these rivers.

The modelling has used current carry-over rules designed for irrigation water use. These are likely to be sub-optimal for environmental water management given the need to reinstate small-medium overbank flow events. This is likely to have influenced which hydrological targets have been met in the modelling.

Have model outputs been synthesised and reported in appropriate ways that are simple to comprehend and explicitly link to stated objectives and targets?

Modelling results for iKEA – indicating the expected frequency of watering events for floodplain and wetland iKEA and various flow metrics for the Coorong-Lower Lakes-Murray Mouth region compared to targets – were provided during the review. During the review the panel provided feedback to MDBA on how to improve the presentation of these results including clearer linking back to the ecological targets. The most recent summary of model outputs seen by the panel (dated 10 August 2011) provided a simple to comprehend synthesis of iKEA results, but did not explicitly link back to ecological targets.

Few modelling results were provided for KEF hydrologic metrics. The hydrologic targets developed for KEF have not been linked to specific ecological targets. This is largely because of an inadequate knowledge base to specify robust and meaningful ecological targets but has been confounded by inadequate work on KEF classification and attribution to flow. These shortcomings mean that even when results for KEF hydrologic metrics become available, they will not be able to be linked directly back to environmental objectives.

A coherent synthesis of the all modelling results and their interpretation against ecological targets in the context of a robust Basin-scale conceptual ecological model has not yet been produced.

Policy Integrity

Are the final expressions of an ESLT evidence-based and consistent with stated environmental objectives and targets?

The panel’s assessments are based on modelling results (date 10 August 2011) provided by MDBA for a “2800 GL/yr reduction scenario”. The modelling results for this scenario provide a sound evidence base for the expected degree of flow regime change and the extent to which this would meet specified hydrologic and thus ecological targets.

The results indicate that for this level of change in consumptive water use, and assuming appropriate management of new environmental water, valuable ecological benefits could be delivered across the Basin including meeting several of the specified ecological targets. As modelled, the proposed SDLs deliver environmental benefits on the areas of the floodplain that can be watered more easily but some dis-benefits for areas of the floodplain that are more difficult to water. This highlights that there are trade-offs to be made between environmental outcomes when managing environmental water.

The modelled 2800 GL/yr reduction scenario considered by the panel does not meet several of the specified hydrologic and ecological targets. In some cases operational constraints prevent delivery of environmental water to meet targets implying that some of the current ecological targets are not consistent with unavoidable operational constraints. In other cases, the shortfalls against targets appear to be a result of (i) insufficient environmental water, (ii) shortcomings in modelling environmental flow regimes in the unregulated rivers of the Basin or (iii) a combination of these factors.

Further analyses, including modelling of water use reduction scenarios above the 2800 GL/yr scenario, are required to more fully assess the reasons for the modelled shortfalls. Given the current evidence base the level of take represented by the 2800 GL/yr reduction scenario is not consistent with the hydrologic and ecological targets provided in the review.

Recommendations

The review makes four general recommendations and twenty-six specific recommendations for future work over the short to long term to strengthen the scientific basis of ELST method and its implementation and to reduce SDL uncertainty.

The most important short-term work is to more clearly articulate the ecological framing for the ELST method and to publish a coherent and comprehensive description of the ESLT method and its implementation. This will greatly improve the transparency and clarity of the technical work and thus increase its defensibility.

We recommend that the documentation include:

1. A coherent conceptual ecological model linking flow regimes to ecological responses, across multiple spatial scales and biogeographic zones, both as a means for guiding the compilation of scientific data and evidence underpinning an ESLT and to support effective communications of the science and analyses.
2. Description of the final modelling methods stating the key assumptions and sources of uncertainty.
3. A summary of the modelling results that support the proposed ESLT and SDLs indicating which hydrologic targets can be met under current constraints, the likely overall ecological consequences and the extent to which these are consistent with the higher-level environmental objectives of the Basin Plan.
4. A Basin-scale synthesis of expected environmental benefits from the proposed ESLT and SDLs.

1. REVIEW CONTEXT AND TERMS OF REFERENCE

1.1. Context for the review

Threats to river health

Water diversions and other types of flow regime change have led to significant changes in river health in the Murray-Darling Basin; this review is focussed on the science and analyses to guide recovery and management of water for increased environmental flows. The panel recognises however, that in addition to water diversions, land-use change and land management, invasive species, river "improvement" works, water resources infrastructure and their operation all influence river health. The outcomes that can be achieved with a well-designed environmental flow regime cannot be achieved by other management options; however, integrating environmental flows with strategic use of water infrastructure and catchment management is likely to be synergistic. More comprehensive treatment of these issues is given in Thoms et al. (2000), Norris et al. (2001) and Gawne et al. (2011).

Requirements of the Water Act

Under the *Water Act (2007)* the Murray-Darling Basin Authority (MDBA) is required to prepare a Basin Plan to promote the objects of the Act. Central to the focus of this review is the requirement that the Basin Plan provide for:

(a) The establishment and enforcement of environmentally sustainable limits on the quantities of surface water and ground water that may be taken from the Basin water resources (including by interception activities);

(b) Basin-wide environmental objectives for water dependent ecosystems of the Murray Darling Basin and water quality and salinity objectives; and

(c) The use and management of the Basin water resources in a way that optimises economic, social and environmental outcomes.

Section 21 of the Act outlines the general basis on which the Plan is to be developed. Particularly relevant as context to this review are the following:

> Para (2) The Basin Plan must be prepared having regard to: (i) the fact that the use of the Basin water resources has had, and is likely to have, significant adverse impacts on the conservation and sustainable use of biodiversity; and (ii) the fact that the Basin water resources require, as a result, special measures to manage their use to conserve biodiversity. The Plan must promote sustainable use of the Basin water resources to protect and restore the ecosystems, natural habitats and species that are reliant on the Basin water resources and to conserve biodiversity.
>
> Para (3) The Basin Plan must also: (i) promote the wise use of all the Basin water resources; and (ii) promote the conservation of declared Ramsar wetlands in the Murray-Darling Basin.
>
> Para (4) In preparing the Basin Plan the Authority must: (i) take into account the principles of ecologically sustainable development; and (ii) act on the basis of the best available scientific knowledge and socio-economic analysis.

In November 2010, MDBA released for consultation and stakeholder comment, *The Guide to the Proposed Basin Plan*. The *Guide* reported "analysis undertaken indicates that the amount of additional surface water needed for the environment is between 3,000 GL/y and 7,600 GL/y (long-term average)" and after socio-economic considerations presented a set of "Sustainable Diversion Limit (SDL) scenarios" for consideration of reductions in long-term average annual surface water use of 3000, 3500 and 4000 GL/yr.

In late 2011 the MDBA intends to take to community consultation the proposed Basin Plan that will specify SDLs for the Basin as a whole and for each water resource plan area. These SDLs are required under the Act to "reflect an environmentally sustainable level of take" (ESLT). MDBA requested CSIRO, acting through its Water for a Healthy Country National

Research Flagship, to assemble a team of appropriately qualified experts to undertake a review of the determination of the ESLT.

Prior to the publication of the *Guide*, MDBA commissioned several peer-review processes; these are now compiled and available on the MDBA website. These reviews focus on the development of the central methods and approaches used in preparing the *Guide*; a high-level international review of the overall approach to the Basin Plan was also undertaken. The international review panel provided advice and recommendations on nine themes; the most pertinent as context for the review activity reported herein is the comment under the heading *A Critical Need for Strategic Direction*: "Our single most important concern is about the lack of strategic direction very late in a process with a goal to produce a plan which is clear and would achieve broad public acceptance. Our conclusion is that much excellent work has been done on the components and details of the plan. But how the parts add up to a whole is not clear to us."

Integrated water resources management

The *Water Act* recognises that managing the water resources of the Basin is a multi-faceted challenge requiring an integrated approach. Over the past two decades Integrated Water Resources Management (IWRM) has evolved into a consistent approach that is widely adopted internationally as best practice for complex water resource management problems.

A widely accepted definition developed by the Global Water Partnership defines IWRM as "*a process that promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems*." IWRM is thus about finding socially equitable ways to share the benefits from water resources between different interest groups and between current and future generations. IWRM involves policy judgment, but should be informed by a robust, transparent and accessible evidence base of environmental, social and economic information and analysis.

The second of the four IWRM "Guiding Principles" articulated in the Dublin Statement that from the 1992 International Conference on Water and the Environment calls for a participatory process: "*water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.*" A participatory process does not necessarily lead to consensus and conflict resolution mechanisms are often required.

Solving the complex water resources problems thus requires robust science and technical analyses, a consideration of environmental, social and economic values, and broad participation in the decision process. This review deals only with the first of these ingredients.

Prior Environmental Flow Assessments for the Murray-Darling

A brief summary of the findings of prior environmental flow assessments for the Murray-Darling river system provides useful context for this review of recent modelling and analysis.

Environmental flow assessments prior to the *Guide* focussed on the connected southern system: the Murray, Goulburn and Murrumbidgee rivers and the Darling River below Menindee Lakes. Jones et al. (2002) assessed five environmental flow scenarios; one of these – an additional 3350 GL/yr – was assessed as having a high probably of achieving a "healthy working River Murray system". SRP (2003) assessed three environmental flows – additional flow volumes of 350, 750 and 1500 GL/yr relative to the 1993/4 Cap on Diversions – and concluded "a further 1500 GL/yr can provide moderate whole of river and local ecological habitat benefits".

The *Guide* suggested that for the entire Basin restoration of 60-80% of flow volumes across the full range of natural variability would require an additional 3000-7600 GL/yr. The *Guide* considered three scenarios (3000, 3500 and 4000 GL/yr) in more detail and concluded that under the 3000 Gl/yr scenario not all the environmental targets would be met. CSIRO (2011) assessed the ability of the *Guide* scenarios as modelled to meet MDBA and SA Government environmental objectives for the River Murray in South Australia. CSIRO (2011) concluded that these scenarios represent sufficient average annual volumes to meet MDBA environmental water requirements in South Australia and, with the exception of the 3000 GL/yr scenario, also present sufficient average annual volume to meet the South Australian government environmental water requirements for the Riverland–Chowilla.

