A science review of the implications for South Australia of the Guide to the proposed Basin Plan: synthesis

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Director’s foreword

I am privileged to present, on behalf of the Goyder Institute for Water Research, this science review of the Guide to the proposed Basin Plan to the Government of South Australia and the community and stakeholders within the Murray–Darling Basin. This report constitutes an important contribution to the feedback on the Murray-Darling Basin Authority’s proposals from a South Australian perspective.

The *Water Act (2007)* requires the Murray–Darling Basin Authority to prepare and implement a Basin Plan for the integrated and sustainable management of water resources in the Basin. The October 2010 release of the Guide to the proposed Basin Plan is a first step in this process and a major milestone for water management in Australia. Given our recent experiences of devastating floods and uncompromising droughts, public interest in how water is managed is very high. All of us who are involved in the management of water resources – through policy, advocacy, R&D and resource management – share the responsibility to ensure the Basin Plan will be as good as it can be and will bring lasting benefits for all Australians.

Like all of the States that share management of the Murray–Darling Basin, South Australia has an interest in how the Plan is put together and how it will benefit its people. In many ways, South Australia is in a unique position due to its location at the end of the River Murray system. The Basin Plan should ultimately result in increased flows across the South Australian border benefiting environmental assets in the lower River Murray.

The Goyder Institute for Water Research has been formed to enhance the South Australian Government’s capacity to develop and deliver science-based policy solutions in water management, and contribute to water reform in Australia. This report provides a valuable contribution towards this aim by helping to raise our levels of understanding of the possible implications for South Australia of the proposed sustainable diversion limits described in the Guide.

In developing proposed sustainable diversion limits in the Guide, the Murray–Darling Basin Authority has explored a number of scenarios to understand the trade-offs between risk to the environment and social and economic effects. Upon release of the Guide, the South Australian Government, through the Goyder Institute for Water Research, commissioned a science review of the Guide proposals in order to provide a South Australian perspective on the environmental and socioeconomic implications of the proposed sustainable diversion limits. Furthermore, we have used and modified a range of modelling tools in order to develop and test the feasibility of proposed and modified flow scenarios that could meet South Australia’s environmental water requirements.

This review has been conducted by CSIRO as a member of the Goyder Institute. In reporting the findings of this review, the scientific team has worked closely with South Australian Government agency staff in order to ensure relevance of the findings to state and national water policy. The analyses and associated tools used in this study also provide new insights into the development of uniform and transparent techniques and methodologies that could be used to help analyse environmental and socioeconomic aspects of the Basin Plan when it is released.

I trust that this report will be seen as a positive and constructive contribution to the discussions about the proposed sustainable diversion limits for the Murray-Darling Basin.

Dr Tony Minns

Director

Goyder Institute for Water Research

Adelaide

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Terms and abbreviations

The report uses terminology used by MDBA in their Guide to the proposed Basin Plan (MDBA, 2010a; 2010b), except where this is inconsistent or conflicts with the reporting needs of this review.

ARI	average return interval (usually expressed as '1-in-5 years', for example)
BSMS	The MDBA's Basin Salinity Management Strategy
CDL	current diversion limit
cease-to-flow	'zero' flow, i.e. no water is coming down the river from upstream
CLLMM	The Coorong, Lower Lakes, and Murray Mouth – a key environmental asset
EC	electrical conductivity; a measure of salinity – the more salt the higher the EC. EC is usually expressed in microSiemens per cm at 25°C (µS/cm)
EWRs	environmental water requirements
GL/year, GL/y	gigalitres per year (10^9 litres per year)
Key ecosystem function site	equivalent to 'hydrologic indicator site for key ecosystem functions' as used in the Guide
Key environmental asset	equivalent to 'hydrologic indicator site for key environmental asset' as used in the Guide
MDBA	Murray–Darling Basin Authority
ML/year, ML/y	megalitres per year (10^6 litres per year)
Riverland–Chowilla	a key environmental asset
SDL	sustainable diversion limit
tonnes/year, tonnes/y	tonnes per year
the Basin	the Murray-Darling Basin
the border	the River Murray at the South Australian border
the Guide	the Guide to the proposed Basin Plan
the Plan	the Basin Plan

Scenarios and EWR optimised flows

Baseline	the flow that comes across the border under the current water sharing plans in all regions in the Basin. In the Guide it represents an average annual flow of 6783 GL at the border.
Without development	the baseline scenario with storages, urban and domestic usage and all river management rules removed. Since unregulated inflows are not adjusted for upstream usage or change in landuse in this scenario, it is not the same as a pre-development (or 'natural') flow sequence. In the Guide it represents an average annual flow of 13,592 GL at the border.
3000	the current sharing plans adjusted for 3000 GL/year of water being returned to the environment, spread across the regions of the Basin. In the Guide it represents an average annual flow of 8661 GL at the border.
3500	the current sharing plans adjusted for 3500 GL/year of water being returned to the environment, spread across the regions of the Basin. In the Guide it represents an average annual flow of 8966 GL at the border.
4000	the current sharing plans adjusted for 4000 GL/year of water being returned to the environment, spread across the regions of the Basin. In the Guide it represents an average annual flow of 9290 GL at the border.

MDBA Riverland–Chowilla EWRs optimised flow	a daily flow series at the border, optimised to meet the EWRs for Riverland–Chowilla as they are described in the Guide
SA Riverland–Chowilla EWRs optimised flow	a daily flow series at the border, optimised to meet the EWRs for Riverland–Chowilla as specified by SA for the purposes of this assessment (see Chapter 2)
MDBA CLLMM EWRs optimised flow	a daily flow series at the border, optimised to meet annual volumes at the barrages required to meet the EWRs for the CLLMM as described in the Guide (MDBA, 2010)
SA CLLMM EWRs optimised flow	A daily flow series at the border, optimised to meet annual volumes at the barrages required to meet the EWRs for the CLLMM as specified by SA for the purposes of this assessment (see Chapter 2).

Models and data

Guide annual model Guide annual (volumes)	The model used to derive the long-term average annual volumes reported in the Guide, and the annual volumes made available in December 2010, noting that these were aggregated from monthly results
BigMod daily model BigMod daily (flow) BigMod annual (volumes)	The MDBA's MSM-BigMod model and its results. A configuration of the model was provided for each scenario, together with daily flow and diversions data. These data were aggregated to annual volumes for comparison with Guide annual volumes.

Executive summary

Introduction

In October 2010 the Murray–Darling Basin Authority (MDBA) released the Guide to the proposed Basin Plan[1] (the Guide) for public consultation. Within the Guide, the MDBA described scenarios that could 'meet the environmental water requirements for the Basin'[2]. The scenarios describe long-term average sustainable diversion limits for the Basin designed to return additional water to the environment.

Prior to the release of the Guide, the South Australian Government invited the Goyder Institute for Water Research to determine whether the proposed sustainable diversion limits would meet the South Australian Government's environmental water requirements and improve or maintain water quality. The review was also to assess the socioeconomic implications of reductions in diversion limits to the major water users within South Australia.

This synthesis report describes the findings of the review. Four accompanying peer-reviewed technical reports describe the methods and findings of the work undertaken:

- an analysis of the South Australian Government's environmental water and water quality requirements and their delivery under the Guide to the proposed Basin Plan
- an independent peer review of the science underpinning the environmental water requirements of the Coorong, Lower Lakes, and Murray Mouth
- a report on the socioeconomic implications of the Guide to the proposed Basin Plan, and
- a compilation of reports informing a socioeconomic review of the Guide to the proposed Basin Plan.

The Guide to the proposed Basin Plan

The Guide proposes three scenarios that describe Basin-wide reductions in average annual surface water diversions designed to return additional water to the environment of 3000, 3500 and 4000 GL/year.

The Guide scenarios result in an increase in average annual volumes across the border to South Australia from 6783 GL/year under current water sharing arrangements to 8661 GL/year, 8996 GL/year or 9290 GL/year under the 3000, 3500 and 4000 scenarios, respectively.

The Guide scenarios also include reductions in diversions within South Australia; average annual diversion limits are reduced by 173, 203 and 232 GL/year from the current limit of 665 GL/year as a result of the 3000, 3500 and 4000 scenarios, respectively.

The Guide identifies two key environmental assets in South Australia; these are the Riverland–Chowilla, and the Coorong, Lower Lakes, and Murray Mouth (CLLMM). The MDBA and the South Australian Government[3] have both determined environmental water requirements for these assets based on estimates of the flows required by riverine, floodplain-wetland and estuarine ecosystems. The ecological objectives for the environmental assets – and the corresponding environmental water requirements – are broadly consistent between the Guide and the South Australian Government, although the South Australian Government considers more of the ecological communities within the Riverland–Chowilla.

Work undertaken

CSIRO[4] undertook a scientific review of aspects of the Guide and conducted additional investigation, by:

- obtaining modelled annual volumes and daily flow sequences from the MDBA that represent the 3000, 3500 and 4000 scenarios (Guide scenarios)

[1] The Guide to the proposed Basin Plan, MDBA, 2010a; 2010b
[2] Page 102, MDBA, 2010a
[3] DWLBC, 2010
[4] CSIRO undertook this project as a partner in the Goyder Institute for Water Research.

- assessing the ability of these modelled representations of the Guide scenarios to deliver South Australia's environmental water requirements and meet water quality and salinity targets
- assessing the socioeconomic impacts of the Guide scenarios on major water users in South Australia
- developing optimised modelled flow scenarios that would meet South Australia's environmental water requirements
- assessing the feasibility of delivering these optimised flows.

The modelling period is 114 years, from 1 July 1895 to 30 June 2009. This period covers a wide range of climatic conditions, including the recent Millenium Drought (2000–2009). This provides adequate climatic variability to consider the effect of the Guide scenarios under extreme wet and dry conditions.

The analyses described in this report are based on daily flow data; the South Australian Government's environmental water requirements for Riverland–Chowilla include magnitude, duration and frequency of environmental flow events that can only be assessed by modelling expected daily flows. This is different to the sustainable diversion limits, and environmental water requirements, in the Guide that are based on average annual volumes.

Through a peer-reviewed and critical scientific assessment, CSIRO has assessed:

- whether environmental water requirements, as determined by the MDBA and the South Australian Government can be delivered under the Guide scenarios
- whether water quality and salinity targets will be met under the Guide scenarios
- the socioeconomic impacts of reductions in diversions within South Australia, and
- optimal flow scenarios that could meet the South Australian Government's environmental water requirements and the feasiblilty of delivering these flows.

Environmental water requirements and delivery

Overall, the Guide scenarios substantially increase flows in the lower River Murray compared to now, and therefore increase the likelihood of maintaining or improving ecological condition.

There is potentially sufficient average annual volume under each of the Guide scenarios to meet both the MDBA and South Australian Government's environmental water requirements for the CLLMM. Analysis of the Guide scenarios show that some of the environmental water requirements for the CLLMM are met some of the time, but are unlikely to always be met, mainly due to how and when flows are delivered. If the delivery of flows were optimised under the 4000 scenario, all of the environmental water requirements for the CLLMM could be met.

There is also potentially sufficient average annual volume under the Guide scenarios to meet the MDBA environmental water requirements and, with the exception of the 3000 scenario, to meet the the South Australian Government's environmental water requirements for the Riverland–Chowilla. However, these environmental water requirements specify timing, magnitude and duration of flows and these are unlikely to be delivered under any of the Guide scenarios. Even if the timing of flow delivery were optimised, the environmental water requirements are unlikely to be met every year because of constraints on the storage and release of water. Even so, the Guide scenarios reduce the length of time that some floodplain-wetlands are dry, particularly where redgum forest and woodland communities are located, and this would be expected to have environmental benefits.

Under the Guide scenarios, it is anticipated that there will be more frequent environmental releases and that this will result in less water being retained in storage. Consequently, high flows will be less common than now, as these flows rely on spills from storages (when storages are at 100% capacity). This means that areas of the floodplain at and above the 100,000 ML/day threshold are likely to be drier and black box communities are therefore at a higher risk of change.

This means that how water is delivered, particularly the operation of upstream storages and assets will be critical to the meeting of the South Australian Government's environmental water requirements.

Salinity and water quality

Overall the Guide scenarios improve water quality compared to current conditions although the differences between the three scenarios are small.

Under the Guide scenarios, there is a slight decrease in the occurrence of low flows in summer (below 7000 ML/day) and this is expected to reduce the risk of cyanobacterial blooms in the River Murray. Water levels in the Lower Lakes drop below sea level less often and for shorter periods; this is expected to maintain stable lake alkalinity and therefore lower the risk of acidification.

At Morgan, the South Australian Government's salinity targets and those from the MDBA Basin Salinity Management Strategy are met; the risk of exceeding 800 EC (electrical conductivity units) is reduced and the risk of exceeding 1400 EC is virtually eliminated. Despite these improvements the MDBA's target for salt export through the barrages is not met under any of the scenarios[5]. The Guide concludes that: 'failure to achieve the target is likely to result in salt accumulation in wetlands and on floodplains, resulting in a decline in condition of those systems, as well as elevated salinity across the Basin, which may impact on consumptive uses'[6].

Socioeconomic impacts

Overall the socioeconomic impacts for major water users in South Australia are similar under the three Guide scenarios.

During the recent Millenium Drought expenditures to protect against reduced water quality, damage from riverbank slumping, road damage, curtailed ferry services, as well as tourism revenue losses were estimated at over $790 million. Under the Guide scenarios, similar mitigation and adaptation expenditures and damage costs may be avoided in the future.

The Guide scenarios do represent costs for South Australian water users. If reductions in diversions were implemented in South Australia solely through reductions in allocation available for irrigation the cost could be up to 5% of the average annual gross value of irrigated agricultural production in the South Australian portion of the Basin (under the 3500 scenario).

Costs to the irrigation sector can be reduced if the reductions in irrigation allocations – required to achieve the sustainable diversion limits – are achieved by purchasing water entitlements or investing in infrastructure as this will generate new regional economic activity to offset lost regional irrigation economic activity.

Irrigation sector costs can be further reduced by sharing the reductions in diversions within the State between municipal and industrial water and irrigation. Removing remaining impediments to water trade and allowing equitable access to dam storage capacity for carry-over for irrigators would also have a positive impact.

Next steps

This review was able to assess whether the Guide scenarios could meet the environmental water requirements as determined by the South Australian Government for CLLMM and the Riverland–Chowilla. The review could not determine what impact partially meeting the environmental water requirements would have on these ecosystems.

Future work is needed to:

- quantify the environmental outcomes from (partially) meeting environmental water requirements
- develop knowledge and management tools to optimise flow regimes for environmental and other outcomes
- consider risks (threats and consequences) including likely impacts of climate change, and
- refine understanding of socioeconomic impacts of the Basin Plan.

The skills and tools developed during this project can be applied elsewhere and for assessing future flow scenarios for South Australia.

[5] This is acknowledged in the Guide.
[6] Page 118, MDBA 2010a

Contents

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1 Context

This chapter provides background information to the project and the work undertaken in fulfilling the project's terms of reference. It provides background on the:

- terms of reference
- report structure
- assessment region (South Australian portion of the Murray-Darling Basin)
- scenarios
- models and model data
- modelling approach
- companion documents.

1.1 Terms of reference

In September 2010, the South Australian Government invited the project team to review and interpret the science underpinning the Guide to the proposed Basin Plan (MDBA, 2010a; 2010b) (the Guide) to better understand the implications of the Guide for South Australia. This review was undertaken by a CSIRO team through the Goyder Institute for Water Research. The objectives of the review were to:

- coordinate and engage scientific expertise from Government and Goyder partners who have the skills required to review and interpret the science underpinning the Guide to better understand its implications for South Australia
- interpret the science underpinning the Guide and provide advice on the implications of the proposed sustainable diversion limits, water quality and salinity management, and environmental water requirements for the South Australian Murray-Darling Basin including the environmental, social and economic impacts
- independently review and assess the modelling underpinning the proposed sustainable diversion limits (SDLs) and environmental water requirements
- undertake additional modelling, literature review and analysis as agreed with the South Australian Government's Basin Plan Chairs' Coordinating Group to support a South Australian Government response to the Guide
- provide expert verbal and written advice to support the review of the Guide by South Australian Government's Expert Reference Groups as agreed with the Basin Plan Chairs' Coordinating Group
- provide data and information to support alternative options and approaches to those identified in the Guide as agreed with the South Australian Government's Basin Plan Chairs' Coordinating Group
- document a scientific evidence base to support the delivery of a scientifically robust submission from South Australia to the Guide
- complete a consolidated Science Review of the Guide for the South Australian Government's Basin Plan Chairs' Coordinating Group.

The review was conducted over the period October 2010 to March 2011, with the bulk of the modelling work conducted in February 2011.

This report represents a synthesis of that review which, together with companion technical reports, form the major deliverables of the project.

1.2 Report structure

Reflecting the terms of reference to review the impacts of the Guide, and to extend that review to explicitly link EWRs to flow regimes (and by implication to sustainable diversion limits), the report has two parts:

- Review of the implications of the Guide scenarios
    - Chapter 2 – Assessing South Australia's environmental water requirements
    - Chapter 3 – Water quality and salinity
    - Chapter 4 – Socioeconomic analysis
- Assessing the feasibility of delivering flows to meet environmental water requirements
    - Chapter 5 – Delivering a flow regime to meet South Australia's environmental water requirements.

Chapter 2 contains an assessment of the Guide scenarios' ability to meet environmental water requirements (EWRs) for South Australia's key environmental assets – Riverland–Chowilla, and the Coorong, Lower Lakes, and Murray Mouth (CLLMM); and key ecosystem functions at three locations along the River Murray.

Chapter 3 describes the assessment of the impacts of the Guide scenarios on water quality and salinity.

Chapter 4 contains an assessment of the socioeconomic approach adopted in the Guide, and a socioeconomic assessment of the impacts of the Guide scenarios.

Chapter 5 describes the additional analysis to create a set of optimised flows and annual volumes at the border from the EWRs (and thus meet them) and then assess the ability of the Guide scenarios to deliver these optimised flows.

The implications of these reviews and assessments for South Australia and for the further development of the Basin Plan are considered in Chapter 6 (Next steps).

1.3 Assessment region

The review has been confined to the South Australian portion of the Murray-Darling Basin (Figure 1.1). The EWR assessment is made against two key environmental assets: Riverland–Chowilla and CLLMM; and three key ecosystem function sites. Water quality is assessed at Lake Alexandrina and Morgan; salinity and salt loads are assessed at the border, Berri, Morgan, Murray Bridge, Tailem Bend, Wellington, Lake Alexandrina and the barrages.

Riverland–Chowilla

Riverland–Chowilla is located downstream of the Murray–Darling junction, encompassing the Riverland Ramsar site and adjacent wetlands extending to Renmark, the Chowilla floodplain, and the Lindsay–Wallpolla Islands. The site is characterised as a mosaic of anabranch creeks, wetlands, lagoons, lakes and floodplains. The dominant communities are black box woodlands, lignum shrublands, red gum woodlands, localised red gum forest and grasslands. The model gauge used to assess the flow requirements for this site is located at the South Australian border.

Coorong, Lower Lakes, and Murray Mouth (CLLMM)

The CLLMM are located at the terminus of the Murray-Darling Basin, and is composed of a diverse range of freshwater, estuarine and marine habitats. The River Murray passes through Lake Alexandrina, the Murray estuary and the Murray Mouth. Lake Albert is a terminal lake connected to Lake Alexandrina, and these make up the Lower Lakes. The lakes are freshwater and are separated from the Murray Mouth and Coorong by a series of barrages. The Coorong is an estuarine lagoon system, which ranges from brackish to hypersaline and is connected to the Southern Ocean via the Murray Mouth. The site provides important habitat for bird and fish species. This project assessed the flow requirements for this site using a combination of flows at the barrages.

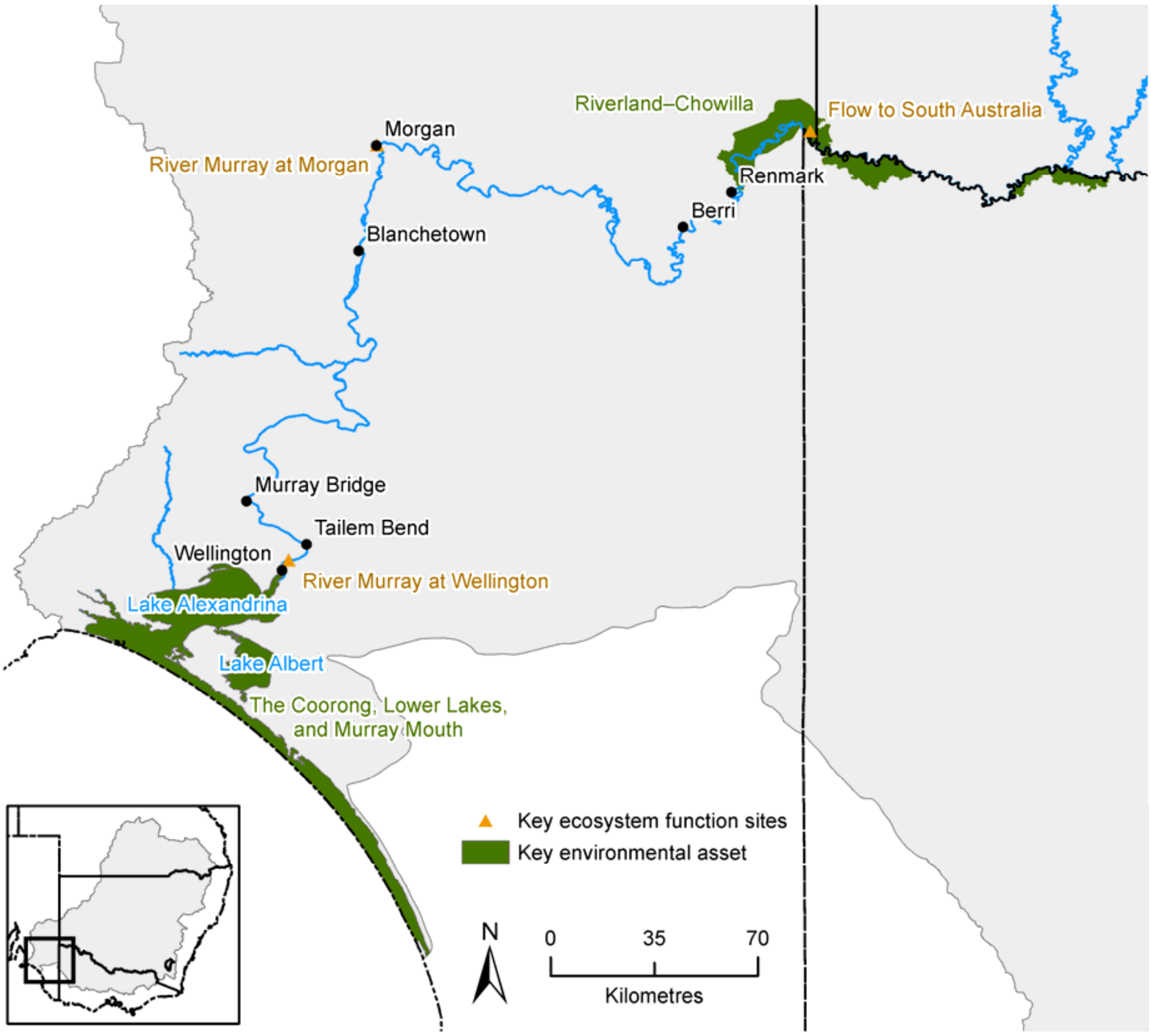

Figure 1.1 Map showing the River Murray in SA, key environmental assets and ecosystem function sites; and other locations referenced in this report

1.4 Scenarios

Five scenarios were provided by Murray–Darling Basin Authority (MDBA) and analysed as part of this review.