1.2. Review terms of reference

This review considers the environmental and hydrologic modelling and analyses undertaken to inform the determination of an ESLT. It does not consider the socio-economic analyses and policy judgments that have also influenced the determination of an ESLT.

The original terms of reference are:

1. Assemble a panel of suitably qualified and experienced individuals to undertake the review. Seek MDBA endorsement of the proposed panel membership.
2. Work with MDBA to develop an agreed conceptual framework that captures the main elements of the development of surface water SDLs, focussing on the part of this process being considered by this review.
3. Use the agreed conceptual framework to guide the review. The review will address the critical questions around the access and use of available environmental and hydrological science and around ensuring the integrity of evidence-based policy shown in Table 1. The review will consider the Basin-scale focus and the time constraints imposed on the MDBA. The review will consider:
    a. The completeness and relevance of the knowledge-base of existing environmental and hydrological scientific literature and data sets accessed by MDBA in the development of the Basin Plan.
    b. The published and unpublished documents prepared by MDBA and its consultants describing the methods, analyses and modelling undertaken to guide development of the proposed Basin Plan, including any relevant previous peer reviews of components of the work.
    c. Presentations from, and interviews with, senior MDBA staff around components of the scientific and technical work, especially those components for which documentation is currently incomplete.
    d. The documents being drafted by MDBA to describe the technical methods, analysis and modelling for use the consultation process for the proposed Basin Plan.

Review Focus	**Key Questions**
Foundation information	• Has the best available scientific information (climate, hydrology and ecology) been accessed? • Have the best available hydrologic and environmental models been used?
Interpretations and assumptions	• Has the use of the scientific information been consistent and defensible? • Is the approach to determining key environmental assets and key environmental functions scientifically defensible and are the resulting objectives and targets clear and appropriate in the context of a managed water resource system? • Is the concept of *indicator sites* sound? • Are the expressions of environmental water requirements to meet specified objectives and targets scientifically sound?
Modelling, analysis and result interpretations	• Are the hydrologic and environmental modelling that has been undertaken and the associated analyses transparent, appropriate and defensible? • Have model outputs been synthesised and reported in appropriate ways that are simple to comprehend and explicitly link to stated objectives and targets?
Policy integrity	• Are the final expressions of an *environmentally sustainable level of take evidence-based and consistent with the stated environmental objectives and targets?*

Table 1: Review questions

4. Deliver a draft review report to MDBA for comment by early July 2011 accompanied by a briefing on the draft findings to members of the Authority Board and the senior

executive. (*This time frame was extended by MDBA to allow the Panel to critique the draft documentation on the technical methods*).

5. Publish the final review as a CSIRO report to MDBA at a time to be determined in consultation with MDBA. This report will be authored by the members, will note their institutional affiliations and give full disclosure of the current and past relationships between MDBA and the individuals and their respective institutions.

In late September 2011 following consideration of the Interim Report, MDBA invited CSIRO to address, in this the Final Report, a broader terms of reference. The additional questions (*Questions of Sufficiency*) that MDBA invited CSIRO to consider are:

1. Overall, is the body of science sufficient to make an informed decision on an environmentally sustainable level of take for the Basin?
2. Are the methods adopted fit for purpose?
3. Does the body of work undertaken represent a sufficient basis to begin an adaptive management process around the level of take in the Basin?

The second and third of these questions were posed in the context of the recommendations for improvements to the methods and the documentation of the methods that were made in the Interim Report and that included also in this Final Report.

Although the responses to these additional questions rely heavily on the detailed assessment for the questions in the original terms of reference, they are presented herein (Section 3) before the more detailed responses as they are more over-arching and forward-looking and thus are judged to be of more immediate interest to many readers.

During the review period, and in response to early recommendations from the review panel, the MDBA began the process of producing more comprehensive and coherent documentation of the scientific and technical work undertaken to inform development of the proposed Basin Plan.

2. CONCEPTUAL FRAMEWORK

As required under the terms of reference for the review, a conceptual framework or program logic to illustrate the main elements of the development of surface water SDLs (Figure 1). This evolved from an early version prepared by CSIRO and was refined with input from and through dialogue with MDBA. Figure 1 indicates the portion of the process that is the focus of the review; the focal review questions relate to the key steps within this portion of the process. The review however, does not consider the steps outside of the red box in Figure 1 nor groundwater SDLs or the associated issue of surface-groundwater connectivity.

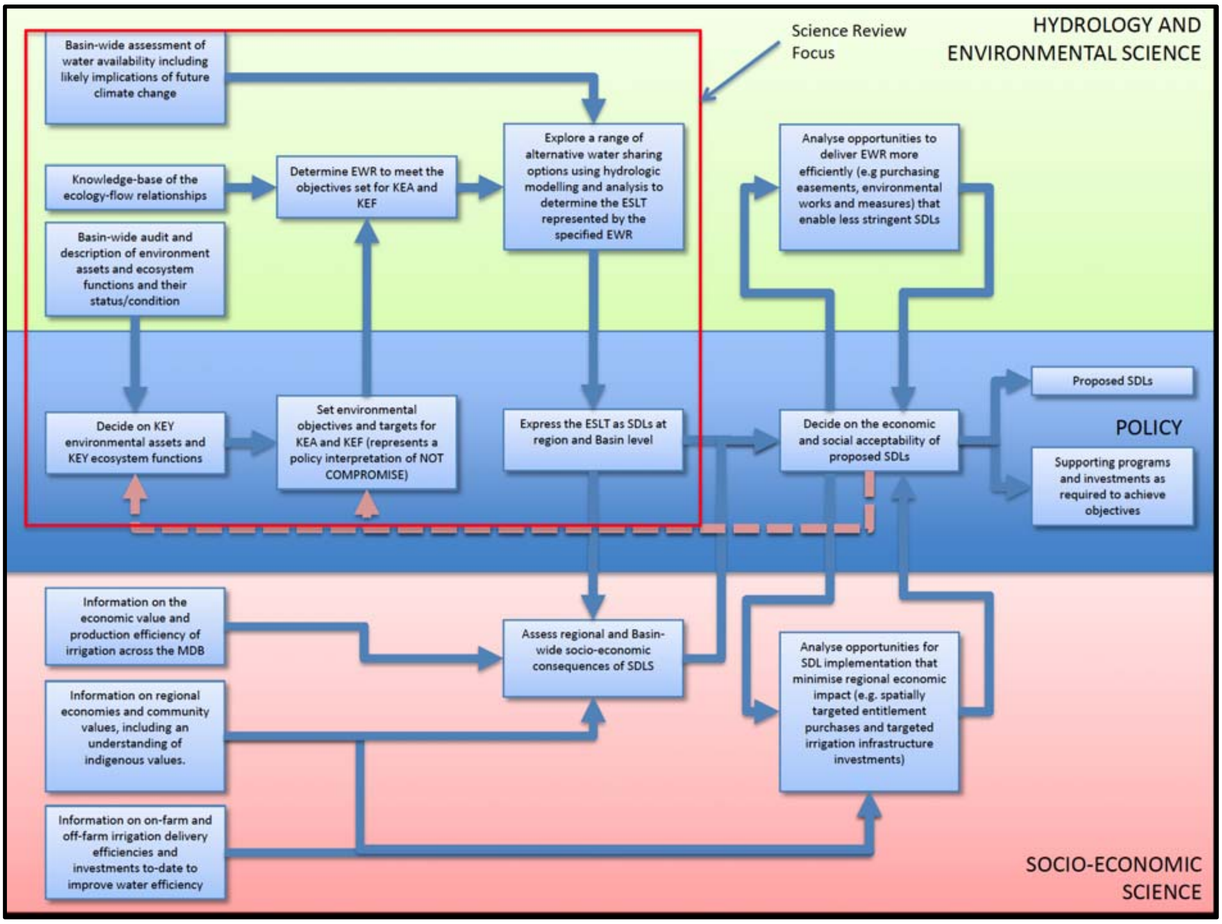


Figure 1: Conceptual framework for surface-water SDL determination.

For the consideration of the technical work guiding determination of surface water SDLs it is useful to use a simpler sequence of steps (Figure 2) that encapsulates the core aspects of the more detailed conceptual framework.

The first step of establishing high-level environmental objectives and outcomes for the Basin Plan is primarily a policy judgment reflecting implicit trade-offs with social and economic outcomes from the consumptive use of water; this step is however, informed by scientific knowledge. Step 2 involves the scientific task of identifying and describing environmental assets and functions and the policy judgments (informed by scientific information) of determining which of these are "key".

Step 3 involves determining ecological targets, which while primarily a scientific task, includes the policy judgment of what targets are required to "not compromise" key assets and functions. Step 4 is entirely a scientific task of determining appropriate hydrologic targets that if met will ensure ecological targets are met; given the partial knowledge base available this step necessarily requires scientific judgment.

Step 5 involves several modelling tasks including determination of environmental water demands to include in the model and iterative model runs with proposed SDLs in order to identify SDLs required to meet the hydrologic targets. Step 5 is primarily a scientific or technical step requiring technical judgments in several tasks, however, the policy judgment is also involved if not all targets are fully met, as is the case for the proposed SDLs. In the case where not all hydrologic targets are met there are critical feedback loops firstly to assess and interpret the likely ecological consequences, and secondly, where these consequences are significant, a loop back to assess whether or not the high-level environmental objectives are expected to be met.

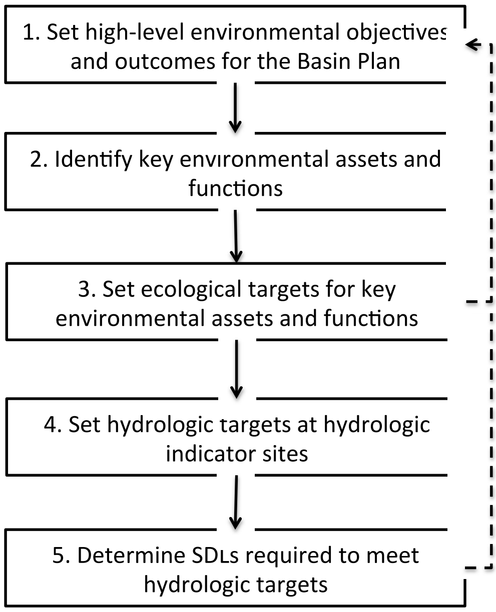


Figure 2. Sequence of steps (with important feedbacks) in the ESLT method linking desired environmental objectives and outcomes through to proposed SDLs.

3. QUESTIONS OF SUFFICIENCY

In response to the panel's Interim Report to MDBA that addressed the original terms of reference for the review, MDBA posed three new "questions of sufficiency" around the knowledge base and body of work undertaken. The assessment against these questions below is based on the more detailed assessments provided in Sections 4–7.

3.1. Overall, is the body of science sufficient to make an informed decision on an environmentally sustainable level of take for the Basin?

Given the knowledge derived from over thirty years of Australian water research, and in the context of an adaptive management framework being adopted for the implementation of the Basin Plan, there is sufficient scientific knowledge to make an informed decision on an ecologically sustainable level of take.

In this context, it is important that two key issues be understood. Firstly, just like economic, social and cultural systems, basin-scale ecosystems are complex and dynamic. Scientific understanding of such complex ecosystems – as they are now, and as they may be in the future under different water management and climate regimes – will always be imperfect and incomplete. Nevertheless, it is unequivocal that the majority of Basin ecosystems are under very significant hydrological stress and are consequently in poor or declining ecological health.

Secondly, while noting issues relating to delivery constraints and current water management rules (e.g., carryover rules), the scientific evidence presented to the panel indicates that an ESLT based on a water recovery target larger than 2800 GL/yr would be required if all the ecological targets being considered by the Authority at the time of the review are to be met. The scientific rationale and method(s) by which the available body of science is used to allocate the final ESLT for the Basin to individual river valleys requires further explanation.

3.2. Are the adopted methods fit for purpose?

The adopted methods can be disaggregated into those applied for each of steps 2–5 in Figure 2 above. Detailed assessments of the fitness for purpose of the methods are provided in Sections 4–7 and recommendations for improvements to these methods are provided in Section 9. The improvements recommended represent opportunities to reduce ESLT uncertainty. However, as indicated in Section 8, many of the current methodological limitations do not contribute strongly to ESLT uncertainty. Summary statements of fitness for purpose of the methods are given below for each step of the ESLT method.

Identify KEA and KEF: this step is only a minor source of ESLT uncertainty; the methods adopted are fit for purpose in the context of initiating an adaptive management process. Several recommendations are made for improving these methods (and the underlying knowledge base) in the short, medium and long term.

Specify ecological targets: this step is a moderate source of ESLT uncertainty; the methods adopted for KEA are fit for purpose (for KEF no ecological targets have been specified) in the context of initiating an adaptive management process. Some recommendations are made for improving these methods (and the underlying knowledge base) in the short, medium and long term.

Specify environmental water requirements and hydrologic targets: this step is a moderate source of ESLT uncertainty (primarily associated with KEA water requirements); the methods adopted are fit for purpose in the context of initiating an adaptive management process. Several recommendations are made for improving these methods (and the underlying knowledge base) in the short, medium and long term.

Determine SDLs that meet targets: this step is a moderate source of ESLT uncertainty; the methods adopted are fit for purpose in the context of initiating an adaptive management process. Many recommendations are made for improving these methods (and the underlying knowledge base) in the short, medium and long term, including a number of short-term tasks that are critical for supporting consultation on the proposed Basin Plan.

3.3. Does the body of work undertaken represent a sufficient basis to begin an adaptive management process around the level of take in the Basin?

As noted above, the body of work undertaken can be considered for each of steps 2–5 in Figure 2 above. As in Section 3.2 the overall assessment is that the body of work undertaken is substantial and represents a sufficient basis to begin an adaptive management process around the level of take. In response to early recommendations from the panel, MDBA increased their effort on developing the necessary documentation. At the time of the review the technical documentation of this body of work was incomplete.

As noted in Sections 3.1 and 3.2 and described in more detail later in this report, there are inevitable gaps in the current scientific knowledge base and available relevant models. It is unrealistic to expect these to be overcome in the short-term – many, if not most, will require long-term monitoring of environmental responses to hydrologic variability driven by both planned and unplanned watering events. An appropriate approach to dealing with such uncertainty is to adopt an adaptive management approach, which “embraces uncertainty” (Walters and Martell, 2004) by using existing knowledge and models to derive plausible ‘candidate’ management options, which are then tested over time (Walters, 1986; Walters and Martell, 2004). Success in adaptive management depends strongly on long-term commitment to the process, including engagement with stakeholders and with the science community.

There is of course a tension in the adaptive management approach between acknowledging uncertainty and the potential need to alter policies in the future, and the goal of providing certainty for those affected by those policy decisions. Many of the uncertainties identified in in this report will remain unresolved in the short to medium term. Importantly though, the panel’s view is that the current knowledge base, and application of that knowledge in the Basin Plan, is a suitable starting point to begin an adaptive management process.

4. FOUNDATION INFORMATION

The panel was provided with a number of documents that MDBA indicated were important foundation information for the development of the ESLT method (Appendix A). MDBA has also compiled a database (BPKID – Basin Plan Knowledge and Information Database) of several thousand publications and datasets relevant to the development of the Basin Plan; the review considered documents in BPKID where directly relevant.

4.1. Has the best available scientific information been accessed?

Summary assessment

MDBA has accessed much of the existing relevant formal scientific information. MDBA could have accessed additional scientific information that would have strengthened the scientific basis of the proposed Basin Plan. There is no evidence however, that this would have materially changed the magnitude of the proposed ESLT and SDLs.

Because of limited formal scientific knowledge to guide environmental water planning, expert opinion remains an important component of best available scientific information. MDBA has made limited use of expert scientific opinion in developing the proposed Basin Plan.

Detailed assessment

Identification of best available science is complicated (Ryder et al., 2010) as is defining what constitutes best available science *in the context of the determination of an ESLT for the Basin*. It is more useful and appropriate to comment on the science MDBA has accessed and the possible effects of including or excluding parts of the current knowledge base.

The panel considers environmental flows to be a relatively new scientific discipline and thus a significant fraction of what can reasonably be considered as best available science is still in the realm of “expert opinion” rather than in the scientific literature. While MDBA consulted with the science community in the early stages (2009) of developing the ESLT method, this consultation ceased after a month or so and the method was then developed and applied with no close expert input or guidance other than formal peer reviews.

The determination of an ESLT required steps outlined in Figure 2. These steps required application and integration of a large body of material. In some cases it has been possible to evaluate the material used, but in other cases MDBA has relied on material developed for other processes (primarily State government processes), for which the primary sources of information are not documented.

The first step in the process – defining high-level environmental objectives – is primarily a policy process and thus is outside the terms of reference for this review. Nonetheless, setting these high-level environmental objectives should be informed by science (at least in an advisory sense), as should the feedback loop to this step indicated by the dotted arrow on Figure 2. The science used for steps 2-4 is discussed in the sub-sections below. The final step is dependent on the modelling and the access to and use of models is discussed in Section 4.2

Identification of key environmental assets and functions

The list of KEA has been compiled using best available science. Notwithstanding, there remains a critical need to strengthen the knowledge base through an adaptive approach to water management and targeted research.

MDBA has used a variation of the criteria developed by the Australian Government for identifying high conservation value aquatic ecosystems to identify more than 2000 key environmental assets (KEA) across the Basin. Assessment against five criteria was undertaken using data from Commonwealth and state government databases. Different government agencies have collected data to describe assets at different scales and using different methods, creating difficulties for the uniform application of the criteria.

The inclusion of key environmental functions (KEF) in the ESLT method represents a challenge, as the relevant knowledge base is more limited than for KEA. The identification of KEF was based largely on Alluvium (2010) and in isolation this work does not represent best available science. Alluvium (2010) relied heavily on environmental flow determinations undertaken in other systems for other processes and as a result, the identification of KEF lacks a robust ecological framework. As earlier peer reviews of this work observed, some important functions (e.g., recruitment) are not included while others (e.g., hydraulic habitat) are included inappropriately. MDBA has advised that they are working to strengthen the conceptual basis for this work following early recommendations from the panel.

Setting ecological targets for KEA and KEF

For KEA, ecological targets were developed for 18 “indicator” sites (iKEA) linked to asset-specific objectives that in turn were based on the asset-specific selection criteria. The approach focussed on setting targets for the vegetation communities or habitat types that support the species that were identified in nominating the site as a KEA. In most cases the ecological targets are to maintain vegetation communities in good condition. In the context of the iKEA approach (see Section 5.3 for comments on this approach), the scientific information that has been used is appropriate.

Many of the iKEA ecological targets include an areal extent; however, the basis for setting these areal extents is unclear. In many cases the target is 100 per cent of the existing area of particular ecological community, while in other cases the target is for a lesser area. For some of these cases the lower targets are linked to the “threshold of acceptable change” in the Ramsar character descriptions (e.g., Gunbower-Koondrook-Perricoota forest). In other cases however, no justification is given for targets set at less than 100 per cent of the current area.

In addition to vegetation communities and habitat types, ecological targets have also been set for waterbirds on the basis that birds are “at the top of the food chain and therefore serve as useful indicators of overall ecosystem health” (Scott, 1997). Robinson (2011) suggests that waterbirds are not a good indicator of individual asset condition as they respond to habitat availability at continental scales and readily move between wetland systems. Waterbirds are, however, the focus of international treaties and their protection is important.