- Baseline
  - the current water sharing plans in all river valleys in the Basin.
- Without development
  - the baseline scenario with storages, urban and domestic usage and all river management rules removed. As unregulated inflows are not adjusted for upstream usage or change in landuse in this scenario, it is not the same as a pre-development (or 'natural') flow sequence. However it does serve a very useful purpose for comparing the effect of river regulation on flow patterns.
- 3000, 3500 and 4000
  - the three scenarios developed by the MDBA. They represent the current sharing plans adjusted for 3000, 3500 and 4000 GL/year of water being returned to the environment, spread across all of the regions of the Basin. These are collectively referred to as the Guide scenarios.

To be able to analyse environmental water delivery, four optimised flow files were developed (Chapter 5):

- MDBA Riverland–Chowilla optimised flows
    - the daily flow pattern required to come across the border to meet the EWRs for Riverland–Chowilla as described in the Guide (MDBA, 2010b).
- SA Riverland–Chowilla optimised flows
    - the daily flow pattern required to come across the border to meet the EWRs for Riverland–Chowilla as identified for the purposes of this assessment (see Chapter 2).
- MDBA CLLMM optimised annual volumes
    - the annual volumes required at the barrages to meet the EWRs for the CLLMM as described in the Guide (MDBA, 2010b).
- SA CLLMM optimised annual volumes
    - the annual volumes required at the barrages to meet the EWRs for the CLLMM as identified for the purposes of this assessment (see Chapter 2).

1.5 Models and model data

From MDBA

The MDBA released annual flow volumes for key environmental asset sites on their website in December 2010 <http://www.mdba.gov.au/basin_plan/model-data>. These annual data were aggregated from monthly results by an in-house MDBA model. Within this report, we refer to this model as the **Guide annual model**. These data are plotted in Figure 1.2 and referenced in the EWR analysis in Chapter 2.

Daily flows and salinity data model results and model configurations for the baseline, without development and Guide scenarios were provided to the project team by the MDBA on 20 January 2011 and are the basis for the analysis of daily flows as required for the assessment of EWRs, EWR delivery, water quality and salinity, and socioeconomic analyses. Only the model that represents the South Australian River Murray, i.e. the MDBA's MSM-BigMod model, for the five scenarios listed above, was made available. This restricted this review and analysis of the implications of the Guide to that part of the river below the South Australian border, and to the 3000, 3500 and 4000 scenarios. The MSM-BigMod daily flow model and results for the Guide 7600 scenario were not provided to the project team.

MSM-BigMod is used by MDBA for river planning for the Murray, including South Australia. MSM is a monthly timestep model that simulates the management (allocations, demands, dam operations, etc.) of the Murray and Lower Darling River System. BigMod is a daily timestep flow and salinity transport model that runs from above the border to the barrages between Lake Alexandrina and the sea. It routes flow and salt through the system. Its key outputs are daily flow, salinity and water levels. The modelling period is 114 years: from 1 July 1895 to 30 June 2009. This period covers a wide range of climatic conditions, including the recent drought. This provides adequate climatic variability required to consider the effect of the guide scenarios under extreme wet to extreme dry conditions.

The MSM-BigMod model configurations and results (for each scenario) were provided with caveats on their interpretation, in line with the caveats that MDBA has more recently published at <http://www.mdba.gov.au/basin_plan/model-data>. Issuing caveats with models is industry practice and it is important to read and understand the implications of these. Nevertheless, MSM-BigMod is routinely used by MDBA in their operational and planning activities, and the models were reviewed as part of the Basin Plan process and declared fit-for-purpose (Podger et al., 2010).

Results are reported from both the Guide annual and BigMod daily models to provide consistency between chapters and with the Guide. To assist the reader, and where it is important for clarity, the models and their results are referred to as:

- Guide annual model (as used by MDBA to underpin the Guide)
- BigMod daily model (the MSM-BigMod model as provided by MDBA).

These data sources are not congruent, i.e. annual and average annual volumes calculated from the BigMod daily model are similar to, but not the same, as those from the Guide annual model. This is mainly due to a different modelling approach. This does have an impact on results and their interpretation, and the MDBA provides caveats around the use of the MDBA daily model results. Nevertheless the analyses presented in this report could not have been conducted without the provision of the daily model. Table 1.1 and Figure 1.3 show some key statistics of the Guide scenarios, showing the difference in results, depending on the model.

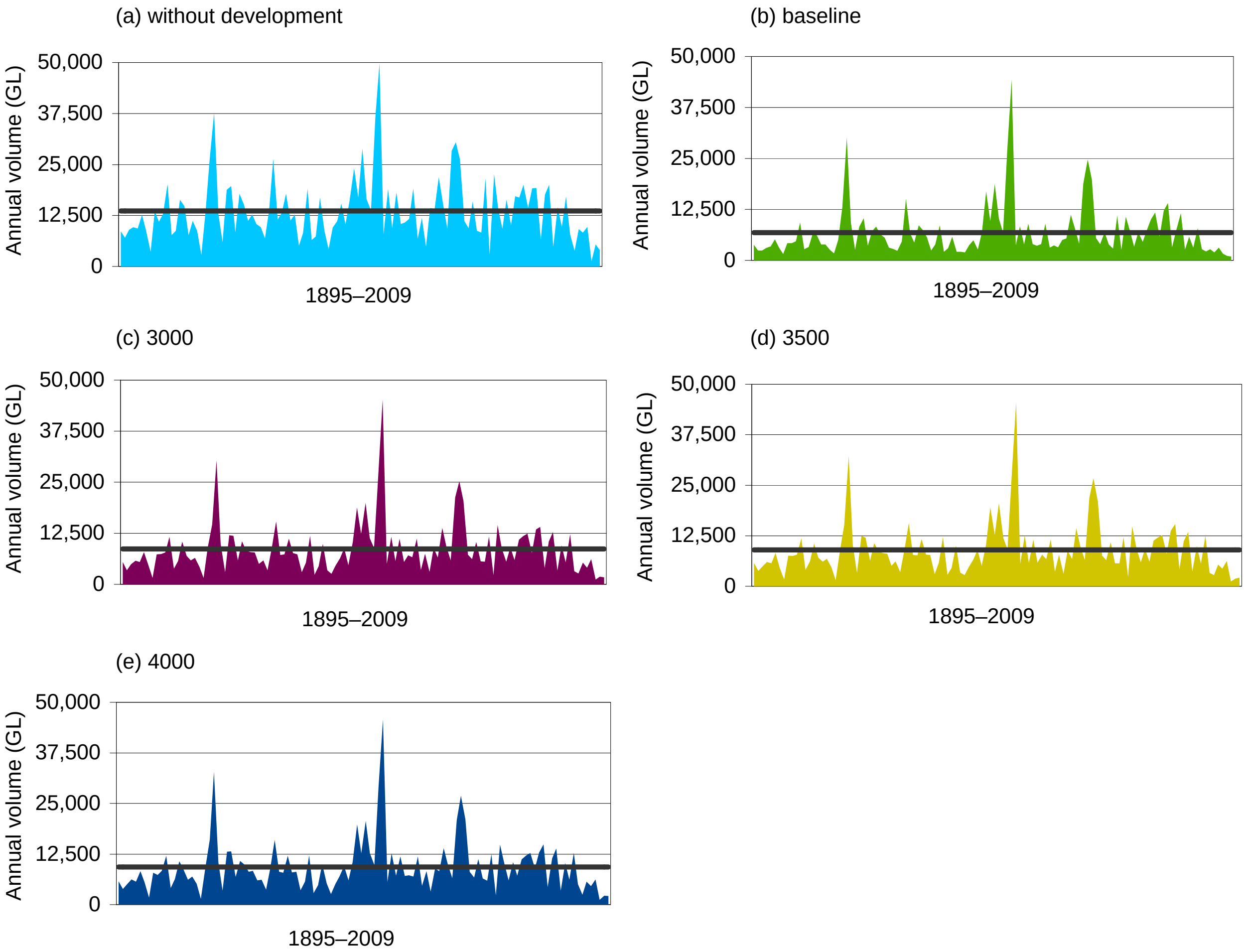

Figure 1.2 Annual volumes at the SA border under the (a) without-development, (b) baseline and (c–e) Guide scenarios, with the long-term average annual volume (as reported in the Guide) under each scenario shown as a black line

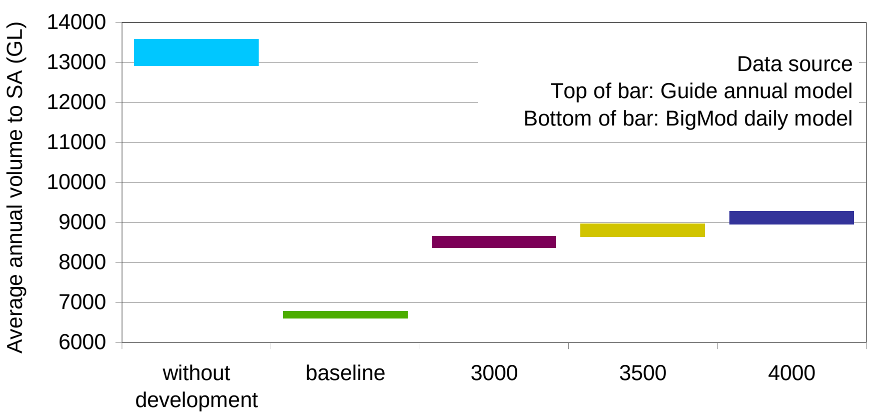

Figure 1.3 Average annual volumes at the SA border under the without-development, baseline and Guide scenarios, showing the difference in results sourced from the Guide annual model (top of bars) and the BigMod daily model (bottom of bars)

Table 1.1 Key flow and diversion limit statistics under the without development, baseline and Guide scenarios

	Scenario				
Source	without development	baseline	3000	3500	4000
	GL/y				
Average annual flow at the SA border					
Guide annual model	13,592	6783	8661	8996	9290
BigMod daily model	12,918	6603	8368	8644	8958
Difference in flow at the SA Border from without development					
Guide annual model	na	–6809 (–50%)	–4931 (–36%)	–4596 (–34%)	–4302 (–32%)
BigMod daily model	na	–6315 (–49%)	–4550 (–35%)	–4274 (–33%)	–3960 (–31%)
Difference in flow at the SA Border from baseline					
Guide annual model	na	na	1878 (28%)	2213 (33%)	2507 (37%)
BigMod daily model	na	na	1765 (27%)	2041 (31%)	2355 (36%)
Sustainable diversion limit (SDL)					
As specified in the Guide	na	665*	492	462	433
Change from CDL*	na	na	–173 (–26%)	–203 (–31%)	–232 (–35%)

na – not applicable
* Current diversion limit (CDL) is 665 GL/y as specified under the baseline scenario

Assessing environmental water requirements

eFlow Predictor v2.0.3 and the River Analysis Package (RAP) from the eWater modelling toolkit (www.toolkit.net.au) were used for creating flow series from the EWRs and performing flow-spell analyses. Microsoft Excel was also used for some components of the analysis and for producing plots. The use of eFlow Predictor is described in the companion technical report 'A science review of South Australia's environmental water and water quality requirements and their delivery under the Guide to the proposed Basin Plan' (Pollino et al., 2011).

Unless otherwise stated in the chapter, the assessments are based on results from the BigMod daily model.

Water quality and salinity

The assessments in Chapter 3 are based on BigMod daily flow, water level and salinity results. Where the assessment criteria were based on flow and/or water levels, the full 114-year historical period record was used. For salinity, results were available for the 34.5-year historical period from 1 January 1975 to 30 June 2009. The results from BigMod are the best available information for undertaking the analyses, but were not used by the MDBA in assessing water quality and salinity as reported in the Guide. More details on the use of this model are given in the companion technical report (Pollino et al., 2011).

Socioeconomic analysis

The models used for the socioeconomic analysis were developed in-house and include an irrigation-sector economics model, an SA Water economic impacts model and an ecosystem services and environmental benefits model. The irrigation-sector economics model was developed and solved with the General Algebraic Modelling System (GAMS) software. The SA Water economic impacts model was developed in Microsoft Excel with additional analysis conducted with @Risk, and the ecosystem services and environmental benefits model was developed in Microsoft Excel. These are described in the companion technical report 'Socioeconomic implications of the Guide to the proposed Basin Plan – methods overview' (Connor et al., 2011).

A baseline was derived from the 114 years of BigMod data for diversions under current diversion limits, using the entire 114-year period. To understand how allocations and irrigation sector costs might vary under different degrees of water scarcity, two decades were chosen to represent extreme dry scenarios (2000–2009 and 1910–1919, the Millennium Drought and a continuation of the Federation Drought, respectively) and one to represent median flow and allocations (1970–1979).

With regards to potential benefits under the Guide scenarios, a methodology was developed for quantifying potential economic benefits of meeting base flows and EWRs. Using the experience of the Millennium Drought and applying expenditure-based valuation techniques, the ecosystem service losses associated with low system inflows were valued.

In addition to new quantitative analysis, this study considered recent work conducted by the Centre of Policy Studies at Monash University on regional and employment impacts of sustainable diversion limits (SDLs) and a Commonwealth-initiated purchase of environmental water. Results were obtained from the TERM H2O computable general equilibrium model.

Assumptions on which the modelling was based, and caveats on its use, are described in Chapter 4.

Environmental flow delivery

eFlow Predictor and in-house programs were used to derive EWR optimised flows and transfer them to the border. These flows were then run through MSM-BigMod. Microsoft Excel was used for producing plots.

eWater Source Rivers v2.10.1 (eWater, 2010b) was used to develop a model that considered the delivery limitations of upstream storages to supply water to meet SA's EWRs. Further details are in Chapter 5 and the companion technical report 'Analysis of South Australia's environmental water and water quality requirements and their delivery under the Guide to the proposed Basin Plan' (Pollino et al., 2011).

1.6 Integration

Figure 1.4 shows the key components in the analysis, as determined by the project structure, and their linkages.

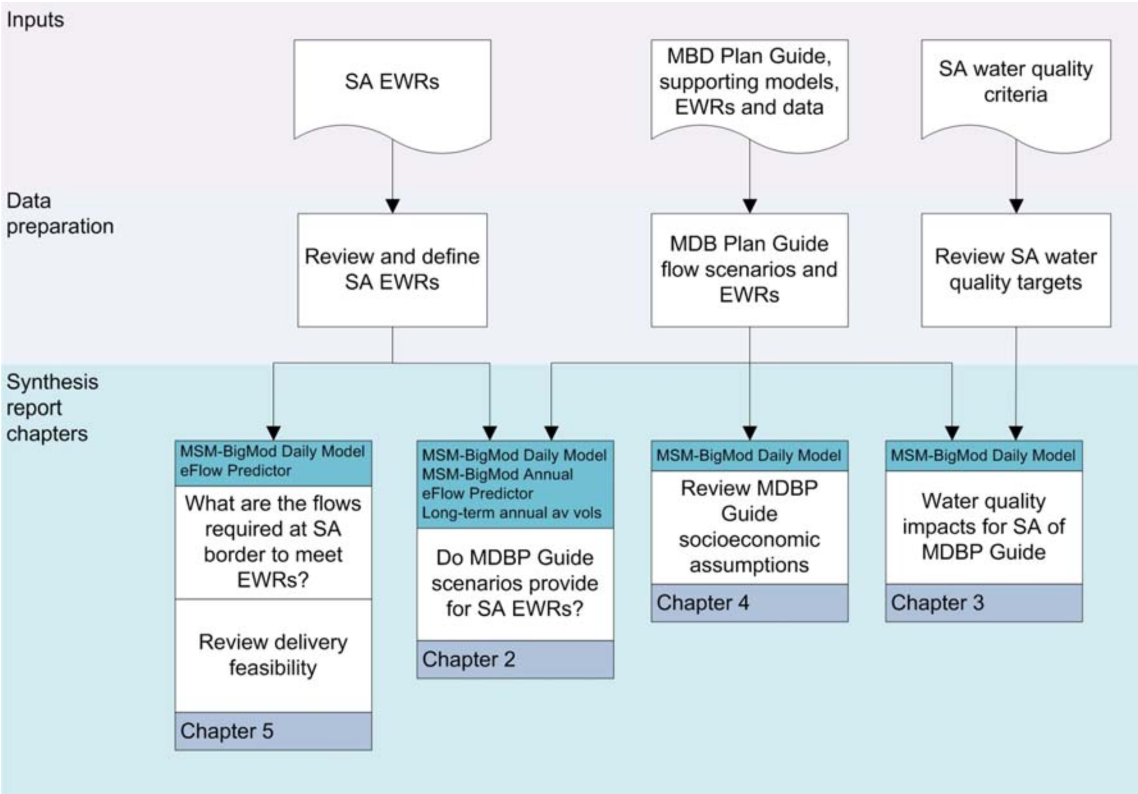

Figure 1.4 The key components of the assessment, of the implications to South Australia of the Guide to the proposed Basin Plan, showing the linkages between data, the analyses, and the chapters in this report

1.7 Assumptions and limitations

There are a number of assumptions that underlie the approach and the modelling. These are either inherent in the models themselves (as they are by definition approximations of the real world) or have been made in the interests of progressing the analyses in the time available. These include:

- sufficient accuracy of the climate predictions and river models
- delivery and operating rules of basin-wide infrastructure and extractions will continue as currently used in the river models
- the decrease from the current diversion limit within South Australia as proposed under the Guide scenarios is fully absorbed by the irrigation sector, i.e. there are no reductions in the water available for environmental flows or meeting human and industrial water needs
- meeting the EWRs will minimise risks to assets and functions. While targets are based on best-available science, more site-specific monitoring and evaluation is required to confirm that meeting the EWRs does ensure sustainable environmental good condition
- meeting the EWRs for Riverland–Chowilla will meet the EWRs for the whole of the River Murray in South Australia
- factors other than flow will be managed to achieve good environmental condition.

The methodology used in the research was designed for fit-for-purpose and to meet resource constraints. There are a number of limitations of this approach which includes:

- limitations on the predictions of likely ecological outcomes from the assessment of a suite of eco-hydrological thresholds. The EWRs used in this analysis are based on flow thresholds of frequency, duration and timing. The ecosystem response is likely to be much more complex and components such as gradual responses including health, vigour and recruitment, cumulative responses, spatial connectivity, habitat and biodiversity, nutrient cycles and food webs are unable to be modelled using thresholds
- limitations on the ability to model water quality and salinity
- limitations on the range of social and economic benefits and costs able to be considered
- other risks pertaining to the knowledge and evidence base on which the EWRs are derived. This is particularly so for ecosystem function metrics assessed within the Guide, where flow metrics are poorly linked to biophysical attributes of the system, and are based on untested acceptability criteria.

1.8 Companion technical reports

The project had a number of intermediate deliverables in the form of project working documents. These have been collated into four technical reports to provide supporting technical material for this synthesis report. The collations reflect the project structure and are based on the information and data available at the time of writing.

The companion technical reports are:

- Analysis of South Australia's environmental water and water quality requirements and their delivery under the Guide to the proposed Basin Plan (Pollino et al., 2011), containing
  - determination of the most suitable South Australian environmental water requirements for comparison with those in the Guide, and an assessment of these against the scenarios presented in the Guide
  - river system modelling
  - response on proposed South Australian water quality and salinity targets
- A compilation of reports informing a socioeconomic assessment of the Guide to the proposed Basin Plan (Connor (ed.), 2011), containing:
  - Basin Plan socioeconomic literature collation
  - Basin Plan socioeconomic approach review
  - Basin Plan socioeconomic science review
- Socioeconomic implications of the Guide to the proposed Basin Plan – Methods and Findings (Connor et al., 2011)

- Synthesis review of the science underpinning the environmental water requirements of the Coorong, Lower Lakes, and Murray Mouth (Maltby and Black, 2011), containing:
    - Synthesis review of the environmental water requirements
    - Synthesis review of the hydrological modelling

2 Assessing South Australia's environmental water requirements

This chapter assesses the likelihood of South Australian environmental water requirements (EWRs) being met given the scenarios presented in the Guide to the proposed Basin Plan. The focus of the assessment is on the review of EWRs for Riverland–Chowilla and the Coorong, Lower Lakes, and Murray Mouth (CLLMM), being key environmental assets identified by the Murray–Darling Basin Authority (MDBA). The EWRs that MDBA and the South Australian Government have specified for these assets are similar but not coincident and are listed in Appendix A (Table A.1 and Table A.2 for Riverland–Chowilla and Table A.3 for CLLMM). These sets are referred to in this chapter as MDBA EWRs and SA EWRs.

This chapter also includes an assessment of hydrological metrics (e.g. frequency of flows of a specified magnitude) being met for these assets (Sections 2.3.1 and 2.3.2) and for key ecosystem function (Section 2.3.3).

The assessment uses three data sources: (i) Guide long-term average annual, and annual, volumes published by the MDBA (<http://www.mdba.gov.au/basin_plan/model-data> accessed December 2010); and (ii) annual volumes and (iii) daily flows from the MDBA MSM-BigMod model (provided by MDBA for use by CSIRO on 20 January 2011). As the assessment of EWRs under the Guide scenarios is sensitive to the model chosen, these sources are distinguished in the text by using the terms 'Guide annual', 'BigMod annual' and 'BigMod daily'.

More details on the derivation and analyses of EWRs are presented in the companion technical report (Pollino et al., 2011).

To determine the volume and pattern of delivery of flows to the border to meet EWRs, optimised daily flows were derived for Riverland–Chowilla and CLLMM, and the feasibility of being able to source these flows from upstream was also assessed. This modelling work is reported in Chapter 5.