Ecological targets have not been specified for KEF. This is primarily because of the limited knowledge of relationships between flow and ecological functions for rivers of the MDB. In the absence of ecological targets for KEFs, surrogate hydrological targets have been set. These hydrological targets have been set using generic approaches either as a proportion of the without development flow regime (for base flows) or as restoration of specific in-channel flow events (freshes – these being the flow events relevant to KEF that had the greatest in-channel water demand). There is considerable uncertainty associated with this method; however, the consequences for SDLs are likely to be small. Hydrologic targets for KEF are potentially significant for water sharing during extended droughts and so further work is recommended over the longer-term to reduce the uncertainties in this component of the method. Despite the high uncertainty in this component of the work (and the conceptual weaknesses noted above in the identification of KEF) the targets set for KEF appear to have accessed best available science. Location-specific hydrologic targets may be possible for some KEF and this could be investigated in the medium-term.

Underpinning the specified ecological targets are descriptions of ecological values for KEA and KEF. KEA values were based on the information used to identify KEA and thus reflect the selection criteria. The criteria focus on biodiversity and hence the KEA value descriptions list ecosystem types and species present, but do not consider ecosystem services, ecosystem functions and “support for the productive base”. MDBA has commissioned work to improve the understanding of key ecosystem services. But limited knowledge of these values means it is currently unlikely to be possible to develop meaningful and robust ecological targets for KEA based on values beyond biodiversity.

KEF values have been poorly described, in part reflecting the limited knowledge of the relationship between flow regime and KEF for rivers of the MDB. Scientific information is available to describe the value of some KEF to water-dependent ecosystems, and some of this appears to have been accessed indirectly through reports on the development of environmental flows that do consider the primary literature. Clearer specification of the sources of scientific information used for this work is recommended.

Specification of water requirements and hydrologic targets

The specification of environmental water requirements for KEA was based on estimation of water requirements to meet the ecological targets for the 18 iKEA. iKEA were characterised as being comprised of a limited number of ecosystem types characterised by their physical habitat or dominant vegetation. The species of value were linked to one of the ecosystem types and the water requirements of that ecosystem type were used to develop the overall iKEA water requirement.

This approach relies on the strength of the relationship between the persistence of an ecosystem type and nominated species. As knowledge of the water requirements of many species is limited this approach has several advantages: (i) it is a scientifically justifiable simplification enabling an estimate of water requirements to be developed comparatively easily, (ii) it is based on the water requirements of a small group of species for which there is robust knowledge and (iii) it simplifies modelling to enable workable evaluation of scenarios.

There is however, additional scientific information that could be incorporated into future refinements of the determination of water requirements. This includes existing information on the water requirements of other species such as Moira grass, lignum, Golden Perch and Silver Perch. Assessment of other species' water requirements would provide an estimate of the uncertainty around the habitat modelling estimates and help identify any species for which the water requirements exceed those of their primary habitat. This would help determine if there are species still at risk under the initial SDLs.

For KEF, hydrologic metrics were defined for assessment at a further 88 hydrologic indicator sites. The hydrologic targets for these metrics were set simply as ranges for ratios to the without-development flow regime value – typically as either 60-80% of 80-100% of the without-development value. Current scientific knowledge is not sufficient to set more definitive targets (especially with respect to any important thresholds in the flow-ecology relationship), so these targets are best considered as hypotheses to be testing through an adaptive management approach.

4.2. Have the best available hydrologic and environmental models been used?

Summary assessment

The best available hydrologic models for the Murray-Darling Basin have been used enabling integrated Basin-wide modelling of water sharing scenarios. For the Coorong, the best available hydrodynamic model has been used together with a simple ecosystem state model.

MDBA has made limited use of available floodplain inundation models but other than for the Coorong has not used available ecological response models. As a part of an adaptive approach, broader application of, and improvements to, such models would both reduce ESLT uncertainty and provide a more comprehensive description of the expected ecological outcomes from the Basin Plan.

Detailed assessment

MDBA has used the currently best available hydrologic models as originally developed by MDBA and state agencies and as linked to form a Basin-wide model by CSIRO in the Murray-Darling Basin Sustainable Yields Project. This Integrated River System Modelling Framework (IRSMF; Podger et al., 2010) has been further improved for MDBA by CSIRO and partners to enable it to be applied to the complex Basin Plan task. These improvements have enabled MDBA to run many 100s of scenarios and ensure a full audit trail of all modelling inputs and outputs. The modelling methods adopted using IRSMF are discussed under Section 5.1.

The complexity of the existing hydrologic modelling suite means that setting up and running large numbers of scenarios while possible, is very time consuming – especially the manual steps of preparing data inputs (such as time series environmental water demands) and processing outputs into easily understood results summaries. The development of a simpler scenario model for the entire basin (still based on all available hydrologic data but using simplified representations of water management) is recommended. This would enable rapid screening of multiple alternative scenarios and exploration of parameter sensitivity prior to comprehensive modelling. A simplified model could also be useful in stakeholder engagement and communication of modelling results.

MDBA is a key participant in the eWater CRC. The main effort of the CRC has been the development of a new generation of modelling tools (SOURCE) for water resources planning and management. Over the longer-term, it is expected that MDBA and MDB state agencies will transition to a new MDB SOURCE-based modelling suite. Implementation of new detailed models will improve the consistency of approach to hydrological modelling and provide the opportunity to more fully represent environmental aspects of water management. SOURCE would also be the appropriate basis for developing any simpler model as described above.

Several models exist for simulating the inundation of floodplains, wetlands and riverine lakes across the Basin. These range from simple statistical models predicting total inundation areas, to complex hydrodynamic models predicting flow paths, depths and velocities. Various models also exist to assess the ecological responses to alternative environmental watering scenarios; Saintilan and Overton (2010) describe many of the available models. These models enable the ecological consequences of different watering regimes for floodplain environments to be modelled. During the review the panel was not provided with information to indicate whether models of this type were used in the development of the Basin Plan. However, in response to the panel's Interim Report, MDBA advised it had used some inundation models (and/or the relationships captured in these models), not to evaluate SDL scenarios, but help set ecological and hydrologic targets.

While comprehensive analysis using such models may not have been warranted for the development of the Basin Plan (given time and resource constraints) application for key locations such as the Riverland-Chowilla floodplain would help assess the sensitivities of the SDLs to different extents and frequency of inundation in the hard-to-achieve high-flow range. It is recommended that greater use (with appropriate further development) be made of inundation models and ecosystem response models to guide an adaptive approach to implementation of the Basin Plan. Such models have particular utility in guiding the development of efficient and effective environmental watering regimes in order to optimise the use of environmental water.

At the Basin-scale, an example of such a model that is under ongoing development is the MDB Flood Inundation Model (Overton et al., 2009). This model could be used to explore the number and types of KEA across the Basin that are likely to be inundated under the target flow regimes described for the iKEA. This would provide evidence to support the hypothesis implicit in the ELST method that watering iKEA will also adequately water all KEA across the Basin. Use of this model would also help demonstrate current infrastructure and operational constraints on floodplain environmental watering regimes.

EcoModeller – a tool developed by eWater CRC – includes a library of ecological response models; other ecological response models also exist. The response models in the EcoModeller library are refinements of the models originally developed as components of the Murray Flow Assessment Tool (MFAT; Young et al., 2003), which was used in the development of the Living Murray Initiative. These ecological response models are based on habitat preference curves, underpinned by conceptual models articulated by experts and parameterised primarily using expert opinion. It is recommended that targeted use and improvements to models of this type would be beneficial in guiding adaptive implementation of the Basin Plan, especially at the regional scale in consultation with stakeholder groups.

Appropriate use has been made of a 1-dimensional hydrodynamic model of the Coorong developed by Webster (2007) to explore the barrage flows required to maintain a healthy Coorong – especially with respect to salinity levels in the south lagoon. Similarly, appropriate use has been made of the simple ecosystem state model for the Coorong (Lester and Fairweather, 2009), noting its limitations, that uses outputs from the hydrodynamics model.

5. INTERPRETATIONS AND ASSUMPTIONS

5.1. Has the use of scientific information been consistent and defensible?

Summary assessment

The use that MDBA has made of individual items of scientific information is defensible. The use that MDBA has made of the collected body of scientific information is not fully consistent because of the absence of a clear over-arching conceptual ecological model linking site-based KEA and KEF assessments to regional and Basin-scale ecological condition and flow regime change.

To-date the work lacks a biophysical classification able to demonstrate that the iKEA and KEF indicator sites adequately represent the full range of ecosystem types across the Basin. While this is unlikely to materially affect the Basin-scale SDL, it may introduce significant uncertainty for individual water resource plan areas if indicator sites within a water resource plan area are not adequately representative of the range of ecosystem types in that area.

MDBA has modelled the likely impacts of climate change to 2030 on water availability and this modelling is robust. MDBA has not used this information in the determination of SDLs for the proposed Basin Plan but rather has determined SDLs using only the historical climate and inflow sequences. The panel understands that this reflects a policy decision by MDBA to accept the climate change risk sharing amongst users that is represented in current water sharing plans. Under most current water sharing plans planned environmental water is the least secure water share under a drying climate.

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Detailed assessment

The application of individual items of scientific information is defensible. Collectively however, the use of scientific information is not fully consistent because of the absence of a clear over-arching conceptual ecological model linking site-based KEA and KEF assessments to regional and Basin-scale ecological condition. Additionally, some important assumptions have not been tested. In particular, it is asserted that the iKEA are representative of the range of ecosystem types found across the Basin, however, this has not been demonstrated. A classification of KEA based on biophysical characteristics is needed to test this assumption.

MDBA has adopted the ecological terms used in the *Water Act (2007)* but has given insufficient attention to ensuring the definitions and interpretations of these terms are couched within a clear and well documented conceptual ecological framework. For example, the KEF currently identified overlook the basic population functions of breeding and recruitment even though the water requirements to trigger these functions are central to the water requirements described for most iKEA. These shortcomings are unlikely to have had a material impact on SDL determination, but they hinder clear communication and dialogue about the approaches used and their scientific basis.

The modelled historical without-development time-series has been used as the sole basis for setting objectives for iKEA and for determining likely water availability. Given that scenarios of water availability in the Basin do exist for a range of possible climate futures, it is not clear why an investigation of the risk climate change poses to the environmental objectives of the Basin Plan has not been undertaken.

MDBA has made a policy choice not to directly address the projected impacts of future climate change on water availability in the determination of SDLs for the proposed Basin Plan. MDBA has determined SDLs using the historical climate and inflow sequences and has not modelled the consequences of future climate on the ability to meet the hydrologic targets under the proposed SDLs. No view has been given on whether the ecological targets would be changed should the climate change as projected. If climate change impacts do unfold as projected lower SDLs would be required to maintain the level of environmental protection offered by the currently proposed SDLs. This represents a significant risk in the longer term and a smaller risk in the short term.

The panel understand MDBA's policy approach to climate change to be an extension of an underlying policy position of "not *requiring* a change to water users' rights". The Australian Government's policy position of "bridging the gap" by acquiring entitlements (either through purchases or savings from infrastructure projects) means the Basin Plan will not require a change in entitlement reliability. Future climate change is expected to reduce entitlement reliability both for irrigators and the Commonwealth Environmental Water Holder. The policy position on climate change has been explained to the panel by MDBA as "accepting the climate change risk sharing amongst users that is represented in the current water sharing plans".

As clearly demonstrated by CSIRO (2008) most existing water sharing plans significantly protect entitlement holders from the impacts of future climate change, and shift the majority of the impact to non-entitlement water, especially during extended dry periods. As the majority (70-80 per cent) of environmental water is non-entitlement water (and will remain so under the Basin Plan) this policy represents a significant risk to the environment during future extended dry periods, especially should these be more severe than in the past as a result of future climate change. A dry period more extreme that has occurred in the past could occur during the first implementation period for the Basin Plan; the planning approach adopted by MDBA does not consider such an eventuality.

5.2. Is the approach to determining KEA and KEF scientifically defensible and are the resulting targets clear and appropriate in the context of a managed water resource system?

Summary assessment

The method for determining KEA is scientifically defensible and appropriate given currently available environmental data sets. The ecological and hydrologic targets for KEA are all clear.

The method for determining KEF is not fully defensible because the KEF classification is scientifically weak, the links between KEF and hydrologic variability are poorly described and there is a lack of scientific evidence to justify the hydrologic targets adopted.

The appropriateness of the targets set is considered in other sections of this report.

Detailed assessment

MDBA have defined KEA as water-dependent ecosystems that meet one or more of five criteria. In the absence of a pre-existing comprehensive list of environmental assets for the Basin KEA were identified using a collation of existing government geographic datasets. This takes a solely site-based view of what constitutes an asset. The approach is scientifically defensible and appropriate given currently available environmental data sets, and as noted in Section 4.1 the approach has used best available science.

In the longer-term it is recommended that an ecosystem or landscape perspective on defining KEA be considered. This would support consideration of the role of interactions between sites in maintaining biodiversity and as well as consideration of ecological processes operating at a valley or basin-scale. For example, migratory waterbird populations rely on different sites at different times given the mosaic of wetland wetting and drying across the Basin, and Basin-scale protection of these populations is difficult using a site-based approach.

The initial peer review of the methods for identifying KEA noted that the protection of biodiversity at the ecosystem level requires a classification of ecosystems to ensure that selected assets are representative of the diversity of ecosystems found in the Basin. A classification would facilitate identification of rare or unique ecosystems. Currently there is no single broadly accepted classification of riverine and floodplain ecosystems available and the information required to classify assets was neither readily available nor could be generated within the required timeframe. However, the consequence of this is that some ecosystem types may not be represented in the planning process.

Having identified KEA, indicator sites (iKEA) were identified; this step is discussed in Section 5.3. Ecological targets have only been set for these iKEA, and the clarity and scientific appropriateness of these targets are discussed in Section 4.1 and so are not repeated here. The appropriateness of these targets in a managed water resource system is considered in Section 7.1

MDBA (2011a) describes in detail how the specific criteria were interpreted and applied to identify KEA, and describes limitations of data availability and quality and how these were addressed. It is not clear how many potential KEA were culled by not meeting any of the criteria. It appears that none may have been culled, in which case it is unclear how the criteria were useful. Earlier reviews noted problems with the consistency and currency of information extracted from the various databases and jurisdictions, however, the list of KEA has subsequently been reviewed and revised. It is important that the KEA database is maintained and updated with new information as it becomes available, to provide an important tool to help evaluate the longer-term outcomes from Basin Plan implementation.

Conceptually there is a strong scientific basis for consideration of KEF in the ESLT method, and arguably, protection of KEA is not possible without also protecting KEF. However, there are two significant weaknesses with the KEF component of the method. The first weakness is that while KEF were identified using a “systematic analysis of the functions occurring in rivers in the basin”, both the KEF classification and the assessment of where in the Basin specific KEF are relevant are poor. These aspects are overly dependent on a crude geomorphic view without reference to the large body of published scientific literature describing the links between flow variability and ecological functions, and how these vary along climate and physiographic gradients.

While the practical implementation of the conclusions of MDBA (2011a) is defensible, the specific conclusion “that all components of the flow regime are important in all river types” is an ambiguous interpretation of a more general idea, and the methods used to arrive at the conclusion are clumsy. In essence, this conclusion is similar to the ‘natural flow paradigm’ (Lytle and Poff, 2004), which hypothesises that the functions that drive and underpin the ecological character of a river are intimately tied to the natural patterns of flow variability and that deviations away from that natural flow regime will alter the rate and extent to which those processes occur. In time, this will lead to an altered ecological character.

This links to the second weakness of the KEF method, which is that the hydrologic targets set for the various flow metrics are largely arbitrary, with no ecological targets specified and no real sense given of the ecological improvements that meeting KEF flow targets will deliver. To support the KEF method a river classification that considers hydrology should be developed, which, combined with some relatively simple models, might allow a more sophisticated approach to be used in setting the hydrologic targets for different river types. More important will be the development of appropriate monitoring programs to refine these targets in the long term.

A limitation of the reporting of KEF hydrologic metrics is that only proportional changes in have been considered. MDBA (2011a) refers to this as an issue of “low numbers”; for example, an increase in the frequency of a specific event from 1 to 2 events while proportionally the same as an increase from 50 to 100 events is likely to have very different ecological consequences. This is not an issue of “low numbers” but simply a limitation of only using proportions for assessing change. To aid interpretation of ecological outcomes absolute as well as proportional changes in KEF flow metrics should be assessed.

5.3. Is the concept of indicator sites sound?

Summary assessment

The use of indicator sites to assess overall environmental water requirements is an appropriately pragmatic approach, as is using sites with high water requirements rather than using random (or stratified-random) approach to site selection. It has not been demonstrated that the indicator KEA are ecologically representative of the range of water-dependent ecosystems across the Basin.

MDBA has assumed that the water requirements of iKEA encompass the water requirements of the full set of KEA; this assumption is untested. This assumption is unlikely to be an important source of uncertainty at the Basin scale but may be an important source of uncertainty for individual water resource plan areas.

Detailed assessment

The ESLT method uses a set of “hydrologic indicator sites” for KEA and KEF, although the selection rationale for KEA indicator sites is quite different to that for KEF indicator sites. The concept of indicator sites is sound, however, there are important untested assumptions in the process of site selection.

KEA indicator sites were identified as those that met one or more of the following criteria: (i) the additional flows required are at the high end of the flow spectrum, (ii) the site is located in a valley with significant water resource development, (iii) the additional environmental water demand is large in a regional context, (iv) the site contributes to a geographic spread of indicator sites across the Basin, and (v) selection of the site avoids overlap and repetition in potential water requirements. The 18 iKEA sites were thus selected primarily on a hydrologic basis to help determine SDLs. As most of the iKEA are floodplain sites the collective water requirements of these sites have a big influence on the estimation of the ESLT. However, as previously noted, the assumption that these iKEA represent the diversity of the full list of KEAs identified has not been tested.

A further untested assumption is that the volumes of water recovered to meet the requirements of the iKEA will be sufficient to also meet the water requirements of all identified KEA. This assumption should be tested and if shown to be reasonable it will be important during the implementation phase of the Basin Plan to assess whether any environmental works and measures used to increase the efficiency of environmental watering undermine achieving these broader outcomes.

A number of KEA (e.g., Barmah Forest, Gunbower-Koondrook-Perricoota Forests, Hattah Lakes, Chowilla Floodplain and the Edward-Wakool system) do not meet the last two of the above criteria of creating a geographic spread and having non-overlapping water requirements. However, recent improvements to the methods for setting environmental water demands in the models in a way that recognises the interdependencies between these sites means that “repetition” between water requirements for these sites is avoided.

Indicator sites for KEF were selected where reliable modelled data were available with a focus on rivers most influenced by diversions and potentially influenced by the Basin Plan. Where possible these coincided with sites used in the SRA hydrologic assessments. This is robust approach. The only shortcoming (as noted earlier) is the absence of a demonstrated coverage of the range of river ecosystem types. This shortcoming should be addressed but is unlikely to be a major source of uncertainty in the initial determination of a Basin-wide ESLT.

5.4. Are the expressions of environmental water requirements to meet specified objectives and targets scientifically sound?

Summary assessment

The expressions of environmental water requirements are scientifically sound. The expressions of water requirements are primarily – although not solely – based on the robust information available on the water requirements of floodplain vegetation. Incorporating into the analysis information available on the water requirements of other species associated with iKEA would increase the confidence in the specification of iKEA water requirements.

Detailed assessment

iKEA water requirements have been expressed in terms of the frequency of events of a particular magnitude, duration and seasonal timing. This approach is scientifically sound as these are well recognised as environmentally important characteristics of river flow regimes. However, there are other flow characteristics that are important for many floodplain species, in particular the maximum period between flood events. While targets have not been specified for the maximum period between flood events for iKEA, it is recommended that this flow metric is reported and compared to without-development and baseline modelling results.

Because the specified objectives for iKEA are focussed on floodplain vegetation, the method may overlook flows required by other species that are directly or indirectly dependent on the floodplain vegetation of iKEA. Fuller analysis of the water requirements of other species associated with iKEA may demonstrate these are sufficiently captured in the vegetation requirements, and thus help strengthen the case for the vegetation-focussed approach.