2.1 Key messages

Review of environmental water requirements

- Riverland–Chowilla
  - A broad review of asset plans demonstrated that asset objectives, target communities and associated EWRs are broadly consistent across documents. The ecological character of the asset is defined by SA and MDBA as including black box, red gum, lignum, waterbirds and fish.
  - The definition of the spatial extent of the assets, downstream of the border, is consistent between SA (DWLBC, 2010) and the MDBA (MDBA, 2010b); however, the Guide includes the Lindsay and Wallpolla Islands which are upstream of the border.
  - The EWRs specified by SA consider more of the ecological communities within the asset, where requirements are specified for maintaining mosaic of habitats, fish, waterbirds and lignum, in addition to the EWRs specified in the Guide, being inundation area, red gum and black box.
- CLLMM
  - A review of documents with EWRs for the CLLMM found that a wide range of approaches had been used to determine targets, and a variety of overlapping spatial boundaries had been used to define the area of interest. Despite this, the objectives and spatial boundaries of the asset are broadly consistent between SA and the MDBA.
  - EWRs specified by the MDBA (2010) are likely to be sufficient, in terms of volumetric requirements, to meet the environmental water requirements of the CLLMM as specified by the SA Government. Additional specification of the regime of flow delivery, including specification of low- and no-flow periods, would provide greater certainty in meeting asset requirements.

Meeting environmental water requirements

- Riverland–Chowilla
    - EWRs are specified as a flow regime and cannot be rigorously assessed using average annual volumes (as per MDBA approach)
    - Not all the Riverland–Chowilla flow regime requirements, as specified by both SA and MDBA, are met under any of the Guide scenarios. However, the Guide scenarios represent an improvement on baseline conditions, with EWRs of less than 100,000 ML/day being met more frequently.
    - There is sufficient volume on an annual basis to meet SA EWRs under the 4000 scenario, and under the 3500 scenario (the latter depending on the model), but not under the 3000 scenario.
- Coorong, Lower Lakes, and Murray Mouth
    - While not all EWRs are met under the Guide scenarios, they represent an improvement on baseline conditions for all EWRs and, in some cases, they represent a large improvement.
    - More EWRs are met under the 4000 scenario than under the 3500 scenario, and under the 3500 scenario than under the 3000 scenario, respectively.

Table 2.1 Assessment of meeting the volume requirements of EWRs for Riverland–Chowilla and CLLMM under the Guide scenarios, showing the number of EWRs that are met

	MDBA EWRs			SA EWRs		
Data source	Scenario					
	3000	3500	4000	3000	3500	4000
Riverland–Chowilla (EWRs listed in Tables A.1 and A.2)						
Guide annual	◆	◆	◆	●	◆	◆
BigMod annual	◆	◆	◆	●	●	◆
	number of EWRs met					
BigMod daily	0 of 6	0 of 6	0 of 6	0 of 10	0 of 10	0 of 10
CLLMM (EWRs listed in Table A.3)*						
Guide annual	2 of 4	2 of 4	3 of 4	3 of 9	5 of 9	6 of 9
BigMod annual	2 of 4	3 of 4	3 of 4	3 of 9	5 of 9	5 of 9

◆ indicates that the volume requirements of EWRs are met.
● indicates that the volume requirements of EWRs are not met.
Six EWRs are specified by MDBA and 10 by SA for Riverland–Chowilla.
* Five EWRs are specified by MDBA and 10 by SA for CLLMM. However, 2 of these were not quantified and were not included in the modelling. These are identified in Table A.3.

While the EWRs are not met, on a pass-fail analysis when using the BigMod daily results, under the Guide scenarios (Table 2.1), they do represent a significant improvement on baseline as can be seen in Table 2.3, Table 2.4, Table 2.5 and Table 2.6.

2.2 Identifying South Australia's environmental water requirements

A review of EWRs was undertaken to determine which were most suitable for characterising the Riverland–Chowilla and CLLMM assets. Analyses focused on the consistency of EWRs against modelled without-development and baseline sequences and with published wetting requirements for target species. Riverland–Chowilla EWRs are expressed as temporal flow characteristics, for example, daily flow or annual volume, event timing (seasonality, frequency, return period), event duration. CLLMM targets are expressed as annual volumes. EWRs for Riverland–Chowilla and CLLMM are listed in Appendix A.

For Riverland–Chowilla, the review concluded that the SA EWRs (Table A.2) were the most appropriate for meeting the asset objectives stated in the Guide (MDBA, 2010b) and by SA (DWLBC, 2010). This conclusion is based on the SA EWRs being more representative of the ecological character of the asset, which includes black box, red gum, lignum, waterbirds and fish. In the Guide, it is assumed that red gum and black box water requirements meet other target species requirements, but there is little evidence to demonstrate this. The species flow requirements for black box and red gum specified by SA and MDBA are broadly consistent and representative of species requirements.

For CLLMM, the review concluded that the MDBA EWRs (Table A.4) are likely to be sufficient. The EWRs specified were site-wide, focusing on long-term and medium-term rolling averages (e.g. 3 years), with return frequencies of higher flow events. Further specification of the inter-annual regime of flow delivery, including specification of the maximum length of low- and no-flow periods, would provide greater certainty in meeting asset requirements. It is also recommended that detailed targets for high flows are specified, rather than the general target that is currently used by MDBA.

2.3 Meeting South Australia's environmental water requirements under the Guide scenarios

The annual volume estimates used in the Guide show clear differences to annual volumes derived from the BigMod daily model. As the model used in the Guide cannot support analysis of flow regime requirements that change intra-annually (e.g. short, seasonal inundation events of 1 to 2 months), all analyses presented in this section are based on the BigMod daily model. A comparison of results arising from the two models, undertaken for CLLMM, showed reasonable consistency, although targets were slightly more likely to be met under the BigMod daily model. This means that the difference in model used for these analyses, compared with what is presented in the Guide, is unlikely to alter the conclusions that are drawn.

2.3.1 Riverland–Chowilla

Average annual volumes – water requirements

The average annual volumes required at the border to meet MDBA and SA EWRs were quantified (using the eFlow Predictor tool) (Table 2.2) where the event was set to mimic a return frequency of the without-development flows, and the duration of the event was forced to meet the specified EWR.

Table 2.2 Average annual volumes required at the SA border to meet MDBA and SA Riverland–Chowilla EWRs

MDBA EWRs	SA EWRs
average annual volume*	
GL	
8040	8729

* average annual volumes calculated using eFlow Predictor

The analysis demonstrates that the average annual volume requirements for Riverland–Chowilla MDBA and SA EWRs at the border are met under the 4000 scenario, and under the 3500 scenario (using volumes from the Guide annual model, not from the BigMod daily model), but not under the 3000 scenario. Volumes across the border under the Guide scenarios are listed in Table 1.1. This analysis is further expanded in Chapter 5.

Daily flows – flow regime requirements

The BigMod daily model was used to assess whether the inter-annual and intra-annual regime requirements of Riverland–Chowilla are met under the Guide scenarios. Performance measures used were comparisons against baseline and without-development flows and against the EWR as expressed by the MDBA or SA. Considering the frequency of events over the modelled 114-year flow periods, all EWRs are met at a lower frequency than under without-development, although the majority of EWRs represent an improvement from the baseline (Table 2.3).

In this analysis, the assessment of the frequency of events is determined as an average over the modelled 114 years. Using this criterion, the event requirements specified by the MDBA and SA are met under the without-development scenario, on an average annual basis. However, year-by-year analysis of the without-development scenario shows that the events are clustered according to climate variability, such that there are periods that do not meet (i.e. exceed) the requirements, particularly during dry periods. The period between events is specified for each flow requirement (Table 2.4). Although some periods between events are shorter under the without-development scenario than under other scenarios, EWRs are not always met as specified. This reflects the variability within the natural system.

Table 2.3 Number of times that MDBA and SA Riverland–Chowilla EWRs are met in the 114-year period under without development, baseline and Guide scenarios. The symbols present the results for the Guide scenarios compared to baseline

		Scenario					Scenario		
Flow requirements of EWRs*	Target	without development	baseline	3000	3500	4000	3000	3500	4000
Volume, duration, frequency*		number of times EWRs are met					compared to baseline		
MDBA EWRs (full description of EWRs, including seasonality, in Table A.1)									
40 GL, 30 days, 1-in-1 years	**89	89	41	65	67	70	◆	◆	◆
40 GL, 90 days, 1-in-2 years	56	64	22	37	41	45	◆	◆	◆
60 GL, 60 days, 1-in-3 years	37	43	12	22	22	26	◆	◆	◆
80 GL, 30 days, 1-in-5 years	28	36	11	14	16	18	◆	◆	◆
100 GL, 21 days, 1-in-7 years	12	22	8	6	7	6	○	○	○
125 GL, 7 days, 1-in-9 years	12	19	6	5	5	5	○	○	○
SA EWRs (full description of EWRs, including seasonality, in Table A.2)									
40 GL, 60 days, 1-in-1 years	**80	80	31	49	51	54	◆	◆	◆
40 GL, 90 days, 1-in-2 years	56	64	21	37	39	43	◆	◆	◆
60 GL, 60 days, 1-in-3 years	37	41	10	16	16	19	◆	◆	◆
70 GL, 30 days, 1-in-3 years	37	45	13	23	24	27	◆	◆	◆
70 GL, 60 days, 1-in-4 years	28	32	8	12	13	15	◆	◆	◆
80 GL, 30 days, 1-in-4 years	28	36	11	14	16	18	◆	◆	◆
80 GL, 30 days, 1-in-4 years	28	35	10	13	15	18	◆	◆	◆
85 GL, 30 days, 1-in-5 years	22	28	9	9	9	11	■	■	◆
90 GL, 30 days, 1-in-5 years	22	26	8	9	9	9	◆	◆	◆
100 GL, 20 days, 1-in-5 years	22	23	7	6	7	6	○	■	○

◆ result is better than under the baseline
■ result is the same as under the baseline
○ result is worse that under the baseline
* Space prevents including all attributes of the EWRs and only volume, duration and frequency are listed here to differentiate the EWRs. See Tables A.1 and A2 for their full description.
** EWR frequency reset to match without-development targets

Table 2.4 Maximum period between events in years for MDBA and SA Riverland–Chowilla EWRs under without-development, baseline and Guide scenarios. The symbols present the results for the Guide scenarios compared to baseline

	Scenario					Scenario		
Flow requirements of EWRs	without development	baseline	3000	3500	4000	3000	3500	4000
Volume, duration, frequency	maximum period (in years) between events					compared to baseline		
MDBA EWRs								
40 GL, 30 days, 1-in-1 years	3	12	4	4	4	◆	◆	◆
40 GL, 90 days, 1-in-2 years	3	19	11	7	7	◆	◆	◆
60 GL, 60 days, 1-in-3 years	6	19	18	18	18	◆	◆	◆
80 GL, 30 days, 1-in-5 years	9	17	17	16	16	■	◆	◆
100 GL, 21 days, 1-in-7 years	4	17	31	31	31	○	○	○
125 GL, 7 days, 1-in-9 years	4	25	29	29	29	○	○	○
SA EWRs								
40 GL, 90 days, 1-in-2 years	4	20	6	6	6	◆	◆	◆
40 GL, 60 days, 1-in-1 years	4	12	8	8	8	◆	◆	◆
60 GL, 60 days, 1-in-3 years	6	30	28	28	26	◆	◆	◆
70 GL, 60 days, 1-in-4 years	8	20	18	18	18	◆	◆	◆
70 GL, 30 days, 1-in-3 years	5	20	12	12	12	◆	◆	◆
80 GL, 30 days, 1-in-4 years	10	19	19	18	18	■	◆	◆
80 GL, 30 days, 1-in-4 years	8	19	19	18	18	■	◆	◆
85 GL, 30 days, 1-in-5 years	7	19	30	30	30	○	○	○
90 GL, 30 days, 1-in-5 years	8	19	30	30	30	○	○	○
100 GL, 20 days, 1-in-5 years	6	31	31	31	31	■	■	■

◆ result is better than under the baseline
■ result is the same as under the baseline
○ result is worse that under the baseline

The Guide scenarios improve the mid- to low-flow EWRs and reduce the time between mid- to low-flow event. However, under the Guide scenarios, events of ≥100,000 ML/day are met less frequently than under the baseline scenario, and events of ≥80,000 ML/day have periods where flow requirements are equivalent to under the baseline scenario, or worse. These findings have implications for EWRs targeting the high floodplain, specifically the black box communities and suggest that these communities are at a higher level of risk under the Guide scenarios (than under the baseline).

Sensitivity analysis

Sensitivity analyses were used to determine how sensitive EWRs were to changing duration requirements in EWRs, where results give an indication of how sensitive EWRs are to knowledge uncertainty and model uncertainty. Duration requirements were changed by ± 5%, 10% and 20%. Findings show that EWRs are generally insensitive to change, with the majority of EWRs still not being met, even when duration requirements are reduced by 20%.

2.3.2 Coorong, Lower Lakes, and Murray Mouth

For the SA and MDBA CLLMM EWRs, the average volumes and proportion of time EWRs passed at the barrages were quantified using average annual volumes derived from the BigMod daily model (Table 2.5).

Overall, Guide scenarios represent an improvement on baseline conditions for all EWRs and in some cases, these changes represent a large improvement, noting that no EWRs are met under the baseline scenario (though all are met under the without-development scenario).

SA's high-flow EWRs are met under the Guide scenarios, but important low-flow requirements are not. Under the Guide scenarios, the MDBA EWR of a three-year rolling average barrages flow of 1000 GL/year in 100% of years is achieved in 99% of years, while salt export EWRs are met under the 3500 and 4000 scenarios.

Table 2.5 Assessment of meeting MDBA and SA CLLMM EWRs under without-development, baseline and Guide scenarios

EWRs	Scenario				
	without development	baseline	3000	3500	4000
MDBA EWRs					
5100 GL/y long-term average	11,782	4870	6804	7107	7446
	percent of years				
2000 GL/y rolling average over 3 years in 95% of years	100%	78%	97%	99%	99%
1000 GL/y rolling average over 3 years in 100% of years	100%	94%	99%	99%	99%
High flow requirements (exact volumes not specified)	na	na	na	na	na
3200 GL/y 10-y rolling average for salt export in 100% years*	100%	77%	99%	100%	100%
SA EWRs					
Absolute minimum of 650 GL 95% of years	100%	91%	95%	96%	97%
4000 GL minus previous year in 95% of years	100%	75%	94%	95%	96%
6000 GL minus previous 2 years (adjusted) in 95% of years	99%	72%	92%	94%	96%
SA min. flow (max of three previous EWRs) in 95% of years	99%	72%	90%	92%	93%
Flows sufficient to replace evaporative losses in Lakes	na	na	na	na	na
2000 GL minus previous year in 100% of years	100%	89%	98%	98%	98%
3000 GL minus previous 2 years (adjusted) in 100% of years	100%	87%	98%	98%	98%
SA min. flow (max of three previous EWRs) in 100% of years	100%	87%	98%	98%	98%
	frequency				
6000 GL/y 1-in-3 year frequency (as a long-term average)	1:1	1:3	1:2	1:2	1:2
10,000 GL/y 1-in-7 y frequency (as a long-term average)	1:2	1:9	1:6	1:5	1:5

Note: Return frequencies for high flows are given as the average number of years between flows of the magnitude specified. All other entries are the percentage of years in which the target volume is met.

na – not applicable

* This target differs from the salt export load target in the Water Quality and Salinity chapter. Both of these targets are published within the Guide and represent an inconsistency therein.

Incremental improvements and declines are observed for EWRs at the barrages as volume requirements are modified by ±5%, 10% and 20% (Table 2.6). As for the Riverland–Chowilla, there is relatively little sensitivity to modifications of this order. This is largely due to method of delivery of flow within the scenarios, whereby additional flow is not delivered in years where it is required to meet the EWRs (as per findings in Chapter 5). Low-flow requirements are not being met under most scenarios and so the blanket alteration of target volumes by ± 5%, 10% and 20% does little to redress the shortfall in very dry periods. Altering the timing of flow to reduce the number of very low flow years, rather than the average volume at the SA border is required to ensure that ecological targets for the CLLMM are met. This is evident from the fact that flow targets for 95% of years are increasingly met across the 3000, 3500 and 4000 scenarios, but targets for 100% of years are not met under any scenario with any proportional decline in target volume.

Table 2.6 Sensitivity analysis of results for CLLMM MDBA and SA EWRs under the Guide scenarios, where target volumes are reduced by 5%, 10% and 20%

	Scenario		
EWRs	3000	3500	4000
MDBA EWRs			
5100 GL/y long-term average	◆	◆	◆
2000 GL/y rolling average over 3 years in 95% of years	◆	◆	◆
1000 GL/y rolling average over 3 years in 100% of years	🔴	🔴	🔴
High flow requirements (exact volumes not specified, see below)	na	na	na
3200 GL/y 10 year rolling average for salt export	🟦	◆	◆
SA EWRs			
Absolute minimum of 650 GL 95% of years	◆	◆	◆
4000 GL minus previous year in 95% of years	🟧	◆	◆
6000 GL minus previous 2 years (adjusted) in 95% of years	🟧	◆	◆
SA minimum flow (max of three previous EWRs) in 95% of years	🔴	🟫	🟦
Flows sufficient to replace evaporative losses in Lakes	na	na	na
2000 GL minus previous year in 100% of years	🔴	🔴	🔴
3000 GL minus previous 2 years (adjusted) in 100% of years	🔴	🔴	🔴
SA minimum flow (max of three previous EWRs) in 100% of years	🔴	🔴	🔴
6000 GL/year 1-in-3 year frequency (as a long-term average)	◆	◆	◆
10,000 GL/year 1-in-7 year frequency (as a long-term average)	◆	◆	◆

Results indicate if EWRs are ◆ met without altering the target volume, 🟦 met by a 5% reduction, 🟧 met by a 10% reduction, 🟫 met by a 20% reduction, 🔴 not met by the target volume.

2.3.3 Key ecosystem functions

The sixteen hydrological metrics for assessing key ecosystem function are those derived published by Alluvium (2010) (Table A.4):

- base flows (low and high season)
- cease-to-flow (low, high and all seasons)
- freshes (low and high season)
- bankfull (ARI of 1-in-1.5 years)
- overbank (ARI of 1-in-2.5 years and 1-in-5 years).

Gauge stations for analysis are the River Murray at the SA border (F59), Morgan (F61) and Wellington (F62).

Metrics were quantified using the BigMod daily model for the without-development, baseline and Guide scenarios.

All guide scenarios improve the ability to meet key ecosystem functions, compared to baseline (Table 2.7) with the greatest improvement in returning flow metrics to an acceptable level of change occuring under the 4000 scenario.

For all sites, there is little improvement in the low-flow baseflow metrics. Cease-to-flow attributes are lost from the river at Morgan and Wellington under baseline and Guide scenarios. Comparison of seasonal metrics (not reported here) show that the timing of low-flow and high-flow periods do not change between without-development, baseline and Guide scenarios.

Table 2.7 Number of key ecosystem function metrics met under the Guide scenarios

	Scenario			
Key ecosystem function site	baseline	3000	3500	4000
	number of metrics met (out of 16)			
SA border	7	12	14	15
Morgan	1	7	9	10
Wellington	2	7	8	10

2.4 Risks

2.4.1 Analysis of the Guide

The scenarios presented in the Guide were determined based on the return of a percentage of without-development end-of-system flows, not on the flow regime requirements specified in the EWRs. Consequently, under the Guide scenarios, the flow requirements of South Australian assets are not always met, although for the majority of target communities, they do represent an improvement from the baseline. However, for black box communities of Riverland–Chowilla, the Guide scenarios represent a perverse outcome. As black box communities occur on the higher part of the floodplain, where high tributary inflows and dam spills are required, communities are increasingly likely to become isolated under the Guide scenarios.

2.4.2 Residual risks beyond those addressed in the Guide

As applied in the Guide, an implicit assumption in deriving EWRs for South Australia is that meeting these will minimise risks to assets and functions. Although there is sufficient evidence to demonstrate that flow is a fundamental driver of water dependent ecosystems, and their communities, other factors will influence whether providing or restoring flow will achieve ecological objectives, including:

- surrounding landuse and land management practices impacting on wetland, floodplain and riverine habitats
- deterioration in water quality (e.g. salinity, nutrients, nuisance algae, sediment, local acid generation), from local and upstream sources
- introduced species, such as carp and willows
- operation of infrastructure, such as irrigation channels and weirs
- barriers, such as those to migration of aquatic communities
- recreation activities, such as fishing and boating
- floodplain and coastal developments
- clearing of vegetation.

From a planning and operations perspective, risks to water being delivered for environmental use are:

- poor implementation and enforcement of water plans
- operational constraints limiting the timing and volume of environmental water able to be delivered
- competing requirements for various assets across the Basin
- illegal take of water
- inherent inaccuracies in river system and other models
- limited representation of inundation dynamics in inundation models
- lack of consideration of factors such as a changing climate in estimating flows to environmental assets.

Other risks pertain to the knowledge and evidence base on which the EWRs are derived. This is particularly so for ecosystem function metrics assessed within the Guide, where flow metrics are poorly linked to biophysical attributes of the system, and are based on untested acceptability criteria.

3 Water quality and salinity

This chapter focuses on the potential impacts on water quality and salinity in the River Murray, in South Australia, under the Guide scenarios. The potential impacts have been analysed using the results from the BigMod daily model provided by the Murray–Darling Basin Authority (MDBA) (as described in Section 1.5). Results were available for flows and water levels for the 114-year historical period from 1 July 1895 to 30 June 2009. For salinity, results were available for the 34.5-year historical period from 1 January 1975 to 30 June 2009 but it should be noted they are a by-product of flow modelling, and not the results of a salinity modelling project. The results from the BigMod daily model are the best information currently available for the analyses undertaken. However, they were not used by the MDBA in assessing water quality and salinity as reported in the Guide. It is emphasised these results can be expected to be sensitive to the assumptions and constraints in the modelling but nevertheless they provide a useful indication of likely responses under the Guide scenarios.

The following criteria were selected for assessing impacts on water quality and salinity:

- alkalinity in the Lower Lakes – water level targets in Lake Alexandrina
- river cyanobacteria bloom risk – summer flow at Morgan
- South Australian Government's 'working' salinity targets proposed for the border, Berri, Morgan, Murray Bridge, Tailem Bend and Lake Alexandrina (Milang) – prescribed as EC thresholds for a percentage of time
- South Australian Government's management and emergency response thresholds of 800 EC and 1400 EC respectively
- MDBA's Basin Salinity Management Strategy (BSMS) EC and salt load targets at Morgan
- MDBA's planning EC targets at the border, Berri and Murray Bridge (as set in the *Water Act 2007*).