The target watering frequencies for iKEA are expressed as a range between a “low risk” frequency and a “high risk” frequency. In several cases it is not clear that “high risk” and “low risk” are appropriate labels for the actual watering frequencies being considered and this confounds interpretation of the modelling results. It is recommended that either the target watering frequencies or the risk nomenclature be reviewed to ensure consistent use of risk nomenclature and thus aid interpretation of modelling results.

KEF water requirements are very uncertain. There are no ecological targets specified for KEF. The specified hydrological targets are expressed as either a proportion of the without development flow regime (base flows) or the restoration of specific in-channel events (freshes). This makes it difficult to identify the desired ecological outcomes. KEF should be clearly defined, the scale at which they operate identified and their flow requirements described in generic terms. Once this has been completed KEF could be regionalised and ecological outcomes and performance indicators defined. This is only be possible for a limited number of KEF, but would enable better articulation of in-stream flow requirements and greater transparency of trade-offs.

6. MODELLING, ANALYSES & RESULTS INTERPRETATION

6.1. Are the hydrologic and environmental modelling and associated analyses transparent, appropriate and defensible?

Summary assessment

The hydrological and environmental modelling and analyses undertaken to guide ESLT and SDL determination were not fully documented by the conclusion of this review (October 2011) making it difficult to assess the appropriateness and defensibility of this work.

The draft documentation and verbal descriptions provided suggest that the hydrologic and environmental modelling and analyses are appropriate. Undocumented assumptions and modelling choices are a source of uncertainty in SDL determination. The modelling of environmental flow regimes for the unregulated rivers of the Basin appears to have been problematic with lower confidence in the modelling results for these rivers.

The modelling has used current carry-over rules designed for irrigation water use. These are likely to be sub-optimal for environmental water management given the need to reinstate small-medium overbank flow events. This is likely to have influenced which hydrological targets have been met in the modelling.

Detailed assessment

The determination of SDLs has focussed on the use of the complex Basin-wide hydrologic modelling suite (IRSMF) and associated pre- and post-processing tools. This has been a challenging and time-consuming effort.

Prior to the publication of the *Guide*, the intended hydrologic modelling methods were formally documented (Podger et al., 2010) and independently peer-reviewed (MDBA, 2010). These peer reviews recognised the complexity of the modelling task, noted limitations of the proposed approach, but endorsed the proposed approach as appropriate to the task given the available time. The reviews noted that the complexity and magnitude of the modelling effort was of a scale not attempted previously anywhere in the world. Importantly however, the SDL scenarios presented in the *Guide* were not derived using these modelling methods but using a simpler and less robust “end-of-system” flow analysis.

While IRSMF was deemed fit for purpose by the peer reviews, early application of these methods revealed significant limitations and uncertainties: (i) water requirements for KEF were not represented in the modelling, (ii) the methods used to recover water in upstream models as contributions to environmental water demands in downstream models were undefined, and (iii) treating environmental water demands at different locations along connected systems (particularly the connected southern system) as independent was unrealistic.

The first of these uncertainties has been partly overcome by identifying key sites at which to include environmental water demands for “freshes” and base flows to drive improvements in hydrologic metrics for KEF.

The second of these uncertainties arose because the modelling suite does not enable a downstream model to “order” environmental water from an upstream model. Thus the distribution across tributary models of the additional environmental water (over and above within valley needs) to meet environmental water needs in downstream models, and the mechanisms to recover this water need to be determined prior to running the models. Different mechanisms to recover the additional water in the model (for example, “purchasing” entitlements, reducing allocations or reducing irrigation demand by reducing planted areas) have different efficiencies in terms of the reduction in use required to recover a given volume of water for the environment. The more recent modelling has assumed all new environmental water will be entitlement-based. Entitlement-based water may not always be well suited to meeting high flow environmental water demands as discussed below. The more recent modelling has also adopted a single method for determining the distribution across tributary models of additional water, although the resulting distribution will not necessarily match what occurs in reality.

The third of the above uncertainties is especially significant in the southern connected system, where Barmah Forest and Gunbower-Koondrook-Perricoota, for example, are typically watered by the same flood events as they pass downstream. The early use of eFlow Predictor (Version 1.2.1B; Marsh, 2009) to derive the environmental water demand for each site independently meant it was difficult to optimise environmental ordering and watering across sites. It was expected that better temporal alignment of environmental water demands across the southern connected system could significantly reduce the total adjustment volume.

Subsequent to the publication of the *Guide*, MDBA developed a new spreadsheet tool (Pick-a-Box) to assist with the preparation of environmental water demand time series and to help overcome this third limitation of the early modelling. At the time of writing there was no documentation describing the development, assumptions and use of Pick-a-Box in the Basin Plan modelling work. However, the tool and its use were described to the panel. Pick-a-Box takes a time series of flows including all the possible high flow events from eFlow Predictor, and a time series of allocations to assumed new environmental water entitlements from the baseline run of the detailed hydrologic modelling. This of course requires specification of the proposed SDLs (new environmental water entitlements – number and type) prior to determination of the environmental water demand time series. The modelling with the demands included then enables testing that the proposed SDLs will in fact be able to deliver the necessary environmental watering regime.

Pick-a-Box is used to manually identify which high flow events to include in an environmental water demand time series for use in the detailed hydrologic modelling of SDL scenarios; it is essentially used to filter the time series from eFlow Predictor to overcome limitations in the version of eFlow Predictor used by MDBA – in particular the inability to precisely set target average watering frequencies (more recent versions of eFlow Predictor offer greatly flexibility in setting target watering frequencies). Pick-a-Box is used iteratively across iKEA in the connected southern system enabling the development of environmental water demand time series that are synchronised between sites.

Although the use of Pick-a-Box represents a marked improvement over the use of eFlow Predictor alone for preparing environmental water demand time series, the method has several manual steps requiring judgments by individual modellers that have been not been documented and hence the process is not entirely repeatable. It is important that the use of eFlow Predictor and Pick-a-box to derive environmental water demands is clearly documented.

As noted above, the SDL modelling has represented all new environmental water as entitlement-based water and used existing carry-over rules. In many locations it is likely to be difficult to meet environmental water demands efficiently using entitlement-based water under existing carry-over arrangements and these arrangements may be preventing some of the hydrologic targets being met in the modelling. While it is technically difficult and time-consuming to comprehensively investigate alternative carry-over arrangements, these implicit assumptions in the modelling are likely to be a significant source of uncertainty in some of the proposed SDLs.

Overall, the post-*Guide* approach to setting the environmental water demands in the hydrologic models has overcome significant limitations inherent in the pre-*Guide* modelling. However, at the time of writing there was no coherent documentation of the new modelling methods as applied, meaning this review relied on verbal descriptions from the MDBA modelling team. A shortcoming of the current methods is the adherence to existing carry-over arrangements, which is likely, in some valleys, to represent a significant constraint to efficiently achieving desired environmental outcomes using environmental water entitlements. Additionally, MDBA indicated verbally that the modelling of environmental flow regimes for the unregulated rivers of the Basin has been problematic with lower confidence in the modelling results for these rivers.

In analysing the more recent modelling results MDBA has categorised the hydrologic targets according to the degree to which current operational constraints prevent targets being met. There will of course always be uncertainty about which current system constraints could be reasonably overcome through, for example, new outlet structures on dams, buying of easements to allow flooding or relaxing operating constrains related to channel capacity. However, the approach is appropriate and defensible and an improvement on the earlier methods.

At present there is insufficient transparency around the modelling and analysis in support of the determination of SDLs, primarily because the final modelling methods and results are not documented. The Panel strongly encourages MDBA to provide clear documentation of (i) the modelling methods as used, stating the assumptions and uncertainties, and (ii) the results of the modelling and their interpretation. The results should demonstrate the extent of any shortfalls in meeting the environmental water targets for stated environmental objectives under proposed SDLs, and the likely ecological consequences of such shortfalls.

6.2. Have model outputs been synthesised and reported in appropriate ways that are simple to comprehend and explicitly link to stated objectives and targets?

Summary assessment

Modelling results for iKEA – indicating the expected frequency of watering events for floodplain and wetland iKEA and various flow metrics for the Coorong-Lower Lakes-Murray Mouth region compared to targets – were provided during the review. During the review the panel provided feedback to MDBA on how to improve the presentation of these results including clearer linking back to the ecological targets. The most recent summary of model outputs seen by the panel (dated 10 August 2011) provided a simple to comprehend synthesis of iKEA results, but did not explicitly link back to ecological targets.

Few modelling results were provided for KEF hydrologic metrics. The hydrologic targets developed for KEF have not been linked to specific ecological targets. This is largely because of an inadequate knowledge base to specify robust and meaningful ecological targets but has been confounded by inadequate work on KEF classification and attribution to flow. These shortcomings mean that even when results for KEF hydrologic metrics become available, they will not be able to be linked directly back to environmental objectives.

A coherent synthesis of the all modelling results and their interpretation against ecological targets in the context of a robust Basin-scale conceptual ecological model has not yet been produced.

Detailed assessment

The panel was provided with various iterations of modelling results during the review period. The approaches to the synthesis and reporting of results continue to improve reflecting early feedback from the panel. The assessments herein are based on modelling results that are compilation dated 10 August 2011 based on run #836 for the Lachlan and run #832 for the other rivers of the Basin. This tabulation of results compares the frequencies of key watering events to target and baseline values for the 18 iKEA and a small number of sites where demands were included in the models for KEF. KEF metric reporting for the majority of the hydrologic indicator sites was not provided.

To-date there has been no comprehensive, structured synthesis and reporting of the modelling results, and no ecological interpretation of the results at the Basin-scale. Basin-scale interpretation is challenging because of the absence of a robust conceptual model linking asset-scale to basin-scale ecological outcomes. In the absence of such a conceptual model, the logic trail from "*protect and restore the environmental values*" (through the criteria used for selection of assets and functions) to the species used to estimate water requirements, is complex and difficult. In particular, it will be difficult for stakeholders to gain an understanding of the likely environmental character of the Basin under the Basin Plan compared to alternate scenarios, or to understand how outcomes for a particular asset or river reach are linked to Basin-scale outcomes and vice-versa.