3.1 Key messages

Water quality is generally improved and salinity reduced under the Guide scenarios compared to baseline conditions. There is relatively little difference between the Guide scenarios in terms of their effects on water quality and salinity. These key messages are summarised in Table 3.1.

Alkalinity in the Lower Lakes

- Water levels in Lake Alexandrina above 0.0 and –0.5 m AHD were identified by the South Australian Department of Environment and Natural Resources (DENR) as suitable water level–based indicators for lake alkalinity stability. Under the Guide scenarios, occurrences of water levels below –0.5 m AHD are eliminated; and occurrences below 0.0 m AHD are shorter in total duration and water levels do not fall as low, compared to baseline conditions (but not eliminated).

River cyanobacteria bloom risk

- Summer flow at Morgan of ≤7000 ML/day was agreed with SA Water as a suitable flow-based indicator of increased risk of cyanobacteria blooms in the river. Under the Guide scenarios, occurrences of this flow are only slightly reduced overall compared to baseline conditions.

Salinity

- South Australian Government's and the MDBA's Basin Salinity Management Strategy (BSMS) salinity targets at Morgan are met under all three Guide scenarios (Table 3.1) and the without-development scenario. However they are not met under baseline conditions.
- South Australian Government's EC targets for Lake Alexandrina are met under all three Guide scenarios (Table 3.1), but are not met under baseline conditions.

- A threshold of 800 EC is used by the South Australian Government as a management target. Under the Guide scenarios, exceedances of this threshold are reduced in severity and duration at all locations compared to baseline conditions, but not eliminated (Table 3.5).
- The MDBA planning target at the border, as defined in the *Water Act 2007,* is not met under the baseline or Guide scenarios but is met under without-development conditions. However, the MDBA targets at Berri and Murray Bridge are met under all three Guide scenarios. The MDBA target at Murray Bridge is also met under baseline conditions.
- Due to the high probability of salt mobilisation from environmental watering events, achieving the salinity targets may be sensitive to the particular application of environmental flow delivery rules.

Salt load

- The MDBA's BSMS basin salt load target of on average 1.76 million tonnes/year at Morgan is met under all three Guide scenarios.
- MDBA's salt load export target of a minimum of 2 million tonnes/year through the barrages on a ten-year rolling average basis (i.e. 20 million tonnes in any ten-year period) is not met except during persisting wet conditions under the baseline scenario or any of the three Guide scenarios.

Table 3.1 Summarised assessment of meeting key water quality, salinity and salt load indicators under the without-development, baseline and Guide scenarios

	Scenario				
Key indicators and targets	without development	baseline	3000	3500	4000
Alkalinity (Lake Alexandrina) (see Table 3.2)					
Water level ≥0.0 m AHD	◆	●	■	■	■
Water level ≥–0.5 m AHD	◆	●	◆	◆	◆
Cyanobacteria risk (see Table 3.3)					
Summer flow at Morgan of >7000 ML/day	■	●	■	■	■
MDBA's salinity targets (see Table 3.4)					
at the border	◆	●	■	■	■
at Morgan (also SA's target)	■	●	◆	◆	◆
at Murray Bridge	◆	◆	◆	◆	◆
SA's salinity targets (see Table 3.4)					
at the border	■	●	■	■	■
at Murray Bridge	■	●	■	■	■
for Lake Alexandrina	●	●	◆	◆	◆
Salt load (see Table 3.4)					
BSMS basin salt load target at Morgan	◆	●	◆	◆	◆
BSMS salt export target at barrages	◆	●	■	■	■

◆ the target is met.
■ the target is not met, but it is better than baseline.
● the target is not met and is the same, or worse than, baseline.
Actual figures are given in Table 3.2, Table 3.3 and Table 3.4.

3.2 Assessment indicators

3.2.1 Alkalinity in the Lower Lakes

Water levels in Lake Alexandrina above 0.0 and –0.5 m AHD were identified by DENR as being suitable water level–based indicators for lake alkalinity stability. Modelled water levels at Milang over the 114-year historical period were used for assessing occurrences and results are summarised in Table 3.2. The results show that under the Guide scenarios, occurrences of water levels below –0.5 m AHD are eliminated; and occurrences below 0.0 m AHD are shorter in total duration and water levels do not fall as low, compared to baseline conditions (but not eliminated).

Table 3.2 Key statistics of occurrences of low water levels in Lake Alexandrina under without-development, baseline and Guide scenarios

	Scenario				
Indicators	without development	baseline	3000	3500	4000
Lowest level (m AHD)	0.03	–0.55	–0.23	–0.24	–0.25
Water levels less than or equal to 0.0 m AHD					
Number of events	0	4	5	3	3
Longest event (days)	na	186	160	164	166
Mean event duration (days)	na	135	95	142	145
Total duration of events (days)	na	539	476	426	435
Water levels less than or equal to –0.5 m AHD					
Number of events	0	1	0	0	0
Event duration (days)	na	82	na	na	na

na – not applicable

3.2.2 River cyanobacteria bloom risk

Summer (December to February) flow at Morgan of less than or equal to 7000 ML/day was agreed with SA Water to be a suitable flow-based indicator of increased risk of cyanobacteria blooms in the river. Above this threshold, flows are seen to be sufficient to prevent the formation of persistent thermal stratification in the main river channel. The setting of this threshold took into account information in Maier et al. (2001) and Maier et al. (2004). Statistics of occurrences of flows at Morgan below this threshold were evaluated using results from the BigMod daily model for the historical period with results summarised in Table 3.3. The results show that under the Guide scenarios, occurrences of this flow were only slightly reduced overall compared to baseline conditions.

Table 3.3 Key statistics of occurrences of summertime flows being ≤7000 ML/day at Morgan under without-development, baseline and Guide scenarios

	Scenario				
Occurrence	without development	baseline	3000	3500	4000
Mean of yearly numbers of events	0.7	1.8	1.4	1.3	1.4
Mean of summer days with flow ≤7000 ML/d	12.9	47.4	46.8	42.7	43.1

3.2.3 Salinity and salt loads

Scenario salinity results were compared with South Australia's proposed salinity targets and MDBA's BSMS targets at the SA border (upstream Lock 6), Berri (MDBA target location), Morgan, Murray Bridge, Tailem Bend (surrogate for Wellington) and Lake Alexandrina (Milang). Results are presented in Table 3.4, expressed in terms of the number of percentage points by which the results differ from the target non-exceedance percentile.

Statistics of annual salt loads at Morgan using full years (1 July 1975 to 30 June 2009 (34 years)), and for the BSMS Benchmark Period (baseline scenario only) were also derived and compared with the BSMS salt load target. Salt loads were derived by combining daily flow and salinity results (with a unit conversion from EC to mg/L using the factor of 0.6 as used in BigMod). Ten-year rolling average annual salt load exports through the barrages were compared with MDBA's proposed salt load export target. These exports were calculated from daily salt loads, with the first ten-year period starting on 1 July 1975 and following periods starting progressively one year later through to 1 July 1999. Salt loads were derived by combining results for flows through the barrages with salinity results for Milang (with unit conversion as above). Results are presented as percentage deviations from average target tonnage in Table 3.4.

Table 3.4 Key statistics of salinity and salt load targets at key locations under without-development, baseline and Guide scenarios

			Scenario				
Source*	target	non-exceedance threshold	without development	baseline	3000	3500	4000
	EC	percent	percentage points				
Salinity – number of percentage points the results differ from the target non-exceedance percentile (rounded to whole percent)							
SA border (upstream of Lock 6)							
SA	<400 EC	**99.7%	–17	–31	–30	–28	–26
MDBA (from the *Water Act 2007*)	<412 EC	80%	4	–8	–7	–6	–4
Berri							
MDBA (from the *Water Act 2007*)	<543 EC	80%	8	–1	3	5	6
Morgan							
SA and MDBA (BSMS target)	<800 EC	95%	–3	–5	1	3	2
Murray Bridge							
SA	<900 EC	**99.7%	–4	–6	–2	–2	–2
MDBA (from the *Water Act 2007*)	<770 EC	80%	14	3	13	15	15
Wellington (Tailem Bend)							
SA	<900 EC	**99.7%	–4	–7	–3	–1	–2
Lake Alexandrina (Milang)							
SA	<1000 EC	95%	–10	–10	0	1	3
SA	<1500 EC	100%	–13	–5	0	0	0
Salt loads – percentage deviation from average target tonnage							
MDBA (BSMS Basin Salt Load Target at Morgan)	1.76 million tonnes/y		55%	-4%	5%	7%	8%
MDBA (salt export target at barrages)	2 million tonnes/y***		81%	–26%	–17%	–15%	–13%

* Source: Identifies whether the source of the target is the South Australian government (SA) or the MDBA
** in a rolling 12-month period
*** ten-year rolling average
Note: the MDBA targets, and SA's Morgan target, are assessed over the 25-year BSMS Benchmark Period.

The salinity results in Table 3.4 show South Australia's proposed targets at the SA border, Murray Bridge and Wellington are not achieved under any of the Guide scenarios, including the without-development scenario. The results also show that South Australia's and the MDBA's Basin BSMS salinity targets at Morgan are not met under baseline conditions but they are met under the without-development and all three Guide scenarios. In addition, they show that South Australia's salinity targets for Lake Alexandrina are not met under baseline conditions, but are met under all three Guide scenarios.

The salt load results in Table 3.4 show MDBA's BSMS basin salt load target of on average 1.76 million tonnes/year at Morgan is met under all three Guide scenarios, and the salt load export target of a minimum of 2 million tonnes/year through the barrages on a ten-year rolling average basis is not met except during persisting wet conditions under the baseline scenario or any of the three Guide scenarios.

Exceedances of thresholds of 800 EC and 1400 EC were also evaluated at these locations and the sensitivity of these to changes in salinity levels was evaluated by reducing the thresholds by 5%, 10% and 20%. The threshold of 800 EC is used by South Australia as a management target and the threshold of 1400 EC is used as a trigger point for emergency response in relation to water supply. Results are presented in Table 3.5 and Table 3.6, respectively.

The results show that under the Guide scenarios, exceedances of the threshold of 800 EC are reduced in severity and duration at all locations compared to baseline conditions, but not eliminated. The results of the sensitivity analysis show exceedances of this threshold are sensitive to changes if salinity levels were to increase by 5%, 10% and 20%, especially the 20% change. The Guide scenarios are more sensitive than baseline conditions at the SA border and Berri, but at Morgan, Murray Bridge, Tailem Bend and Lake Alexandrina the Guide scenarios are less sensitive than baseline conditions. The sensitivity of the Guide scenarios is similar at any given location.

Exceedances of a threshold of 1400 EC occur only under the 4000 scenario and then only at Murray Bridge and Tailem Bend. This may be attributed to river flows dropping to lower rates at various times due to the dams being drawn down faster to supply environmental flow requirements, under this scenario. The impacts are greater under this scenario than under the 3000 and 3500 scenarios, and also when compared to baseline conditions. Refinement of environmental flow rules may assist with managing this issue. The results of the sensitivity analysis show exceedances of this threshold are less sensitive to changes if salinity levels were to increase by 5%, 10% and 20% compared to sensitivity of exceedances of a threshold of 800 EC. The three Guide scenarios are no more sensitive than baseline conditions at locations in the river, while in Lake Alexandrina, the three Guide scenarios are much less sensitive than baseline conditions. At locations in the river, the 4000 scenario is marginally more sensitive than the other two Guide scenarios, while in Lake Alexandrina the 4000 and 3500 scenarios are the least sensitive. This is likely to be due to interactions between low flows from upstream and steady salt loads with groundwater entering the river, and the buffering effect of the storage in the lake.

Table 3.5 Modelled percent exceedances of a salinity threshold of 800 EC, and with threshold reduced by 5%, 10% and 20% under baseline and Guide scenarios

	800 EC	760 EC	720 EC	640 EC
Scenario		–5%	–10%	–20%
	percent of time (in modelled period) threshold value is exceeded			
SA border (upstream of Lock 6)				
baseline	0.1%	0.1%	0.2%	0.9%
3000	0.3%	0.5%	0.7%	1.5%
3500	0.2%	0.3%	0.4%	1.3%
4000	0.5%	0.7%	0.9%	1.9%
Berri				
baseline	0.9%	1.4%	2.2%	7.1%
3000	0.8%	1.4%	2.4%	6.2%
3500	0.7%	1.3%	1.5%	5.1%
4000	0.9%	1.4%	2.2%	6.3%
Morgan				
baseline	9.6%	13.4%	17.7%	30.4%
3000	3.5%	5.1%	6.9%	12.8%
3500	1.7%	3.3%	5.5%	11.0%
4000	2.2%	4.0%	6.3%	11.2%
Murray Bridge				
baseline	13.4%	18.1%	24.5%	34.3%
3000	5.3%	6.8%	9.8%	17.9%
3500	3.6%	4.9%	7.4%	15.9%
4000	3.5%	4.6%	6.4%	13.7%
Tailem Bend				
baseline	16.0%	21.7%	27.0%	37.7%
3000	6.6%	8.7%	12.3%	20.2%
3500	5.1%	7.1%	10.4%	17.9%
4000	4.5%	6.0%	8.8%	16.9%
Lake Alexandrina (Milang)				
baseline	39.5%	45.0%	51.5%	65.3%
3000	11.0%	13.0%	15.8%	25.6%
3500	10.1%	11.4%	14.3%	22.2%
4000	8.6%	10.4%	12.6%	20.1%

Table 3.6 Modelled percent exceedances of a salinity threshold of 1400 EC, and with threshold reduced by 5%, 10% and 20% under the baseline and Guide scenarios

	1400 EC	1330 EC	1260 EC	1120 EC
Scenario		–5%	–10%	–20%
	percent of time (in modelled period) threshold value is exceeded			
SA border (upstream of Lock 6)				
baseline, 3000 and 3500	0%	0%	0%	0%
4000	0%	0.02%	0.03%	0.05%
Berri				
baseline	0%	0%	0%	0.11%
3000, 3500	0%	0%	0%	0%
4000	0%	0%	0%	0.03%
Morgan				
baseline	0.1%	0.2%	0.4%	0.9%
3000	0%	0%	0%	0.2%
3500	0%	0%	0%	0.1%
4000	0%	0%	0.06%	0.4%
Murray Bridge				
baseline	0.2%	0.4%	0.7%	1.7%
3000	0%	0%	0.07%	0.3%
3500	0%	0%	0%	0.3%
4000	0.02%	0.07%	0.2%	0.4%
Tailem Bend				
baseline	0.3%	0.5%	1.0%	1.9%
3000	0%	0.07%	0.2%	0.4%
3500	0%	0%	0.1%	0.3%
4000	0.1%	0.1%	0.2%	0.5%
Lake Alexandrina (Milang)				
baseline	4.6%	5.8%	6.5%	11.0%
3000	0%	0.7%	1.4%	2.7%
3500	0%	0%	0.2%	1.3%
4000	0%	0%	0%	1.2%

3.3 Risks and caveats

- Salinity results are a by-product of flow modelling and not the results of a salinity modelling project, but the results are the best available at present.
- Water quality and salinity results can be expected to be sensitive to the sequencing and period of historical data, to assumptions made about delivery of environmental water under Guide scenarios and, in the case of salinity, to assumptions made in modelling salinity.
- The input data to the BigMod daily model does not take climate change into account. If climate change results in reduced water availability then there could be severe adverse impacts on water quality and salinity. Possible impacts of climate change, and caveats on the assessment of these, are further discussed in Chapter 5.
- For water quality (i.e. alkalinity and cyanobacteria), the only analyses possible with the model results available were based on water quantity based metrics. For Lake Alexandrina, water level–related criteria were supplied by DENR and for cyanobacteria, flow criteria were agreed with SA Water. They could not be compared to criteria in the Guide where the alkalinity metric was pH and criteria for cyanobacteria bloom risk were expressed in terms of nutrients, turbidity, etc.
- The lowest water level in Lake Alexandrina modelled by BigMod was –0.55 m AHD, under the baseline scenario, which is considerably higher than the low water levels observed during the drought ending in 2010. Possible reasons for the discrepancy include:

  - the modelling period ended in June 2009 and if it had been extended, lower levels might have been modelled
  - the baseline scenario differs from current actual conditions
  - the calibration of the BigMod daily model needs refining to enable it to better represent the low water levels observed
  - a combination of the above.
- For South Australia's proposed targets at locations in the river with 99.7% non-exceedance probabilities, this translates to an allowable exceedance of about one day in 365, year after year. The main rationale for the targets appears to relate to urban water supply and it is not clear that a one day exceedance would necessarily be a problem. Therefore, these targets are seen to be overly conservative, and not practical or achievable. Hence, consideration should be given to revising these targets and in doing this the target values and probabilities of non-exceedance should be related more closely to the practical needs of assets and values intended to be protected. (Note the analyses of these targets for this report were much less stringent than the target criteria as performance was evaluated over the full 34.5 year modelling period, rather than year by year.)
- As MDBA's salt load export target is not met except during persisting wet conditions under the baseline scenario or any Guide scenario, consideration could be given to revising the target, if only to take into account that it is not met unconditionally. Preferably it could be based on a review of the purpose of the target and the assets that would be protected by such minimum export requirements. With or without revision, this target may provide the basis of a mechanism for managed dumping of salt from salt disposal basins when river flow conditions are appropriate.
- MDBA's operational targets are based on consideration of 'resource condition limits' for environmental or water usage values at a given location. The 'resource condition limits' do not include consideration of allowable durations and severities of exceedances, or of times between events. Management actions that should be taken when the operational target values are exceeded or expected to be exceeded do not appear to have been considered as yet.

4 Socioeconomic analysis

This chapter addresses the terms of reference for socioeconomic assessment, being to:

- gather and interpret socioeconomic studies relevant to South Australia including recent analysis of the impacts of drought on River Murray and Lower Lakes communities
- interpret the socioeconomic modelling, analysis and regional reports undertaken by the MDBA to support the development of the Basin Plan sustainable diversion limits (SDLs)
- use the above information to interpret the socioeconomic implications (impacts and benefits) of the new SDLs for South Australian communities (main focus) disaggregated to a sub-regional scale.

This assessment was to include consideration of: a) the sub-regional implications (Riverland, Mid-Murray and Lower Lakes and non-River Murray areas) and the implications for different sectors (irrigators, SA Water, other water users and the broader community); b) the implications of mitigation actions (the Commonwealth environmental water buyback, on-farm/off-farm irrigation infrastructure rehabilitation and water trade); c) the implications for stranded assets and structural adjustment; and d) changes to regional economic and social indicators.

The objectives of the study were partially addressed through a review of the substantial body of existing socioeconomic studies that evaluate the Guide to the proposed Basin Plan and related studies of the socioeconomic impact of less water available for diversion. Original work was also carried out to assess potential benefits of avoided future expenditures to protect against reduced water quality, reduced damage cost from riverbank slumping, road damage, curtailed ferry services near river banks with less than normal channel depth, and reduced future tourism revenue losses.

Additionally, new assessments of potential cost to the South Australian Murray-Darling Basin irrigation and municipal and industrial water sector were carried out. These analyses were based on, MDBA supplied,114-year modelling of daily flow and water allocations available for diversion, under current development and system operating rules, for the baseline and three Guide (3000, 3500 and 4000) scenarios.

One important caveat is that, the analysis does not represent a full cost benefit analysis and thus provides only a limited basis for weighing costs against benefits; it does, however, provide quantitative assessment of some potential costs and benefits that were not considered in the Guide to the proposed Basin Plan (the Guide).

An additional qualification to the irrigation sector economic assessment is that the MDBA modelling assumed all reductions in annual water allocation available for diversion in South Australia would occur in the irrigation sector and that the water entitlement for municipal and industrial water would be fully met in every year, even very dry years. Estimates of irrigation sector economic impacts would be less if reductions in water available for diversion were shared differently with some reduction for municipal and industrial diversions and lesser reductions in water available for irrigation.

A final qualification relevant to the irrigation sector economic impact assessment is that the analysis ignores positive income streams that could be experienced in the SA portion of the Murray-Darling Basin from water buyback or infrastructure investment.

4.1 Key messages

- During the recent drought (2000–2009) expenditures to manage the impacts of low flow such as increased salinity, damage from riverbank slumping, road damage, curtailed ferry services near river banks with less than normal channel depth, as well as tourism revenue losses were estimated at over $790 million. Under the Guide scenarios, similar mitigation and adaptation expenditures and damage costs may be avoided during future low flow incidences such as the recent drought.
- This study estimated that if the Guide scenario SDLs were implemented solely through reductions in allocation available for irrigation, the cost for irrigation in the South Australian portion of the Basin would be 4–6% of the average annual gross value of irrigated agricultural production (under the 3500 scenario). During a dry spell (equivalent to the Millenium Drought decade), the cost is estimated to increase to about 8%.

- Plan implementation decisions could lessen this impact, if water for the environment is sourced by water buybacks from willing sellers, economic activity generated from spending of water buyback proceeds is estimated to exceed lost economic activity from reduced irrigation in most regions in the southern portion of the Basin, including South Australia, even if half of buyback proceeds are spent outside of the region (Dixon et al., 2011).
- Plan implementation would be supported by removing remaining impediments to water trade. Allowing equitable access to dam storage capacity for carry-over for irrigators, as is recommended in the *Water Act 2007*, could additionally reduce irrigation sector impacts.
- Irrigation sector costs can be further reduced if some reductions in water available for diversion within the State are shared between municipal and industrial water and irrigation.
- In estimating the losses to municipal and industrial water and irrigated agriculture in SA under the Guide scenarios, an assumption is made that substitute supplies can be bought from the market. However, the flexibility inherent in water market reallocation is contingent on water being available for purchase at prices buyers are willing to pay. Less available water on the market or higher water market prices would mean higher costs for irrigation and municipal and industrial water than estimated here (Connor et al., 2009).

4.2 Approach

The socioeconomic assessment involved three main steps:

- a review of the socioeconomic impact assessment underpinning the Guide
- a review of the most pertinent economics studies
- new economics assessment work to estimate potential costs and benefits of the Guide in comparison to current water allocation arrangements for the categories of benefits and costs outlined in Table 4.1.

The literature reviews have been collated into one companion technical report (Connor ed., 2011b); and the methods and findings are reported in Connor (ed.) (2011a).

Table 4.1 Estimated potential benefits and costs of the Guide to major water users

Benefits	Costs
Irrigation	
Reduced salinity damage	Foregone production
	Purchase of water
Municipal and industrial water	
Reduced salinity damage	Consumer cost of water restrictions
	Purchase of water
	Operating cost of a desalination plant in Adelaide
Other (avoided)	
Infrastructure damage and repair	
Environmental remediation	
Replacement supply and water quality protection infrastructure	
Tourism loss	

4.3 Water available for diversions assumed in economic analysis

The economic impact of the Guide depends on the baseline water available for diversions and how this water availability is affected under the Guide scenarios. Since it is expected that the potential economic impacts of the Basin Plan (the Plan) will differ in dry, average inflow and wet periods, impacts were evaluated over three decade-long allocation and flow sequences:

- years 2000 to 2009 – the Millennium Drought, which is the driest decade on record
- years 1910 to 1919 – continuation of the Federation Drought. Although this decade had historically high allocations, it represents the second lowest allocation levels under the Guide scenarios. The reasons for this considerable shift in allocations are discussed in detail in the companion methodology report (Connor ed., 2011a)
- years 1970 to 1979 – representing the median flow and allocation decade. This decade is treated as representative of the 94 years outside of the three drought decades where allocations to SA were relatively constant under the Guide scenarios.

Figure 4.1 shows the average amount of water available for diversion in SA by decade under the baseline scenario and under all three Guide scenarios. Each ten-year sequence represents the average allocations expressed in GL that irrigators historically received (baseline) or are expected to receive under the Guide scenarios. Decades are ranked from lowest allocations to the highest under the 3500 scenario. The black lines represent the standard error of variation from the average.

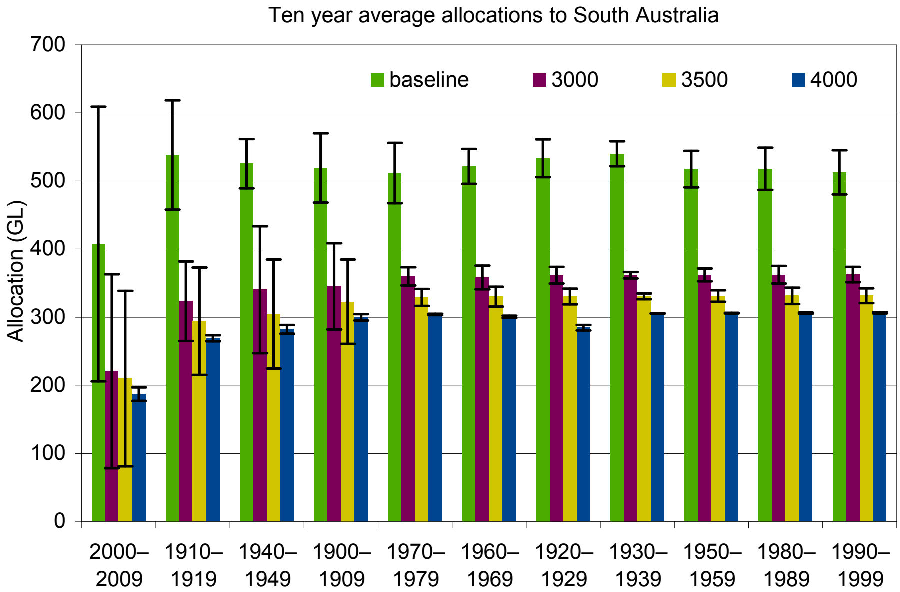

Figure 4.1 Average allocations (as total diversions) per decade with standard error under the baseline and Guide scenarios

The BigMod daily model makes assumptions about how water allocations available to SA would be shared between irrigation and municipal and industrial water entitlements. Specifically, that municipal and industrial water would be provided with full allocation first and then irrigation allocations would comprise the residual allocation available for diversion in SA. The SA government, however, has not determined how to share the state allocation as the SDLs are yet to be finalised. To further understand the potential impacts on water users in SA under the Guide scenarios, the SA Government requested an evaluation of both the MDBA allocation scenario and an alternative scenario involving an equal percentage reductions in water available to municipal and industrial water and to irrigation.

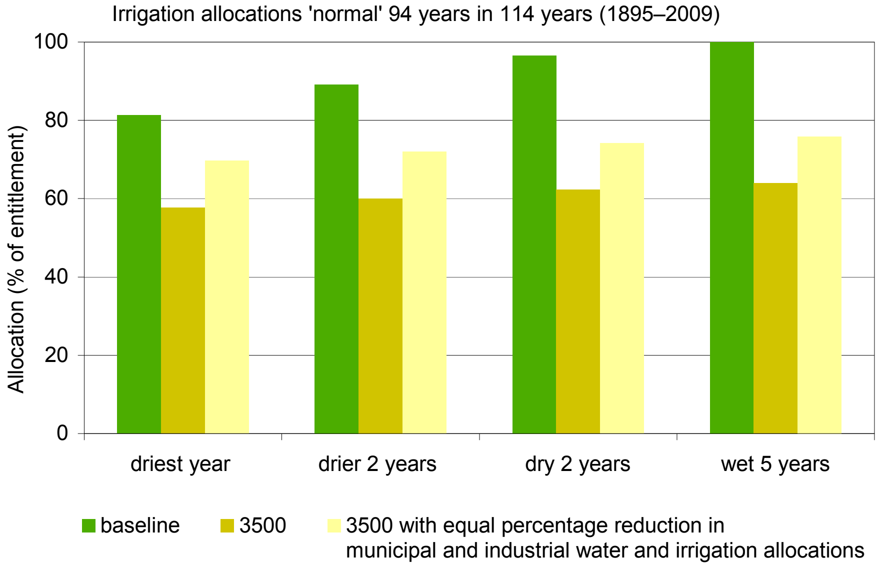

Figure 4.2 Irrigation allocations as percent of entitlement in the normal (8 decades in 11) decades including the driest year in ten, the next two driest years in ten, the fourth and fifth driest in ten and the five wettest years in ten under the baseline and 3500 scenarios

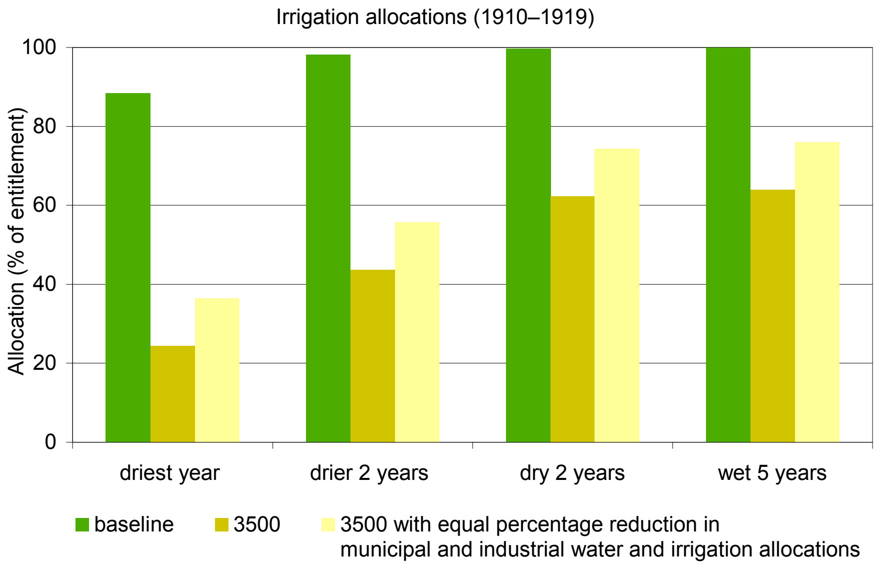

Figure 4.3 Irrigation allocations as percent of entitlement under one of the driest decades (1910–1919) including the driest year in ten, the next two driest years in ten, the fourth and fifth driest in ten and the five wettest years in ten, under the baseline and 3500 scenarios

Figure 4.2, Figure 4.3 and Figure 4.4 show the historical and expected water allocations available to agriculture for diversion under the 3500 scenario both with and without reductions being shared between irrigated agriculture and municipal and industrial water. Allocation reductions are evident across all years and decades although they are most likely to be felt more in the driest years and even more so in the driest decades. It is noteworthy that for approximately 9 decades in 11, significant reductions in allocations are expected, however these allocations are less variable.

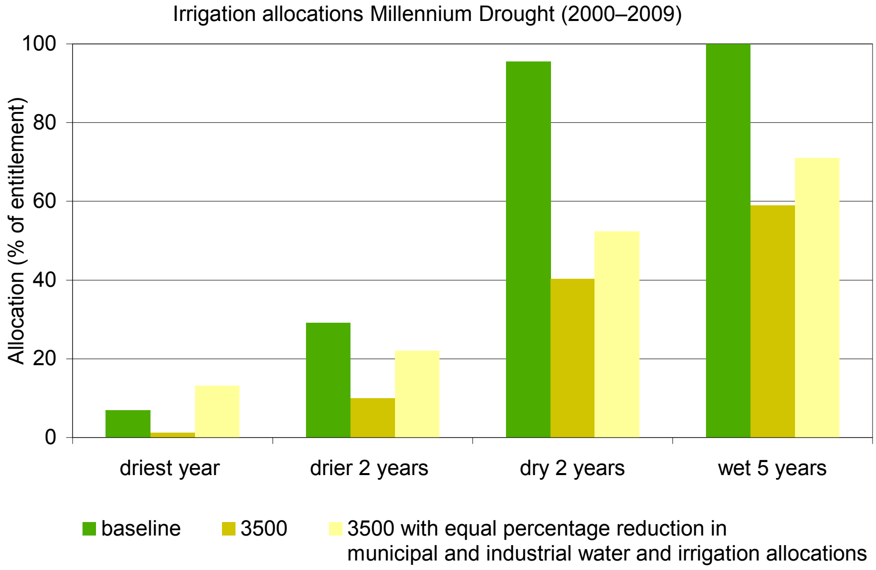

Figure 4.4 Irrigation allocations as percent of entitlement in the driest decade on record (2000–2009) including the driest year, the next two driest years in ten, the fourth and fifth driest in ten and the five wettest years in ten, under the baseline and 3500 scenarios

4.4 South Australian water costs

An assumption implicit in the 114-year flow and water allocation modelling provided for this study by the MDBA was that all reductions in annual water allocation available for diversion in South Australia would occur in the irrigation sector and that the water entitlement for municipal and industrial water would be fully met in every year, even very dry years. The SA Government may decide to share reduction between irrigation and municipal and industrial water users differently.

Terms of reference for this study included an evaluation of the potential costs of municipal and industrial water supply in a scenario where allocation reductions under the Guide scenarios were shared across all water users in proportion to their level of entitlements. To estimate the potential impact of reductions in municipal and industrial water allocations under the Guide scenarios with this alternative assumption, the difference in allocations under the baseline scenario and under Guide scenarios was analysed. Over the 114-year period modelled by the BigMod daily model, assuming equal proportional sharing of reduced allocations, shortfalls in SA Water's allocation for Adelaide under the 3500 scenario were compared with current diversion limits. Estimated shortfalls to SA Water for municipal and industrial supply ranged between 6.2 GL/year and 112.1 GL/year with a mean of 35.6 GL/year.

Depending on conditions such as the quality of water available for diversion, and availability of water on the market, SA Water could meet the shortfall through water restrictions, water market purchases, or by operating of the existing desalination plant at a higher level of production than would otherwise be the case, or through some combination of the three approaches. The cost associated with meeting any estimated shortfall was estimated for all three supply options:

- the cost of doing with less water (water restrictions)
- the cost of buying water from the market
- the additional cost of running the desalination plant,

and ranged from $11 million/year to $47 million/year on average, depending on the system chosen. Analysing various combinations of the three alternatives in an optimisation framework that accounts for timing of availability of alternatives, limits to supply available on the water market, and limits to quality in supply available for diversion from the Murray would be more comprehensive; however, this was outside of the scope of this analysis.

4.5 Avoided damage, mitigation and adaptation costs

Both the SA and Commonwealth Governments incurred costly expenditures to adapt to ecosystem service losses and to mitigate further damage. In the case of the SA portion of the Basin, during the Millenium Drought, reduced inflows into the system pushed ecosystem function beyond various thresholds resulting in significant environmental damage and ecosystem service loss. An ecosystem reaches a threshold when one or more of its attributes are degraded below a specific level. An ecosystem may then transition to a new equilibrium state with albeit an eroded capacity to provide the original range and level of environmental benefits or ecosystem services. A preliminary estimate of the economic value of ecosystem service loss related to reduced river system inflow for the SA portion of the Basin was completed.

Figure 4.5 shows the average annual level of Lake Alexandrina and damage, mitigation and adaptation costs associated with ecosystem service loss as a result of ongoing reduced system inflows over the Millenium Drought. Monitoring and planning costs increase significantly when lake levels dropped to between 0.0 and –0.5 Australian Height Datum (AHD). Between 2008 and 2009, a threshold was reached when lake levels dropped below sea level. With this threshold breached, there was steep increase in ecosystem service loss as measured by damage, mitigation and adaptation expenditures. The cumulative value of this loss was estimated at over $790 million.

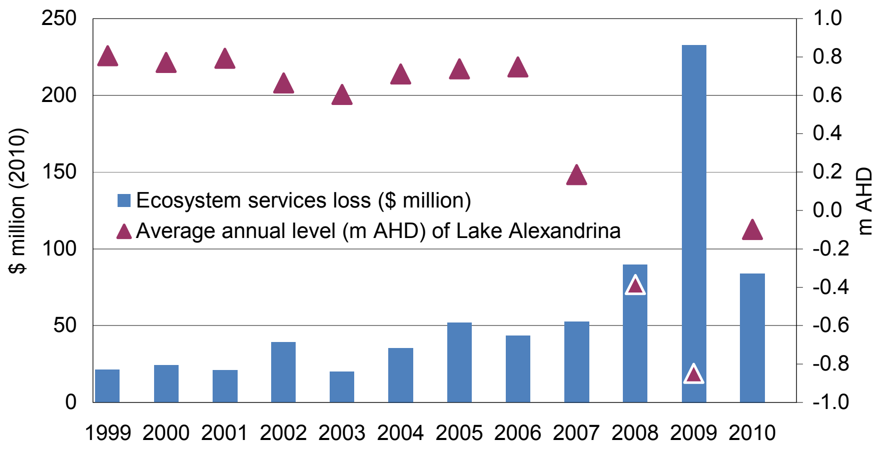

Figure 4.5 Magnitude of ecosystem services loss (in $ million) and levels (m AHD) of Lake Alexandrina

Most of these damages can be related to three ecological thresholds. First, reduced inflows into the SA portion of the Basin and the Lower Lakes specifically meant inflows were exceeded by evaporative losses in the system. A lake level of –1.0 m AHD had never before been reached until 2009. With the exposure of saturated sulphidic sediment, large areas of the former lake bed acidified upon drying producing acid sulphate soils. These soils are problematic for the acidic water they create which then releases heavy metals and toxins and alters soil structure (Department for Environment and Heritage, 2010). Second, ongoing evaporative losses and reduced system inflow resulted in the breaching of salinity thresholds which rendered locally-sourced water unfit for human or irrigated agricultural use without expensive treatment. A third threshold was maintenance of a minimum in-river channel water depth. When channel water depth did not meet minimum thresholds, riverbanks began to collapse, floodplains and levees cracked, roads and other infrastructure required remediation, and significant investment in laser levelling of paddocks and irrigation infrastructure efficiency upgrades was lost.

Surpassing the aforementioned thresholds has resulted in significant economic consequences for the SA and Commonwealth Governments as well as individual citizens. Table 4.2 provides a snapshot of the environmental damage caused in the absence of adequate base and environmental flows during the Millenium Drought. Regulating ecosystem services were the most affected, representing a loss of over $421 million in value. Next were cultural and amenity values for an ecosystem service loss of over $294 million. Habitat losses, in particular, maintaining a base water level in Lake Albert to preserve critical ecosystem services and the management of acid sulphate soils amounted to ecosystem service losses of $24 million. Finally, a conservative estimate of the loss of provisioning services surpassed $50 million, primarily the consequence of a significant contraction in the dairying industry around the Lower Lakes. These ecosystem service losses may have been significantly reduced had the system been provided with base and environmental flow requirements.

Table 4.2 Damage, mitigation and adaptation costs of ecosystem services losses for the South Australian Murray System and Lower Lakes (2000–2009)

Ecosystem function	Costs
	$ (2010 base)
Provisioning	
Agriculture and livestock[1]	50,739,840
Regulating	
Dredging Murray Mouth[2]	32,000,000
Salinity damage cost [3]	122,434,969
Levee remediation[4]	11,380,000
Repairs to bridges, ferry landings and pipelines[4, 5, 6, 7]	1,000,000
Lost expenditure from irrigation upgrades and laser levelling[4]	82,000,000
Flow regulators, bunds and pipelines[2]	160,000,000
Riverbank collapse including property damage[4, 8]	12,520,000
Habitat	
Acid sulphate soil works[1, 2]	10,000,000
Water pumping[2]	14,000,000
Cultural and amenity	
Tourism[9]	294,830,000
Total	**790,904,809**

[1] Department for Environment and Heritage, 2009
[2] Kingsford et al., 2010
[3] CSIRO salinity damage cost calculations; equations detailed in Allen Consulting, 2004
[4] SA DfW, Riverbank Collapse Hazard Program
[5] DTEI as reported to SA DfW, Riverbank Collapse Hazard Program
[6] SA Water as reported to SA DfW, Riverbank Collapse Hazard Program
[7] Councils for affected infrastructure as reported to SA DfW, Riverbank Collapse Hazard Program
[8] Local Councils as reported to SA DfW, Riverbank Collapse Hazard Program
[9] Department of Resources, Energy and Tourism, 2010

The damage, mitigation and adaptation costs of ecosystem service loss are presented here as a one-off payment made as a result of the Millenium Drought. The expectation is that intermittent droughts will also occur periodically in the future. To compare annualised costs to irrigated agriculture to the benefits of avoiding ecosystem service loss under the Guide scenarios would require annualising the benefits of avoided damage, adaptation and mitigation over future sequences of allocations, flows and droughts. The annualised benefit of ecosystem service loss avoided would depend heavily on how climate change impacts develop, the frequency and duration of future droughts, the effect of discounting, and the sequencing of drought; that is, whether drier periods are anticipated to occur in the earlier or later years of the period of analysis. More lengthy droughts occurring earlier in the next decades lead to higher estimates of annualised benefits under the Guide scenarios.

It should be noted that cost and expenditure-based estimates enumerated for this study can lead to both under and over estimation. On the one hand, economists tend to argue that they underestimate benefits as they do not capture non-use values such as bequest value, existence value and values communities place on the aesthetics of a healthy system. To provide an indication of the relative magnitude of these values for the Murray region, Australians valued a 1% increase in native vegetation at $79 million; a 1% increase in native fish populations at over $73 million; a 1 year increase in colonial waterbird breeding at $375 million; a unit increase in the number of waterbirds and other species at $12 million; and improving the condition of the Coorong from poor to good health at $4.3 billion (Morrison and Hatton MacDonald, 2010).

On the other hand, since expenditure-based techniques are based on actual expenditures realised, they are often regarded as more reliable estimates (King and Mazzotta, 2000). Where mitigation expenditures become far removed from societal preferences, however, an expenditure may in fact exceed society's real willingness to pay for the mitigation of environmental *bads* (Garrod and Willis, 1999). Essentially, the argument is that in some cases public expenditure may not necessarily represent least cost measures and may not always be justified by the benefits that result. However, it seems difficult to argue that the expenditures quantified in this work, from acid sulphate soil mitigation to levee remediation and riverbank collapse hazard monitoring are not aligned with society's preferences and the role of government in keeping the public safe.

4.6 Irrigation costs

Reduced diversion limits under the Guide scenarios will require adaptation within the irrigation sector, including buying additional water on the market. reducing irrigation applications rates, reducing irrigated area, and changing crop mix.

An economic model of the irrigation sector was developed to assess the likely adaptation pattern and costs to reduced water allocations under the Guide scenarios. Economic impacts were estimated for three sub-regions (Figure 4.6):

- the area above Blanchetown (also known as the Riverland)
- the area between Blanchetown and Wellington (also known as the Murray Gorge)
- and the area below Wellington, also referred to as the Lower Lakes (Figure 4.6).

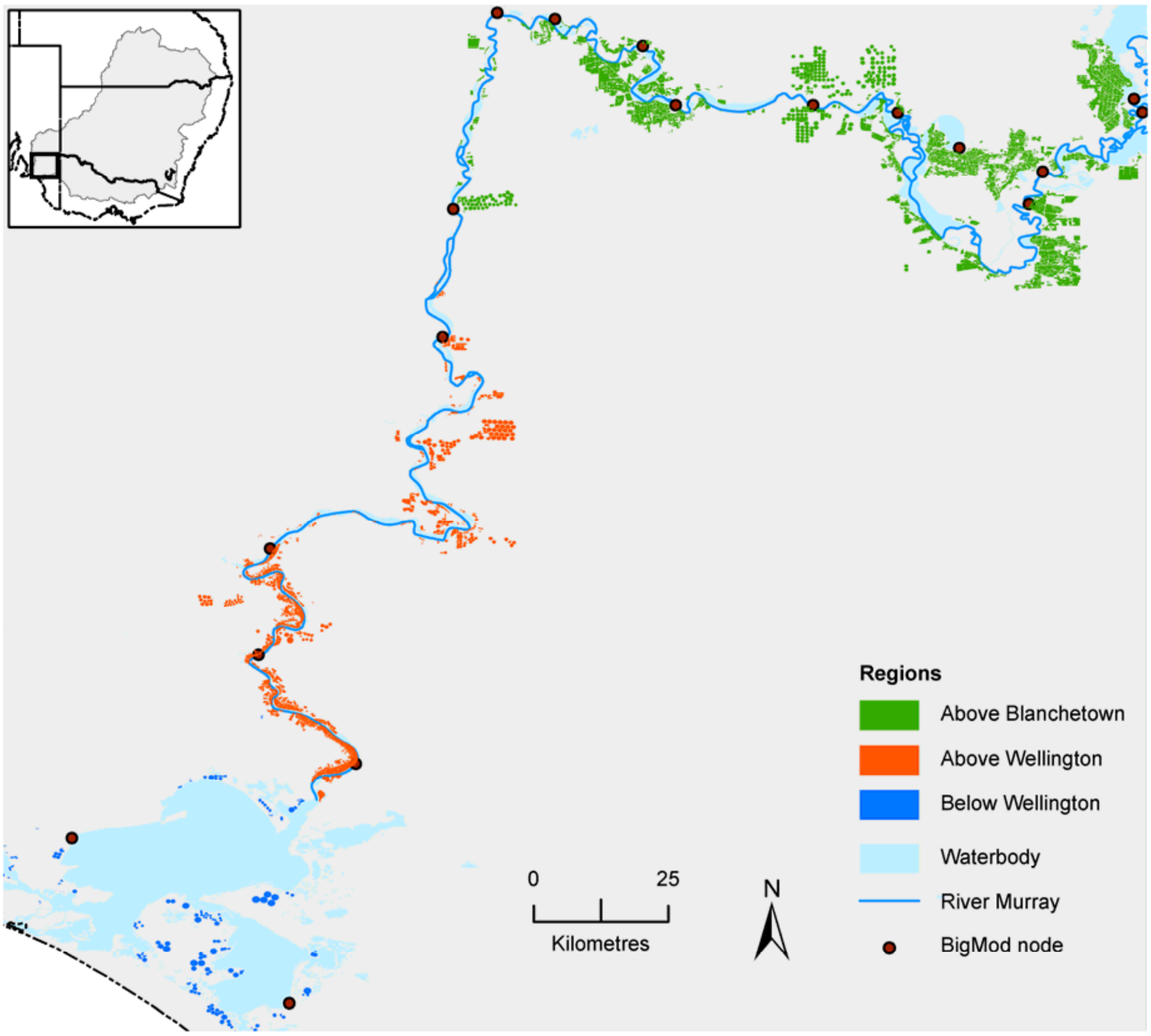

Figure 4.6 Sub-regions considered in irrigation sector economic impact assessment

The irrigation costs discussed in this section are best interpreted as an upper bound because we estimate the cost of meeting the SDL as the cost of reducing water available for diversion in South Australia and without offsetting regional income from buybacks or infrastructure investment. In fact, the Commonwealth Government have committed to recovering all the water that is required under the Basin Plan by purchasing water from willing sellers or investing in water efficiency measures under the Water for the Future program. Through this program the Commonwealth have already recovered a significant portion of the water that is likely to be required under the final Basin Plan, thereby reducing potential impacts on water entitlement holders. Should the Commonwealth Government achieve their aim of recovering all the water required through purchase from willing sellers or investment in efficiency measures there may be little residual impact on water entitlement holders; first because sale of entitlement to the Commonwealth may well primarily take place elsewhere than South Australia and second because if purchase of water or efficiency investments do take place in South Australia, they are also likely to generate regional economic activity which will offset at least some of the lost economic activity from reduced irrigation in the South Australian portion of the Basin.