For iKEA, it is recommended that model outputs be synthesised and reported against the outcomes being sought. Currently model outputs are synthesised and reported for iKEA in terms of average frequencies or a percentage of years; these are critical but where hydrological targets are not met the ecological consequences have not been described. It is recommended that when formally documenting the modelling results, any shortfalls against hydrologic targets and the likely environmental consequences of these shortfalls be described. It is also recommended that a Basin-scale synthesis of the expected environmental benefits from the proposed SDLs be prepared.

The panel was not provided with summary reporting of KEF metrics for the SDL scenario. KEF reporting against targets should include absolute changes as well as relative changes, otherwise the magnitude of the pre- and post-SDL metric values are unknown. As there is no clear link at present between KEF targets and underlying ecological targets, synthesising and reporting against ecological targets is not possible. The lack of KEF objectives and ecologically based targets undermines the MDBA's capacity to report the predicted outcomes of the Basin Plan or to articulate the trade-offs.

The high level of uncertainty associated KEF flow requirements should be considered when comparing modelling results to KEF targets – is not appropriate to treat these targets as precise in assessing SDL performance.

7. POLICY INTEGRITY

7.1. Are the final expressions of an ESLT evidence-based and consistent with stated environmental objectives and targets?

Summary assessment

The panel's assessments are based on modelling results (date 10 August 2011) provided by MDBA for a "2800 GL/yr reduction scenario". The modelling results for this scenario provide a sound evidence base for the expected degree of flow regime change and the extent to which this would meet specified hydrologic and thus ecological targets.

The results indicate that for this level of change in consumptive water use, and assuming appropriate management of new environmental water, valuable ecological benefits could be delivered across the Basin including meeting several of the specified ecological targets. As modelled, the proposed SDLs deliver environmental benefits on the areas of the floodplain that can be watered more easily but some dis-benefits for areas of the floodplain that are more difficult to water. This highlights that there are trade-offs to be made between environmental outcomes when managing environmental water.

The modelled 2800 GL/yr reduction scenario considered by the panel does not meet several of the specified hydrologic and ecological targets. In some cases operational constraints prevent delivery of environmental water to meet targets implying that some of the current ecological targets are not consistent with unavoidable operational constraints. In other cases, the shortfalls against targets appear to be a result of (i) insufficient environmental water, (ii) shortcomings in modelling environmental flow regimes in the unregulated rivers of the Basin or (iii) a combination of these factors.

Further analyses, including modelling of water use reduction scenarios above the 2800 GL/yr scenario, are required to more fully assess the reasons for the modelled shortfalls. Given the current evidence base the level of take represented by the 2800 GL/yr reduction scenario is not consistent with the hydrologic and ecological targets provided in the review.

Detailed assessment

This final question of the original terms of reference is intended to provide an overarching assessment of policy integrity, given the available knowledge base and the body of hydrologic and environmental technical work undertaken in support of the proposed ESLT. The assessment of policy integrity here is limited to the components of the process within the scope of this review – indicated by the red box on Figure 1. Thus we have limited this final question to a consideration of the specified ecological targets (Step 3 in Figure 2) as described in the appendices to the *Guide*, which MDBA has indicated are the targets being used for the proposed Basin Plan.

A caveat on these assessments is that at the time of writing MDBA had not finalised its view on an ESLT, or on the final magnitude of proposed SDLs. MDBA provided a verbal description from MDBA on how SDLs will be set out in the proposed Basin Plan including a description of a "shared component" that will be prescribed for the southern Basin and for the northern Basin.

In addressing this final question the panel has used the modelling results provided by MDBA dated 10 August 2011 and labelled "draft – work in progress". These results are a compilation from run #836 for the Lachlan and run #832 for the other rivers of the Basin. The results are for a scenario representing a 2800 GL/yr average reduction in surface water diversions. These results indicate performance against the specified hydrologic targets for the 18 iKEA as well as for five other locations in the northern Basin where demands for "freshes" to improve KEF have been included in the modelling. The results compilation provided did not include hydrologic metrics for KEF at the other 83 hydrologic indicator sites.

Although the modelling results provided do not directly indicate the proposed SDLs for each SDL area, the proposed Basin-wide SDL is clearly implicit and the panel understands that the proposed SDLs have been fully represented in the hydrologic modelling. The results provided are clearly evidence-based. The hydrologic modelling results appear to be robust, however, MDBA has indicated they believe some of the models (e.g. the Gwydir IQQM) are not able to adequately represent iKEA flow regimes and that modelling of environmental flow regimes for the unregulated rivers of the Basin appears has been problematic with lower confidence in the modelling results for these rivers.

It is beyond the scope of this review to critique the performance of individual models, however, MDBA should ensure any such concerns with model performance for Basin planning purposes are documented and subject to expert review prior to discounting counter-intuitive or unexpected modelling results.

The modelling and analyses undertaken by MDBA indicate that under the proposed SDLs (a 2800 GL/yr average annual reduction in basin-wide surface water diversions) significant increases in the frequencies of watering of major floodplain wetland systems across the Basin could be achieved as well as improvements to within channel environmental flow regimes. The modelling suggests that for this level of change in consumptive water use, and with appropriate management of new environmental water, valuable ecological benefits could be delivered across the Basin.

The modelling indicates that in some cases operational constraints prevent delivery of environmental water to meet targets, and in presenting the modelling results MDBA has categorised the hydrologic targets into (i) “achievable under current operating conditions” (91 targets), (ii) “achievable under some conditions (constrains limit delivery at some times)” (16 targets) and (iii) “difficult to influence achievement under most conditions (constraints limit delivery at most times)” (13 targets). Given the 13 targets in the last category, it is currently unclear whether all the proposed ecological targets and high-level environmental objectives are fully consistent with a managed water resource system.

The degree to which the 2800 GL/yr reduction scenario meets the hydrologic targets across these categories is summarised in Table 2. The SDLs modelled in this scenario do not achieve the majority of the hydrologic targets; they meet 55% of the “achievable” targets at either the “high risk” or “low risk” frequency. The 2800 GL/yr reduction scenario is thus not consistent with the currently stated environmental targets.

Category	**No. Targets Reported Against**	**Met at “low risk” frequency**		**Met at “high risk” frequency**		**Not Met But Improvement Likely**		**No Improvement**		**Worse than Baseline**	
		No	%	No	%	No	%	No	%	No	%
Achievable under current operating conditions	83	22	27	23	28	27	33	10	12	1	1
Achievable under some conditions	16	1	6	4	25	7	44	3	19	1	6
Difficult to influence achievement under most conditions	13	0	0	0	0	2	15	7	54	4	31
Total	**112**	**23**	**21**	**27**	**24**	**36**	**32**	**20**	**18**	**6**	**5**

Table 2. Number and per cent of hydrologic targets met by category under in the 2800 GL/yr reduction scenario modelled by MDBA as indicated by results summary of 10 August 2011.

While operational constraints preclude the meeting of some hydrologic and ecological targets, in other cases the shortfalls against targets appear to be a result of insufficient environmental water, the shortcomings in modelling environmental flow regimes in unregulated rivers or a combination of these factors. Modelling and analysis of water use reduction scenarios above the 2800 GL/yr scenario are required to more fully assess the reasons for the modelled shortfalls. The level of take represented by the 2800 GL/yr reduction scenario is not consistent with the currently stated hydrologic and ecological targets given the available evidence base.

The panel understands that other reduction scenarios have been modelled, but the panel has not seen modelling results for these other scenarios, and thus it is not clear how the 2800 GL/yr reduction proposal was arrived at. The panel assumes this proposal was arrived at as a result of socio-economic considerations by MDBA (as per the logic in Figure 1), but a consideration of socio-economic analyses is beyond the terms of reference for this review. As indicated in the logic of Figure 1 the feedbacks following socio-economic considerations require a revision to the environmental targets (or to KEA and KEA) in order for the proposed ESLT to be consistent with the stated objectives and targets.

The panel accepts that the modelling results provided do not necessarily represent the optimal environmental outcomes that could be achieved under a "2800 GL/yr reduction" scenario. Limitations in the modelling and assumptions about how environmental water would be used mean that the modelled outcomes from the proposed ESLT are likely to be less than what could be achieved in practice. Further work is required to explore more optimal environmental watering under the proposed Basin Plan. Nonetheless, the modelling results are currently the best available evidence base for the expected environmental performance of the proposed ESLT.

It appears that MDBA has not yet followed the feedback loops in Figure 2 to interpret the likely ecological consequences of this level of hydrologic performance and to assess if the proposed high-level environmental objectives are likely to be met under the proposed SDLs.

The modelling indicates that if environmental water were to be managed as modelled, the proposed SDLs would increase the frequency of smaller beneficial floods but reduce the frequency of reservoir spills thus decreasing the frequency of larger beneficial floods. As modelled, the proposed SDLs would thus deliver environmental benefits on the areas of the floodplain that can be watered more easily, but would deliver some dis-benefits for areas of the floodplain that are difficult to water (for example, parts of the Riverland-Chowilla Floodplain). This highlights that there are trade-offs to be made between different environmental outcomes in managing environmental water.

In summary, the modelling indicates that the proposed SDLs would be highly unlikely to meet the specified ecological targets even in the absence of future climate change. Operational constraints are a key reason for this, but a large number of achievable targets are also not met in the modelling. MDBA has undertaken a robust assessment of which hydrologic targets are currently achievable and which would be difficult to achieve. This assessment however, does not seem to have led to revision of the ecological targets to remove those unachievable given unavoidable constraints. An interpretation of what, ecologically, can be realistically achieved with the Basin Plan under the proposed SDLs has not yet been clearly articulated, either at a site level or at a basin level.

With respect to climate change, it is recommended that MDBA indicate whether, if the drying projections for the Basin come to pass, the MDBA's intention would be to revise the environmental objectives for the Basin Plan, enforce more stringent SDLs to ensure environmental protection, or adopt some compromise between the two.