Figure 4.7 shows the estimated average annual irrigation sector cost under the Guide scenarios. Both the total cost and the portion of that total cost estimated to be the cost of water purchases are shown. Notably, the results show a relatively linear relationship between increasing costs and the Guide scenarios. The estimated irrigation sector costs represent 4.0%, 5.3% and 6.4% of baseline irrigation revenue (gross value of irrigated agricultural production – GVIAP) under the Guide scenarios, respectively. Most of the increased cost is estimated to be the result of the expense of purchasing additional water. The remaining relatively small cost represents the value of reduced irrigated agricultural output. ABARE–BRS estimated a 7% reduction in the value of GVIAP in the SA Murray. The difference can likely be explained by the greater improvement in water use efficiency in response to water scarcity assumed in this study and consistent with the recent drought response.

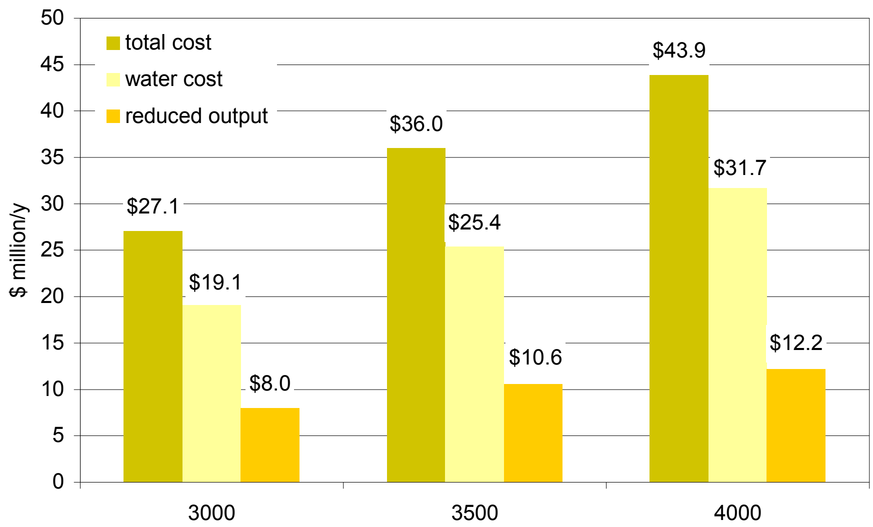

Figure 4.7 Worst case average annual costs to the South Australian irrigation sector under the Guide scenarios

More detailed results are summarised here for a comparison of the current diversion limits and the 3500 scenario. Figure 4.8 summarises the estimated annual costs for South Australian River Murray irrigation on average for 94 of 114 years where relatively constant allocations are expected, estimated average costs for a period similar to the Millennium Drought (2000–2009), and estimated average costs over a 114-year period. The average annual cost over the 114 years under the 3500 scenario is $36 million/year. Figure 4.8 also shows that the costs are estimated to be considerably greater during dry periods such as the Millennium Drought as more severe allocation reductions are predicted and also because the model accounts for water prices which are predicted to be higher under more water scarce scenarios.

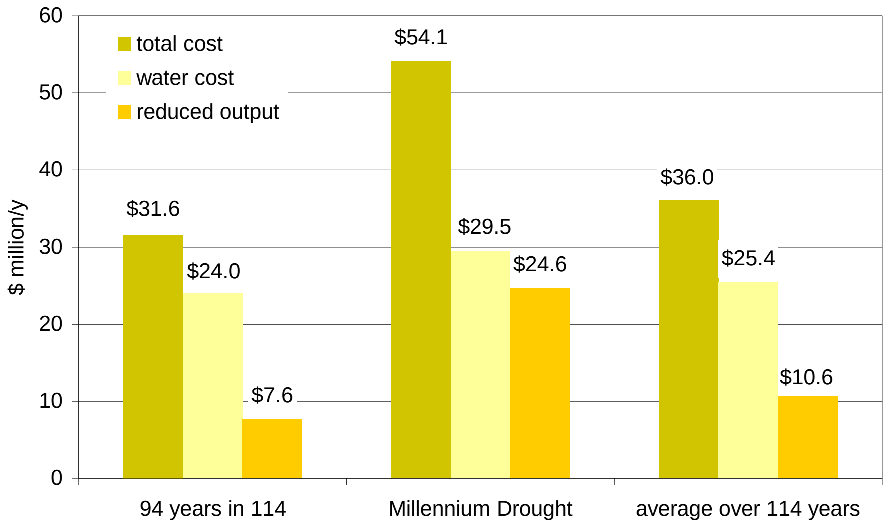

Figure 4.8 Worst case average annual costs to the South Australian River Murray irrigation sector in dry and average periods under the 3500 scenario

Figure 4.9 and Figure 4.10 show how economic impacts under the Guide scenarios are likely to vary across sub-regions.

Figure 4.9 shows that in absolute terms, the Riverland is expected to bear the greatest impact; this is because the region produces the largest share of irrigated output in SA and the highest value crops per ML and hectare with its predominance of horticultural and viticultural crops. As shown in Figure 4.10, the Lower Lakes region below Blanchetown is estimated to be most severely impacted in relative terms (the cost incurred under the Guide scenarios is highest as a percentage of GVIAP). This is primarily because of the predominance of irrigated pasture for grazing in the region. Recent drought experience shows that pasture is only marginally economical with high water prices and it is predicted in this modelling to be left fallow under very low allocation conditions such as the 1-in-10 and 3-in-10 dry years in the Millennium Drought sequence. As noted in Section 4.2, one result of the modelling underpinning the Guide is that there will be a significant reduction in water availability in dry years and dry sequences. Buying water is not a cost-effective response for those irrigating pastures, so they reduce production. As irrigated grazing pasture is the dominant activity in the Lower Lakes, this region suffers the greatest cost impacts as a percentage of the gross value of irrigated agricultural output.

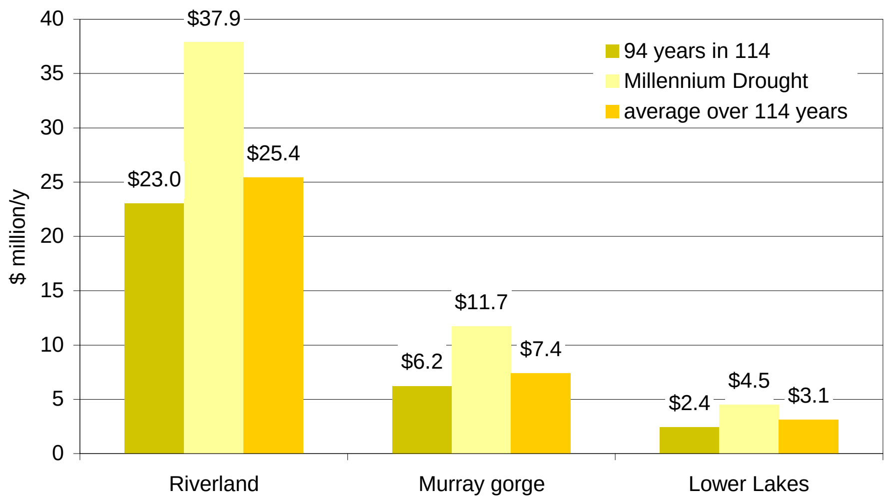

Figure 4.9 Worst case average annual costs to South Australian irrigation sub-regions in dry and average periods under the 3500 scenario

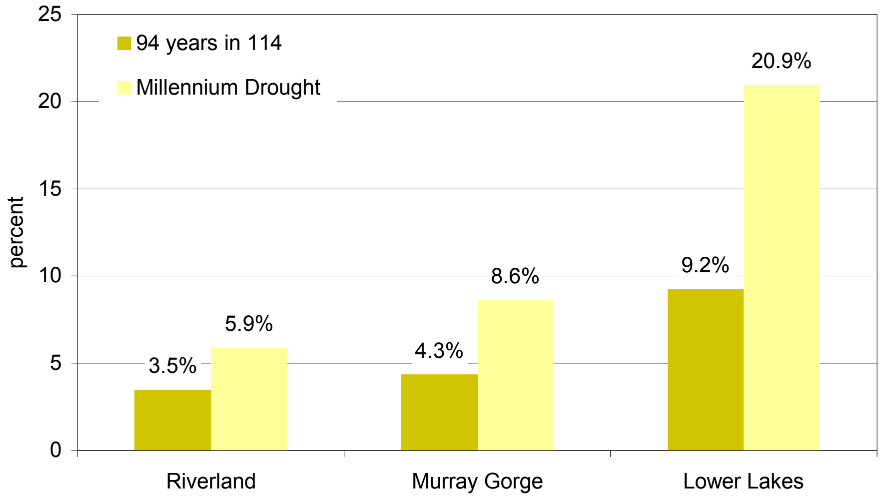

Figure 4.10 Worst case average annual costs to South Australian irrigation sub-regions, expressed as percent of baseline irrigation revenues, in dry and average periods under the 3500 scenario

Estimates of potential future irrigation sector costs necessarily have a degree of uncertainty, as the exact pattern of response to increased water scarcity under the Guide scenarios is not perfectly foreseeable. The extent to which the figures provided here are likely to represent over or under estimates depends critically on two key assumptions:

1. Buying water is a key modelled and observed response to water scarcity amongst irrigators in SA. An assumption of increasing water price with increasing water scarcity is factored into this analysis. In reality, water prices might be more or less than assumed depending on how supply and demand evolve across the Basin in response to the Plan. If in fact, water were simply not available to meet the gap between supply and demand, cost could be significantly higher (Connor et al., 2009).
2. Relatively little irrigation area reduction response is modelled here as a result of our calibration to ABS and SAMRIC data. Both of these data sources show some reductions in the area of irrigated pasture in the SA Murray from 2005–06 to 2008–09, but no clear trend of decreasing vineyard or orchard area. Recent aerial survey data on changes in irrigated area have come to the project team’s attention late in the project that do show declines in orchard and vineyard area over the course of the recent drought (PIRSA, 2010). Re-calibrating the model to this new data would likely result in a greater reduction in irrigated area and consequently a greater cost incurred under the Guide scenarios.

Although point 2 might tend to suggest an underestimation of the irrigation sector impact and point 1 could lead to either an over or underestimation, the mobility of farm assets might suggest an overestimation of the net impact.

4.7 Regional income impacts and structural adjustment

The irrigation sector analysis presented in Section 4.6 did not consider the flow-on effects under the Guide scenarios on the regional South Australian Basin economy nor the potential offsetting impacts of the purchase of water for the environment through a Commonwealth-initiated buyback process. Such analysis requires an economy-wide modelling framework, known to economists as a computable general equilibrium approach. Researchers at Monash University’s Centre of Policy Studies have developed such a model (TERM H_20) for analysis of water policy on disaggregated Basin regions. Their research demonstrated that, if the buyback were fully implemented, then the negative impacts of the SDLs on national and regional gross domestic product, income, and employment would be negligible. This is because the buyback represents an income transfer and the studies assume that irrigators spend buyback revenues in the same way that they spend irrigation revenue boosting demand for local and regional goods and services. Dixon et al. (2011) tested the implications of 50% of buyback revenues being spent in the region and 50% spent outside of the region and found that the buyback still results in a net benefit for the Basin. CGE models can also be used to test: other buyback structures and sequencing; changes in technology; future climate scenarios; and opportunities for easing and facilitating structural adjustment.

There is a link between the regional economic impacts of the Plan and pressures for structural adjustment. A concern for government are situations where stranded assets might concentrate, for instance in a particular irrigation district and the associated local community impacts. Consideration of local contextual information suggests that: small- to medium-size irrigation enterprises, particularly those currently owned by older farmers without successors, those blocks irrigated for crops and varieties facing the most significant downward price pressures, and those small public irrigation trust blocks with less modern delivery and ordering to farm gate, are most vulnerable (Thompson, 2006).

There are a suite of key drivers of structural change in the irrigation industry in the SA portion of the Basin apart from water availability that will be impacted by the Plan, such as: market conditions; exchange rates and consumer preferences; regional demographic trends; government policy; and combinations of these factors. The exact impact of SDLs are difficult to quantify ahead of time as Plan implementation may coincide with plentiful or scarce water allocations, high or low commodity prices, etc. However, policy can generally either impede or facilitate adjustment (Young and McColl, 2005). Policies facilitating structural adjustment include measures to further free market trade in water and to develop carryover arrangements. Other programs might include targeted investments in irrigation district reconfiguration and buybacks to increase irrigation system efficiency and provide multiple co-benefits such as enhanced ecosystem service provision, reduced salinity loads and carbon sequestration (Crossman et al., 2010). The Plan itself and its roll out can be designed to facilitate autonomous structural adjustment. Depending on how they are implemented, the accreditation guidelines for state environmental watering plans could promote good practices in co-managing irrigation and environmental water within a shared system that might be rewarded by significant efficiencies. Policies that currently impede structural adjustment could be revisited, such as the structure of exit packages (ACCC, 2006).

5 Delivering a flow regime to meet South Australia's environmental water requirements

In addition to reviewing the science underpinning the Guide, the project team undertook additional modelling, beyond that provided by the MDBA, to determine the flows needed to deliver environmental water to South Australia, if the flow regime to satisfy South Australia Government's EWRs were adopted. For this purpose, four optimised daily flow scenarios were developed, based on MDBA and SA Government EWRs. The terms used to identify these flows in this chapter are:

- SA Riverland–Chowilla EWRs optimised flow
- MDBA Riverland–Chowilla EWRs optimised flow
- SA CLLMM EWRs optimised flow
- MDBA CLLMM EWRs optimised flow.

There were three components to the work:

1. deriving the optimised flows to meet EWRs for Riverland–Chowilla and CLLMM, and translating the barrage flow required for CLLMM EWRs to the South Australian border (Section 5.2)
2. analysis of being able to deliver these flows under the water available under the Guide scenarios as a water delivery regime (Section 5.3), including an analysis of the shortfall years (Section 5.4)
3. analysis of sourcing the flows (Section 5.5) and considering release limitations of upstream supply storages (Section 5.6).

Limitations of upstream supply storages were determined using a Source model (eWater, 2010) of the upstream supply storages, that considered shortfalls in meeting SA EWRs optimised flows, storage characteristics, travel times and delivery efficiencies. The supply storages were forced to store volumes associated with the 4000 scenario.

5.1 Key messages

- How water is delivered, particularly the operation of upstream storages and assets will be critical to the meeting of the South Australian Government's environmental water requirements.
- The project has identified optimised flows at the border for both Riverland-Chowilla and CLLMM which meet all the EWRs specified for South Australia. In meeting the Riverland-Chowilla EWRs optimised flows, there is also sufficient volume to meet the CLLMM EWRs optimised flow. Consequently the EWRs for South Australia are governed by meeting the Riverland-Chowilla EWRs.
- Climate change impacts could significantly reduce the volume supplied under all of the scenarios and reduce the ability to meet SA's EWRs optimised flows.

Delivery of environmental water requirements

- Riverland–Chowilla
  - The Riverland–Chowilla EWRs optimised flows are met under the 4000 scenario on an average annual volume basis, but not every year. However, these shortfalls only occur in 44 years in the 114-year period, and could be met in most years by additional releases from upstream storages, except when there is insufficient volume in upstream storages.
- CLLMM
  - The CLLMM EWRs optimised flows are met under all Guide scenarios, on an average annual volume basis, when downstream use is accounted for. They are not met in every year, though the shortfall is only 12 years in the 114-year period. This is a significant improvement on the 71 shortfall years under the baseline.
  - The SA CLLMM EWRs optimised flow is based on low flows and consequently is easier to deliver than the high-flow requirements of the SA Riverland–Chowilla EWRs optimised flow.

Table 5.1 contains a summary of whether EWRs optimised flows can be delivered under the Guide scenarios, on an average annual, annual, and five-year rolling average basis.

Table 5.1 Meeting the delivery of MDBA and SA Riverland–Chowilla and CLLMM EWRs optimised flows under the without-development, baseline and Guide scenarios, on an average annual, annual and five-year rolling average basis

	scenario				
	without development	baseline	3000	3500	4000
Delivery of Riverland–Chowilla EWRs					
MDBA EWRs on average annual basis	◆	●	◆	◆	◆
SA EWRs on average annual basis	◆	●	■	■	◆
SA EWRs on an annual basis	◆	●	■	■	■
SA EWRs on a five-year rolling average basis	◆	●	■	■	■
Delivery of CLLMM EWRs					
MDBA EWRs on an average annual basis	◆	●	◆	◆	◆
SA EWRs on an average annual basis	◆	◆	◆	◆	◆
SA EWRs on an annual basis	◆	●	■	■	■
SA EWRs on a five-year rolling average basis	◆	●	■	■	◆

◆ target is met
■ target is not met, but is better than baseline
● target is not met
Actual figures are in Table 5.3, Table 5.4, Table 5.5 and Table 5.6

Sourcing flows

- The proportional contribution of upstream regions to SA border flows to meet the SA and MDBA EWRs is similar to the without-development contributions (Table 5.7).
- Under the baseline and Guide scenarios, the proportional contribution of upstream regions to SA border flows is different to the without-development contributions. As an example, under the 4000 scenario, the proportional contributions of upstream regions range from 55% to 99% of the without-development contribution (Table 5.8).

Delivery risks

The ability to deliver water to South Australia will depend on:

- the operation of upstream storages and how this will change the spilling frequency, which will impact on delivering high flows for Riverland and Chowilla
- how environmental water is shared between all assets in the Basin
- how delivery of environmental water is managed in extended dry periods
- the ability of upstream storages to deliver the required flows to South Australia when required.

5.2 Building the EWRs optimised daily flows at the border

Optimised flows for MDBA and SA EWRs were derived using augmented flow series, ensuring that daily flow requirements, including required frequencies, are met. For the SA EWRs, design flows were based on the modified requirements derived as part of the EWR assessment component of the project and are listed in Table A.6. The determination of water requirements at the barrages for the CLLMM used the EWRs in Table A.3.

5.2.1 Riverland–Chowilla

Optimised flows at the border were derived directly for Riverland–Chowilla. The MDBA specifications were taken from the Guide and are listed in Table A.5. Analysis determined that average annual volumes at the border of 8040 GL and 8729 GL are required to meet MDBA and SA Riverland–Chowilla EWRs optimised flows, respectively (Table 5.2).

5.2.2 Coorong, Lower Lakes, and Murray Mouth

Optimised flows at the barrages were built for MDBA and SA CLLMM EWRs.These were transferred to the border by adjusting for delivery time (13 days) and losses and running the estimated required border flow through the without-development configuration of the BigMod daily model. This was an iterative approach where loss factors were adjusted until the desired barrage flow was achieved. This analysis found that annual losses were largest during dry years and ranged between 10% and 100%. Analysis determined that average annual volumes at the border of 6116 GL and 5379 GL are required to meet MDBA and SA CLLMM EWRs optimised flows, respectively (Table 5.2).

5.2.3 South Australia

There is sufficient volume each year in the SA Riverland–Chowilla EWRs optimised flow to also meet the SA CLLMM EWRs optimised flow each year. Consequently the SA EWRs are governed by meeting the SA Riverland–Chowilla EWRs optimised flow and are not reported on separately in this chapter. It must be noted that operationally it may not be possible to meet these requirements due to upstream environmental requirements or limitations on upstream stores to deliver the required flow.

Table 5.2 Average annual volumes required to meet MDBA and SA Riverland–Chowilla and CLLMM EWRs optimised flows

	MDBA EWRs	SA EWRs
	average annual volume (GL)	
Riverland–Chowilla (SA) at the border	8040	8729
CLLMM at the border	6116	5379
CLLMM out the barrages	5110	4389

5.3 Delivering EWRs optimised flows under the Guide scenarios

The assessments in this section use average annual volumes calculated from the BigMod daily model, compared to average annual volumes reported in the Guide.

5.3.1 Riverland–Chowilla

- The MDBA Riverland–Chowilla EWRs optimised flow requires an average annual volume of 8040 GL at the border, which is met under all Guide scenarios.
- The SA Riverland–Chowilla EWRs optimised flow requires an average annual volume of 8729 GL at the border, which can only be met under the 4000 scenario.

The average annual volumes to South Australia required to meet the MDBA and SA Riverland–Chowilla EWRs optimised flows under the without-development, baseline and Guide scenarios are shown in Figure 5.1 and Table 5.3, and include both irrigation and urban usage, and delivery and evaporative losses. Table 5.3 also shows a comparison between volumes as extracted from the BigMod daily model and the Guide annual model.

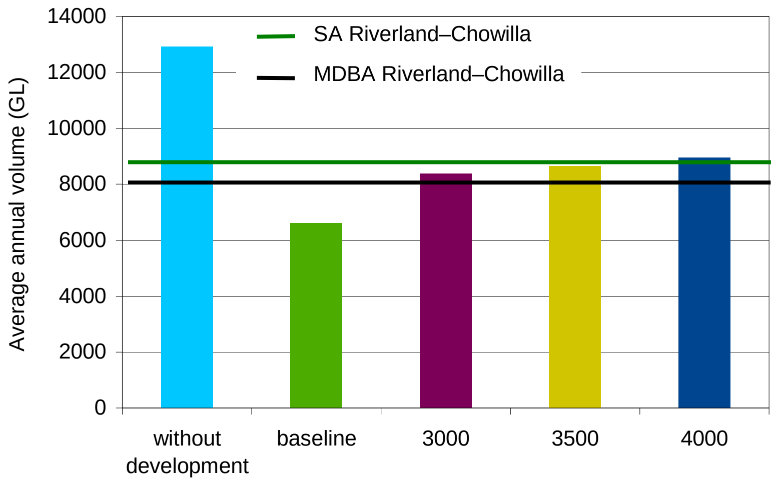

Figure 5.1 Average annual volume (GL) to Riverland–Chowilla under the without-development, baseline and Guide scenarios compared to the volumes required to meet MDBA and SA Riverland–Chowilla EWRs optimised flows (shown using the black and green horizontal lines respectively)

Table 5.3 Average annual volume (GL) to Riverland–Chowilla under the without-development, baseline and Guide scenarios (with comparison to volumes published in the Guide)

	Scenario				
Source	without development	baseline	3000	3500	4000
	GL/y				
MDBA daily model	12,918	6,603	8,368	8,644	8,958
Guide annual model	13,592	6,783	8,661	8,966	9,290

The Riverland–Chowilla EWRs optimised flows have been developed to ensure the required frequencies are met.

5.3.2 Coorong, Lower Lakes, and Murray Mouth

- The SA CLLMM EWRs optimised flow requires an average annual volume of 4389 GL out the barrages, which can be met under the baseline and all Guide scenarios. This requirement translates to an average annual volume of 5379 GL at the border.

The average annual flows out the barrage to meet MDBA and SA CLLMM EWRs optimised flows under the Guide scenarios are shown in Figure 5.2 and Table 5.4. A comparison between flows extracted from the MDBA daily model and the Guide annual model is also shown in Table 5.4. These volumes do not include irrigation and other uses as these have been extracted prior to flows out the barrages.

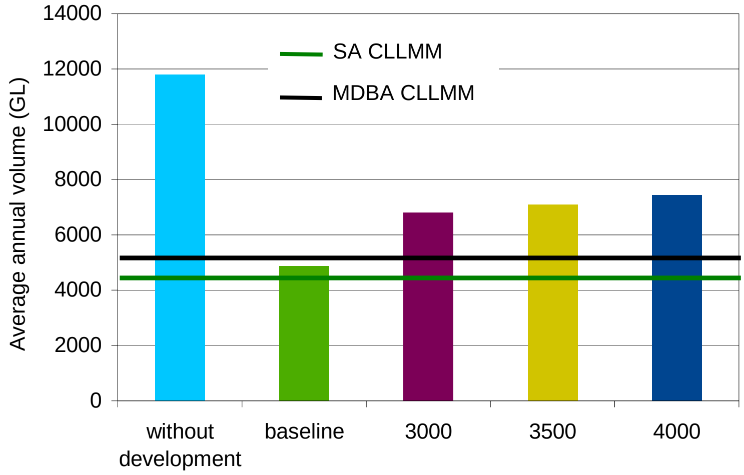

Figure 5.2 Average annual volume (GL) out the barrages under the without-development, baseline and Guide scenarios compared to the volumes required to meet MDBA and SA CLLMM EWRs optimised flows (shown using the black and green horizontal lines respectively)

Table 5.4 Average annual volume (GL) out the barrages under the without-development, baseline and Guide scenarios (with comparison to volumes published in the Guide)

	scenario				
source	without development	baseline	3000	3500	4000
	GL/y				
MDBA daily model	11,789	4870	6804	7107	7447
Guide annual model	12,503	5105	7151	7481	7828

Table 5.4 and Figure 5.2 show that the average annual volume of 5100 GL required out the barrages to meet MDBA CLLMM EWRs optimised flow and the average annual volume of 4389 GL required to meet SA CLLMM EWRs optimised flow are met under all Guide scenarios. The SA CLLMM EWRs optimised flow is also met under the baseline scenario, on an average annual basis.

5.4 Annual flow shortfall across the border and out the barrages

Assessments in this section use annual volumes calculated from the BigMod daily model, compared to annual volumes from the Guide annual model.

5.4.1 Riverland–Chowilla

- Despite being met on an average annual volume basis, the SA Riverland-Chowilla EWRs optimised flows are not met in every year. The best outcome is under the 4000 scenario with 44 shortfall years compared to 97 shortfall years under the baseline scenario. Many of the shortfall years are grouped together in dry periods.
- The SA Riverland–Chowilla EWRs optimised flow is not met on a five-year rolling average basis under any of the Guide scenarios. This shows that there are periods of five years where not all SA EWRs are met.
- The annual shortfall volume could be met in most years by additional releases from upstream storages, except when there is insufficient volume in upstream storages to meet the shortfall. This is subject to sufficient environmental volume being available in these years in the upstream storages.

Figure 5.3 shows the additional volume required to meet the SA Riverland–Chowilla EWRs optimised flow at the border under the baseline and Guide scenarios, on an annual basis.

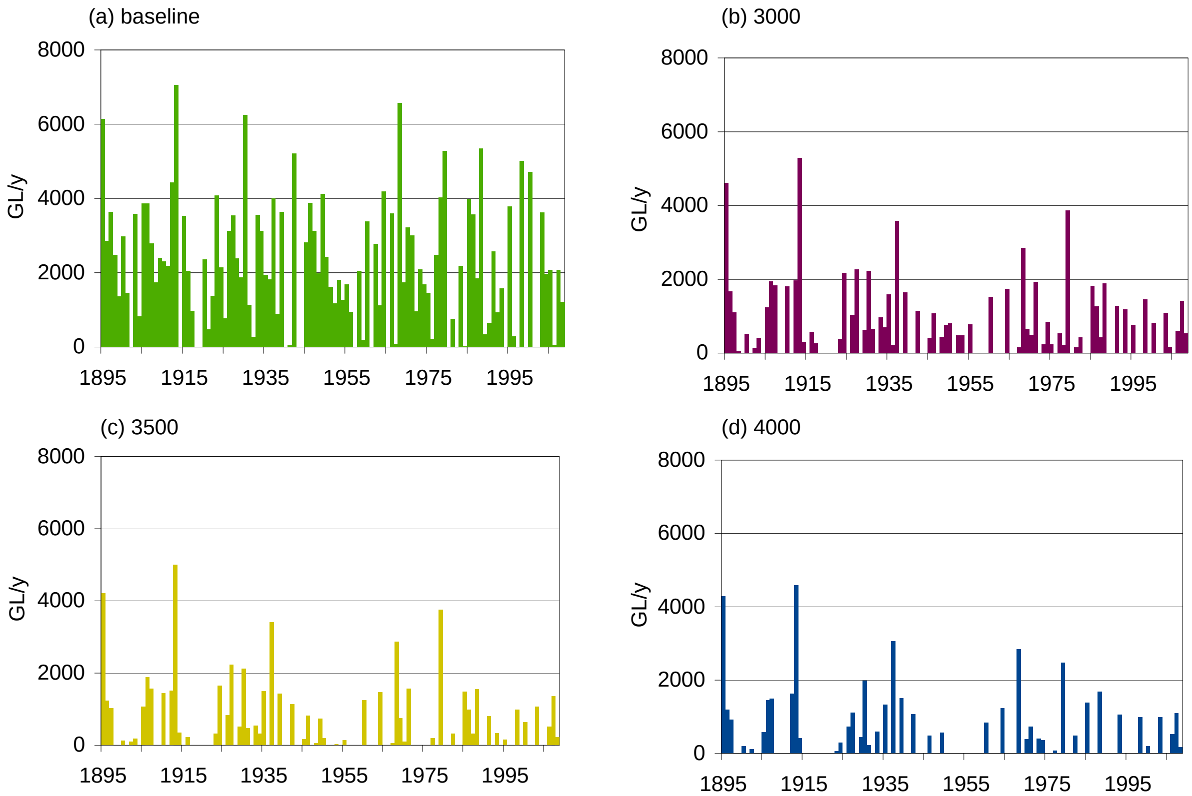

Figure 5.3 Additional annual volume (GL) required at the border to meet the shortfall in delivering SA Riverland–Chowilla EWRs optimised flow under the (a) baseline and (b–d) Guide scenarios

Table 5.5 shows there are 44 years of shortfall under the 4000 scenario, with the largest shortfall of 4589 GL in 1913. There are 97 years of shortfall under the baseline scenario with the largest shortfall of 7062 GL in 1913. Table 5.5 shows that by spreading the requirements over five years, the SA Riverland–Chowilla EWRs optimised flow cannot be met under any of the Guide scenarios. The SA Riverland–Chowilla EWRs optimised flow is not met in 1913, 1937, 1979 and 2006 under the without-development scenario. These are years where, in creating the optimised flow, the event size has been extended beyond without-development conditions to achieve the required event frequency.

Table 5.5 Years in which SA Riverland–Chowilla EWRs optimised flow is not met under the without-development, baseline and Guide scenarios

	Scenario				
Statistic	without development	baseline	3000	3500	4000
	years of shortfall				
Annual	5	97	67	57	44
Five-year rolling average	0	110	76	51	34

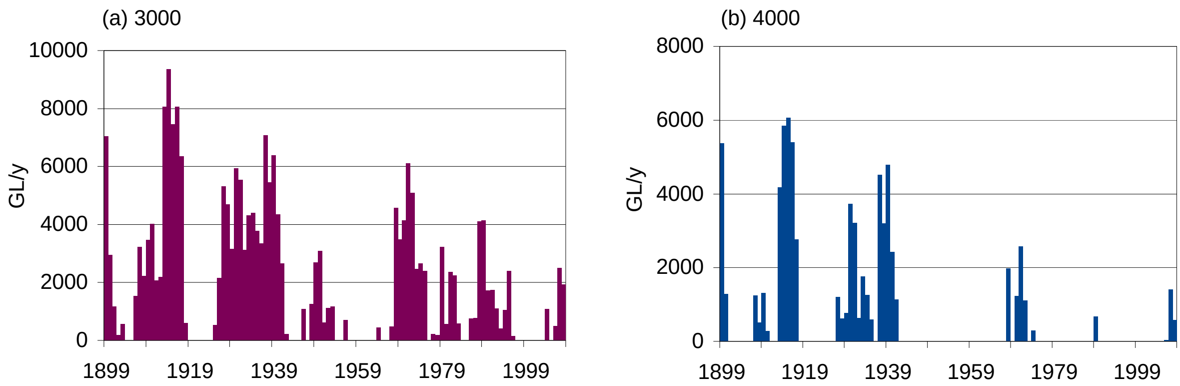

Figure 5.4 Five-year moving average shortfall (GL) in delivering SA Riverland–Chowilla EWRs optimised flow at the border under the (a) 3000 and (b) 4000 scenarios

Figure 5.4 shows a five-year moving average shortfall in meeting SA Riverland–Chowilla EWRs optimised flow under the 3000 and 4000 scenario. The result under the 4000 scenario shows that shortfalls are driven by extended dry periods, such as the Federation Drought, 1927–1941, 1970–1974 and 2006–2008. It is unlikely that sufficient environmental water could be held in reserve to meet the optimised flow in these extended dry periods.

5.4.2 Coorong, Lower Lakes, and Murray Mouth

- Despite being met on an average annual basis, the SA CLLMM EWRs optimised flow is not met in every year. The best outcome is under the 4000 scenario with 12 shortfall years, which is a significant improvement compared to 71 shortfall years under the baseline scenario. The shortfall years are scattered throughout the record.
- The SA CLLMM EWRs optimised flow is met on a five-year rolling average basis under the 4000 scenario. This suggests that a change in management of held environmental water could ensure SA CLLMM EWRs are met in every year.

Figure 5.5 shows the annual volumes required to meet the SA CLLMM EWRs optimised flow under the baseline and Guide scenarios. All of the requirements captured in the optimised flow are met under the without-development scenario.

Table 5.6 shows that there are 12 years of shortfall under the 4000 scenario with the largest shortfall of 1908 GL in 1902. There are 71 years of shortfall under the baseline scenario with the largest shortfall of 2900 GL in 1945. Table 5.6 shows that by spreading the requirements over five years, the SA CLLMM EWRs optimised flow can be met under the 4000 scenario. This indicates that by managing environmental water in dry years the SA CLLMM EWRs optimised flow could be met.

Table 5.6 Years in which SA CLLMM EWRs optimised flow is not met out the barrages under the baseline and Guide scenarios

	Scenario			
Statistic	Baseline	3000	3500	4000
	years of shortfall			
Annual	71	25	21	12
Five-year rolling average	57	3	2	0

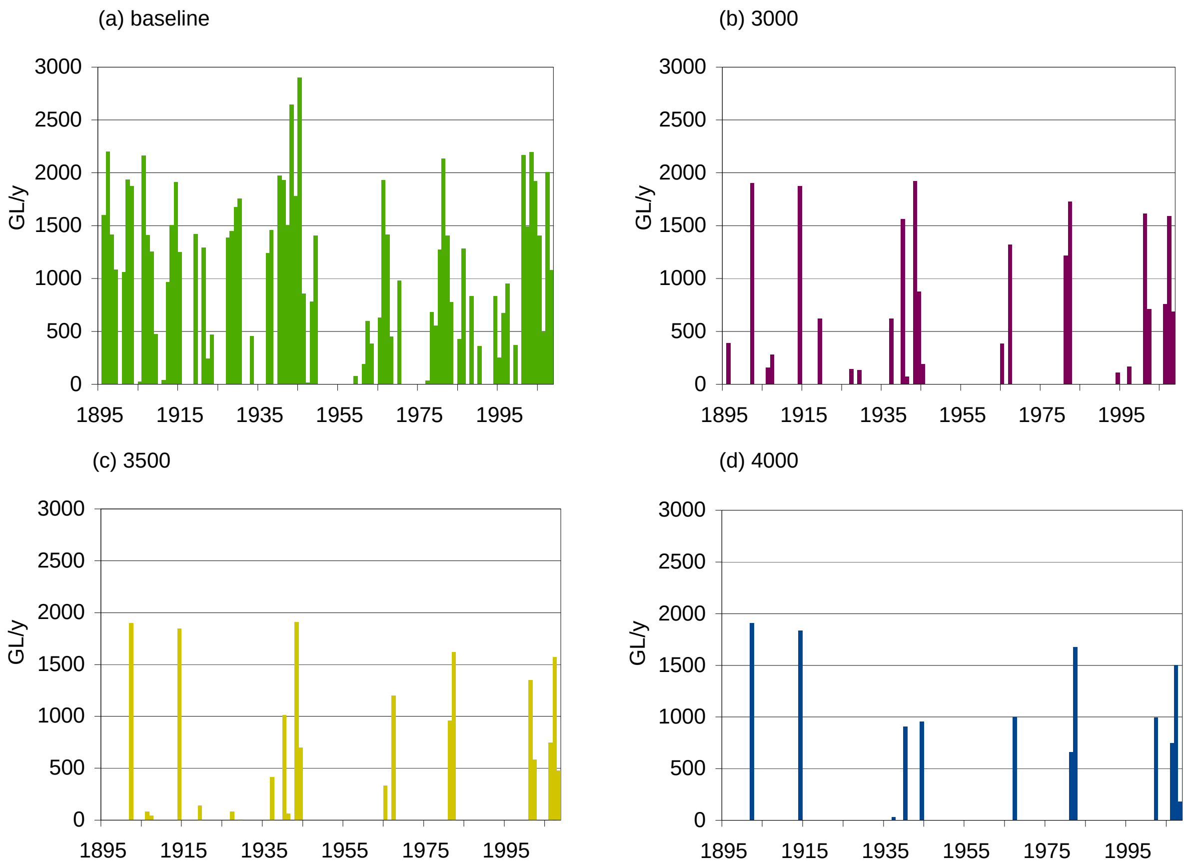

Figure 5.5 Annual volumes (GL) required at the barrages to meet the shortfall in delivering SA CLLMM EWRs optimised flow under the (a) baseline and (b–d) Guide scenarios

5.5 Sourcing optimised flows to the South Australian border

- The proportional contribution of upstream regions to SA border flows to meet the SA and MDBA EWRs is similar to the without-development contributions (Table 5.7).
- Under the baseline and Guide scenarios, the proportional contribution of upstream regions to SA border flows is different to the without-development contributions. As an example, under the 4000 scenario, the proportional contributions of upstream regions range from 55% to 99% of the without-development contribution (Table 5.8).

5.5.1 Under the without-development scenario

Table 5.7 shows the proportion of without-development flow contributed from upstream to meet the MDBA and SA EWRs optimised flows. The table also shows the regional contribution of without-development flows at the border.

Table 5.7 Contributions of upstream regions to without-development border flows and to MDBA and SA EWRs optimised flows

	Contributing region				
Scenario	Murray	Ovens	Goulburn Campaspe Loddon	Murrumbidgee	Darling
Without development	0.27	0.11	0.25	0.20	0.16
MDBA EWRs	0.27	0.12	0.26	0.20	0.16
SA EWRs	0.28	0.12	0.26	0.20	0.15

The table shows that the contributions of the upstream regions to meeting EWRs optimised flows are similar in both cases to the without-development contributions. This is not surprising as the EWRs optimised flows are constrained to the without-development flows at the border. It should be noted that this analysis is based on historical conditions and does not consider changes that will occur under future climate change and water management plans. Nevertheless the findings are useful as a baseline for analysis of the Guide scenarios.

5.5.2 Under the Guide scenarios

A comparison was made between the upstream contributions under each of the Guide scenarios. This comparison is shown in Figure 5.6 and Table 5.8. The upstream regions are considered as inflows at:

- Downstream Hume less NSW Cap, NSW Non-Cap and Victoria Cap diversions
- Ovens at Peechelba
- Goulburn at McCoy's Bridge, Campaspe at Rochester and Loddon at Appin South
- Murrumbidgee at Darlot and Balranald
- Darling at Burtundy.

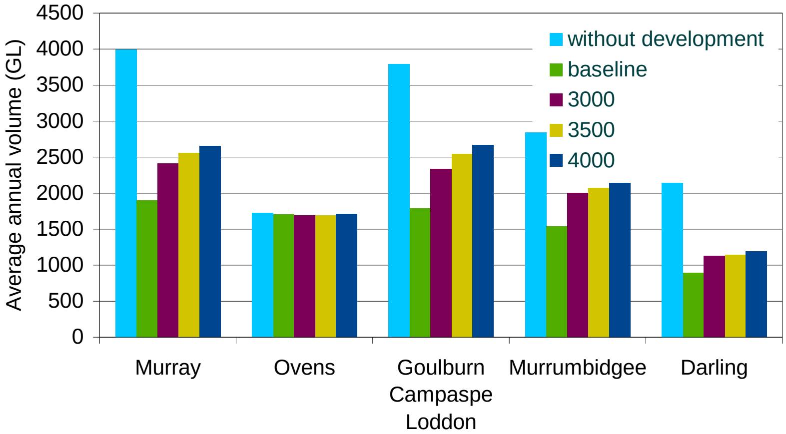

Figure 5.6 Upstream contributions (GL) to flows at the South Australian border under the without-development, baseline and Guide scenarios

Table 5.8 Contributions of upstream regions as a proportion of without-development contributions under the baseline and Guide scenarios

	Contributing region				
Scenario	Murray	Ovens	Goulburn Campaspe Loddon	Murrumbidgee	Darling
	proportion of without-development contributions				
Baseline	0.48	0.99	0.47	0.54	0.42
3000	0.60	0.98	0.62	0.71	0.53
3500	0.64	0.98	0.67	0.73	0.53
4000	0.66	0.99	0.71	0.75	0.55

Table 5.8 shows that under the baseline scenario the Darling contribution is less than other regions and that the Ovens is approximately the same as without-development conditions. The contributions are more evenly sourced under the 4000 scenario with Murrumbidgee and Goulburn-Campaspe-Loddon at 75% and 71% of without-development contributions respectively. The Murray and Darling contributions are less at 66% and 55% respectively. The small increase in the Ovens contribution under the 4000 scenario is due to a reduction in usage.

In determining the upstream contributions, the Hume inflows were reduced by the Murray usage. For all other upstream regions the usage is implicit in the flow as these gauges are located at the most downstream point in the region. The Murray calculation does not include delivery losses to the consumptive users that would further reduce the amount contributed to the environment. During operations the contributions from upstream regions is used to meet regulated requirements but this is rolled up in the total usage for the Murray. This shows the impact that Murray usage has had on flows delivered to South Australia. The Guide scenarios recover between 65% and 69% of the water that is available under without-development conditions.

5.6 Release limitations

- There are 44 years when there are outlet limitations on upstream storages in meeting the shortfall in daily flow requirements at the border. This is subject to the outlet capacity being fully available for environmental releases on the required day.

Release limitations have been considered based on annual and daily shortfalls, and available volume.

The analysis found that on an annual basis all shortfall years can be met by additional releases from upstream storages. Note this analysis assumed that all the remaining volume in storage is available for environmental release. This may not be the case as stored water may belong to other users including critical human water needs.

There are 44 years where there is insufficient daily outlet capacity in upstream storages to meet daily flow shortfall requirements at the border. Note that this analysis does not take into consideration existing release requirements, attenuation of hydrographs or reductions in outlet capacity due to the required releases. Consequently, this analysis is an under estimate of the likely constraints on meeting daily flow requirements.

The only year where there is insufficient volume held in upstream storages to meet SA EWRs is 1913. The remaining stored volume may not be available for environmental release.

No consideration was given to holding reserves in previous years to meet environmental water requirements. As many of the shortfalls occur in consecutive years, large reserves would need to be held for several years to meet extended periods of shortfalls.

5.7 Risks

The ability to deliver water to South Australia will depend on:

- the operation of upstream storages and how this will change the spilling frequency, which will impact on delivering high flows for Riverland and Chowilla
- how environmental water is shared between all assets in the Basin
- how delivery of environmental water is managed in extended dry periods
- the ability of upstream storages to deliver the required flows to South Australia when required.