8. ESLT UNCERTAINTY

The five-step process for ESLT and SDL determination (Figure 2) provides a framework for summarising the relative uncertainties and sources of uncertainty and assessing the materiality of these to the magnitude of the ESLT and SDLs. Table 3 provides preliminary qualitative assessments of uncertainty based on the expert opinion of the panel in the context of the material reviewed. This emphasises that the largest source of material uncertainty in the ESLT and SDLs is the policy choices involved in defining environmental objectives.

The Panel recommends that MDBA adopt this or similar frameworks to both assess and communicate the types and sources of uncertainty and to direct future technical effort and research endeavours. Ideally this could be refined to indicate quantitative levels of uncertainty. Given the uncertainties involved the Panel strongly recommends MDBA commit to an adaptive approach to implementation of the Basin Plan informed by a well-designed ongoing environmental monitoring and evaluation program that supports longer-term knowledge generation in order to iteratively refine the ESLT and SDLs.

Step	**Relative Uncertainty**		**Sources of Uncertainty**	**Materiality of Uncertainty to Magnitude of ESLT and SDLs**
Define environmental objectives	--		Primary: policy choice	high
Identify KEA and KEF	KEA	low	Primary: MDBA methods Secondary: scientific knowledge	low
	KEF	high	Primary: scientific knowledge Secondary: MDBA methods	low
Specify ecological targets	KEA	moderate	Primary: scientific knowledge Secondary: MDBA methods	moderate
	KEF	--	*No targets specified*	low
Specify EWR & hydrologic targets	KEA	moderate	Primary: scientific knowledge Secondary: MDBA methods	moderate
	KEF	high	Primary: scientific knowledge Secondary: MDBA methods	low
Determine SDLs that meet targets	moderate		Primary: MDBA methods Secondary: scientific knowledge	moderate

Table 3. Summary of relative uncertainty for each step of the ESLT and SDL determination process, sources of uncertainty and their materiality to the ESLT and SDLs.

9. RECOMMENDATIONS FOR FUTURE WORK

Ongoing improvements can be made over the coming months and years in the application of best available science to the determination and management of an ESLT for the Basin. Future investments in ecological research and monitoring are critical to guide an adaptive approach to implementation of the Basin Plan, and to ensure that the ecological outcomes gained from every mega-litre of applied environmental water continue to improve.

In the assessments presented in Sections 3–7 numerous recommendations are made for future work that relate directly to the terms of reference of the review. These are consolidated in Table 4 (work recommended for the short term), Table 5 (work recommended for the medium-term) and Table 6 (work recommended for the long-term) against the five steps in the SDL determination process (Figure 2).

These time frames are defined as follows: short term – prior to the finalisation of the Basin Plan in 2012; medium term – in the period prior to the 2015 (when SDLs are expected to be reviewed); long term – ongoing beyond 2015. Some of the work recommended for the short term is considered critical for supporting consultation on the proposed Basin Plan – these tasks are indicated in italics in Table 4. The remaining work recommended for the short term is not considered critical but represents a relatively small effort that would usefully strengthen the body of work.

In addition to the recommendations in Tables 4–6, several general recommendations were also made in the preceding sections:

1. The KEA database should be maintained and expanded to support adaptive implementation of the Basin Plan.
2. All modelling input and output data should be archived as an audit trail of the modelling and to enable future analysis.
3. In developing and applying the 'body of science' to the Basin Plan a more open and inclusive engagement with the water science community is recommended.
4. The development of new river models for the Basin using the eWater CRC SourceRivers modelling platform should continue to be supported.

The most important additional work in the short term is completing and publishing coherent and comprehensive documentation of the ESLT analyses. This will greatly increase the transparency and defensibility of the work. We recommend that the documentation include:

1. A coherent conceptual ecological model linking flow regimes to ecological responses, across multiple spatial scales and biogeographic zones, both as a means for guiding the compilation of scientific data and evidence underpinning an ESLT and to support effective communications of the science and analyses.
2. Description of the final modelling methods stating the key assumptions and sources of uncertainty.
3. A summary of the modelling results that support the proposed ESLT and SDLs indicating which hydrologic targets can be met under current constraints, the likely overall ecological consequences and the extent to which these are consistent with the higher-level environmental objectives of the Basin Plan.
4. A Basin-scale synthesis of expected environmental benefits from the proposed ESLT and SDLs.

The recommendations for future work in Tables 4–6 that have been identified in the course of this review only relate to the Basin-scale water resource planning process. Other research and technical work would be expected to assist in regional-scale water resources planning. Additionally, implementation of the Basin Plan represents a major challenge that would be sensibly supported by targeted research, especially to guide the effective and efficient management of environmental water. It is beyond the scope of this review to present a strategic research plan to guide adaptive water planning and adaptive water management in the Basin. However, a number of the panel members have separately prepared such a document and provided this to MDBA to the Commonwealth Department for Sustainability, Environment, Water, Population and Communities.

Step	Key Additional Work to Reduce ESLT and SDL Uncertainty
Define environmental objectives	• *Review the proposed ecological targets and high-level environmental objectives to ensure they are consistent with unavoidable system constraints (such as the presence of major dams).*
Identify KEA & KEF	• Clarify and clearly document the conceptual basis for the inclusion of KEF in the ESLT method. • Specify more clearly the sources of scientific information on which the articulation of KEF values has been based.
Specify ecological targets	• Clarify where necessary the basis for the areal extent of iKEA ecological targets.
Specify EWR & hydrologic targets	• More fully document the links between KEF and flow metrics based on the peer-reviewed scientific literature. • Review either the target watering frequencies or the associated risk nomenclature to ensure consistent use of risk nomenclature.
Determine SDLs that meet targets	• *Report both absolute and proportional changes in KEF flow metrics relative to the modelled baseline, as well as the maximum period between iKEA watering under the proposed SDLs.* • *Clearly communicate to stakeholders the policy choices around climate change implicit in the proposed Basin Plan, and demonstrate how the Basin Plan would perform during the worst extended drought sequence in the historic record, and ideally, the worst drought sequence from one or more future climate scenarios.* • *Improve the consistency between proposed SDLs, specified ecological targets and high-level environmental objectives. This could be via revision to targets or SDLs or both, and/or commitment to a program of works and measures.*

Table 4. Recommended future work for the short term, with critical tasks indicated in italics.

Step	Key Additional Work to Reduce ESLT and SDL Uncertainty
Define environmental objectives	
Identify KEA & KEF	• Develop a biophysical classification of KEA in the MDB to support both the existing methodology and to guide future research and monitoring programs, as well as to test the representativeness of iKEA. • Strengthen the approach to including KEF in the methods, including an improved classification, a regionalisation of KEF and a "mapping" of KEF importance across the Basin. Use the classification to test the representativeness of KEF indicator sites.
Specify ecological targets	• Specify more clearly the ecological outcomes associated with KEF flow targets.
Specify EWR & hydrologic targets	• Undertake a fuller analysis of the water requirements of species associated with iKEA to demonstrate whether these are sufficiently captured in the vegetation requirements that have been assessed. • Explore the scope for location-specific hydrological targets for KEF. • Test that KEA and KEF indicator sites are sufficient to represent the full set of environmental water requirements and their redistribution across the Basin. It is recommended that this is approached by assessing the sensitivity to the Basin-wide environmental water requirement to the number and distribution of indicator sites – incrementally increasing the number of indicator sites used in the analysis to determine whether the Basin-wide environmental water requirements change.
Determine SDLs that meet targets	• Undertake floodplain inundation modelling for a few key sites such as the Riverland-Chowilla to test the sensitivity of ecological outcomes in higher floodplain areas to variations in the basin-wide SDL. • Undertake Basin-wide inundation modelling to determine how many KEA, and of what types, will be watered under the target flow regimes described for iKEA. • Undertake modelling of floodplain wetland inundation and ecological responses to guide determination of efficient and effective environmental water regimes. • Explore the sensitivity of SDLs to carry-over rules to ensure the most efficient use can be made of recovered environmental water. Initially, simplified modelling approaches could be explored. This should be explored in the context of assessing how operational constraints could be overcome as these aspects of water management strongly interact. • Undertake modelling to assess the extent to which works and measures could enable existing constraints to be overcome and thus improve ecological outcomes. • Consider development of a simpler basin-wide hydrologic model explicitly linked to ecological and economic outcomes in order to rapidly explore multiple SDL options and the implications of model parameter uncertainty. • Determine the magnitude of future adjustments to SDLs that would be required under a range of future climate change scenarios to maintain the level of environmental protection offered by the currently proposed SDLs. • Communicate the approach to sharing the longer-term risks associated with climate change between water users and the environment.

Table 5. Recommended future work for the medium term.

Step	Key Additional Work to Reduce ESLT and SDL Uncertainty
Define environmental objectives	
Identify KEA & KEF	• Broaden the perspective on KEA from a site-focus to encompass an ecosystem or landscape view (within the framework of a KEA classification).
Specify ecological targets	• Explore opportunities to broaden ecological targets to incorporate consideration of ecosystem services and other ecological values beyond biodiversity.
Specify EWR & hydrologic targets	• Strengthen the linkages between hydrologic targets and ecological outcomes for KEA and KEF based on evaluation of long-term monitoring data supported where appropriate by targeted research.
Determine SDLs that meet targets	

Table 6. Recommended future work for the long term.

10. APPENDIX A: MATERIAL PROVIDED FOR THE REVIEW

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ACRONYMS & GLOSSARY

ESLT	Environmentally Sustainable Level of Take
IRSMF	Integrated River System Modelling Framework
IWRM	Integrated Water Resources Management
KEA	Key Environmental Asset
KEF	Key Ecosystem Function
iKEA	Indicator Key Ecosystem Asset
MDBA	Murray-Darling Basin Authority
MFAT	Murray Flows Assessment Tool
SDL	Sustainable Diversion Limit
SRP	Scientific Reference Panel
TLM	The Living Murray

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