Environmental releases from upstream storages can draw storages down to levels lower than the baseline, this impacts on the volume spilled from storages. In many cases these spill volumes influence the high flow requirements for the Riverland and Chowilla. Consequently there is a reduction in high flow events for the 4000 scenario where the extra environmental releases reduce the spill volume of upstream storages.

To meet the Riverland–Chowilla EWRs optimised flow during dry periods large carry-overs of environmental water would be required. The CLLMM EWRs optimised flow would not require large reserves as it is met in most years. Operationally it may be difficult to hold water during dry periods when other environmental assets in the Basin may require watering.

Some of the EWRs driving the SA Riverland–Chowilla EWRs optimised flow require large flows. Due to outlet constraints, meeting these flows relies upon storage releases ‘piggy-backing’ on downstream events to meet the targets.

The MDBA did not supply any climate change scenarios so it was not possible to undertake analysis on the impacts of climate change. However a subjective assessment of the impacts has been made using results from the Murray-Darling Basin Sustainable Yields Project (CSIRO, 2008a).

Table 4-16 in the Sustainable Yields report Water Availability in the Murray (CSIRO, 2008b) suggests that under the median 2030 climate scenario (Scenario Cmid) flows will decrease by 17%. This would suggest that a further 17%, in addition to that under the 4000 scenario, would be required to meet the average annual EWRs optimised flows under a 2030 climate. As the median 2030 climate impacts increase the number of dry years it is likely that the number of years that are not met is also increased.

6 Next steps

Chapters 2 to 4 of this report describe a science review of the Guide to the proposed Basin Plan, and Chapter 5 describes how to derive a flow regime required to come across the SA border to meet South Australian environmental water requirements and how to source and deliver that water.

6.1 Key outcomes

In addition to the review findings themselves, the project has delivered a number of products that can be immediately applied to any further analysis of the Basin Plan. These include:

- an independent, peer-review of the science underpinning the CLLMM EWRs says that the science is robust and fit-for-purpose
    - reported in Maltby and Black (2011)
- a review of environmental water requirements for key assets has assessed their suitability and a modified set is now available for assessing future flow scenarios
    - reported in Pollino et al. (2011)
- water quality and salinity targets have been compiled and reviewed and their suitability assessed
    - reported in Black (2011) in Pollino et al. (2011)
- an evaluation of MDBA's socioeconomic approach has led to the development of a method for assessing ecosystem services that can be applied across the Basin
    - reported in Connor et al. (2011)
- a methodology for building a flow regime at an upstream location (e.g. the SA border) based on environmental water requirements of multiple downstream key assets
    - reported in Podger (2011) in Pollino et al. (2011).

6.2 Future work

From a methodological perspective, and due to time constraints, the approach adopted for the review has only provided a 'yes' or 'no' to whether an EWR is met (or not) under a specific flow scenario. A more comprehensive approach would be to undertake an ecosystem response assessment that can take into account a much broader range of ecological outcomes as well as provide quantitative assessments. An example of the outcomes of this analysis could be the spatial extent of river red gum forests maintained under a specified flow scenario.

The key steps for a comprehensive ecological response would be to:

- undertake spatial ecological response modelling including inundation extent, depth and duration to predict the extent and condition of vegetation; habitat suitability for fish, birds, other species and guilds; and the presence of threatened species (where modelling can predict these)
- improve methods for assessment of ecosystem function
- explore representation of ecological communities/assets outside the two key environmental assets, and assessing the hydrological connectivity between different assets.

This comprehensive ecosystem response could then be assessed for potential socioeconomic assessment using an ecosystem services framework.

Figure 6.1 identifies these further steps in the assessment of impacts to South Australia from flow scenarios as specified under the Basin Plan.

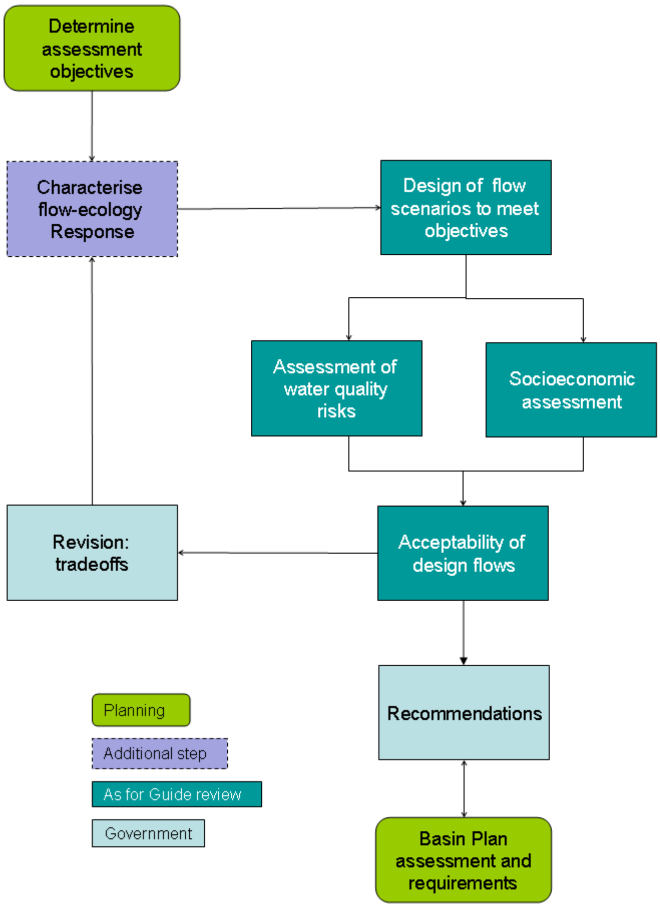

Figure 6.1 Proposed next steps in the integrated analysis of environmental, water quality and socioeconomic impacts in South Australia under Plan scenarios

Environmental water requirements

- In the assessment, all EWRs were treated equally. Further work on identifying the most critical EWRs is recommended.
- This review was limited in its ability to predict environmental implications of not meeting prescribed EWRs as there is little scientific evidence that provides thresholds of tolerance of ecosystems. This is a result of a significant lack of monitoring data available on a range of ecosystem components. This report, like many others in this field of science, strongly promotes the development of more comprehensive monitoring and evaluation programs that can provide the required evidence for future analysis.
- The use of eco-hydrological indicators to both represent the watering needs of key ecological assets and then assess the ability of flow regimes to meet those needs is a rapidly developing science. However it is presently limited to key ecotypes (e.g. river red gum forest, black box woodlands) and does not easily lead to the quantification of the benefits of environmental watering. Ongoing support for research into more powerful and utilitarian functional response models is recommended.

Water quality

- For South Australia's proposed targets at locations in the river with 99.7% non-exceedance probabilities, this translates to an allowable exceedance of about one day in 365, year after year. These targets seem to be overly conservative, and not practical or achievable. Hence, consideration should be given to revising these targets and in doing this the target values and probabilities of non-exceedance should be related more closely to the practical needs of assets and values intended to be protected.

- As MDBA's salt load export target is not met except during persisting wet conditions under the baseline scenario or any Guide scenario, consideration could be given to revising the target, if only to take into account that it is not met unconditionally. Preferably it could be based on a review of the purpose of the target and the assets that would be protected by such minimum export requirements.

River modelling and assessing of water delivery

- The models used by MDBA, and by the project team, are under constant development to reflect changes in river management and improved calibration. There would be benefit in reviewing the configurations of the models used for this assessment in light of these developments.
- While the use of the 114-year historical period captured a wide range of climate variability, it does not adequately address the significant changes in rainfall, evaporation and streamflow as predicted under future climate change. Flow scenarios under climate change need to be provided and run through the assessment approach to gauge the range of likely responses under future climate.
- The current assessment was constrained by only having the model for the South Australian portion of the River Murray. To be able to do a comprehensive assessment, a fully integrated Basin-wide model, as used by MDBA for developing the Guide and the Plan, is required.
- There is also potential to explore hydrological scenarios that aim to 'optimise' management strategies of flows above and below the SA border, which include scenarios that include infrastructure (e.g. the operation of regulators on floodplains). Optimisation of water purchases for delivery to South Australia could also be considered.

Socioeconomic assessment

- Whilst the assessment of damage, adaptation and mitigation costs (as described in this report) provides valuable information, further work is required to gain confident insight into the expected future benefit of avoiding these costs through the implementation of SDLs as under the Plan.
- There is significant scope for deepening these estimates through a range of additional considerations such as the value of forgone development due to riverbank instability and other related hazards, and increased treatment costs for water quality attributes not yet considered such as cyanobacteria, turbidity and heavy metals.
- Relatively little irrigation area reduction response is modelled in the irrigation sector economic impact assessment as a result of the calibration to ABS and SAMRIC data used in this study. Both of these data sources show some reductions in the area of irrigated pasture in the SA Murray from 2005–06 to 2008–09, but no clear trend of decreasing vineyard or orchard area. Recent aerial survey data on changes in irrigated area show declines in orchard and vineyard area over the course of the recent drought (PIRSA, 2010). Re-calibrating the economic model to these new data is recommended.
- While Dixon et al.'s (2011) analysis provided a snapshot of the economic off-setting impacts of a water buyback under one SDL scenario, there is considerable scope for extending this analysis for the South Australian portion of the Basin. Net impacts of the Plan would vary from these estimates depending on:
  - buyback structure and sequencing
  - technological gains, particularly those related to water-saving technologies that increase returns per unit water
  - future weather and climate
  - more detailed analysis of employment effects
  - opportunities for easing and facilitating structural adjustment.

Integrated assessment

- There is some risk for SA that if the accreditation process and the underpinning scientific basis for environmental watering plans are not adequate, less than the full potential benefits of the Plan may be realised in the State, while high costs to irrigators in dry periods could result. Further development and use of best economic and science practice would be helpful to States and the MDBA in future development, accreditation and implementation of the Plan and its integrated elements. The Guide to the Plan set out the rationale for SDLs but it is just one pillar of Basin reform: in the implementation phase, a suite of other plans will support the Plan. States have to develop, and the MDBA accredit, environmental watering plans, and plans for water conveyance, water quality and critical human water needs are being developed in parallel to support the Plan. There are likely simultaneous impacts, possible synergies and also tradeoffs between for example: irrigation water availability and water for the environment within a shared system; environmental watering and salinity impacts; and SDLs and more consistently meeting conveyance requirements, water quality standards, and critical human water needs. An integrated analysis could address these interdependencies and tradeoffs in order to adaptively manage environmental watering and Basin water quality and to maximise whole-of-system net benefits from the Plan.

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Appendix A Environmental water requirements

This appendix provides details on the environmental targets and objectives underpinning the environmental water requirements for Riverland–Chowilla and the Coorong, Lower Lakes, and Murray Mouth. They are referred to in Chapter 2 and Chapter 5.

Table A.1 MDBA Riverland–Chowilla EWRs (from MDBA, 2010)

Target	Event			Proportion of years event required to achieve target	
	Flow	Duration	Timing	Low uncertainty	High uncertainty
	ML/d	days	season	percent	
Maintain 80% of the current extent of wetlands in good condition	40,000	30	June to December	70%	50–60%
Maintain 80% of the current extent of red gum forest in good condition	40,000	90		50%	33%
	60,000	60		33%	25%
Maintain 80% of the current extent of red gum forest in good condition, Maintain 80% of the current extent of red gum woodland in good condition	80,000	30	preferably winter/spring but timing is not constrained to reflect that high flows are dependent on occurrence of heavy rainfall and will be largely unregulated events	25%	17%
Maintain 80% of the current extent of black box woodland in good condition	100,000	21		17%	13%
	125,000	7		13%	10%

Table adapted from MDBA (2010), p.664, Table B15.3

Table A.2 SA Riverland–Chowilla EWRs (from DWLBC, 2010)

Objective	Flow	Duration	Timing	Frequency	Max time between events
	ML/d	days	season	years	years
Temporary wetlands					
Maintain and improve majority of the lower elevation temporary wetlands in healthy condition (20% of all temporary wetlands)	40,000*	90	August to January	1-in-2	3
Maintain and improve 80% of temporary wetlands in healthy condition (includes lower and higher elevation temporary wetlands)	80,000	>30	June to December	1-in-4	5
Inundation of lower elevation temporary wetlands (~ 20% of temporary wetlands) for small scale bird, and frog and fish breeding events, i.e. provision of nutrients	40,000	90	commencing in July to September	1-in-2	3
Inundation of temporary wetlands (~ 80% of temporary wetlands) for bird breeding events and frog breeding events	80,000	>30	commencing in August to September	1-in-4	5
Red gum					
Maintain and improve the health of 80% of the River Red Gum woodlands and forests (adult tree survival)	80,000 to 90,000	>30	July to January	1-in-4	5
Successful recruitment of cohorts of River Red Gums, i.e. recruitment must equal or exceed River Red Gum mortality	80,000	60	August to October	in successive years (at least 2 consecutive for successful recruitment)	na
Waterbirds					
Provide habitat for waterbirds breeding events	70,000	60	starts August to October	1-in-4	6
Black box					
Maintain and improve the health of ~50% of the Black Box woodlands	85,000	30	spring or summer	1-in-5	8
Successful recruitment of cohorts of Black Box at lower elevations, i.e. recruitment must equal or exceed River Red Gum mortality	85,000	20	spring or early summer	consecutive years	na
Maintain and improve the health of ~60% of the Black Box woodlands	100,000	20	spring or summer	1-in-5	8
Maintain and improve the health of 80% of the Black Box woodlands	>100,000	20	spring or summer	1-in-6	8
Successful recruitment of cohorts of Black Box at higher elevations, i.e. recruitment must equal or exceed River Red Gum mortality	>100,000	20	spring or early summer	consecutive years	na
Lignum					
Maintain and improve the health of ~50% of the Lignum shrubland	70,000	30	spring or early summer	1-in-3	5
Maintain and improve the health of 80% of the Lignum shrubland	80,000	30	spring or early summer	1-in-5	8
Maintain lignum inundation for Waterbird breeding events	70,000	60	starts August to October	1-in-4	6
Mosaic habitat					
Provide variability in flow regimes at lower flow levels	variable flows from Pool to 40,000	variable	annually	1-in-1	na
Provide mosaic of habitats, i.e. larger proportions of various habitat types are inundated	60,000	60	spring or early summer	1-in-3	4
	70,000	60	spring or early summer	1-in-4	6
	80,000	>30	spring or early summer	1-in-4	5
	90,000	30	spring or early summer	1-in-5	6

Objective	Flow	Duration	Timing	Frequency	Max time between events
	ML/d	days	season	years	years
Bird breeding					
Inundation of lower elevation temporary wetlands for small scale bird, and frog and fish breeding events, i.e. provision of nutrients	40,000	90	commencing in July to September	1-in-2	3
Maintain lignum inundation for Waterbird breeding events	70,000	60	starts August to October	1-in-4	6
Provide habitat (River Red Gum communities) for waterbirds breeding events	70,000	60	starts August to October	1-in-4	6
Inundation of temporary wetlands for larger scale bird breeding events	80,000	>30	commencing in August to September	1-in-4	5
Fish					
Provide variability in flow regimes at lower flow levels (in channel)	variable flows from Pool to 40,000	variable	annually	1-in-1	na
Inundation of lower elevation temporary wetlands for small scale bird, and frog and fish breeding events, i.e. provision of nutrients	40,000	90	commencing in July to September	1-in-2	3
Inundation of temporary wetlands for larger scale bird breeding events and frog breeding events, Stimulate spawning, provide access to the floodplain and provide nutrients and resources.	80,000	>30	commencing in August to September	1-in-4	5

na – not applicable

Table A.3 MDBA and SA CLLMM EWRs

MDBA EWRs[1]
5100 GL/y long-term average
2000 GL/y rolling average over 3 years in 95% of years
1000 GL/y rolling average over 3 years in 100% of years
High flow requirements (exact volumes not specified)[3]
3200 GL/year 10-year rolling average for salt export
SA EWRs[2]
Absolute minimum of 650 GL in 95% of years
4000 GL minus flow in the previous year in 95% of years
6000 GL minus flow in the previous 2 years (adjusted) in 95% of years
SA minimum flow (max of three previous targets) in 95% of years
Flows sufficient to replace evaporative losses in Lakes[3]
2000 GL minus flow in the previous year in 100% of years
3000 GL minus flow in the previous 2 years (adjusted) in 100% of years
SA minimum flow (max of three previous targets) in 100% of years
6000 GL/year 1-in-3 year frequency (as a long-term average)
10,000 GL/year 1-in-7 year frequency (as a long-term average)

[1] Adapted from MDBA (2010), p.684, Table 16.4

[2] Source: DLWBC (2010)

[3] These EWRs were not included in the set when deriving the CLLMM optimised flows used for the Chapter 5 analysis

Table A.4 Ecosystem Function metrics at the SA border, Morgan and Wellington under baseline and Guide scenarios relative to the without-development scenario

Flow component	Metric	Baseline	3000	3500	4000
		% relative to without development			
SA border					
Baseflow	Low flow season	50%	54%	55%	54%
	High flow season	43%	57%	60%	63%
Cease-to-flow: low flow season	No. of years	100%	100%	100%	100%
	Average no. of years	100%	100%	100%	100%
Cease-to-flow: high flow season	No. of years	100%	100%	100%	100%
	Average no. of years	100%	100%	100%	100%
Cease-to-flow: all seasons	Average duration – commence-to-fill	100%	100%	100%	100%
Fresh: low flow season	No. of years – fresh	42%	54%	61%	69%
	Average no. of years – fresh	38%	52%	56%	67%
	Average duration – fresh	51%	63%	63%	63%
Fresh: high flow season	No. of years – fresh	42%	69%	70%	75%
	Average no. of years – fresh	40%	70%	73%	79%
	Average duration – fresh	76%	67%	70%	68%
Bankfull	1-in-1.5 years	59%	82%	88%	91%
Overbank	1-in-2.5 years	58%	77%	79%	83%
Overbank	1-in-5 years	64%	80%	81%	84%
Morgan					
Baseflow	Low flow season	40%	50%	51%	50%
	High flow season	45%	58%	60%	64%
Cease-to-flow: low flow season	No. of years	0%	0%	0%	0%
	Average no. of years	0%	0%	0%	0%
Cease-to-flow: high flow season	No. of years	0%	0%	0%	0%
	Average no. of years	0%	0%	0%	0%
Cease-to-flow: all seasons	Average duration – commence-to-fill	0%	0%	0%	0%
Fresh: low flow season	No. of years – fresh	34%	57%	60%	67%
	Average no. of years – fresh	30%	50%	55%	66%
	Average duration – fresh	55%	69%	68%	67%
Fresh: high flow season	No. of years – fresh	41%	60%	63%	64%
	Average no. of years – fresh	38%	61%	65%	70%
	Average duration – fresh	73%	63%	65%	64%
Bankfull	1-in-1.5 years	54%	79%	82%	49%
Overbank	1-in-2.5 years	55%	81%	83%	87%
Overbank	1-in-5 years	61%	80%	81%	83%
Wellington					
Baseflow	Low flow season	38	44	47	45
	High flow season	37	57	60	64
Cease-to-flow: low flow season	No. of years	0	50	67	67
	Average no. of years	0	59	57	90
Cease-to-flow: high flow season	No. of years	33	33	0	0
	Average no. of years	34	8	0	0
Cease-to-flow: all seasons	Average duration – commence-to-fill	28	60	55	87
Fresh: low flow season	No. of years – fresh	30	49	49	53
	Average no. of years – fresh	26	45	49	54
	Average duration – fresh	57	68	68	69
Fresh: high flow season	No. of years – fresh	42	68	70	74
	Average no. of years – fresh	39	74	77	83
	Average duration – fresh	72	64	65	65
Bankfull	1-in-1.5 years	50	71	78	89
Overbank	1-in-2.5 years	54	53	55	57
Overbank	1-in-5 years	62	70	76	80

Table A.5 EWRs used to derive the MDBA Riverland–Chowilla EWRs optimised flow (for Chapter 5)

	Objective	Flow	Duration	Timing	Frequency
		ML/d	days		years
1	Maintain 80% of the current extent of wetlands in good condition	40,000	30	June to December	1-in-1
2	Maintain 80% of the current extent of red gum forest in good condition	40,000	90		1-in-2
3		60,000	60		1-in-3
4	Maintain 80% of the current extent of red gum forest in good condition, Maintain 80% of the current extent of red gum woodland in good condition	80,000	30	not constrained	1-in-4
5	Maintain 80% of the current extent of black box woodland in good condition	100,000	21		1-in-9
6		125,000	7		1-in-9

Table A.6 EWRs used to derive the SA Riverland–Chowilla EWR optimised flow (for Chapter 5)

	Objective	Flow	Duration	Timing	Frequency
		ML/d	days		years
1	Maintain and improve majority of the lower elevation temporary wetlands in healthy condition (20% of all temporary wetlands)	40,000	90	Commencing in July to September	1-in-2
	Inundation of lower elevation temporary wetlands (~ 20% of temporary wetlands) for small scale bird, and frog and fish breeding events, i.e. provision of nutrients				
2	Provide variability in flow regimes at lower flow levels	40,000	60	annually	1-in-1
	Provide variability in flow regimes at lower flow levels (in channel)				
3	Provide mosaic of habitats, i.e. larger proportions of various habitat types are inundated	60,000	60	Spring or early summer	1-in-3
4	Provide habitat for waterbirds breeding events	70,000	60	Starts August to October	1-in-4
	Maintain lignum inundation for Waterbird breeding events				
	Provide habitat (River Red Gum communities) for waterbirds breeding events				
	Provide mosaic of habitats	70,000	60	Starts August to October	1-in-4
5	Maintain and improve the health of ~50% of the Lignum shrubland	70,000	30	Spring or early summer	1-in-3
6	Maintain and improve 80% of temporary wetlands in healthy condition (includes lower and higher elevation temporary wetlands)	80,000	30	June to December	1-in-3
	Maintain and improve the health of 80% of the river red gum woodlands and forests (adult tree survival)				
	Maintain and improve the health of 80% of the Lignum shrubland				
	Provide mosaic of habitats				
7	Inundation of temporary wetlands (~80% of temporary wetlands) for bird breeding events and frog breeding events	80,000	30	Commencing in August to September	1-in-4
	Inundation of temporary wetlands for larger scale bird breeding events and frog breeding events, Stimulate spawning, provide access to the floodplain and provide nutrients and resources.				
	Inundation of temporary wetlands for larger scale bird breeding events				
8	Maintain and improve the health of ~50% of the black box woodlands	85,000	30	Spring or summer	1-in-5
9	Provide mosaic of habitats	90,000	30	Spring or early summer	1-in-6
10	Maintain and improve the health of ~60% of the black box woodlands	100,000	20	Spring or summer	1-in-7
	Maintain and improve the health of 80% of the black box woodlands				